The Electrochemical Society

INTERFACE™

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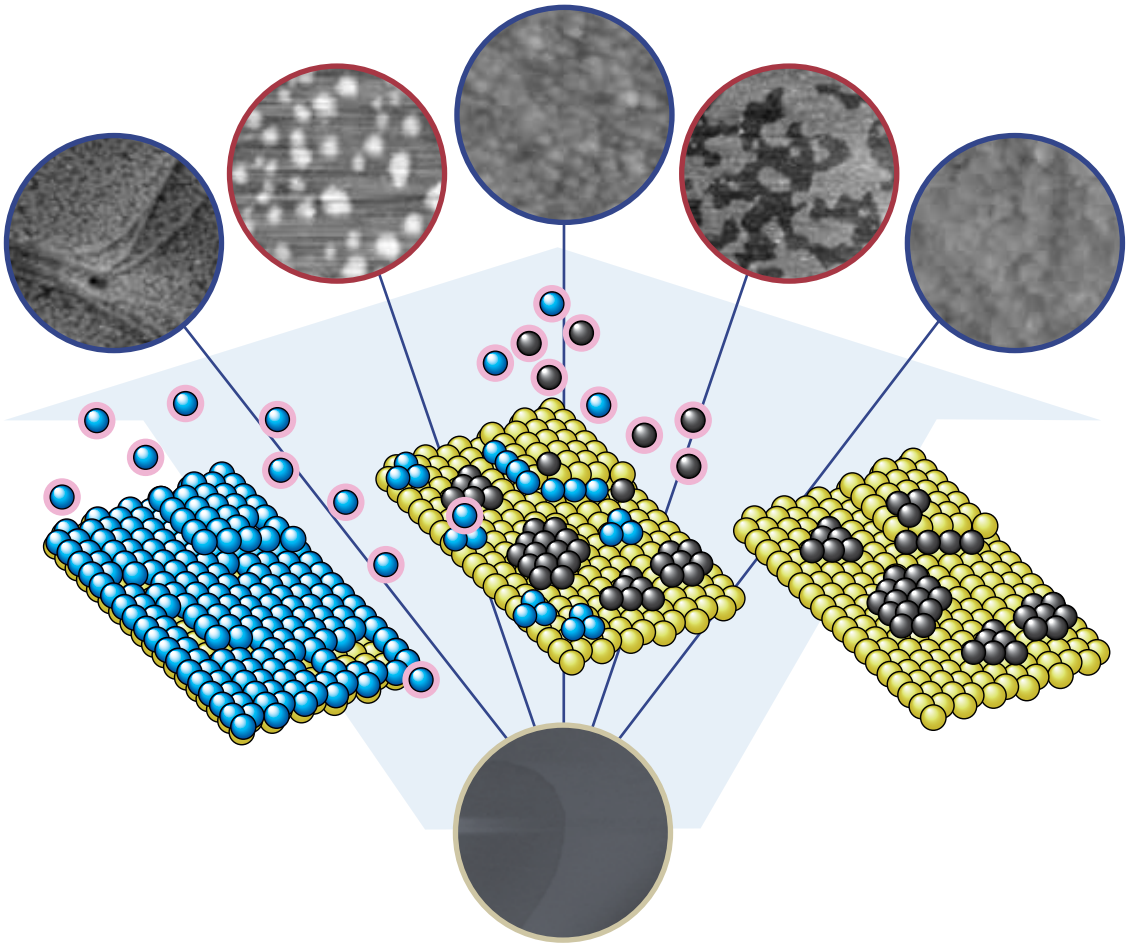
Summer 2018



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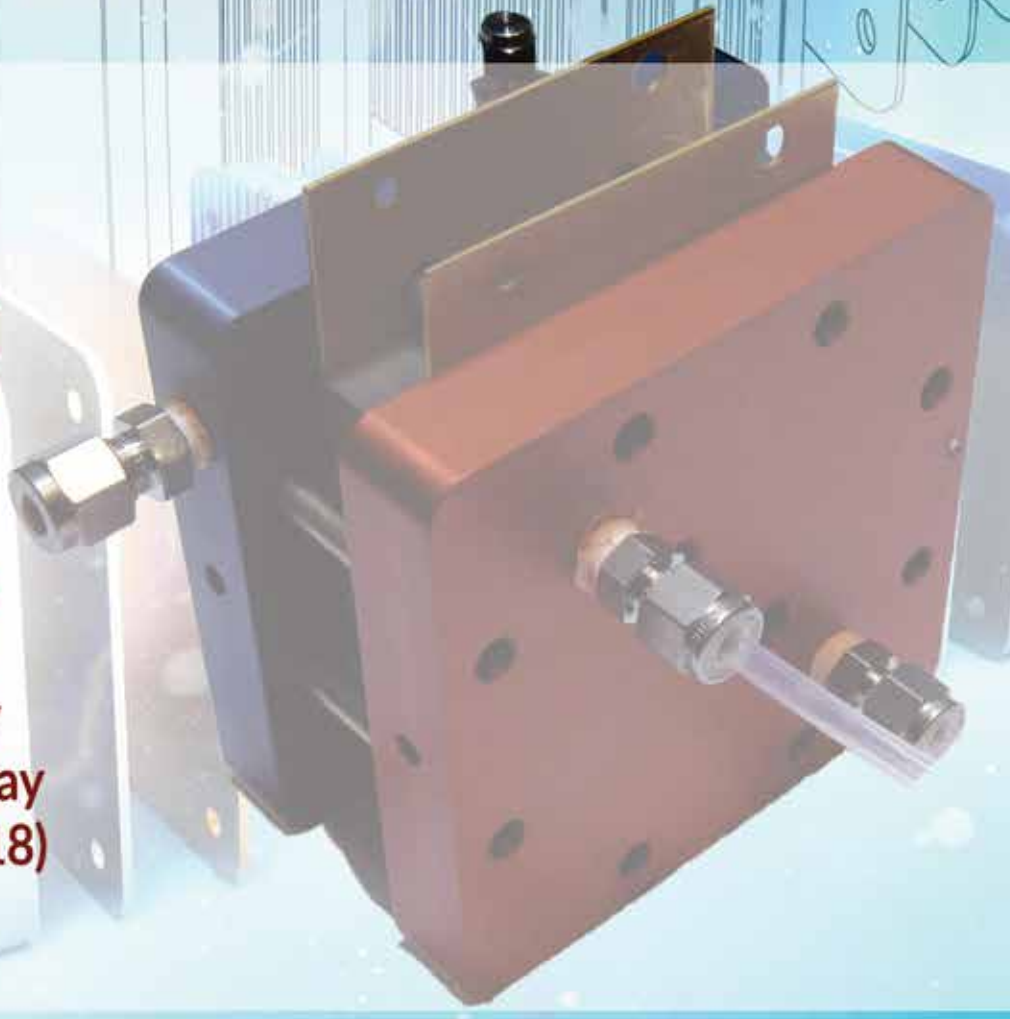

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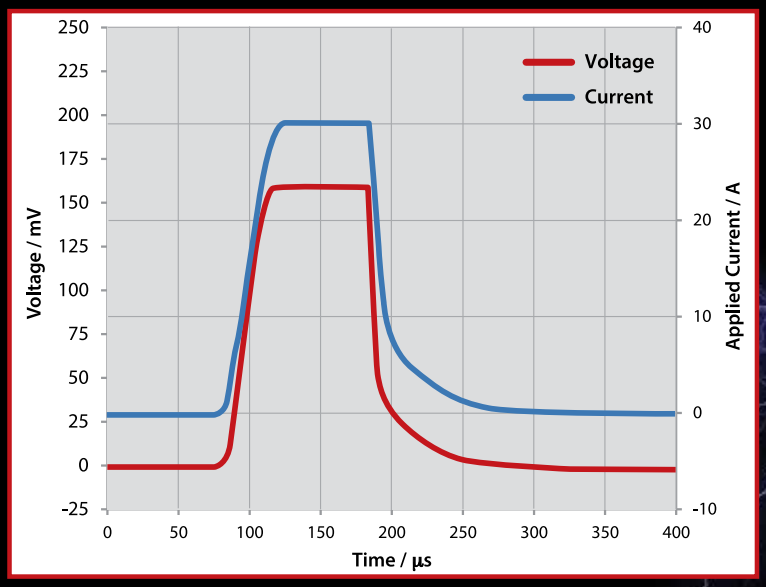

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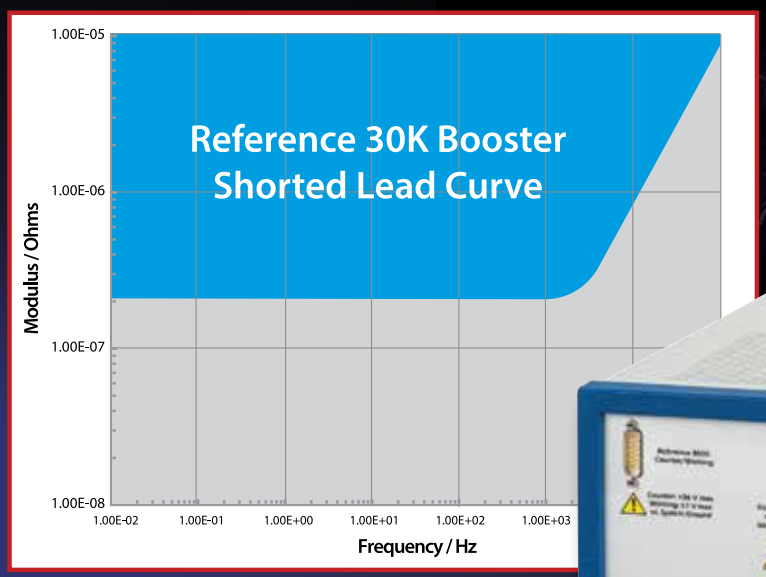

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A Double-Edged Plastic Sword

The graduation season is just ending in schools and colleges as I compose this editorial. And I wonder what the neighbor Mr. McGuire would have now said after buttonholing the newly minted graduate Benjamin Braddock (played by Dustin Hoffman) in the movie *The Graduate* with the famous quote, "One word: plastics." As human civilization progressed from one era to the next, the future loomed bright with every new type of material, be it iron, steel, silicon, or now, carbon. Plastics were no exception. I was astounded to read (*National Geographic*, June 2018) that fully half the amount of plastic ever made was produced only during the past 15 years! While the average service life of a plastic bag is a few minutes, plastics require forever to assimilate into our ecosystem after use.

For an ecosystem to be completely sustainable, the fluxes have to be delicately poised such that the input into the system (materials or energy) balances the output. When this is not the case, the consequences may be unpredictable, or worse, catastrophic. We do not have to look beyond the global climate situation in which man-made emissions of greenhouse gases (e.g., CO_2) are overwhelming the rates at which they can be assimilated by natural sinks (e.g., plants). In a similar vein, the production of plastics has far outrun the rate at which they can be safely or permanently disposed, especially in the most populous parts of the globe.

It is sociologically interesting that most innovations are double-edged. For example, malaria was largely eradicated with the discovery of the chemical DDT. However, its wanton and irresponsible use also resulted in long-lasting health effects, such as cancer and so on, importantly unforeseen at the time of its widespread use—so much so that agricultural use of this chemical has been banned in the U.S. for the past 40 years. (The DDT story has been highlighted by Rachel Carson's best seller *Silent Spring*, within the broader context of the overuse of pesticides.) There is no debate that plastics revolutionized our way of life on this planet in myriad ways. They even save lives in terms of use as airbags, safety helmets, and water containers. However, our dependence on plastics has grown to such proportions that landfills cannot handle them anymore, and we have to haul huge amounts on ships to other countries for disposal or recycling. Plastic wastes that do not make it to these disposal routes are transported by river streams from densely populated areas and ultimately end up in our oceans as microplastics with disastrous consequences on marine life.

In tackling this challenge, the answer clearly does not lie solely with cutting back the use of technological materials such as plastics. Albeit at smaller scales, we have been able to refine recycling into a fine art with the use of lead (as a battery material), and previously silver (as an analog photography material). There is no reason to believe that plastics recycling cannot be just as efficient. At the same time, human ingenuity has to be put to work in the discovery of biodegradable alternatives to plastics as we know them today. In this respect, we can take a cue from the use, in many rural parts of the world (or even posh resorts!), of thatched huts for living or banana leaves for eating needs; these materials are completely biodegradable. In this regard, the recent, serendipitous discovery of a mutant enzyme that eats plastics is worthy of note. (See www.theguardian.com/environment/2018/apr/16/scientists-accidentally-create-mutant-enzyme-that-eats-plastic-bottles.) Can we possibly engineer synthetic analogs of such natural materials using clever chemistries? And better still, can we add value to disposable plastics by converting them into useful chemicals (e.g., liquid fuel)? Stay tuned.

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The Electrochemical Society
INTERFACE

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The Electrochemical Society is an educational, nonprofit 501(c)(3) organization with more than 8,500 scientists and engineers in over 75 countries worldwide who hold individual membership. Founded in 1902, the Society has a long tradition in advancing the theory and practice of electrochemical and solid state science by dissemination of information through its publications and international meetings.

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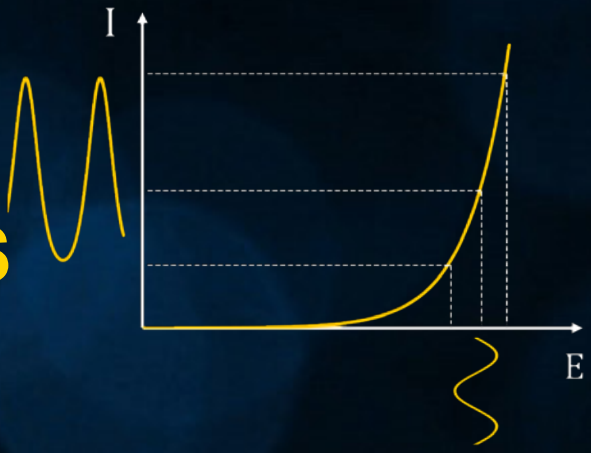

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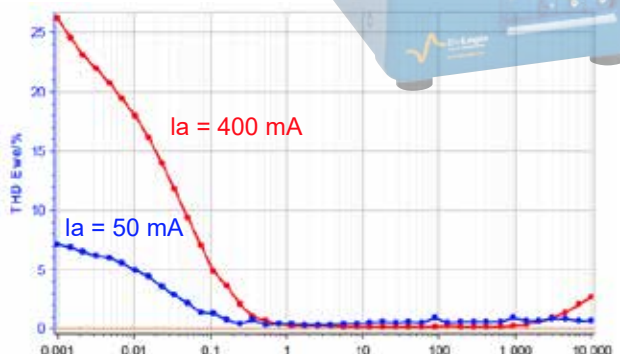

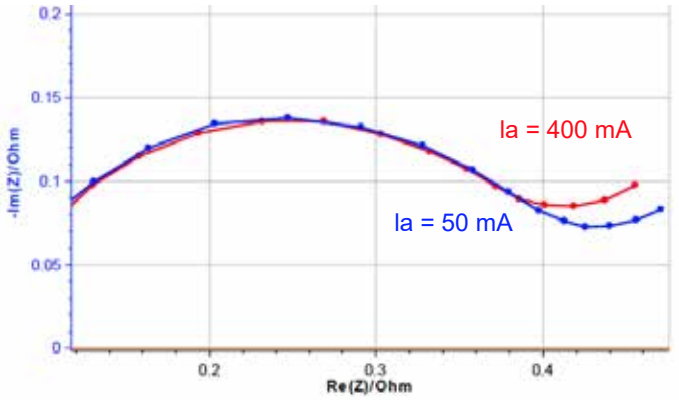

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The Electrochemical Society

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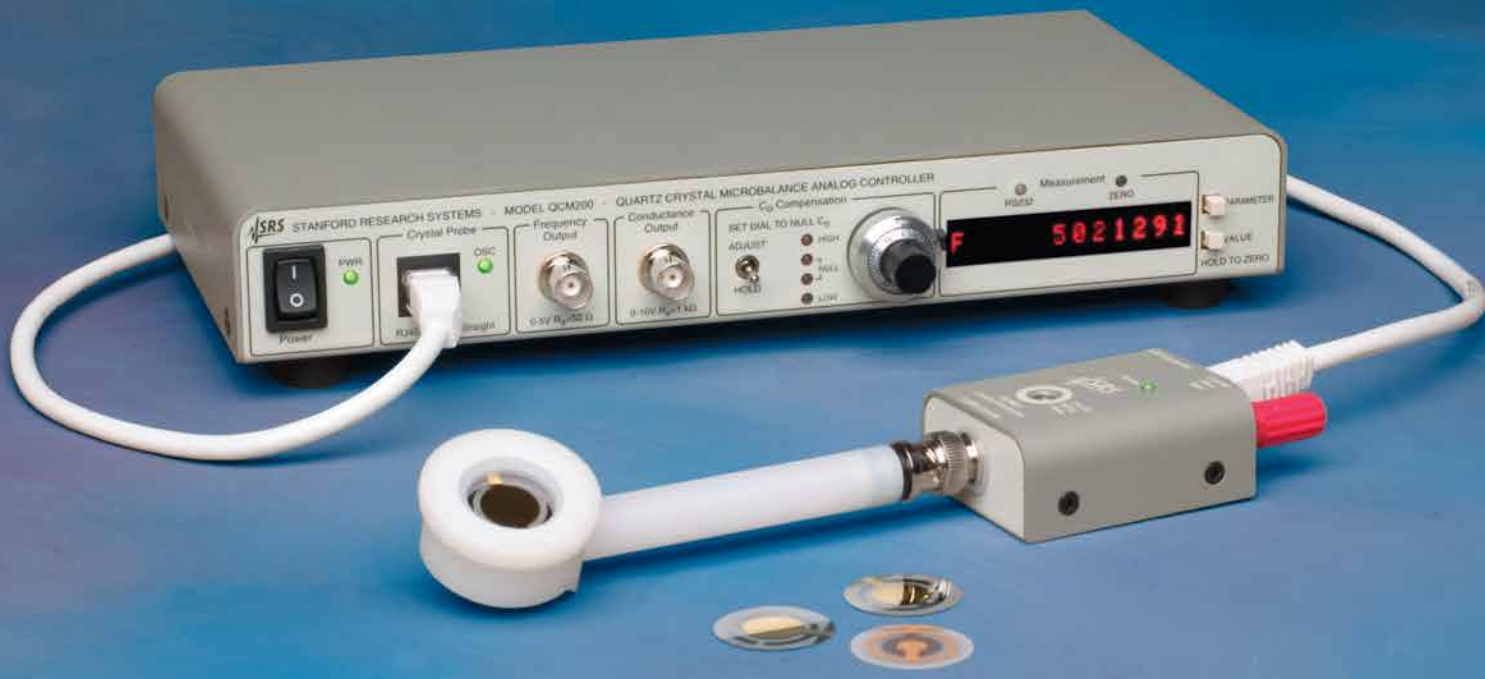

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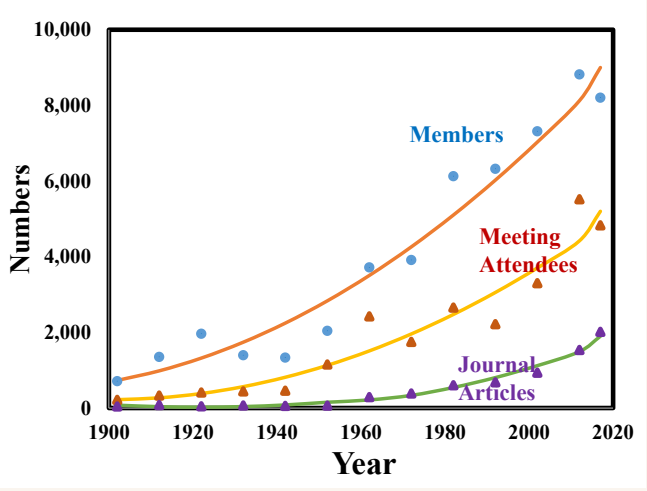
Past Performance Is No Guarantee of Future Results *But* 116 Years of Continuous Success Is a Sign of a Great Future

When one inquires for an investment service, no matter how well the company, fund, or stock is performing, the following statement always appears in the brochure or comes out of the advisor's mouth: "Past performance is no guarantee of future results." Obviously, it is a cautious warning on making one's intelligent decision. It is also wise advice for anyone making important professional decisions, such as in what field to devote efforts or with which professional society to be involved. Indeed, The Electrochemical Society is a dynamic society with things changing constantly and at a moment's notice. Scientifically and philosophically, no one can predict the future unless he or she can time-travel. In scientific terms, it is dangerous to extrapolate data out of range. However, experience has taught us that the possibility of future success could be high if the data range is very large and the measurement method is accurate. ECS and its 116-year-old history is a prime example for this statement.

The quantum jump of the modern human history to a great extent started from the demonstration of the existence and practical applications of electrons, including their generation, transferring, and storage through scientific methods. The fields of electrochemical and solid state science and technology rose to prominence near the end of the 19th century. Shortly after that, exactly 1902, ECS was founded. The impact ECS has had on the advancement of science and industry is extensive, deep, and continuous. In fact, ECS founders and early members were mostly distinguished scientists, engineers, and inventors, such as Herbert H. Dow, who founded the largest American chemical company: Dow Chemical; Edward G. Acheson, who first synthesized graphite and artificial diamonds; Charles M. Hall, who invented the low-cost aluminum manufacturing process; Edward Winston, whose Weston cell became the international standard for EMF; and Thomas Edison, who invented the first commercially viable incandescent light bulb, among many others. In the past century, eminent members have reported numerous breakthroughs in ECS journals and conferences, which established the foundation of today's electrochemical and solid state industries. One example is the first disclosure of Moore's law on the IC development trend in an ECS San Francisco conference by ECS life member Gordon E. Moore. In addition, among many ECS-affiliated Nobel Prize winners,[1] ECS life member Isamu Akasaki, who received the prestigious ECS Gordon E. Moore Medal, has published papers in ECS journals since 1966. He presented the first blue LED at the 175th ECS Meeting in Los Angeles in 1989.[2]

The figure below shows numbers of ECS members as well as meeting attendees and journal articles in the past 116 years. It is clear that all major factors, such as membership, meeting attendees, and publications, increased throughout the time in spite of two world wars and many serious disturbances in the world during the period. The short time variations of these numbers are unavoidable due to the fluctuation of many society factors. ECS is truly a global society with members coming from academia, industry, and governments in about 80 countries. ECS contains balanced core subjects including traditional topics that progressed continuously for over 100 years with the strong industry base and new hot research areas of which the knowledge becomes available due to recent science or technology breakthroughs.



Statistics of ECS members, meeting attendees, and journal articles. (Data provided by ECS staff.)

In summary, ECS activities have closely contributed to the advancement of science and industry. In many ways, new directions in electrochemical and solid state science and technology are derived from these works. The distinguished record of the evolvement of ECS for over one century can guarantee—or be a strong indication of—continuous success in the future. Of course, this requires collaborative efforts of all current and new-generation members as well as the strong support of ECS staff.

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1. www.electrochem.org/history-ecs/.
2. *Electrochem. Soc. Interface*, **26**(1), 9 (2017).

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37 YEARS with Roque Calvo

ECS Executive Director **Roque Calvo** has served as a steward of The Electrochemical Society for over 37 years, guiding the Society through tremendous changes while remaining dedicated to the Society's mission to advance electrochemical and solid state science and technology. Now, as Calvo comes to the end of his tenure and begins transitioning out of his role at ECS, we are looking back at some of the Society's greatest accomplishments during his time.

Calvo joined ECS in 1980 as the accounting supervisor, managing the financial operations for the headquarters office. After two years, he was promoted to assistant executive secretary. In 1990, as then executive secretary V. H. (Bud) Branneky prepared for retirement, a search committee was established to find the individual who would fill that role and lead the Society into the future.

"Roque just impressed us with his energy and ability," said past ECS president Larry Faulkner, who was a member of the committee that would recommend the hiring of Calvo. "We had high confidence in him and I don't think anyone who was involved in his hiring would have done it differently. Every one of us shared the view that it all turned out even better than we hoped."

Calvo took the role of executive secretary in 1991, just the fourth person to hold that title in the Society's then 88-year history. The title was changed to executive director in 1994.

"The Society was interested in self-renewal and I think we had the leadership and energy at that time with Roque inheriting the agenda," Faulkner said. "Of course, he didn't just inherit that agenda, he shaped it and turned it into something real."

His position would prove over the next three decades to hold significant importance in guiding the Society through a technological shift, which changed the landscape for many nonprofit organizations.

Publishing paradigm

One of the first initiatives Calvo took on as the Society's new leader was to establish ECS's quarterly membership magazine, *Interface*. In a 1989 report, the ECS Long Range Planning Committee recommended creating a news-oriented publication to foster and implement ideas and achieve greater access for members to information on matters affecting the Society. Along with Paul Kohl, then a

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The group that put together the first Interface *magazine in 1992 including the editor* **Paul Kohl** *(seated) and* **Roque Calvo** *(far right).*

member of the ECS Publications Committee, and Barry Miller, who had recently become editor of the *Journal of The Electrochemical Society*, a team started meeting at ECS's headquarters in Pennington, NJ, to brainstorm how to pull the magazine together. However, not all parties involved were on board, citing the potential for financial loss that could hurt the Society.

In Calvo's 26 years as executive director, net assets increased from $3.9M to $19.4M.

"Roque stepped forward and faced the financial consequences and he backed it," said Kohl, who would serve as the first editor of *Interface*. "He was the right person at the right time to get it going and if he wasn't there, it never would have happened."

The ECS Board of Directors approved the new publication at the 1992 spring meeting, and the publication continues to see success to this day, having recently celebrated its 25th anniversary.

The next key initiative Calvo undertook in his new role was the digitization of ECS publications. As new technologies began to emerge and publishers started shifting their business model, Calvo led an aggressive effort to establish what would become the ECS Digital Library, using technology to advance the Society's mission. A venture into unknown territory, much of this process was initially trial and error.

Roque Calvo *and* **Dale Hall** *(ECS president 1999-2000) in Japan planning PRiME 2004 with ECSJ.*

"Roque was bringing energy and vitality to the Society," said Kohl, who served as editor of the *Journal of The Electrochemical Society* from 1995 to 2007, seeing the journal through its transition from an exclusively paper model to an online publication. "For so many people, if it's not their concern and requires some work, they just pass the buck somewhere. But Roque would stand and try to address these issues."

That positivity and forward thinking would help propel the Society into the digital age. Not only did Calvo undertake the immense project of overseeing electronic submission and the digitization of the publications, he also spearheaded the Society's first website. In such a trying time with many unknowns and dozens of technological challenges, Calvo's vision and hallmark positivity kept everyone engaged and focused on accomplishing the task at hand.

Roque Calvo *in 2008 at the 228th ECS Meeting in Phoenix, AZ.*

"Roque never said we couldn't do something," Kohl said. "It would always be, 'Is there a way to do this? Let's figure it out.' That attitude was absolutely critical because every time we came to a stumbling block, Roque would find a new way to accomplish our goal."

The ECS Digital Library was launched in 2006, and ECS chose the American Institute of Physics' *Scitation* platform to be the host for its library. In addition to hosting all the newly published journal manuscripts, the effort also included work to archive past papers, dating back to 1930. The continued expansion of the ECS Digital Library also led to the inclusion of *ECS Transactions*, which the Society began publishing in 2005 as a replacement for ECS Proceedings Volumes.

Through it all, Calvo's business sense allowed him to control overall budgets and successfully navigate the publications entry into the digital world. The paradigm shift represented great opportunity for ECS, but as a small nonprofit publisher, the Society faced significant challenges, particularly in generating the necessary financial resources. Calvo's ability to drive technological advancements and effectively manage the budget is one of the main reasons for the financial security and programmatic success that ECS is experiencing today.

International expansion

When ECS was founded in 1902, there were nine countries represented on the charter membership roster. As a result of Calvo's guidance, the Society currently has members and involvement in more than 75 countries, having created a dynamic international community of electrochemists and solid state scientists and engineers.

Before Calvo became executive director, ECS ran its first joint international meeting in Honolulu, HI, in 1987. As assistant executive secretary during that time, Calvo was able to gain hands-on experience and establish relationships with Japanese partners. Due to the increased interest and engagement at this meeting, Calvo knew it would be an enduring opportunity for the Society.

In 2017, 55% of meeting abstracts and 75% of journal manuscripts were from international authors.

Upon gaining the executive director title, Calvo began to tackle new ventures in joint international meetings, overseeing strategy and relationship-building with organizations around the world.

It wasn't until 1993 when the chips fell into place again, marking the Society's return to Hawaii for its second joint international meeting. Seeing the potential, Calvo began initiatives in branding this meeting, resulting in what we know today as PRiME. Global partnerships with The Electrochemical Society of Japan and later the Korean Electrochemical Society acted as the catalyst for the development of this highly successful meeting, with additional sponsorship from five other organizations from Australia, China, Korea, and Japan. PRiME has grown into the largest, most significant research conference in electrochemical and solid state science and technology.

"PRiME helped to significantly raise the prominence of ECS," said Fernando Garzon, ECS president during the PRiME 2012 meeting. "The meeting set a precedent that was then copied by other scientific societies. They saw the success of our meeting and that Hawaii was an excellent venue to bring together our Asian partners within the Society."

Roque Calvo *at PRiME 2008 with ECSJ members.*

PRiME now occurs every four years in the very same venue in which the inaugural meeting took place, its level of attendance having grown from approximately 2,500 participants to now nearly 4,000 researchers from all corners of the world. The eighth PRiME meeting is scheduled for October 2020 and is expected to surpass existing benchmarks.

Calvo continued the joint meeting branding strategy through the creation of the Americas International Meeting on Electrochemical and Solid State Science, which this year will be held in October. This global partnership strategy was extended to the Sociedad Mexicana de Electroquímica in 2006 when the two organizations held the first of a continuing series of joint international meetings in Cancun, Mexico. After another successful joint meeting in 2014, the conference took on its own, unique identity. AiMES 2018 will include sponsorship from the Sociedade Brasileira de Eletroquímica e Eletroanalítica and the Sociedad Iberoamericana de Electroquímica, with high expectations of AiMES being the most important meeting in our field ever convened in the Americas.

Under Calvo's guidance, ECS has also held joint partnership meetings in China and Europe, and Calvo has established both sponsored and satellite meetings, opening the door to integrate such significant meetings as the International Meeting on Lithium Batteries, the International Symposium on Solid Oxide Fuel Cells, and the China Semiconductor Technology International Conference.

Roque Calvo *planting a tree at the Central Electro Chemical Research Institute in Karaikudi, India, to commemorate his visit.*

Through international partnership efforts, Calvo led ECS to continue fulfilling its mission by advancing the science on an international scale, building relationships with over a dozen professional societies, including the Chinese Society of Electrochemistry, the Society for Advancement of Electrochemical Science and Technology (India), the International Society of Electrochemistry, the International Conference on Solid State Ionics, the Institute of Electrical and Electronics Engineers, and others already mentioned in this article.

Meetings, meetings, meetings

In addition to international expansion, Calvo piloted ECS to significant growth through the implementation of new programs at its biannual meetings. He guided the development of the Electrochemical Energy Summit, with the first summit taking place in 2011 during the 220th ECS Meeting in Boston, MA. Since the inaugural event, the energy summit has taken place every year during the fall biannual meeting, bringing together policy makers and researchers to discuss the critical issues of energy needs and the pivotal research in electrochemical energy. He also shepherded the first Science for Solving Society's Problems Challenge in 2014, which was created in partnership with the Bill & Melinda Gates Foundation and awarded a grand total of $360,000 in funding to innovative researchers working to address world sanitation issues.

Calvo's leadership has also significantly impacted symposia planning at ECS biannual meetings, leading to larger and more diverse meetings and a steady increase in attendance. In 1995, utilizing new technologies, ECS began accepting electronic abstract submissions, which has led to major improvements in program development. In the same year, ECS introduced technical exhibits at biannual meetings, which have led to long-term success in providing a venue for exhibitors to interact with world-renowned researchers.

But technological shifts were not always easily embraced within the Society. From his oversight of the implementation of electronic abstract submission to the development of a comprehensive constituent database, Calvo consistently used his managerial and business sense to back decisions and deliver clear, concise communications on the importance of these moves to a diverse scientific community.

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In 37 years, Calvo has championed the success of 75 consecutive ECS biannual meetings.

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"Implementing these changes really took the skill of an international diplomat," Garzon said. "We joke at the university that trying to organize scientists and engineers is like herding cats. Roque is very good at herding cats."

His work with U.S. funding agencies also allowed the various ECS symposia to grow and expand, with Calvo communicating the importance of the work of the Society's scientists to major institutions.

"Roque was very good at working with divisional leadership to make sure that the symposia we have in the Society reflect the national research interests," Garzon said. "He made people understand that ECS was the place for their program managers to discuss the major research in areas like battery technology, fuel cells, and photovoltaics. And one of the greatest values that ECS provides its membership and meeting attendees, is that the Society has very high credibility with the folks who fund science."

Christina Bock *(ECS treasurer 2010-2014) with* **Roque Calvo** *in 2013 at the 223rd ECS Meeting in Toronto, Canada.*

Student investments

Prior to Calvo's tenure as executive director, the Society's student activities relied heavily on university faculty networks to seed the new generation of scientists. Knowing that the Society's future success depends on that, Calvo began investing in and expanding student programs.

One way student opportunities started to grow was through increased support and recognition of young researchers. Currently, ECS has 13 student awards, 9 of which were established during Calvo's tenure, including the biannual meeting student poster session awards, which are among the now robust portfolio of student awards.

Shortly after Calvo became executive director, he and the ECS Education Committee realized that a poster session could function as an ideal platform for students to present their work, network with the top researchers in the field, and be recognized for their accomplishments. The first General Student Poster Session was held in 1993 at the 184th ECS Meeting in New Orleans with a successful showing for the inaugural event, which featured a few dozen student posters. By now, this event has grown into an enormously effective program, highlighting young researchers from around the world, with 102 posters presented at the 233rd ECS Meeting in Seattle in 2018.

The objective was to enable an easier, more accessible opportunity for students to attend ECS meetings and create more interaction once they got there. Calvo directed the implementation of the ECS Student Mixer, creating a unique opportunity at the time for students to network with senior scientists and engineers, fellow students from around the world, and like-minded thinkers. And, working with the ECS divisions, he has enabled the awarding of around $75,000 in student travel grants annually to assist students with attending ECS biannual meetings.

Roque Calvo *and* **Esther S. Takeuchi** *(ECS president 2011-2012) at the 227th ECS Meeting in Chicago, IL.*

The development of ECS student chapters allowed for students to continue exploring new opportunities outside of meeting settings. Student chapters were established under Calvo's leadership in the late '90s through the ECS Council of Sections. During that time, a group of students from Penn State came to the Society looking for official recognition from a professional society to gain full access to university resources as a student affiliation. Upon this request, Calvo and Daniel Schwartz, then chair of the Council of Sections, worked together to draft the guidelines for what would become ECS student chapters.

In Calvo's 26 years as executive director, student participation in ECS programs has more than doubled.

"The student chapters have become one of the more vibrant membership-oriented activities over the years," Schwartz said. "Roque shepherded this program through leadership so that we were actually able to have the chapters. ECS is a good organization for students, and the chapters provided one more opportunity and kicked off a whole student program that would be built around this."

The creation of student chapters allowed young researchers new opportunities to network with the Society's constituents, gain funding to support chapter activities, get access to career resources, and partner with local sections. Student chapters have become wildly successful, with over 70 having been established around the world, providing students the opportunity to pursue new opportunities and ECS the ability to establish communication with this vital group of researchers.

Membership and constituent programs

With Calvo's tenure came a more robust honors and awards program. Changes were implemented and new awards were established, leading to a total today of 53 Society, student, division, and section awards. The development of new awards allowed for researchers to be recognized for their accomplishments, giving those individuals stature in the field as well as the potential to get more funding for the programs due to this increased recognition.

Roque Calvo *interviewing* **John B. Goodenough** *for the ECS Masters series in 2016 at PRiME in Honolulu, HI.*

ECS's membership now stands at over 8,000 constituents, with the Society consistently developing new opportunities for members to advance their professional careers and access innovative grant programs. These include several new summer fellowships and the addition of the ECS Toyota Young Investigator Fellowship in 2014, which provides yet another resource for early researchers to connect with a major industrial organization and receive funding to pursue innovative work.

In Calvo's 26 years as executive director, 29 new awards were established.

With committee and staff assistance, Calvo managed the creation of a professional development program in 1997. This program consists of workshops, professional panels, and career resources that help both early-career researchers and experienced professionals learn integral information about the field and propel their careers in the right direction. These programs were added to the already established short courses to offer members opportunities to learn about some of the hottest topics in the field from academic and industry experts.

Finally, in 2014, Calvo started the process of expanding member recognition beyond the honors and awards program by establishing the Society's first marketing department. Again, Calvo looked to harness new technological advances and promote the Society and its members by creating a digital media library with videos, podcast, and other new media initiatives.

Roque Calvo *interviewing* **Gordon E. Moore** *in 2016 in Hawaii.*

Free the Science

Throughout his career with the Society, Calvo watched as the amount of research published grew exponentially. With the increased amount of content out there, accessibility started to become an even more important issue, especially in light of the rising subscription costs of large, for-profit publishers.

When Calvo started with the Society in 1980, the scholarly publishing model was vastly different, with only paper journals and subscription prices that were affordable to most universities and institutions. As for-profit publishers began dominating the scholarly publishing field and smaller, nonprofit publishers struggled to compete, the entire publishing model started on a drastic evolution, bringing into question price barriers and access to information.

In a 2010 *Interface* article, "Chasing the Great White Whale," Calvo described this issue and emphasized the need for the free, open dissemination of research. "ECS is the steward of electrochemical and solid state science and technology, which is an increasingly important role now that commercial enterprises dominate scientific publishing and stymie the advancement of our science," he said in the article. "The reality in the new millennium is that scientific publishing can, but should not be, a money-making proposition."

This new publishing reality had significant implications on the Society's mission to disseminate research to advance the science, and this was not lost on Calvo, whose strategic compass was based on the mandate of the ECS mission. This threat compelled Calvo to study and diagnose the issues and changes in research publishing long before the Society's initiative known as *Free the Science* would gain its name.

"High prices represent an obstacle in the dissemination of information and we cannot accept a situation where multibillion dollar corporations, who set high prices to generate large profits, determine what scientific research will cost and what results are publishable," Calvo continued in the 2011 *Interface* article. "Our ultimate goal is to create open access to the ECS Digital Library, which means ECS is planning to eliminate the cost obstacles for the scientific research that we publish."

In 37 years, Calvo has served for 336 ECS board members while attending 89 consecutive board meetings.

The elimination of the price barrier would be Calvo's great white whale, a reference to Herman Melville's *Moby Dick*, a story about one captain's passionate chase around the globe. Calvo continued pursuing this mission-based imperative, finally putting a name to the vision in 2013.

"Our goal is to provide open access to all the content in the ECS Digital Library and literally free the science for researchers in electrochemistry and solid state science all over the world," Calvo said in a 2013 *Interface* article. "This is truly a risky walk across the high wire, but the possibilities of open access have made it an organizational imperative."

That same year, he put together the Committee on Free Dissemination of Research, calling on Larry Faulkner to chair this committee made up of such prolific scientists as Allen Bard, Esther Takeuchi, Mark Wrighton, Tetsuya Osaka, and Martin Winter. The committee was charged with "evaluating the future of open access for ECS and its impact on scientific advancements in our field" and "making recommendations concerning ECS's organizational structure, funding options, and advocacy requirements necessary for an open access model that will lead to successful and uninhibited scientific advancement."

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"Roque was central to our discussion and the work of that committee," Faulkner said. "In fact, the Society's ability to prepare for that committee and gather resources that could get us started toward making the changes we were discussing was heroic."

In March 2014, the committee came to the conclusion that in addition to maintaining the high standards and rigorous peer review associated with ECS journals, the Society should pursue complete open access to keep the publications relevant and sustainable. The initiative kicked off by launching a hybrid open access program for ECS journals called Author Choice Open Access. To gain momentum, ECS began publishing open access manuscripts while providing a generous introductory waiver program for article processing charges.

The ECS Board of Directors approved the launch of the *Free the Science* campaign in 2015 with the long-term goal to help make the entire ECS Digital Library open access, eventually eliminating subscription costs while continuing to allow authors to publish their work for free.

"For me, this is the most important initiative in all my years of service and it is also the most daunting," Calvo said during the plenary at the 229th ECS Meeting. "Undoubtedly, *Free the Science* is a bold vision and just as I have been supported by so many of you over the years, I ask for your support again now so we can advance this critical science at a pace I could never have imagined when this journey started."

During the 229th ECS Meeting in 2016 in San Diego, **Roque Calvo** *launched the* Free the Science *campaign at the plenary session.*

The *Free the Science* initiative has continued to expand over the past two years, incorporating ideas and values from the open science and open data movements. Through initiatives such as the launch of ECSarXiv, a preprint service developed through a partnership with the Center for Open Science, enhanced research dissemination with Research4Life, the Society's first OpenCon event in 2017, and the start of the ECS Data Sciences Hack programming, ECS continues to move toward a future that embraces open science to further advance research in the fields of electrochemical and solid state science and technology.

Since 2014, over 35% of the manuscripts published in ECS journals have been open access, and most importantly, ECS has experienced phenomenal progress in achieving the mission by increasing dissemination from the ECS Digital Library by 220% to over 3.5M downloads last year.

"If you are anywhere for over 37 years, like I have been at ECS things are going to happen," said Calvo recently. "But to truly accomplish anything, it's all about building relationships. As executive director, it has been my pleasure and honor to serve as the staff leader of a great international institution. Success in my position has required partnerships that have lasted for decades and generated ideas and support from volunteer leaders who serve on the board, committees, divisions, and as editors and symposium organizers. And, of course, the staff support has been essential. The many years of meetings and activities blend after a while, the journey is what I'll remember and all the extraordinary people who have shared it with me." ■

Roque Calvo *and his wife* **Marianne Calvo** *at the presidential reception at the meeting in Seattle, WA, in spring 2018.*

In honor of 37 years of service from Executive Director and CEO **Roque Calvo**, The Electrochemical Society has created the Roque Calvo Next Generation Scholarship Fund.

PURPOSE

Ensure the participation of students and young investigators at ECS meetings through travel grants.

GOAL

Raise $500,000 which will fund an additional 50 students per year to attend ECS biannual meetings.

DONATE

Learn more and make a donation at **www.electrochem.org/next-gen.**

If you are interested in other ECS giving opportunities, please contact Ngoc Le at Development@electrochem.org or call 609.737.1902 ext. 102.

Thanks Roque

... for your insights, guidance and support of the ***International Symposium on Solid Oxide Fuel Cells*** *for the last thirty years.*

- Subhash C. Singhal, Founding Chair

Sixteenth International Symposium on Solid Oxide Fuel Cells (SOFC-XVI)

Subhash Singhal

September 8-13, 2019
Kyoto Terssa, Kyoto, Japan

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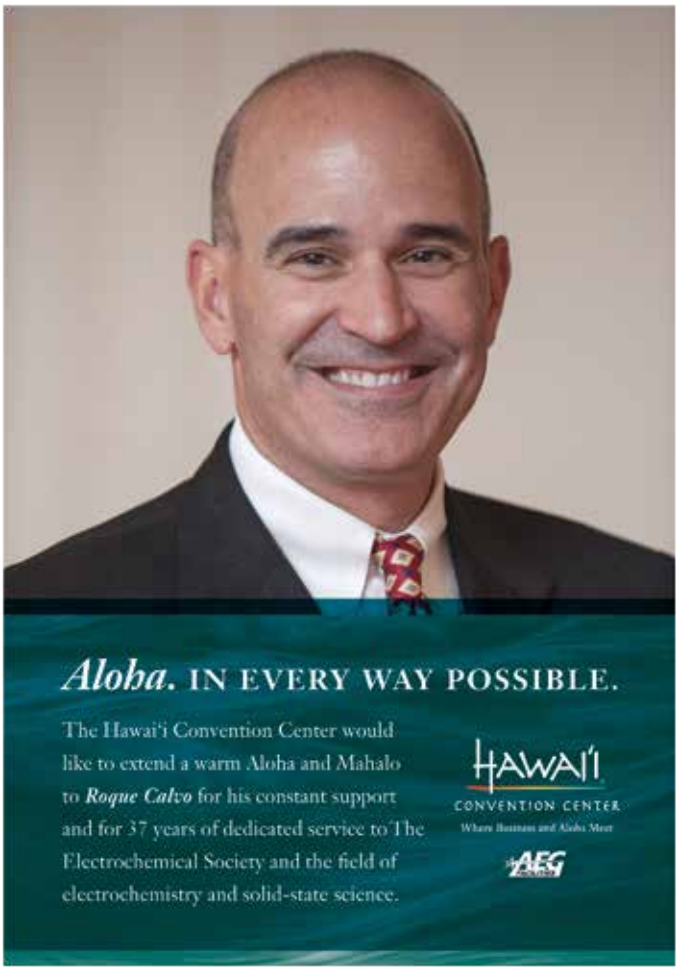

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CONGRATULATE

ROQUE CALVO

on his years of

service and dedication to

THE ELECTROCHEMICAL SOCIETY

AIP American Institute of Physics

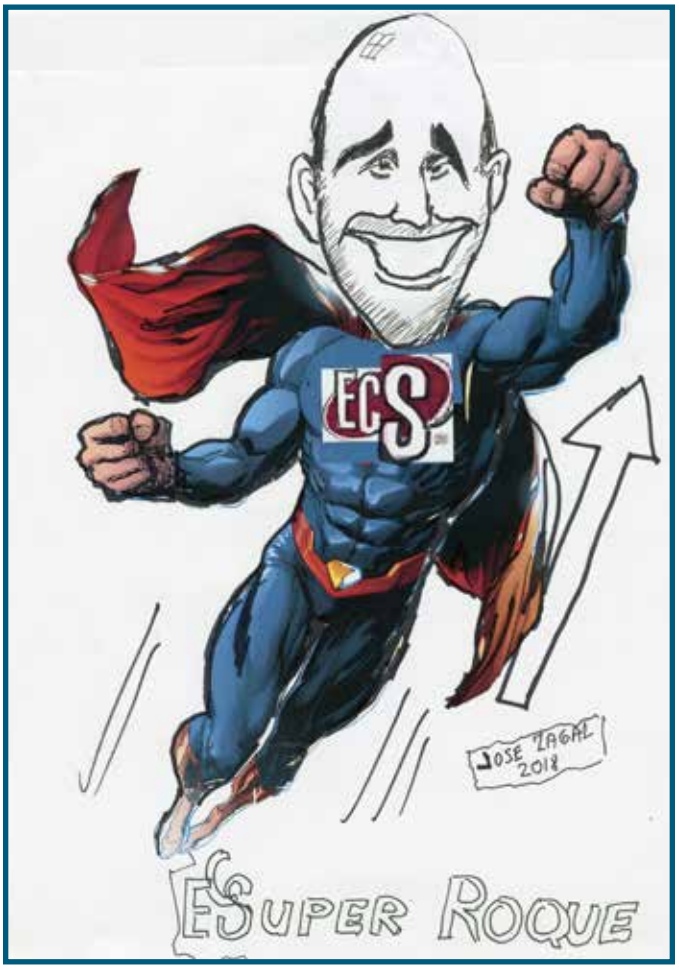
AIP Publishing

Dear Roque

We express sincere congratulations on your retirement, and our deep gratitude for your excellent achievements in building good relations between the ECS and the ECSJ, especially for the successful establishment of the joint meetings and PRiME!

- on behalf of all ECSJ members

The Electrochemical Society of Japan

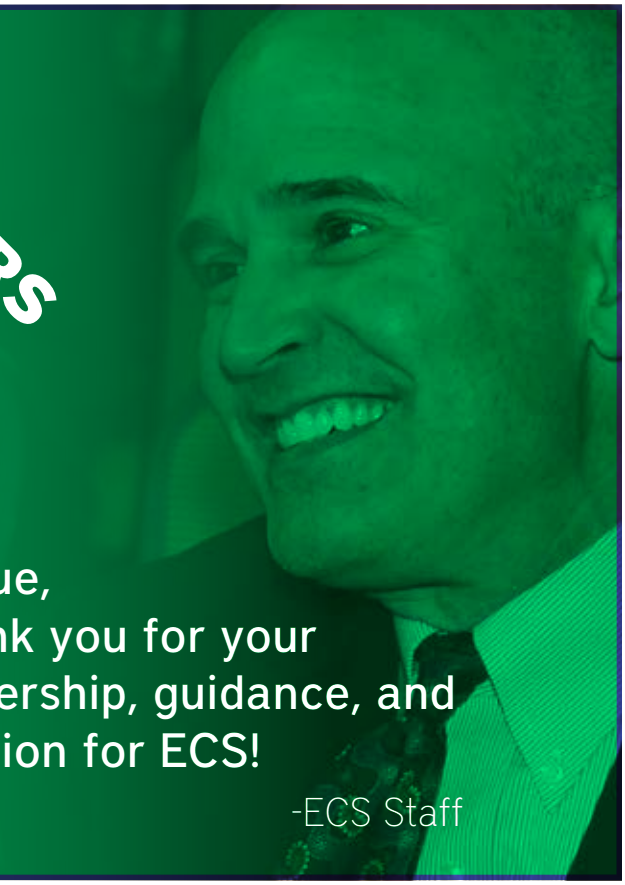


THE KOREAN ELECTROCHEMICAL SOCIETY

Korean Electrochemistry Society (KECS) deeply appreciates Roque Calvo for his 37 years of service and dedication to The Electrochemical Society (ECS) and constant support and contributions to establish KECS-ECS collaborations.

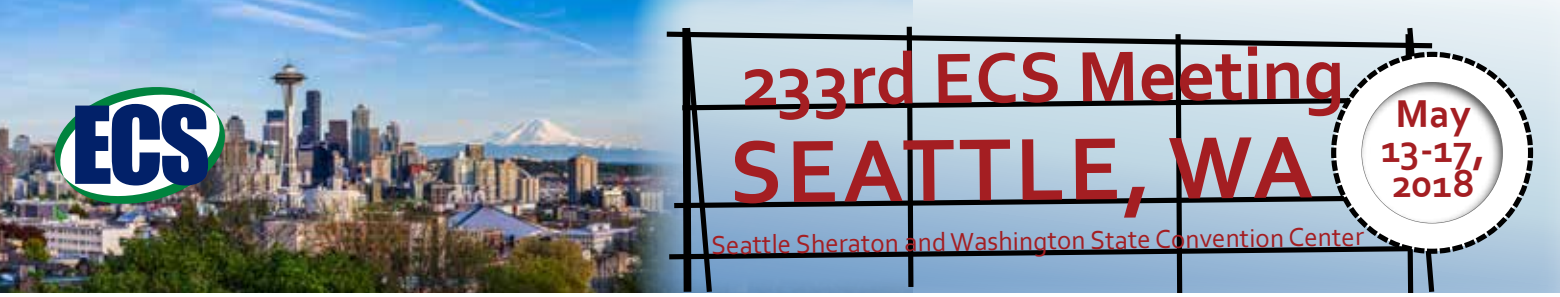
ECS

37 YEARS



Roque,
Thank you for your leadership, guidance, and passion for ECS!

-ECS Staff



Highlights from the 233rd ECS Meeting

Over 2,600 people from 53 countries attended the 233rd ECS Meeting in Seattle, WA, May 13-17, 2018—the largest spring meeting in the Society's history! Participants could choose from 46 symposia, with over 2,000 oral talks and nearly 600 posters, of which almost 700 were student presentations.

Attendees networked while enjoying refreshments at the meeting's opening reception.

ECS Senior Vice President **Yue Kuo** *presented the opening remarks at the 233rd ECS Meeting.*

Opening Reception

A new and improved opening reception kicked off the meeting. Held in a spacious atrium in the Washington State Convention Center, the well-attended Sunday evening social event featured light snacks and an open bar. Visit Seattle personnel were in attendance to provide attendees information on the city and things to do during their stay. The lively event offered attendees ample opportunity to network.

Plenary Session

ECS Senior Vice President **Yue Kuo** welcomed attendees to the meeting during Monday evening's plenary session, an event that wrapped up the day's technical sessions, honored award winners, and featured the meeting's ECS Lecture.

"It's your attendance at our meetings, being a member of ECS, advocating with your libraries to subscribe to ECS publications, and publishing your work with ECS that allows us to continue to *Free the Science*," Kuo said. "You should be proud as we continue to build a

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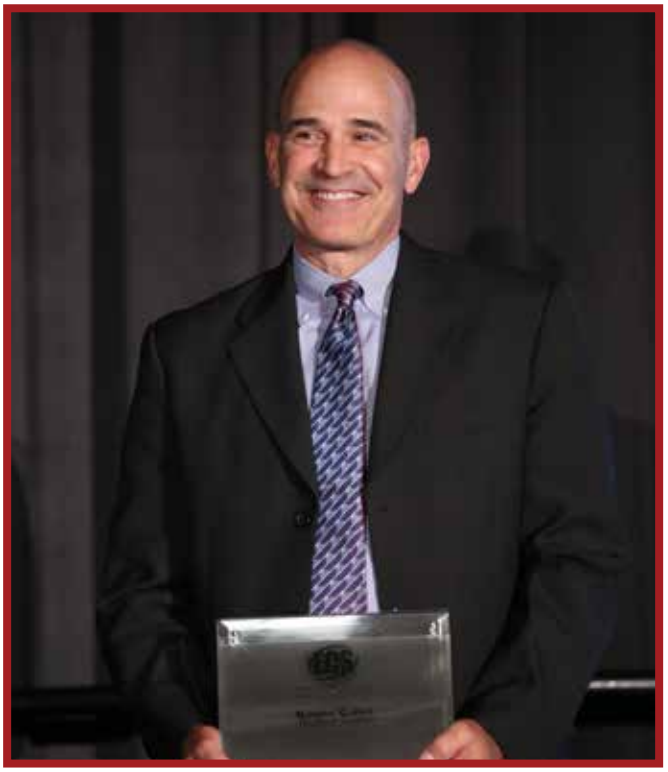

ECS Executive Director and CEO **Roque Calvo** *was granted ECS honorary membership in recognition of all he has done for the Society throughout over 37 years of service.*

rich tradition of open science while supporting the next generation of scientists, ECS meetings, and each other."

During the plenary, Kuo announced the launch of ECSarXiv, the Society's new preprint service, as well as the Amazon Catalyst at ECS program, a new opportunity for ECS members to receive financial support to pursue solutions in health and sustainability.

Before introducing the meeting's ECS Lecture, Kuo took an opportunity to honor the legacy of ECS Executive Director and CEO **Roque Calvo**, who—after over 37 years of service to the Society—is stepping down from his position.

"Roque has served as a steward of the Society for over 37 years," Kuo said, "guiding the Society through tremendous changes while remaining dedicated to its mission to advance electrochemical and solid state science and technology."

Kuo then highlighted some of the most significant accomplishments of Calvo's tenure.

"Roque took the Society from print to digital, created an international audience for our programs and meetings, expanded the ECS Honors & Awards program, and encouraged student participation by instituting student chapters and adding more travel grants and fellowships," Kuo said.

Kuo concluded by announcing the establishment of a new Society travel grant fund for students and early-career scientists and researchers—the Roque Calvo Next Generation Scholarship Fund—and by granting Calvo honorary membership with ECS in recognition of his long-standing devotion to the Society.

The ECS Lecture

Miguel Nicolelis, MD, PhD, delivered the ECS Lecture, "Linking Brains to Machines: From Basic Science to Neurological Neurorehabilitation," to a packed audience Monday evening. Nicolelis is a distinguished professor of neuroscience at Duke University and is the founder of Duke's Center for Neuroengineering. He is founder and scientific director of the Edmond and Lily Safra International Institute for Neuroscience in Natal, Brazil. Nicolelis is also founder of the Walk Again Project, an international consortium of scientists and engineers dedicated to the development of exoskeleton devices to assist severely paralyzed patients in regaining full bodily mobility.

After recounting his early career in John K. Chapin's laboratory, Nicolelis began his fascinating talk with how brain encodes sensory and motor skills in animals and human beings. Some 86 billion brain cells are involved and an understanding of how signals are processed and propagated may have implications in the treatment of many neurological diseases. He showed action potential experiments from surgically implantable devices in the rhesus monkey brain cortex; these electrodes could be left in the brain for years for continued experiments. Such brain/machine interfaces (BMIs) form the basis for discovering a series of key physiological principles that govern the operation of mammalian brain circuits.

Even more intriguing with these BMIs was the demonstration by Nicolelis and coworkers that animals and human subjects can utilize their electrical brain activity to directly control neuroprosthetic devices. He showed videos of monkeys and rats triggering robotic limbs to perform a variety of tasks, although a paraplegic human subject kicking a soccer ball was perhaps the most vivid demonstration of all.

This reporter has covered many plenary talks at ECS meetings and it is no exaggeration to say that this was one of the most compelling and inspirational talks that he had heard in years. This talk provided a fitting start to the technical sessions that followed during the week-long meeting.

Miguel Nicolelis, *the Duke School of Medicine Distinguished Professor of Neuroscience, delivered the ECS Lecture during the plenary session.*

ECS Data Sciences Hack Week

Building on the success of the first ECS Data Sciences Hack Day (October 2017), the Society offered an expanded program at its Seattle meeting. The ECS Data Sciences Hack Week kicked off on Monday and consisted of all-day sessions Wednesday through Friday, as well as optional software training tutorials during the week. These activities culminated with project presentations and an optional clamming expedition—a traditional activity in the Puget Sound area—on Saturday.

Like Hack Day, Hack Week was organized by Daniel Schwartz, David Beck, and Matthew Murbach of the University of Washington. **Daniel Schwartz** is the Boeing-Sutter Professor of Chemical Engineering and director of the Clean Energy Institute at the University of Washington. He brings electrochemistry and modeling expertise to the team. **David Beck** is a senior data scientist with the eSciences Institute at the University of Washington who leads regular

Participants of the ECS Data Sciences Hack Week.

hackathons. He is also the associate director of the NSF Data Intensive Research Enabling CleanTech PhD training program. **Matthew Murbach** is a past president of the ECS University of Washington Student Chapter and an advanced data sciences PhD trainee. He has been leading student section software development sessions on the UW campus and has practical experience coaching electrochemical scientists and engineers in software development.

The goal of the event was to increase the awareness and impact of data science tools, open source software, and shared datasets in electrochemistry and solid state science and technology by bringing together people from different backgrounds to collaborate.

Participants at work during a Hack Week session.

Annual Society Business Meeting and Luncheon

During the Annual Society Business Meeting and Luncheon held on Tuesday, ECS leadership reported on the Society's 2017 successes with a focus on the organization's future.

"Now more than ever," said ECS Senior Vice President Yue Kuo, "you'll want to support ECS by making a donation, renewing your membership, and publishing with us—ideally, open access. These simple contributions allow you to support the next generation of scientists, our meetings, and ECS's initiative to *Free the Science* that aims to make science more open."

David Danielson, *managing director of Breakthrough Energy Ventures, gave a talk during the Annual Society Business Meeting and Luncheon.*

Following the reports, Kuo introduced a speaker—a new addition to the annual event. The speaker was David Danielson, managing director of Breakthrough Energy Ventures, who presented a talk titled "Electrochemistry & the Electrification of Everything in the Era of Low Cost Renewable Energy."

Trip to Microsoft SOFC Powered Data Center

On Thursday a limited number of meeting attendees took part in an excursion to Microsoft's state-of-the-art data center powered by solid oxide fuel cells.

Participants took a tour of the facility and had the opportunity to ask questions about the test center and the SOFC technology involved.

Tickets for this high-demand event sold out quickly.

Award Highlights

Two Society awards were presented during the plenary session.

The ECS Vittorio de Nora Award was presented to **Hariklia (Lili) Deligianni**. Deligianni is a research scientist in IBM's Thomas J. Watson Research Center. Her current research interests include materials and devices for power electronics, bioelectronics, biosensors, and brain-inspired computing.

Deligianni has played a key role developing the solder bump technology that became the standard for the joining of silicon chips to packages. She coinvented copper electrodeposition for on-chip interconnects and was a corecipient of the 2006 Inventor of the Year Award from the New York Intellectual Property Law Association. For these technologies, IBM was recognized with the U.S. National Medal of Technology and Innovation. She has developed an electrodeposition route for the synthesis of solar thin film semiconductors and earth abundant solar materials and has been instrumental in the scale-up of thin film solar energy conversion technologies.

Deligianni holds PhD and MS degrees in chemical engineering from the University of Illinois at Urbana-Champaign and a BS in chemical engineering from Aristotelion University in Thessaloniki, Greece. She has coauthored 58 manuscripts and has 187 patents, with more than 30 patents pending with the United States Patent and Trademark Office. Deligianni is a member of the IBM Academy of Technology and an ECS fellow. In 2012, Deligianni was the first female recipient of the ECS Electrodeposition Division Research Award. She is a past secretary of ECS (2012-2016) and has served as chair of the ECS Education Committee, the ECS Ways and Means

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Hariklia (Lili) Deligianni *(right) received the ECS Vittorio de Nora Award from ECS Senior Vice President* **Yue Kuo** *(left).*

Committee, and the ECS Electrodeposition Division. She is a senior member of the Institute of Electrical and Electronics Engineers and the American Institute of Chemical Engineers and a member of the International Society of Electrochemistry, the American Chemical Society, the Association for Computing Machinery, and the American Association for the Advancement of Science.

The Vittorio de Nora Award was established in 1971 to recognize distinguished contributions to the field of electrochemical engineering and technology.

The ECS Henry B. Linford Award for Distinguished Teaching was presented to **Ralph E. White**. White is a professor of chemical engineering and a distinguished scientist at the University of South Carolina. He graduated from the University of South Carolina with a BS in chemical engineering in 1971. He then attended the University of California at Berkeley and completed his PhD in 1977 under the direction of John Newman.

White began his teaching career at Texas A&M University in 1977. In 1993 he moved to the University of South Carolina, where he served as the chair of the Department of Chemical Engineering for seven years and then as the dean of the College of Engineering and Computing for five years. In 1995 he founded the Center for Electrochemical Engineering.

White has published 338 peer-reviewed journal articles and has graduated 50 PhD and 39 MS students. He is a past treasurer of ECS (1990-1994) and a fellow of ECS, the American Institute of Chemical Engineers, and the American Association for the Advancement of Science. White has received several international awards, including the American Electroplaters and Surface Finishers Society Scientific Achievement Award (2000) for mathematical modeling of the electrodeposition of alloys, the ECS Olin Palladium Award (2013) for contributions to the science of electrochemistry, and the ECS Vittorio de Nora Award (2016) for contributions to the field of electrochemical engineering and technology. He has served as a consultant to several major companies, including Energizer and General Electric.

The Henry B. Linford Award for Distinguished Teaching was established in 1981 to recognize excellence in teaching in subject areas of interest to the Society.

Eight division awards were presented over the course of the meeting.

- The ECS Electronics and Photonics Division Award was presented to **Tae-Yeon Seong** of Korea University.
- The ECS Energy Technology Division Research Award was presented to **Yushan Yan** of the University of Delaware.
- The ECS Energy Technology Division Supramaniam Srinivasan Young Investigator Award was presented to **María Escudero Escribano** of the University of Copenhagen.
- The ECS Energy Technology Division Graduate Student Award sponsored by Bio-Logic was presented to **Deijun Xiong** of Shenzhen Capchem Technology Co., Ltd.

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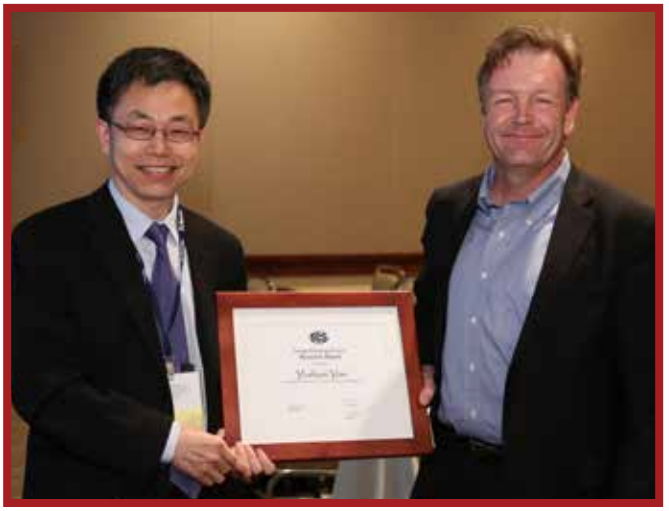
Tae-Yeon Seong, *winner of the ECS Electronics and Photonics Division Award.*

Ralph E. White *(left), recipient of the ECS Henry B. Linford Award for Distinguished Teaching, with his wife,* **Marjorie Nicholson** *(right).*



ECS Energy Technology Division Chair **Andrew Herring** *(right) presented* **Yushan Yan** *(left) with the ECS Energy Technology Division Research Award.*

ECS Energy Technology Division Chair **Andrew Herring** *(left) presented* **María Escudero Escribano** *(right) with the ECS Energy Technology Division Supramaniam Srinivasan Young Investigator Award.*

ECS Industrial Electrochemistry and Electrochemical Engineering Division Chair **Douglas Riemer** *(middle) and division member* **Elizabeth Biddinger** *(left) presented* **Yasser Ashraf Gandomi** *(right) with the ECS Industrial Electrochemistry and Electrochemical Engineering Division Student Achievement Award.*

ECS Energy Technology Division Chair **Andrew Herring** *(middle) and Bio-Logic owner* **Bill Eggers** *(left) presented* **Deijun Xiong** *(right) with the ECS Energy Technology Division Graduate Student Award sponsored by Bio-Logic.*

ECS Nanocarbons Division Chair **Slava V. Rotkin** *(right) presented* **Michael S. Arnold** *(left) with the ECS Nanocarbons Division SES Young Investigator Award.*

Flavio Maran, *winner of the ECS Organic and Biological Electrochemistry Division Manuel M. Baizer Award.*

Soo Kim, *winner of the ECS Industrial Electrochemistry and Electrochemical Engineering Division H. H. Dow Memorial Student Achievement Award.*

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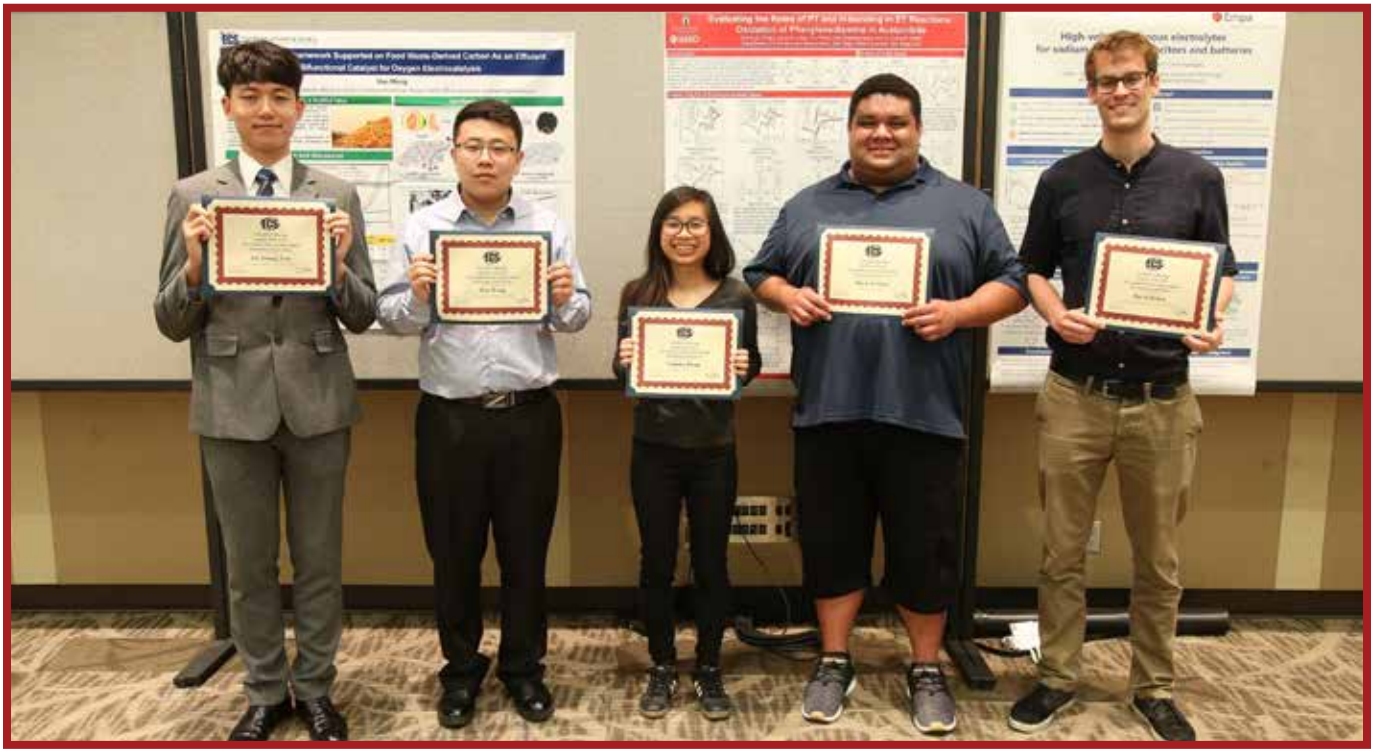
- The ECS Industrial Electrochemistry and Electrochemical Engineering Division H. H. Dow Memorial Student Achievement Award was presented to **Soo Kim** of the Massachusetts Institute of Technology.
- The ECS Industrial Electrochemistry and Electrochemical Engineering Division Student Achievement Award was presented to **Yasser Ashraf Gandomi** of the University of Tennessee, Knoxville.
- The ECS Nanocarbons Division SES Young Investigator Award was presented to **Michael S. Arnold** of the University of Wisconsin-Madison.
- The ECS Organic and Biological Electrochemistry Division Manuel M. Baizer Award was presented to **Flavio Maran** of the University of Padova.

General Student Poster Session

There were 103 posters presented in the General Student Poster Session. The session's award winners are listed below.

- **Mario Cedano**, San Diego State University, "Redox-Responsive Dimerization in a Ferrocene-Ureidopyrimidinone Supramolecular Assembly"
- **Hao Wang**, Beijing University of Chemical Technology, "Metal-Organic Framework Supported on Food Waste-Derived Carbon as an Efficient Bifunctional Catalyst for Oxygen Electrocatalysis"
- **David Reber**, **École Polytechnique Fédérale de Lausanne**, "High-Voltage Aqueous Electrolytes for Sodium-Ion Supercapacitors and Batteries"
- **Jae Young Yoo**, Korea Advanced Institute of Science and Technology, "Comprehensive Analysis of a Tubular, Reversible Solid Oxide Fuel Cell by Using a 3-D Computational Fluid Dynamics Model"
- **Tammy Pham**, San Diego State University, "Evaluating the Roles of Proton Transfer and H-Bonding in the Electron Transfer Reactions of Organic Redox Couples in Non-Aqueous Solvents: Oxidation of Phenylenediamines in the Presence of Pyridine Bases in Acetonitrile"



Winners of the General Student Poster Session (left to right): **Jae Young Yoo**, **Hao Wang**, **Tammy Pham**, **Mario Cedano**, *and* **David Reber**.

The following ECS division members served as student poster judges.

- Battery, Industrial Electrochemistry and Electrochemical Engineering, and Sensor Divisions: **Tissaphern Mirfakhrai**, **Joshua Gallaway**, and **Roseanne Warren**
- Dielectric Science and Technology and Electronics and Photonics Divisions: **Nikolay Dimitrov**, **Douglas Riemer**, **Jan Froitzheim**, and **Paul Gannon**
- Energy Technology Division: **Andrea Bourke**, **Douglas Kushner**, and **Miomir Vukmirovic**
- Corrosion, Electrodeposition, and Physical and Analytical Electrochemistry Divisions: **Iwona Rutkowska**, **Eiji Tada**, and **Sadagopan Krishnan**
- High Temperature Materials, Luminescence and Display Materials, Nanocarbons, and Organic and Biological Electrochemistry Divisions: **Wilson Chiu**, **Mark Allendorf**, **Jeffrey Halpern**, and **Graham Cheek**

ECS thanks the sponsors of the 233rd ECS Meeting, the faculty advisors, and the division members who served as judges for their support of the session.

Sponsors and Exhibitors

Special thanks to the meeting's sponsors and exhibitors, whose support and participation directly contributed to the success of the meeting.

Thank you for developing the tools and equipment driving scientific advancement and for sharing your innovations with the ECS community.

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The New ECS Preprint Service

by Mary Yess

What is a preprint anyway? That has been a recurring question since ECS announced its plans to open a preprint service to support the technical community we serve. Simply put, a preprint is a version of a scholarly or scientific document or other preliminary communication not yet published in a peer-reviewed outlet.

In May, the Society launched the service, called ECSarXiv, and pronounced "ECS archive." At the ECS's spring meeting in Seattle—in the booth, at the info session, and in the halls—the question of what is a preprint was prevalent, and there were many other questions on topics such as discoverability, use, quality, and scooping.

Preprints do not *replace* a journal paper, they *precede* it. Preprints and journal publication work in parallel as a communication system for scientific research. Preprints allow researchers to directly control the dissemination of their work to the community world-wide. Preprints are not formally peer reviewed; so when re-using or citing them, this status should be clearly indicated. In many cases, preprints and journal manuscripts are the same in their basic content. Typically, a preprint is submitted before the manuscript is submitted to a journal.

> ***A preprint is a version of a scholarly or scientific document or other preliminary communication not yet published in a peer-reviewed outlet.***

Are preprints a new phenomenon?

While ECS would love to take credit for the idea of preprints as an innovative way to share content, the idea has been around since 1991. Researchers at the Los Alamos National Laboratory began emailing physics preprints to each other around 1990. Paul Ginsparg then created a central repository that could be accessed from any computer. Today, arXiv.org is a highly-automated electronic archive and distribution system for research articles, home to nearly 1.4 million preprints, and maintained and operated by the Cornell University Library. To date, there are approximately 25 known preprint services across the globe, serving a wide variety of disciplines.[1]

The nature of this first open sharing platform was one of the factors that has led to the open access movement, and since then, many preprint services have been born. ECSarXiv joins 18 other services on a platform developed and hosted by the Center for Open Science (COS).[2]

Submissions

A very important rule for ECSarXiv submissions is that they may not be articles that have already been published in a peer-reviewed journal. All ECSarXiv preprints undergo a screening process to reject content not relevant to the fields ECS covers and/or offensive and/or nonscientific content.[3]

A preprint can offer more freedom of expression. As just one example, for many journals, the short communication article type has strict guidelines for length and formatting. In a preprint, you can extend the introduction, conclusion, and references to provide more context for your work.

Information that is currently difficult to publish (e.g., negative results, results in slide decks, explanations of datasets, etc.) can be submitted. Based upon feedback and/or new data, new versions of a preprint can be presented.

While the scholarly communications ecosystem is rapidly progressing to allow freer communication, some journals are lagging behind in what authors want and need. For example, some journals do not allow a new version to be submitted to a preprint service after that content has been submitted to the journal; and some journals do not allow upload of the copyedited, formatted article. It is very important to always check the policies of individual journals before posting your preprint. ECS does allow preprints to be submitted to our journals, once the preprint has been shaped into a full journal article.[4]

(continued on next page)

A sample preprint.

Enhancing visibility

The fact that most preprints are open access enhances visibility, especially for early-career researchers; and the rapid publication of preprints provides evidence of productivity and accomplishment. Authors can make use of preprint services to develop new collaborations earlier. There also have been instances of journal editors scanning preprint services, seeing posts, and then contacting the authors to submit to their journals.

After a quick moderation process (2-3 business days), preprints are immediately available, allowing funding agencies an early look at research where a journal article might not be ready for months. The US National Institutes of Health encourages investigators to "use interim research products, such as preprints, to speed the dissemination and enhance the rigor of their work."[5] Other agencies are encouraging researchers to submit preprints, for example the UK Wellcome Trust[6] and the US National Science Foundation.

Discoverability and citability

Preprints afford citable documentation of preliminary results of research because they carry a digital object identifier (DOI), which provides a persistent and interoperable link. ECSarXiv provides a choice of citation styles. Most styles (Chicago, MLA, etc.) call for citing the authors(s)' names, the date, the title of the preprint, and the DOI. Be sure to check with the journal where you want to submit for its specific style for citing preprints.

All preprints submitted through the OSF Preprints platform are indexed by Google Scholar (which takes 7-10 days) and SHARE (which only takes minutes). To search Google Scholar for ECSarXiv preprints, enter "https://osf.io/preprints/ecsarxiv *" into the search box. You can replace the * with other search text such as "fuel cells" to refine the search.

To submit or not submit (patent and scooping considerations)

Posting a preprint can help to establish the priority of discoveries because they are date-stamped. In addition, preprints can aid in reproducibility, because preprints can show new, confirmatory, or even contradictory results.

If you plan to file a patent, it's important to understand that patent law is complex as related to publications and public availability. Consequently, authors should always seek legal advice about publishing (in any form), any description of the invention the author desires to patent. That being said, note that authors have complete control over the timing of a preprint release.[7]

Another concern is that a preprint could release information that could have adverse effects on the public at large. In fact, when misinformation is published in a journal, it can be more damaging because journals carry an implied seal of approval from the scientific community. This is a growing issue, not only in preprints, but in journal publishing; and many organizations have measures in place to manage this concern. Nevertheless, preprint services, as well as peer-reviewed journals, will require continued attention from our scientific community.

"Scooping" is another issue, and one that gets a great deal of attention in discussions about preprints. Researchers worry that their ideas and work will be published by others and that they will not receive proper recognition. Postings in most preprint services, like ECSarXiv, however, are date-stamped priority claims, and can actually counter scooping practices. Paul Ginsparg, the founder of arXiv, has contributed to an excellent discussion on scooping.[8]

The current journal system already is challenged by issues of poor quality, irreproducibility, and gaps in peer review; but there is no current evidence that the situation will worsen with preprints. In some cases, preprints can help draw attention to errors, enabling the author to correct them before submitting to a journal. Authors should be aware that a preprint can be flawed, just as a journal paper can be. Researchers work hard to build and maintain excel-

Advisory Board

- Jeff Fergus, Editor, *ECS Transactions*
- Dennis Hess, Editor, *ECS Journal of Solid State Science and Technology*
- Robert G. Kelly, Editor, *Interface*
- Robert Mantz, United States Army Research Office
- Slava Rotkin, Pennsylvania State University
- Robert Savinell, Editor, *Journal of The Electrochemical Society*
- Mary Yess, ECS Chief Content Officer & Publisher
- Beth Craanen, ECS Director of Publications

Submit Meeting Content

Beginning with AiMES (fall 2018), *ECS Transactions* (ECST) will discontinue publishing *standard* issues (or "after meeting" content) for ECS biannual meetings. Instead, ECS encourages presenters to submit this content to ECSarXiv. Although *enhanced* issues (or "before meeting" content) of ECST will remain unchanged, authors submitting to these issues will also be able to submit other types of content from their meeting presentation (such as slideshows, posters, or data) to ECSarXiv. Meeting presenters should check the meeting's call for papers to find out more information about which symposia are publishing content in *ECS Transactions*.

lent reputations in their fields, and they continue these practices when publishing in preprint services.

Choosing a license

Choosing a license can be particularly daunting in the open access environment in which we now live. The appropriate license communicates to others how you will allow others to use your work. ECSarXiv currently allows for a wide variety of licenses, from Creative Commons open access licenses to open source licenses. When submitting a preprint in ECSarXiv, clicking on the "show full text" link (under "choosing a license") will show you the actual license terms of any particular license.

Authors typically choose a Creative Commons (CC) license for preprints, and the CC site has excellent information about these licenses in general, and help in choosing a license.[9]

For those considering attaching software code to their preprint, there are resources that can help with license selection. Check the Free Software Foundation or check the licenses listed as "open source" from the Open Source Initiative.

Researchers looking for the policies of specific journals or funding agencies can make use of two excellent resources. The first is SHERPA Romeo, which can help researchers to find a summary of permissions that are normally given as part of each publisher's copyright transfer agreement. The second is SHERPA Juliet, which enables researchers and librarians to see funders' conditions for open access publication.

Looking ahead

COS develops features and functionality on an ongoing basis for all the preprint services they host. One example of a feature that is coming soon is the integration of hypothes.is. This will allow commenting, providing valuable feedback that can help researchers build a robust article for journal submission. Other development goals include working with technical providers to build additional ways to ensure the discoverability of preprints.

ECS's collaboration with COS to create ECSarXiv helped ECS to take another step in our *Free the Science*[10] initiatives by providing a fast, cost-effective way to provide services and tools for our members to embrace an "open science" way of working. Open science is an umbrella term that supports a broad spectrum of practicing science to enable researchers to collaborate, so that data and other research processes are freely available, and so that others may share and reproduce the research."[11]

ECSarXiv helps us to better serve the community of those working in electrochemistry and solid state science and technology, and ECS will continue to take those kinds of steps to improve the culture of communication within the scholarly community, now and in the future.

A sample preprint.

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2. A full list of all the preprint services on the COS site: https://osf.io/preprints/.
3. The ECSarXiv posting policy: www.electrochem.org/ecsarxiv/#posting.
4. Author instructions for ECS journals, and preprint submissions: https://ecsjournals.msubmit.net/cgi-bin/main.plex.
5. "Reporting Preprints and other Interim Research Products," US National Institutes of Health, https://grants.nih.gov/grants/guide/notice-files/NOT-OD-17-050.html, release date: March 24, 2017.
6. The Wellcome Trust stated, "This change will help us (and those reviewing grant applications) to get a more up-to-date picture of researchers' work." https://wellcome.ac.uk/news/we-now-accept-preprints-grant-applications, release date: January 10, 2017.
7. For more information on patent law, be sure to read the ongoing series published in *Interface*: http://interface.ecsdl.org/content/26/1/41.full.pdf+html, http://interface.ecsdl.org/content/26/2/45.full.pdf+html, http://interface.ecsdl.org/content/26/3/39.full.pdf+html, http://interface.ecsdl.org/content/26/4/57.full.pdf+html, http://interface.ecsdl.org/content/27/1/37.full.pdf+html, and the article in this issue on page 47.
8. "ArXiv founder Paul Ginsparg's thoughts on scooping," http://asapbio.org/preprint-info/preprint-faq#qe-faq-922, downloaded May 22, 2018.
9. The Creative Commons website provides help in selecting a license: https://creativecommons.org/share-your-work/.
10. The *Free the Science* initiative is a broad mission-based initiative launched by ECS in 2014. The goals include working toward full open access for our journals and introducing open science tools and services in support of our constituents, all the while maintaining programmatic and financial sustainability, www.electrochem.org/free-the-science.
11. A diagram of open science and all its branches can be found on the FOSTER e-learning platform, www.fosteropenscience.eu/foster-taxonomy/open-science-definition, downloaded May 22, 2018.

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https://osf.io/eznd3/

New *Interface* Editor: Robert G. Kelly

Robert G. Kelly has been appointed by the ECS Board of Directors as the new editor of *Interface* for a four-year term. Kelly has demonstrated tremendous commitment to the Society over the years—as a division chair, a symposium organizer, and a prominent member of several standing committees. ECS is extremely pleased to welcome him to the position.

Kelly has been conducting research in electrochemical science and engineering for the past 35 years. After completing his PhD studies at Johns Hopkins University (1989), he spent 2 years at the Corrosion and Protection Centre at the University of Manchester (UK) as a Fulbright Scholar and an NSF/NATO postdoctoral fellow. He joined the faculty of the University of Virginia in 1990.

His past work has included studies of lithium/iodine batteries, the corrosion of metals and alloys in marine environments, nonaqueous and mixed solvents, as well as stress-corrosion cracking and other forms of localized corrosion. His present work includes studies of the electrochemical and chemical conditions inside localized corrosion sites in various alloy systems, corrosion in aging aircraft, development of embeddable corrosion microinstruments, microfabrication methods to probe the fundamentals of localized corrosion, and multi-scale modeling of corrosion processes.

Kelly is the codirector of the Center for Electrochemical Science and Engineering at UVA. He was the 2001 recipient of the Robert T. Foley Award from the ECS National Capital Section. In 2010 Kelly was named an ECS fellow, and in 2016 he was awarded the H. H. Uhlig Award of the ECS Corrosion Division. He is also a fellow of NACE International. In 2013 he was awarded the AT&T Professorship. Kelly has won several teaching awards while at UVA, including an All-University Teaching Award in 2004. He has rendered technical assistance to the NRC and DOE concerning the Yucca Mountain Project, the USAF Aging Aircraft Program, the NASA Safety and Engineering Center, and the 9/11 Pentagon Memorial design team. ■

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Five Questions with *Interface* Editor Robert G. Kelly

What excites you about taking on the role of *Interface* editor?

I still remember the pride I felt at the founding of *Interface* when I was a student member. On one hand, it was like a Christmas catalog with the advertisements showing the latest and greatest toys. On the other, it filled an important gap that I did not realize existed: a need to allow members to learn across and outside their technical divisions, whereas the *Journal of The Electrochemical Society* kept everyone at the forefront of their field. I found that the selection of topics and the outstanding authors in *Interface* provided me with enough education about a technical area that I could envision its connections to my own work. Its charter to encourage member participation in the entire range of ECS activities, from conference attendance to student chapters, to award nominations, to publications opened up a range of possibilities. Its focus on reaching across the technical divisions to spur collaborative thinking has been ahead of its time, as has its drawing in of highlights from areas of science outside the standard electrochemical ones. In addition, the older I get, the more history means to me, so I believe *Interface*'s role as the official record of the Society needs to be preserved. Finally, I have long been an advocate of the Society increasing its outreach to the wider scientific community as well as the general public. I am excited to be a part of the exploration of that opportunity.

What role has ECS played in your career up until this point in time?

I joined ECS in 1982 while an undergraduate working for Pat Moran. Since that time, ECS has been my technical home. My first technical interactions with ECS were through the Battery Division, in whose symposia I gave my first technical presentations. I migrated to the Corrosion Division during my PhD work. Since that time, I have attended an ECS meeting virtually every year, helping to organize symposia, chairing numerous sessions, as well as giving talks. The majority of my publications are in ECS vehicles, from the *Journal of The Electrochemical Society* to ECS Proceedings Volumes, to *ECS Transactions*, and even *Interface*. I also served in all of the offices of the Corrosion Division Executive Committee and several other ECS committees (e.g., Audit, Finance, Meetings, Honors and Awards). I look forward to every ECS meeting not only for the technical interactions, but also as a place where I can catch up with friends and colleagues from all over the world. In trying to pass on the wonderful experiences that I have had with ECS, I assisted students in founding the ECS University of Virginia Student Chapter, which has allowed them to participate in a range of career-enhancing activities.

How might *Interface* play a role in promoting open science?

One of the main objectives of ECS is the dissemination of knowledge. *Free the Science* is the flagship initiative of ECS for dissemination of *technical* information via the journals. I believe that *Interface* can be the megaphone for *Free the Science* to ECS members, in particular in explaining its motivation, the progress being made, and the outlook for the future. In addition, *Interface* can expand its role as a means for broad dissemination of electrochemistry and solid state science information in a very accessible format to scientists and engineers in other fields as well as the general public. At a time when the value and reliability of science is under siege, *Interface* can be a means of connecting the general public to the important work ECS members do and how that work has impacted them, does impact them, and will impact them in the future.

What do you see as the untapped opportunities of *Interface*?

Interface has been a great ambassador for ECS, but there is potential for much more. The use of *Interface* for more aggressive outreach to other fields/societies, students, and the general public appears to be an example of a largely untapped opportunity. In addition, I think there is potential to use the magazine more aggressively *within* ECS to make connections across technical divisions. Outreach to leadership of professional societies of high school physics and chemistry teachers may be a means to accomplish the former, whereas the *Interface* Advisory Board and ECS student chapters are two obvious mechanisms by which to accomplish the latter. Last, but certainly not least, the explosion in the capabilities to deliver information electronically via a staggering range of routes represents an incredible opportunity for *Interface*. Exploiting the ever-increasing power of the Internet will allow us to extend the reach of the society dramatically and provide a forum for informal, but important, interactions among people by knocking down barriers of access.

What do you feel is most important for *Interface* readers to know about you?

Most importantly, I understand the jewel that previous editors, ECS staff, and authors have created, and I am committed to doing all I can to make *Interface* a publication that members even more immediately want to open. I also view this opportunity as a fantastic chance to serve ECS, its members, and the wider audience by facilitating connections. Making connections among people is something that gives me a great deal of joy. I will be attentive to my obligation to make sure that the sum of the articles and other entries in *Interface* has balance—among technical divisions, among outreach to ECS members, sponsors, other scientists, as well as the general public. In the spirit of full disclosure, the position will also serve as a means to sneakily address my curiosity about the breadth of the field of electrochemistry. Although I have published in the areas of corrosion, batteries, and electrochemical sensors, there are many times I wish there could be many of me to allow the exploration of all of the technical divisions (I will stipulate that very few people would support the existence of many of me). I feel like the proverbial kid in the candy store. I will have the chance to learn about each of the divisions from the foremost experts in their fields, which sure beats working for a living. ■

Robert G. Kelly may be reached at rgk6y@virginia.edu.

Free the Science Week 2018

#FREE THE SCIENCE™

ECS hosted its second *Free the Science* Week April 2-8, 2018, enabling free, uninhibited access to the entire ECS Digital Library, which by now contains over 141,000 articles and abstracts spanning critical areas of electrochemical and solid state science and technology. The week was characterized by substantial increases—both in digital library visitors and in full-text downloads across all ECS publications.

ECS launched the first *Free the Science* Week in April 2017 in commemoration of the Society's 115th anniversary and in support of its *Free the Science* initiative, a long-term drive toward transformative change in the traditional models of scholarly communication and a future that embraces open science as a means of advancing research and accelerating the development of new solutions in sustainability. The inaugural week saw huge surges in digital library visits and ECS content access.

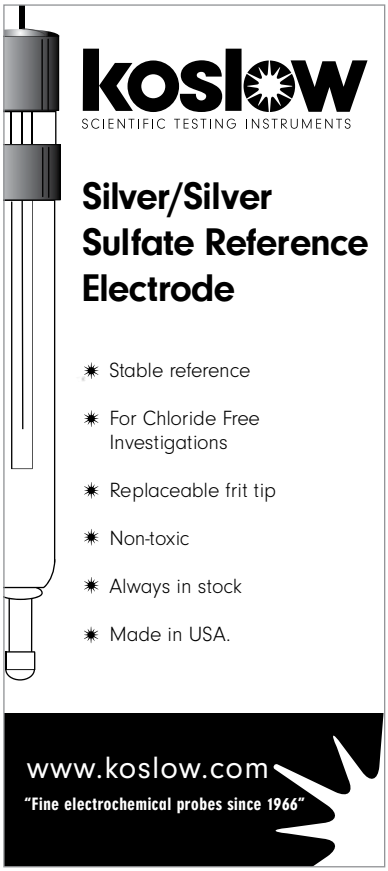
Free the Science Week 2018 elicited a similar response that in some ways even surpassed the success of the first *Free the Science* Week. This year's *Free the Science* Week attracted over 800 more digital library visitors than *Free the Science* Week 2017, as well as a higher percentage of visitors who had never before visited the digital library (2018: 62%, 2017: 49%).

ECS Digital Library™

Nearly all ECS publications saw steeper increases in usage (over their first-quarter monthly averages) in April 2018 than they did in April 2017. The *ECS Journal of Solid State Science and Technology*, which saw a 15% increase in full-text downloads in April 2017, saw a 33% increase in April 2018. *ECS Transactions*, which saw a 47% increase in full-text downloads in April 2017, saw a 64% increase in April 2018—the sharpest increase of any ECS publication during the month.

This year's *Free the Science* Week established April 2018 as the highest usage month of the year to date for ECS publications, both individually and collectively. From a broader perspective, the month marked the second-highest month of April usage, and the fifth-highest month of total usage, since January 2013.

These surges in usage are testaments to the value of open science initiatives and the critical needs in the research sphere they seek to address. *Free the Science* Week, after all, is much more than a week of free paper downloads; it is a celebration of open science and a commitment to the changing of a culture that bars far too many from the keys to innovation. ■



Associate Editor Venkat Srinivasan Reappointed

Venkat Srinivasan has recently been reappointed as an associate editor of the *Journal of The Electrochemical Society* (JES) for a three-year term.

Srinivasan is the director of the Argonne Collaborative Center for Energy Storage Science and the deputy director of the Joint Center for Energy Storage Research. His research focuses upon the development of next-generation batteries for various uses, including vehicle and grid applications. Srinivasan has a strong interest in the design and commercialization of new technologies within the energy storage sector.

Srinivasan has served on the JES Editorial Board since 2013 and specializes in the batteries and energy storage topical interest area. ■

Focus on Focus Issues

ECS publishes focus issues of the *Journal of The Electrochemical Society* and the *ECS Journal of Solid State Science and Technology* that highlight scientific and technological areas of current interest and future promise. These issues are handled by a prestigious group of ECS technical editors and guest editors, and all submissions undergo the same rigorous peer review as papers in the regular issues. As begun in 2017, all focus issue papers are *open access* at no cost to the authors. ECS waives the article processing charge for all authors of focus issue papers as part of the Society's ongoing *Free the Science* initiative.

The following focus issues are currently in production with many papers already published in the ECS Digital Library (http://ecsdl.org):

- **JES Focus Issue on Proton Exchange Membrane Fuel Cell Durability.** [JES **165**(6) 2018] Thomas Fuller, JES technical editor; Jean St-Pierre, Deborah Myers, and Rodney Borup, guest editors.
- **JES Focus Issue on Ubiquitious Sensors and Systems for IoT.** [JES **165**(8) 2018] Rangachary Mukundan, JES technical editor; Ajit Kholsa, Praveen Kuman Sekhar, Peter Hesketh, Charles Henry, and Luca Magagnin, guest editors.
- **JES Focus Issue on the Brain and Electrochemistry Honoring R. Mark Wightman and Christian Amatore.** [JES **165**(12) 2018] Janine Mauzeroll, JES technical editor; Lili Deligianni, Michael Wolfson, Nick Langhals and Mekki Bayachou, guest editors.
- **JSS Focus Issue on Semiconductor-Based Sensors for Application to Vapors, Chemicals, Biological Species, and Medical Diagnosis.** [JSS **7**(7) 2018] Fan Ren, JSS technical editor; Yu-Lin Wang, Ajit Khosla, Rangachary Mukundan, and Toshiya Sakata, guest editors.

The following focus issues are open for submissions. Manuscripts may be submitted at http://ecsjournals.msubmit.net:

- **JES Focus Issue on Electrocatalysis—In Honor of Radoslav Adzic.** [JES **165**(15) 2018] David Cliffel and Thomas Fuller, JES technical editors; Minhua Shao, guest editor.
- **JES Focus Issue on Advances in Electrochemical Processes for Interconnect Fabrication in Integrated Circuits.** [JES **166**(1) 2019] Charles Hussey, JES technical editor; Rohan Akolkar and Peter Broekmann, guest editors.

To see the calls for papers for upcoming focus issues, for links to the published issues, or if you would like to propose a future focus issue, visit www.electrochem.org/focusissues

Results of the 2018 Election of Officers and Slate of Officers for 2019

The ECS Tellers of Election have announced the results of the 2018 society election with the following persons elected: president—Yue Kuo, Texas A&M University; vice president—Eric Wachsman, University of Maryland; and treasurer—Gessie Brisard, Universite de Sherbrooke. The terms of Christina Bock (vice president), Stefan De Gendt (vice president), and James Fenton (secretary) were unaffected by this election.

At the board of directors meeting in Seattle, WA, on May 17, 2018, members voted to approve the slate of candidates recommended by the ECS Nominating Committee. The slate of candidates for the next election of ECS officers, to be held from January to March 2019, include: for president—Christina Bock, and for vice president (one to be elected)—Turgut Gür and Durga Misra. Full biographies and candidate statements will appear in the winter 2018 issue of *Interface*.

Yue Kuo
President

Eric Wachsman
Vice President

Gessie Brisard
Treasurer

2018–2019 ECS Committees

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Yue Kuo, Chair ... *President*, Spring 2019
Christina Bock ... *Senior Vice President*, Spring 2019
Stefan De Gendt ... *Second Vice President*, Spring 2019
Eric Wachsman ... *Third Vice President*, Spring 2019
James Fenton ... *Secretary*, Spring 2020
Gessie Brisard ... *Treasurer*, Spring 2022
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Stuart Swirson ... *Nonprofit Financial Professional*, Spring 2019

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Anne Co ... Spring 2019
Enn Lust ... Spring 2019
Kalpathy Sundaram ... Spring 2020
Alice Suroviec ... Spring 2020
Keryn Lian ... Spring 2021
David Hall ... Spring 2021
Vimal Chaitanya ... Spring 2022
Takayuki Homma ... Spring 2022
Daniel Parr ... Spring 2019
Margaret Calhoun ... Spring 2020
James Fenton ... *Secretary*, Spring 2020
William Mustain ... *Chair, Individual Membership Committee*, Spring 2020

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Rohan Akolkar ... Spring 2019
R. Bruce Weisman ... Spring 2019
Vimal Chaitanya ... Spring 2020
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Jean St-Pierre ... Spring 2020
Viola Birss ... Spring 2021
Shelley Minteer ... Spring 2021
Scott Calabrese Barton ... Spring 2021
Junichi Murota ... Spring 2022
Dev Chidambaram ... Spring 2022
Wei Tong ... Spring 2022
Yue Kuo ... *President*, Spring 2019

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M. Neal Golovin ... Spring 2019
R. Bruce Weisman ... Spring 2020
Timothy Paschkewitz ... Spring 2020
Toshiyuki Nohira ... Spring 2021
Chi-Chang Hu ... Spring 2021
Beatriz Molero Sanchez ... Spring 2019
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Jie Xiao ... Spring 2021
Christopher Beasley ... Spring 2021
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Krishnan Rajeshwar ... *Second Immediate Past President*, Spring 2019
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Stefan De Gendt ... *Chair, Publications Subcommittee*, Spring 2019
E. Jennings Taylor ... *Chair, IST Subcommittee*, Spring 2019
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Robert Savinell ... *JES Editor*, 5/17/2020
Jeffrey Fergus ... ECS Transactions *Editor*, 12/31/2020
Robert Kelly ... Interface *Editor*, 12/31/2022
D. Noel Buckley ... Spring 2019
Scott Calabrese Barton ... Spring 2020
Elizabeth Biddinger ... Spring 2020
Christina Roth ... Spring 2021
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Thomas Moffat ... Spring 2020
Thomas Schmidt ... Spring 2021
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Ways and Means Committee

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Nianqianq Wu ... Spring 2019
John Weidner ... Spring 2019
Durga Misra ... Spring 2020
Yaw Obeng ... Spring 2020
Stefan De Gendt ... *Second Vice President*, Spring 2019
Christina Bock ... *Senior Vice President*, Spring 2019

Other Representatives

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New Division Officers

New officers for the spring 2018–spring 2020 term have been elected for the following divisions:

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2018 Leadership Circle Awards

This year ECS is pleased to honor the following organizations with the **Leadership Circle Award** to demonstrate gratitude for their continued partnership with and commitment to the Society.

Gold Level – 25 Years of Membership

- **Central Electrochemical Research Institute.** CSIR-CECRI is a publicly funded organization that strives for scientific excellence and societal benefits. The organization's vision is to become a global R&D platform for innovation in electrochemical science and technology, leading to inclusive development. Its scientists and engineers blend their passion for excellence in science with societal commitments to develop globally competitive and ecologically benign technologies in energy generation and storage, health diagnostics, corrosion mitigation, and material conservation. www.cecri.res.in

Silver Level – 10 Years of Membership

- **Bio-Logic USA/Bio-Logic SAS.** Founded in 1983, Bio-Logic Science Instruments is an international company that designs, manufactures, and distributes a broad range of high performance measurement instruments for electrochemistry, battery testing, fuel cell materials testing, rapid kinetics, and photosynthesis all around the world. Drawing on experience, innovative ideas, core values, and a commitment to quality and reliability, Bio-Logic continues to develop new products with applications and customer usage in mind. www.bio-logic.info

- **DLR-Institut fuer Vernetzte Energiesysteme e. V.** The DLR Institute of Networked Energy Systems in Oldenburg, Germany, develops technologies and concepts for future energy supply based on renewable energy sources. The institute's major challenge is how to form stable and efficient energy systems from weather-dependent decentralized production units. The research for this transformation process follows a D^3 approach (D^3 = decarbonization, decentralization, and digitalization). www.next-energy.de.

Creating Powerful Partnerships

Institutional membership provides organizations in academia, government, and industry the opportunity to support and advance the dissemination of electrochemical and solid state science research. Member organizations are awarded discounts on ECS subscriptions and marketing opportunities, along with access and ECS membership for their employees.

ECS welcomes its newest institutional member, Microsoft Corporation.

Contact Shannon.Reed@electrochem.org to learn more about institutional membership benefits.

Upcoming ECS Sponsored Meetings

In addition to the ECS biannual meetings and ECS satellite conferences, ECS, its divisions, and sections, sponsor meetings and symposia of interest to the technical audience ECS serves. The following is a partial list of upcoming sponsored meetings. Please visit the ECS website (www.electrochem.org/upcoming-meetings/) for a list of all sponsored meetings.

2018

- **1st Conference on 4D Materials and Systems**; August 26-30, 2018; Yamagata, Japan; https://ecs.confex.com/ecs/4dms18/cfp.cgi
- **69th Meeting of the International Society of Electrochemistry**; September 2-7, 2018; Bologna, Italy; http://annual69.ise-online.org/; **ECS–ISE Joint Symposium**: "Theory: From Understanding to Optimization and Prediction"
- **International Conference on Solid State Devices and Materials** (SSDM); September 9-13, 2018; Tokyo, Japan; www.ssdm.jp/index.html
- **III Colombian Congress of Electrochemistry**; October 2-5, 2018; Cali, Colombia; https://sites.google.com/view/cceq2018/
- **7th Baltic Electrochemistry Conference: Finding New Inspiration** (BEChem 2018); November 4-7, 2018; Tartu, Estonia; http://BEChem2018.ut.ee/

To learn more about what an ECS sponsorship could do for your meeting, including information on publishing proceeding volumes for sponsored meetings, or to request an ECS sponsorship of your technical event, please contact ecs@electrochem.org.

ECS-CSE Joint Symposium on Electrochemical Energy & the Environment (ECEE 2017)

Continuing on a partnership begun in 2014, the ECS-CSE Joint Symposium on Electrochemical Energy & the Environment (ECEE 2017) was held in conjunction with the 19th National Meeting of the Chinese Society of Electrochemistry (CSE) at the Shanghai International Convention Center on December 14, 2017. This focus of this national meeting was "Electrochemistry and Sustainable Development" and covered most essential topics of electrochemistry, with more than 2,800 participants attending multiple parallel sessions during the three-day event.

The ECS Organizing Committee assembled 40 internationally renowned experts to speak on the topics of batteries, fuel cells, and CO_2 reduction, all of whom were well received. The ECEE symposium was well attended; especially during the battery-related talks, with many of the sessions drawing standing room crowds. The overall experience was indicative of the success and potential that this joint meeting has to attract a significant portion of the National Meeting participants.

ECS recognizes and thanks all the invited speakers and members of the organizing committee for their efforts to make this symposium a great success. The Society looks forward to continuing this partnership with CSE for many years to come.

ECS Organizing Committee; Boryann Liaw (Chair), Jun Liu (Battery Division), Minhua Shao (Energy Technology Division), and Xingbo Liu (High Temperature Division).

Invited Speakers; Srikanth Gopalan, Jeffrey Fergus, Ting He, S.P. Jiang, Meilin Liu, Xinbo Liu, Yue Qi, Prabhakar Singh, Xin Sun, Shanwen Tao, Enrico Traversa, Xiao-Dong Zhou, Bryan Pivovar, Deryn Chu, Peter Pintauro, Adam Weber, Yushan Yan, Vojislav Stamenkovic, Hui Xu, Mike Perry, Keith Stevenson, Piotr Zelaney, Jean St. Pierre, Thomas F. Fuller, Liming Dai, Sanjeev Mukherjee, Michael Guiver, Kang Xu, Manthiram Arumugam, Xiao-Qing Yang, Gao Liu, Jiguang (Jason) Zhang, Jie Xiao, Daniel T. Schwartz, Jihui Yang, Boryann Liaw, Shirley Meng, Mei Cai, and Donghai Wang.

Pictured are officers of the Chinese Society of Electrochemistry (CSE), recipients of the CSE awards, members of the Chinese Academy of Science and Engineering, and other assorted VIPs.

ECS Collections of *Interface* Articles

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Visit the ECS Digital Library (DL) now to access recently created collections of articles from the following recurring columns in *Interface*:

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- ECS Classics
- Currents
- The Chalkboard
- Websites of Note
- Tech Highlights
- Looking at Patent Law

More collections will be created and more articles will be added as new issues are published and more back issues are put online.

http://interface.ecsdl.org/cgi/collection

XXXII National Congress of the Mexican Society of Electrochemistry and 10th Meeting of the ECS Mexico Section

The XXXII National Congress of the Mexican Society of Electrochemistry (SMEQ) and 10th Meeting of the ECS Mexico Section was held June 5-8, 2017, in Guanajuato, Mexico. The hosts were academics from the University of Guanajuato led by Jose Luis Nava Montes de Oca, president of the organizing committee.

From an attendance perspective, the congress was a success because it elicited the participation of more than 300 attendees—mostly undergraduate, master's, and doctoral students. But it was also successful in regard to the quality of the papers in the oral and poster sessions, which ECS organized by topic. The session topics encompassed all the major areas of electrochemistry. There were more than 400 works in total, as can be seen in the reports, which can be found at www.smeq.org.mx by searching for ISSN 2448-6191, volume 2, number 1. No less important was the publication of a special issue of *ECS Transactions* (volume 84, issue 1, 2018), to which attendants were able to submit their contributions for publication, expanding and complementing the papers they presented at the congress.

The inaugural ceremony was attended by authorities of the University of Guanajuato, the state government, Francisco Javier Rodríguez Gómez, SMEQ president (2015-2017), and Krishnan Rajeshwar from ECS (University of Texas at Arlington), who also gave the inaugural lecture. There were four other international speakers who gave keynote addresses: Lorenzo Fedrizzi, Robert F. Savinell, Enric Brillas, and Guy Denuault.

SMEQ is also a forum for new professionals in electrochemistry who have recently finished their PhDs. Based on their academic achievements, some were selected to give plenary lectures. In 2017, this honor was granted to Juan Edgar Carrera Crespo, Andy Alán Melo López, Andrea Quetzalli Cerdán Pasarán, Raciel Jaimes López, and Gabriela Coria Rodríguez.

On Tuesday, June 6, 2017, a unique activity was carried out—the electrochemical *hand in hand*— with the participation of Norberto Casillas Santana, Jorge G. Ibáñez Cornejo, and Bernardo Frontana Uribe. In front of a fully filled auditorium, in the manner of a bullfight, the researchers challenged themselves with electrochemical experiments. Then they explained basic concepts as well as more complex concepts. The event served as a very funny, original, and entertaining way to bring electrochemistry to students. This successful session was moderated by Francisco Javier Rodríguez.

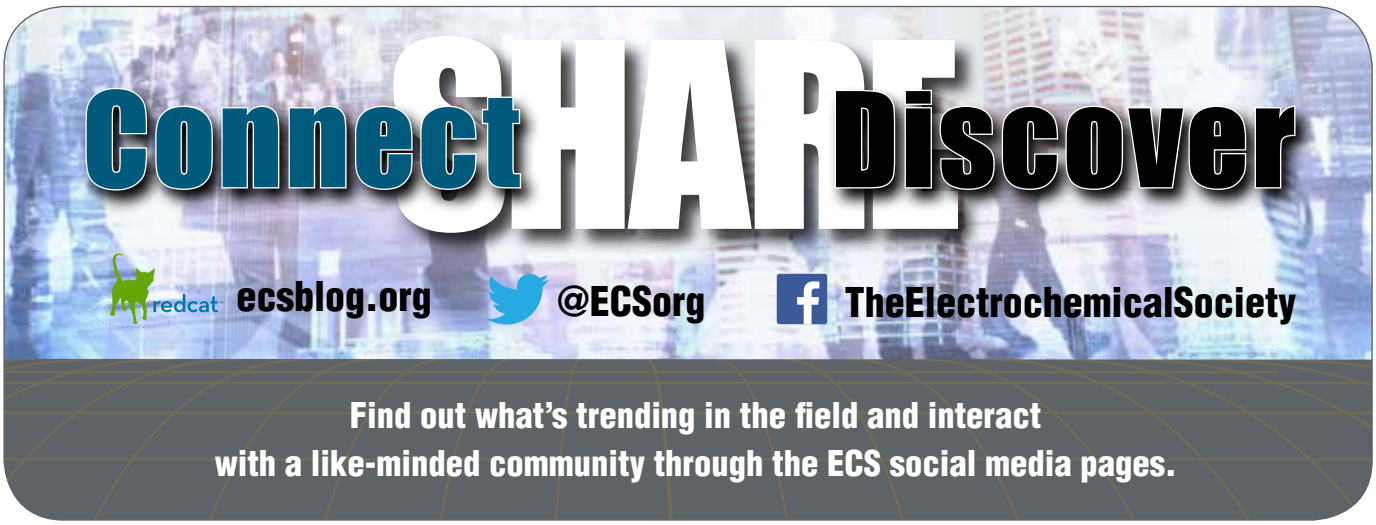
On Wednesday, June 7, 2017, attendees and guests were able to make a half-day visit to the archaeological zone Cañada de la Virgen, which is located near the city of Guanajuato. This archaeological zone is outside the traditional tourist circuit and is less frequently explored despite its abundance of pyramidal buildings.

The last day of the congress, Thursday, June 8, 2017, was very intensive in terms of academic activities. In addition to the lectures and plenary sessions, the poster session was held, featuring the traditional contest organized by SMEQ, which awards prizes by degree (master's/doctorate). The main prize for the best doctorate poster also wins the possibility of being presented at an ECS event thanks to the sponsorship of ECS. This year the winning work was by Miriam Franco Guzmán. It was titled "Study of the Influence on the Electroactive Area of the Nature of the Working Electrode and the Transformed REDOX Molecule." Its coauthors were G. A. Alvarez Romero, L. H. Mendoza Huizar, C. A. Galán Vidal, and G. Roa Morales.

To conclude the congress, the annual assembly of SMEQ was held, in which Francisco Javier Rodríguez passed the title of president of SMEQ to Ricardo Orozco Cruz (Universidad Veracruzana) for the 2017-2019 term. René Antaño López (CIDETEQ) was elected as the new vice president of SMEQ for the 2017-2019 term in accordance with the bylaws.

An emotional moment was the presentation of the 2017 National Electrochemistry Award to Jorge Uruchurtu Chavarín. Uruchurtu was president of SMEQ from 1988 to 1990, as well as president of the organizing committee of the V National Congress of the Mexican Society of Electrochemistry, held in Cuernavaca, Mexico, in 1990. His contributions in the area of corrosion and electrochemical techniques, especially in the use of electrochemical noise, supplement his extensive academic and industrial career of many years. Uruchurtu was part of the team that carried out the Ibero-American Map of Atmospheric Corrosivity (MICAT) project along with other great Ibero-American researchers. Finally, the training of high-level human resources has been one of the most important for the quality of the people who have trained inside and outside the country. Uruchurtu's ever-friendly and cooperative character won him the sympathy of his colleagues, who gave him a standing ovation during the ceremony. He especially thanked his wife and family for the support he has always had.

With the good taste of Uruchurtu's speech of gratitude, the congress closed, inviting the attendees to participate in 2018 in AiMES, an ECS and SMEQ joint international meeting that will be held September 30-October 4, 2018, in Cancun, Mexico.



Advancement News

Longtime ECS Member Paying It Forward

LILI DELIGIANNI

Lili Deligianni was recently awarded the 2018 **ECS Vittorio de Nora Award** for distinguished contributions to the field of electrochemical engineering and technology. Upon receiving this news, she began thinking of ways the $7,500 cash prize could be used to support the larger scientific community. After speaking with the ECS development team, she has chosen to give back the prize money to the ECS Education Fund.

Deligianni had served as chair on the ECS Education Committee in 2008 and again in 2009. Through that experience, she knew that the Education Fund could use the extra support. "I'd like to pay it forward to the new generation of scientists at our Society," Deligianni explains. "As a Society, we have a great number of new and young scientists and I'd like to encourage and help them participate in our community."

Education Committee initiatives include holding student poster awards, creating professional development workshops and short courses at the biannual meetings, and coordinating the summer fellowships. It is also exploring other ways to enhance opportunities for ECS members, especially students and early-career researchers.

As a member of ECS for over 32 years, Deligianni has been invested in the work that the Society has been doing. She has not only volunteered her time and talents to the many activities of ECS, she has served as board secretary (2012-2016), chair of ECS Education and Ways and Means Committees, and chair of the Electrodeposition Division. She began her involvement with ECS as a student and says she has developed lifelong friendships and professional relationships.

With her contribution, she will now be able to support similar students throughout their careers, as they build their network within the ECS community. The Education Fund enables ECS to support emerging scientists through summer fellowships, student programs, and educational programming at biannual meetings.

Listen to Deligianni talk about her career here.

Sponsored Collection to Honor Jan Talbot

JAN TALBOT

ECS is excited to announce a new sponsored collection to honor past ECS president Jan Talbot. Talbot retired on July 1 and the development team would like to honor ECS's mission by fundraising to open her collection in the ECS Digital Library so that all researchers have access to her papers.

ECS sponsored collections are generously supported by the family, friends, students, and colleagues of ECS authors. Compiling all of an author's articles published in ECS journals, these collections honor the author's significant contributions to their particular field, the Society, and the wider scientific community by aiming to make their research freely accessible. There are currently two other sponsored collections honoring Hugh Isaacs and Glenn Stoner.

Talbot was the chair of the UC San Diego Academic Senate in 2003-2004. She was awarded a UCSD Distinguished Teaching Award for 2010. Talbot has been the director of the Jacobs School's chemical engineering program since 2000 and was associate dean of the Jacobs School of Engineering from 2014-2016. From 1975 to 1981, she worked as a development engineer at Oak Ridge National Laboratory in Tennessee.

Talbot has been a longtime ECS member, served as board vice president (1998-2001), president (2001-2002), and became a fellow in 2004. She was also the editor of *Interface* from 1995 to 1998.

"It amazes me that ECS, its journals, and its meetings were the main venue for my research interests over 30 years, which has spanned applications of corrosion, magnetic recording, semiconductor processing, and solid state lighting," Talbot reflects. Throughout her career she has published a total of 44 papers in ECS journals. "It has truly been my professional home."

Talbot's work includes 38 *Journal of The Electrochemical Society* papers and 6 *ECS Journal of Solid State Science and Technology* papers. Her body of work is focused on electrophoretic deposition, electrodeposition, chemical mechanical polishing, display screen processing, solid state lightning materials, materials science, and electrochemical transport phenomena and engineering.

If you are interested in making a donation to free this collection or getting involved in any way, please contact Development@electrochem.org.

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websites of note

by Alice H. Suroviec

Power Electronics Tutorial

- Tutorialspoint.com is dedicated to providing quality online education in the domains of computer science, information technology, programming languages, and other engineering as well as management subjects. The tutorials are designed for novice readers with a basic knowledge of electronics.
  www.tutorialspoint.com/power_electronics/index.htm

Rotating Disk Theory

- Pine Research provides a detailed theory on rotating disk electrochemistry. The use of forced convection influences the current measured. Proper interpretation of the current signal must accurately account for any contributions from solution convection. Hydrodynamic methods are well suited for steady-state experiments. This website provides an excellent starting place to learn more about these methods.
  www.pineresearch.com/dev/shop/knowledgebase/pine-rotating-electrode-theory/

Memristors

- The development of memristors, the fourth passive component type after resistors, capacitors, and inductors, along with other solid state memory devices, takes us one step further to creating cheap, powerful, distributed solutions for sensing and processing. This website provides a site for those looking for the news, articles, and tutorials on memristors.
  www.memristor.org

About the Author

Alice Suroviec is an associate professor of bioanalytical chemistry and chair of the Department of Chemistry and Biochemistry at Berry College. She earned a BS in chemistry from Allegheny College in 2000. She received her PhD from Virginia Tech in 2005 under the direction of Mark R. Anderson. Her research focuses on enzymatically modified electrodes for use as biosensors. She is currently the chair of the ECS Physical and Analytical Electrochemistry Division and an associate editor for the physical and analytical electrochemistry, electrocatalysis, and photoelectrochemistry topical interest area of the *Journal of The Electrochemical Society*. She may be reached at asuroviec@berry.edu.

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In the NEXT *issue of* INTERFACE

- The fall 2018 issue of *Interface* will be a special issue focused on the theme of **Sonoelectrochemistry**. Guest edited by **Bruno G. Pollet** of the Norwegian University of Science and Technology, the issue will feature the following technical articles (titles are tentative): "Sonoelectrochemistry: A 'Sound' and Promising Technology," by **Bruno G. Pollet**; "Introduction to Ultrasound and Sonochemistry," by **Wu Li** and **Muthupandian Ashokkumar**; "Sonoelectrochemistry: Both a Tool for Investigating Mechanisms and for Accelerating Processes," by **Jean-Yves Hihn**, **Marie-Laure Doche**, **Loic Hallez**, **Abdeslam Et Taouil**, and **Bruno G. Pollet**; "Ultrasonic Agitation for Emerging Electrodeposition Systems," by **S. Roy** and **S. J. Coleman**; and "In Situ Ultrasonic Dispersion in Multiphase Electrolysis Systems," by **Mahito Watanabe** and **Frank Marken** .
- A preview of the **AiMES 2018** meeting including interviews with its leaders and technical cosponsors.
- The next installment of the guest column by **E. J. Taylor** and **Maria Inman** that covers intellectual property and patent issues.
- Recognition of the newest class of ECS fellows, as well as winners of these Society awards: the Charles W. Tobias Young Investigator Award; the Edward Goodrich Acheson Award; the Norman Hackerman Young Author Award; and the Bruce Deal & Andy Grove Young Author Award. Several ECS division award winners and a section award winner will be included as well.

New Content Discovery Feature in the ECS Digital Library

ECS has integrated a new feature into the ECS Digital Library (http://ecsdl.org/) to facilitate the discovery of scholarly content—both within the scope of the Society's publications and beyond it.

How It Works

The new content discovery feature uses collaborative filtering and evolving algorithms to identify and recommend scholarly content of potential interest to readers of ECS articles. The twist? Recommended articles are not limited to those published in ECS publications. The feature also recommends content from the world's leading peer-reviewed journals and research news outlets across a wide breadth of academic disciplines, making it easier than ever for readers to locate the information they need to advance their research.

How It Looks

To use the feature, scroll to the end of an abstract or full-text article in the ECS Digital Library. Beneath the words "May be of interest," you will see a two-column listing of recommended content. The left-hand column displays content from internal sources—ECS publications. The right-hand column displays content from external sources—any of the hundreds of other premium scholarly sites in the service's network.

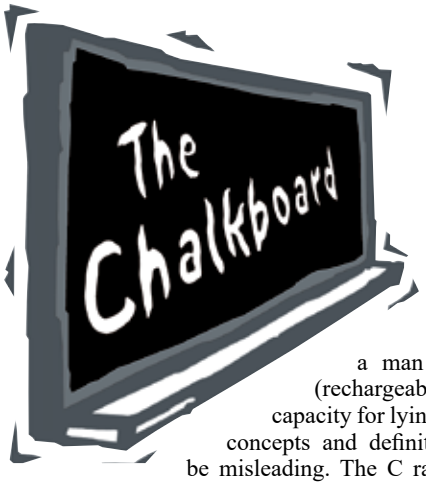
Why It Matters

For readers: The service connects you with relevant articles and developments in your area of study and across academic disciplines, enabling you to expand your knowledge base and further your research.

For authors: The feature promotes ECS content across the hundreds of other scholarly sites in the service's network, exposing your ECS publications to a wider audience and increasing your readership.

For the Society: The service drives the organic expansion of the ECS community. The promotion of ECS content across external platforms will introduce more scholars than ever before to the rigorous, influential work being conducted by the Society's members and constituents.

In sum, ECS's new content discovery feature will profoundly enhance the way leading research in electrochemical and solid state science and technology is discovered and shared across disciplines.



C Rating of Batteries: A Misleading Concept C Flux Rather than C Rate

by Jacob Jorne

In 1908 Thomas Edison said about batteries: "When a man gets on to accumulators (rechargeable batteries) his inherent capacity for lying comes out." A few battery concepts and definitions have been shown to be misleading. The C rating of batteries is such a concept. The C stands for the capacity of a battery usually measured in ampere hours (AH) indicating the amount of active material within the battery available for discharge. Ampere is the measure of a current and gives the number of coulombs per unit time, so current times time gives essentially the amount of charge in coulombs stored within the battery. The C rate measures the rate at which the battery is charged or discharged. If a battery capacity is 10 AH, then if the C rate is 1C, it means that the battery can be charged or discharged at 10 A for 1 hr. C rate of 10C means that the current is 100 A and theoretically can last for 0.1 hr, or 6 minutes. C rate of C/10 means that the current is 1 A and should theoretically last for 10 hours. Thus the C rate indicates the current rather than the current density, which is the current per unit area, usually in A/cm^2. Thus the C rate alone cannot indicate the flux or the current density unless the projected area of the specific battery is given. Electrochemical processes are heterogeneous and must be reported per unit area.

Consider for example the schematics of two batteries with the same C as indicated by the volume or mass of active material. Figure 1 schematically shows two batteries where the volume of each box represents the amount of active material in each electrode, usually expressed in AH. However the two batteries have significantly different cross-sectional area. Battery B has 1/5 the projected front area of battery A. Therefore when both batteries are charged or discharged at the same C rate, the total current is the same, yet the current density of battery B is 5 times larger. Therefore, while battery A operates below its limiting current density, battery B might significantly exceed its limiting current density. Furthermore the internal resistance of each battery is different, and the measured capacity as measured by the time could be significantly different.

Historically the C rate was developed and adopted to compare and evaluate similar batteries, and it is a useful concept for the battery industry, yet it can be manipulated to lead to wrong and sometimes absurd claims. For example, recent publications claim that the lithium-ion battery can be charged at a very high C rate. The implication is that the battery can be charged in a few minutes rather than in hours. The practical claim is that electric cars with lithium-ion batteries can be charged in a service station to near full capacity in a matter of a few minutes. First principles calculations show that the amount of power in watts is enormous and certainly can lead to meltdown. For example, a 10 AH battery charged at 10C will be operated at 100 A for 6 minutes. If the overvoltage is 1 V, then the power is 100 W and cannot be dissipated. Furthermore the current, for example, will exceed the limiting current if the projected area of the battery is 100 cm^2. The reason for these outrageous claims is that the high C rate was applied to batteries with very small capacity per unit area; therefore high current density was maintained for short times and was most likely maintained by the active materials within the electrode where the internal area is high. However in order to maintain the current for longer times, Li^+ ions must be transferred from the cathode to the anode, and this transport is limited by the diffusivity and the available cross-sectional area of the battery.

It is therefore proposed to change the measuring of capacity from C (in AH) to specific C in AH/cm^2. This way the C rate will be changed to C flux, which will indicate the current density rather than the total current. Going back to the first example, if the 10 AH battery has a 100 cm^2 cross-sectional area, then the specific capacity is 0.1 AH/cm^2. Thus charging the battery at 10C means that the current density is 1 A/cm^2 and is definitely exceeding the limiting current density. On the other hand, charging at 0.1C means that the current density is 0.01 A/cm^2, which might be well below the limiting current density.

The need to normalize per unit area is demonstrated below by two practical examples:

Example 1: Commercially available rechargeable Li-ion coin batteries are listed at a capacity of 70 mAH and 110 mAH. For the 70 mAh coin battery, the recommended charge current is 35 mA, and the maximum discharge current is 140 mA. The projected area of these coin batteries is about 3 cm^2; therefore the recommended charge current density is about 10 mA/cm^2. For a battery with C = 70 mAH, at 35 mA, the theoretical charging time is therefore 2 hours. To cut the charging time to let's say 6 minutes, the charge current at 20C should be 1.4 A, corresponding to a current density of 470 mA/cm^2, substantially above the expected diffusional limiting current density.

Example 2: Tesla, the electric car company, claims to charge its Li-ion batteries at a rate of up to 4C. The battery module, which contains 7104 single Li-ion cells, exhibits 310 KW power and 85 KWH energy. Therefore, each single cell has a capacity of about 3 AH. The cross-sectional area of each single cell is estimated to be around 100 cm^2. The claimed charge rate of 4C corresponds therefore to a current of 12 A, or roughly to 0.12 A/cm^2, above the expected diffusional limiting current. Increasing the charge rate to 10C will correspond to 0.3 A/cm^2, well above the expected limiting current density. Therefore, with the existing technology, the claims for very high charging rates, on the order of 5 minutes, are questionable, as it might significantly exceed the limiting current density.

Diffusional limiting current can be avoided using an electrolyte where the transference number for Li^+ ion is 1.0. Under this condition, electrical drift satisfies the electrochemical consumption of Li^+ ions. $t_{Li+} = 1$ can be achieved in an electrolyte where the anions are immobile and the Li^+ ions carry 100% of the current. The transference number of the reactive ion should approach unity to avoid diffusion limitation.

Fast charging requires high current densities, 10-100 times that of normal discharge operation. Several battery and automobile companies have recently claimed that fast and ultrafast charging can be achieved within minutes for batteries where the discharge period is 6 hours or more. These claims are debatable, and a way to overcome these limitations is proposed.

There are two limitations to how fast a battery can be charged—thermal heating and mass transfer limitation. Thermal heating occurs because the internal resistance of the battery generates excessive heat, which must be dissipated to the environment. When charging occurs at very high currents, the heat generated within the battery cannot be removed fast enough, and the temperature quickly rises. Mass transfer of Li^+ ions during fast charge results in diffusion limiting current even if the electrodes are made of nanoparticles with high surface area. While the high surface area allows sufficient rate of lithiation or de-lithiation, the Li^+ diffusion through the cross-sectional area of the electrolyte within the separator is limited. It is quite possible to fast-charge for a limited time restricted to the Li^+ ions already presented in the electrolyte within the electrode. This

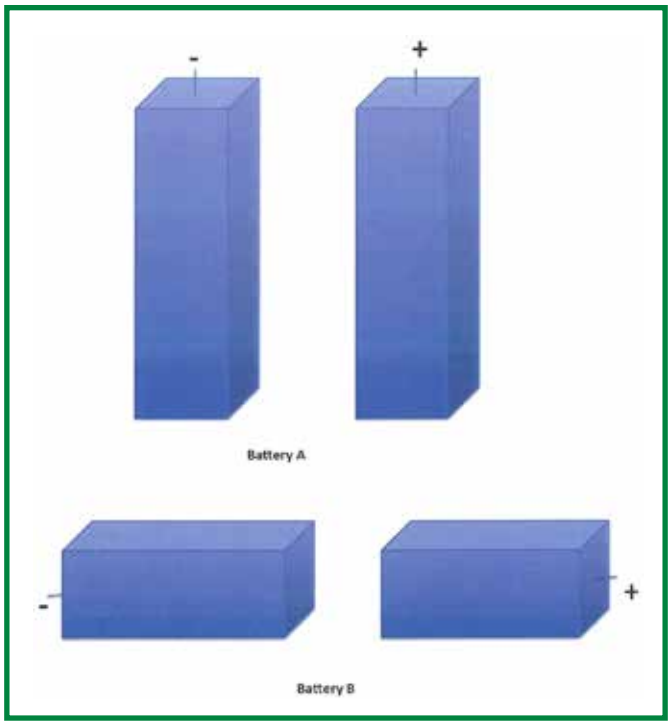


Fig. 1. *Schematic comparison of two batteries, A and B, with the same capacity C but with two different cross-sectional areas A: $C_A = C_B$, $A_A > A_B$.*

unsteady state diffusion can last until the Li^+ ions are depleted and their supply is limited by the cross-sectional area of the battery.

This mass transfer limitation occurs because the transference number of Li^+ is smaller than 1. While Li^+ ions carry a fraction of the current in the electrolyte, they carry 100% of the current at the electrode; thus depletion of Li^+ occurs near the anode, resulting in diffusion limiting current. Any attempt to surpass the limiting current results in solvent decomposition, heating and deterioration of the battery. Since convection is absent within the cell gap, one can overcome diffusion limitation by designing an electrolyte where Li^+ is the only charge carrier, and consequently the transference number of Li^+ is equal to 1. Solid electrolyte where the anions are anchored to the solid matrix is a possibility, like in the case of Nafion solid electrolyte where the sulfate ions are attached to the fluorinated polymer. Yet finding such a solid electrolyte for nonaqueous organic solvent remains a challenge.

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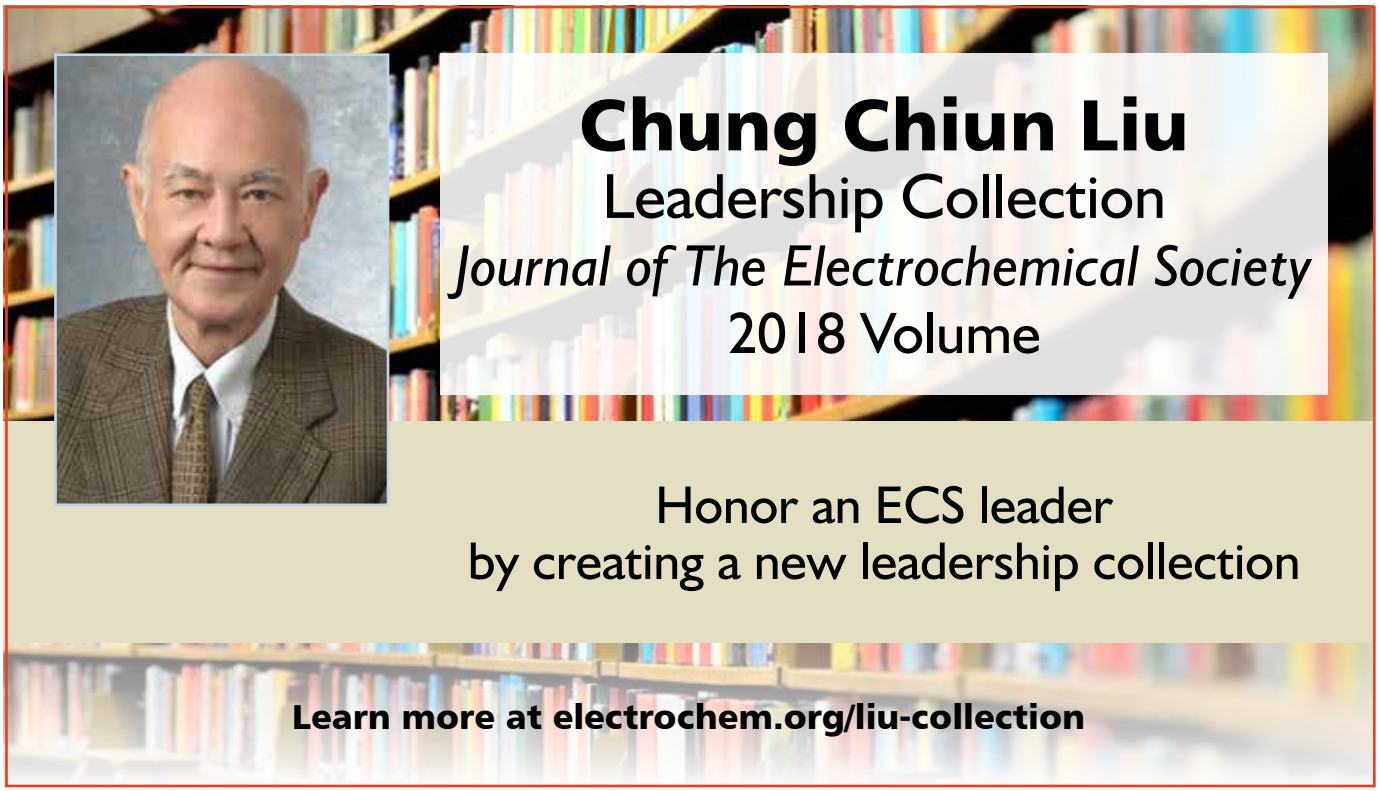
About the Author

Jacob Jorne's research deals with electrochemical energy conversion and storage, hydrogen fuel cells, flow batteries, and lithium-air batteries. Green energy and energy conservation are the themes of his current research and interests. His PhD thesis (University of California Berkeley 1972), entitled "The Electrochemical Behavior of the Alkali Metals in Propylene Carbonate," led to the development of lithium and lithium-ion batteries. He taught at Wayne State University from 1972 to 1982 and joined the University of Rochester in 1982. His group collaborated with General Motors on the development of hydrogen PEM fuel cells for electric vehicles. His group also worked on the research and development of zinc-chlorine flow batteries for the storage of electrical energy. In 1993 he received the Carl Wagner Memorial Award from The Electrochemical Society. He has taught courses in transport phenomena, separation processes, thermodynamics, semiconductors and microelectronics, and electrochemical engineering of batteries and fuel cells. He may be reached at jacob.jorne@rochester.edu.



In Memoriam

Theodore Richard Beck
(1926 – 2017)

Theodore Richard Beck passed away at the age of 91 on May 28, 2017. Beck served as the president of the Society from 1975 to 1976. He was also an ECS fellow and honorary member, who spent over 60 years actively involved in Society affairs.

Beck earned his BS, MS, and PhD degrees in chemical engineering from the University of Washington in 1949, 1950, and 1952, respectively. In 1952 he joined the Jackson Laboratory of DuPont in Deepwater, NJ, as a research engineer in process development. There he conducted pilot plant studies on the manufacture of isocyanates. In 1954 Beck became the group leader of the 10,000A experimental aluminum cell program with the Kaiser Aluminum and Chemical Corporation in Permanente, CA. In 1959 he joined the American Potash and Chemical Corporation in Henderson, NV, as head of the Electrochemical Research Section. Beck joined Boeing's Aerospace Division in 1961 as a research specialist responsible for research in batteries and fuel cells. After he transferred to the Boeing Scientific Research Laboratories in 1965, his research shifted to mechanisms of stress corrosion cracking of metals and streaming current phenomena. Beck began his work with Flow Research, Inc. in 1972, conducting research on pitting, stress corrosion and double layers, the development of electrochemical processes and devices, and consulting. He continued contract research and development within his own company, Electrochemical Technology Corp., from 1975 until 1996, when he closed his laboratory and went into semiretirement. He authored 77 technical papers and received 11 patents.

Throughout his prolific history with ECS, which began in 1954, Beck served as vice chair of the ECS San Francisco Section, chair of the Society's now-defunct Pacific Northwest Section, and secretary, vice chair, and chair of the ECS Council of Sections. He also served as secretary, vice chair, and chair of the ECS Industrial Electrochemistry and Electrochemical Engineering Division and as a Corrosion Division editor for the *Journal of The Electrochemical Society* back when the publication had divisional editors. Beck became the Society's vice president in 1972 and was elected ECS president in 1975.

In 1981 Beck received the Outstanding Achievement Award of the ECS Corrosion Division. The next year, he was named an honorary member of the Society. Beck was awarded the ECS Edward Goodrich Acheson Award in 1990 and became an ECS fellow in 1991.

Beck was active in other societies as well, having served as chair of the Southern Nevada Section of AIChE and the Puget Sound Section of ACS. He was also a fellow of the AIChE, a member of AAAS, ISE, Sigma XI, NACE, and AIC, and a registered professional engineer in the state of Washington.

Beyond the technical domain, Beck served on the boards of the North Cascades Conservation Council, the Seattle Youth Symphony, the Icelandic Club of Greater Seattle, the Nordic Heritage Museum, and the advisory board for the University of Washington's Scandinavian Department.

A 50-year member of the Seattle Mountaineers, he enjoyed traversing the mountains and trails of the Pacific Northwest with his family and friends.

Beck is survived by his wife, Ruth, two daughters, and two grandsons.

Glenn Wherry Cullen
(1931 – 2018)

Glenn Wherry Cullen passed away on January 23, 2018, at the age of 86. Cullen was an honorary member of the Society, an ECS fellow, and a former chair of the ECS Electronics and Photonics Division. In 1982 he received the ECS Electronics and Photonics Division Award.

Cullen earned his PhD in inorganic chemistry from the University of Illinois in 1956. He served as a captain in the U.S. Army, where he also taught electronics. From 1958 to 1999, he worked at RCA Laboratories/Sarnoff Corporation, overseeing the development of materials used in electronic devices. In addition to ECS, Cullen was a member of the American Association for Crystal Growth, the Federation of Materials Society, and the Princeton Officers Society.

Cullen was a multitalented scientist, known particularly for his pioneering work on the deposition of silicon and other semiconductor materials on insulating substrates. At the time of his death, he held 9 patents and was the author or coauthor of 61 publications, including a book, *Heteroepitaxial Semiconductors for Electronic Devices*.

"I remember Glenn as one of the most genial people I ever met, always willing to share his extensive experience and knowledge of electronic materials and processes," says John Blocher, emeritus member and fellow of ECS.

Besides being an excellent scientist and researcher, Cullen was a gifted sculptor who displayed his work in several galleries, including one he cofounded in Kingston, NJ. An Eagle Scout in his youth, he was a fine boatsman, who sailed on Lake Erie near his summer home. For many years, he tutored students at Trenton Central High School, helping them to improve their writing skills.

"Glenn was the first individual that I hired at RCA after I was promoted to group leader," says James A. Amick, ECS emeritus member and fellow. "He was a true gentleman and a fine friend and colleague."

Cullen is survived by his wife, Patricia, and his daughter, Kimberly.

Background information for this notice was contributed by James A. Amick.

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In Memoriam

Irving Shain
(1926 – 2018)

Irving Shain passed away at the age of 92 on March 6, 2018, in Madison, WI. An emeritus member of the Society, Shain served as chair of the ECS Contributing Membership Committee (1988-1990), a standing committee that preceded the ECS Sponsorship Committee in the role of generating institutional members and corporate sponsorship. He introduced the benefactor level of ECS institutional membership and recruited the Olin Corporation as the first company to contribute at that level. In 1988 Shain proved instrumental in securing $30,000 in funding from Olin in support of the ECS Olin Palladium Award, an award the Society continues to bestow.

Born in Seattle, Shain served in the U.S. Army during World War II before earning his PhD in chemistry from the University of Washington. He started teaching at the University of Wisconsin–Madison in 1952. Afterward he served as provost and vice president for academic affairs at his alma mater from 1975 to 1977, the year he returned to UW–Madison as its chancellor. Shain remained chancellor until 1986, when he stepped down and joined the Olin Corporation, where he served as vice president and chief scientist until 1992.

Throughout his career, Shain published highly influential research in the field of electrochemistry. In the late 1950s and early 1960s, new electrochemical experimental protocols abounded thanks to the advent of the Hickling potentiostat, the three-electrode configuration and variations thereof. The dominant protocol to evolve was cyclic voltammetry, and advances were driven by Richard Nicholson and Irving Shain's landmark paper, "Theory of Stationary Electrode Polarography. Single Scan and Cyclic Methods Applied to Reversible, Irreversible, and Kinetic Systems."

"Nicholson and Shain will have their names forever linked because of their collaboration on what must be the most cited paper in the history of the electrochemical literature—the paper that defined cyclic voltammetry: Analytical Chemistry, 36, 706 (1964)," said ECS fellow and honorary member Larry R. Faulkner during a speech at the dedication of the Shain Research Tower. "I did not have to look up the reference. I have known it by heart for decades."

"The paper describes the cyclic voltammetric responses for a variety of fundamental mechanistic examples and does so without burying the reader in a mathematical morass," says Stephen W. Feldberg. "A number of other papers came out of Shain's group at the University of Wisconsin. Now, over 50 years later, the legacy of Irving Shain continues to directly impact electrochemical science in general as well as my own research."

Shain is remembered, nevertheless, for far more than his publications.

"He was a wonderful teacher," says Robert P. Frankenthal, ECS fellow, former president of the Society, and Shain's first graduate student. "He had a way about him. I can't even put it into words."

"I have a somewhat unusual perspective on Irv," says ECS fellow Albert J. Fry, "since as a Wisconsin grad student doing organic chemistry, I took his course on analytic chemistry to satisfy a course requirement. I never thought I'd ever need to know that stuff. After I got my academic position, I began doing electrochemical research and got to know and appreciate Irv in a very different context."

Later in his honorary speech, Faulkner attested that Shain "compiled a truly extraordinary record of achievement over distinct careers in teaching and research on the leading edge of science, in academic administration at the highest level, and in corporate leadership over research and development. Throughout it all, he was known for his courage and superb standards."

"My thanks to Irv for the enlightenment," Feldberg says, "and my condolences to his family."

Shain is survived by four children and three grandchildren.

Background information for this notice was contributed by Robert P. Frankenthal and Stephen W. Feldberg. The photograph of Shain is by Jeff Miller and comes courtesy of Bassam Z. Shakhashiri at UW–Madison.

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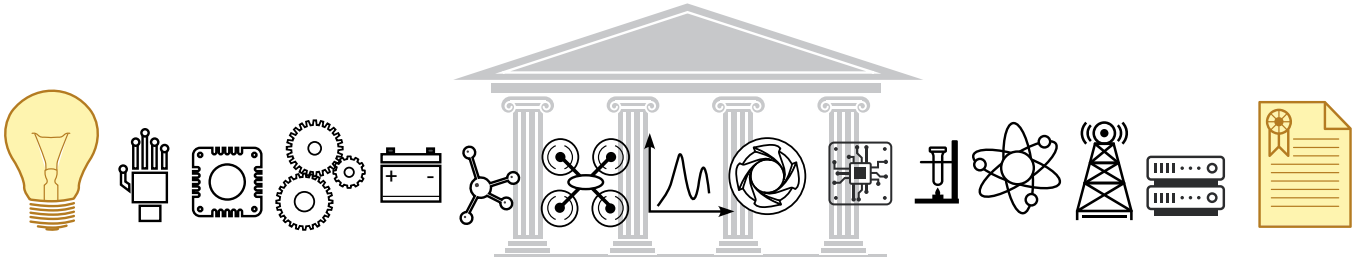
Looking at Patent Law: A Case Study Regarding the Patenting of a Plating Cell Invention *Part II – From Office Actions to Issued U.S. Patents*

by E. Jennings Taylor and Maria Inman



In this two-part article, we present a case study of an electrochemical plating cell invention. Part I of the case study[1] began with the initial concept as described in the Invention Disclosure and highlights key steps in the prosecution of the patent application by the U.S. Patent & Trademark Office (USPTO).

Recall from our previous article,[2] the prosecution history of a patent application is publically available in the file wrapper on the USPTO Patent Application Information Retrieval (PAIR) system and is the basis for this case study.[3] We chose this invention as particularly illustrative of a diverse number of prosecution "events" an inventor may encounter during the prosecution of their inventions. Table I summarizes this journey from the initial documentation and filing of the invention, through various interactions with the USPTO, to the issue of four separate but related patents. Part I concluded with the publication of the patent application eighteen months after filing.

Restriction/Election Requirement Leading to Divisional Patent Applications

On December 1, 2006, the USPTO issued a requirement for "Restriction/Election" for the 10/804,841 patent application in accordance with US patent laws. The "Restriction/Election" basically says that the 10/804,841 patent application contains two or more inventions and the applicant must "elect" which invention to prosecute first:[4]

> ***"If two or more independent and distinct inventions are claimed in one application, … [the USPTO] may require the application to be restricted to one of the inventions."***

The restriction requirement separated the two inventions as those claims directed towards an apparatus and those claims directed towards a process. The "Restriction/Election" requirement stated:

Invention I: Directed towards a distinct apparatus as described in claims 1-20 and 41-43

Invention II: Directed towards a distinct process as described in claims 21-40 and 44-46

As described in the Manual of Patent Examination Practice (MPEP), two inventions are "distinct" if either of the following can be demonstrated:[5]

> ***The process as claimed can be practiced by another materially different apparatus …, or the apparatus as claimed can be used to practice another materially different process.***

We "elected" to prosecute Invention I directed towards an apparatus. The "process claims" that were the subject of Invention II were canceled from the 10/804,841 patent application. We retained the option to prosecute the canceled "process claims" in a subsequently filed "Divisional" patent application provided it was filed prior to the issuance of the original 10/804,841 patent application. As will be described below, we exercised this option in April 2009. This "Divisional" process patent application would have the same "priority date" as that of the "elected" 10/804,841 apparatus patent application and if the 10/804,841 patent application issued as a patent, it cannot be used as a reference against the "Divisional" patent application.[4]

On March 23, 2007, the USPTO issued a "Non-Final Rejection" regarding the "elected" 10/804,841 apparatus patent application. The '841 patent application was rejected based on anticipation[6] and obviousness[7] in light of the prior art. On June 25, 2007, we conducted a telephone interview with the patent examiner in order to better

(continued on next page)

understand the basis for the rejections in lieu of the cited prior art. While telephone interviews can be helpful in clarifying the issue with the examiner, a caution regarding telephone interviews is that a verbal agreement by the examiner does not bind the examiner to the agreement.[8] More specifically, all business with the USPTO should be conducted in writing:[9]

> ***"The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt."***

During the phone call the examiner explained that there was no evidence that the claimed innovations in the apparatus made a difference in the performance of the cell in terms of uniformity, as compared to the prior art. Based on the examiner interview and cumulative information contained in the "Non-Final and Final" rejections of the '841 patent application, we determined that a critical embodiment of our invention that could distinguish us from the prior art was the presence of the porous polymeric cloth (128) in combination with the shaped guides (136) shown in Fig. 1. We needed to perform additional experimental work to demonstrate that this embodiment did positively impact cell performance as compared to the prior art, so we ran tests with and without those embodiments. However, as will be shown below, we did not have time to run these experiments before we received the first Final Rejection of the 10/804,841 patent application. Therefore we had to submit a Request for Continued Examination and file an Affidavit containing the new experimental data.

Table I. Timeline of steps in the subject case study.

Internal Invention Disclosure
Mar 19, 2004: Application filed
Jun 3, 2004: Notice to File Missing Parts
Jul 26, 2004: Submitted Information Disclosure Statement
Apr 4, 2005: Acknowledged federally sponsored research
Sep 25, 2005: Application published
Dec 1, 2006: USPTO required Restriction/Election
Elected Appl. 10/804,841: Apparatus
Elected Div. Appl. 12/431/030: Process
Mar 23, 2007: Non-Final Rejection
Jun 25, 2007: Examiner Phone Interview
Aug 10, 2007: Filed C-I-P Application
Sep 21, 2007: Final Rejection
Jan 22, 2008: Request for Continued Examination
Aug 10, 2007: Filed C-I-P Application
Apr 2, 2008: Non-Final Rejection
Sep 30, 2008: Submitted Affidavit
Jan 8, 2009: Final Rejection
Feb 20, 2009: Amended Claims
Mar 16, 2009: Notice of Allowance
Apr 28, 2009: Application Filed
May 21, 2009: Paid Issue Fee
Jun 30, 2009: 7,553,401 Patent Issued
Aug 20, 2009: Application Published
Sept 10, 2010: Non-Final Rejection & Restriction/Election
Elected C-I-P Appl. 11/836/,903 Apparatus
Elected Div. Appl. 13/086,683: Process
Apr 14, 2011: Application Filed
Sep 11, 2011: Application Published
May 24, 2011: 7,947,161 Patent Issued
Jul 24, 2012: 8,226,804 Patent Issued
Dec 11, 2012: 8,329,006 Patent Issued

Legend

Patent Application 10/804,841: Apparatus
Continuation-in-Part Application 11/836,903: Apparatus
Divisional Patent Application from 10/804,841: 12/431/030: Process
Divisional Patent Application from C-I-P Application 11/836,903: 13/086,683: Process

Submission of Continuation-in-Part Applications Based on Ongoing Research Activities, and Types of Continuing Applications

Soon after the phone call with the examiner, we determined that we had invented a new embodiment related to plating of circuit boards containing through-holes, as a result of on-going plating cell research funded by the National Science Foundation. Based on this new embodiment, we elected to file a Continuation-in-Part patent application. Our "problem-solution" statement for this related invention was:

> ***The problem of …***
> ***electroplating a work piece with small through-holes (z-axis interconnects) through which the plating electrolyte would normally flow too slowly resulting in a poorly plated through-hole***
> ***is solved by …***
> ***generating a differential and alternating plating solution flow velocity on either side of the work piece such that the plating solution is pulled through the through hole, first one side and then the other, by the venturi effect and the combination of prior art elements such as work piece vibration and work piece oscillation leading to an improved plated through-hole.***

In Fig. 2, we illustrate the key elements of our new invention wherein the flow is sequentially alternated from either side of the circuit board creating a differential pressure causing a flow through the z-axis interconnect (through-hole). Since the alternating flow embodiment and the planar workpiece containing through-hole comprised new material compared to our original 10/804,841 patent application, our patent counsel drafted a new patent application and on August 10, 2007, we filed "Continuation-in-Part" (CIP) patent application 11/836,903. The '903 CIP patent application is essentially the same as the 10/804,841 patent application with the exception of the addition of the new material and a new set of claims directed towards the new material. The '903 CIP patent application claims the benefit of the filing date of '841 patent application with respect to patent term, 20 years from filing. However, in terms of prior art, the new material receives the benefit of the filing date of the '903 CIP

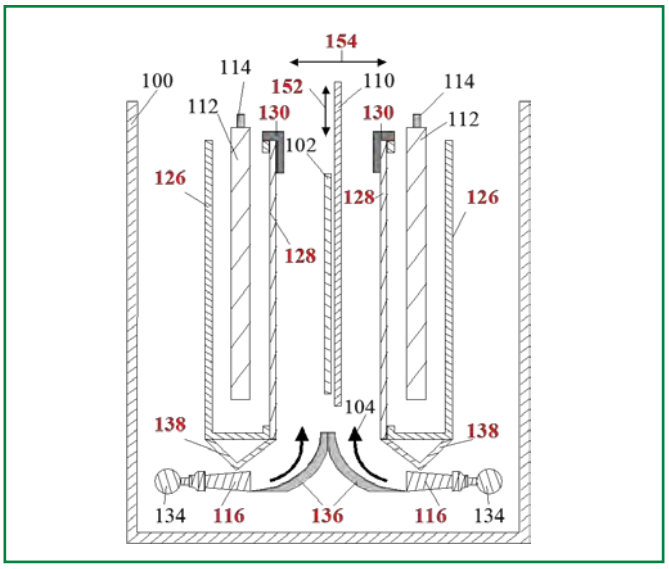


Fig. 1. *Illustration of the subject plating cell invention.*

patent application, not the filing date of the '841 patent application. The '903 patent application was published approximately seven months later on February 14, 2008. Note, the publication is based on eighteen months from the earliest priority date, which for the case of the '903 CIP is the filing date of the '841 patent application. The seven months from filing of the CIP was the time the USPTO needed to get the '903 patent application in a publishable format. On September 30, 2010, the USPTO issued a "Non-Final Rejection" which consisted of a "Restriction/Election" requirement for the '903 CIP patent application for the same reasons as denoted in the original 10/804,841 patent application. Therefore, as will be shown later, we elected to restrict the '903 CIP application to an apparatus patent application, and also file a Divisional process patent application.

Since the new material in the CIP was federally funded, any patents issuing from the 11/836,903 CIP patent application will have the government rights acknowledgement:

> ***"This application was developed under National Science Foundation Small Business Innovative Research Grant No. IIP-0944707."***

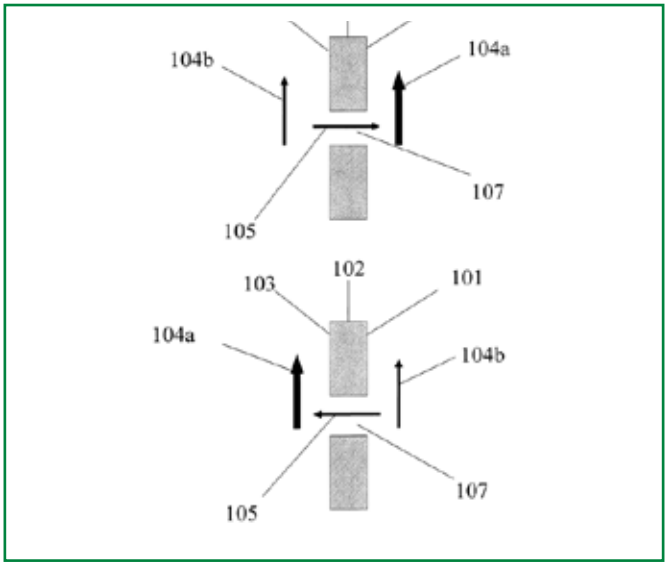


Fig. 2. *Illustration of the subject plating cell invention with alternating electrolyte flow.*

Request for Continued Examination of the Original Application with Affidavits

On September 21, 2007, the USPTO issued a "Final Rejection" regarding the original 10/804,841 patent application. On January 22, 2008, we submitted a "Request for Continued Examination" (RCE) regarding the '841 patent application. A RCE essentially provides another "bite at the apple" after "Final Rejection" of a pending patent application:[10]

> ***"If prosecution in an application is closed, an applicant may request continued examination … by filing a submission and the fee … prior to the earliest of:***
>
> ***1. Payment of the issue fee …***
> ***2. Abandonment of the application, or***
> ***3. The filing of a notice of appeal."***

April 2, 2008, the USPTO issued a "Non-Final Rejection" regarding the 10/804,841 patent application. On September 30, 2008, we submitted an "Affidavit" regarding the '841 patent application. There are generally three types of affidavits which may be submitted during the prosecution of a patent application:

1. Rule 130: To disqualify a disclosure as prior art:[11]
   "[B]y establishing that the disclosure was made by the inventor … [or] by establishing that the subject matter disclosed had … been publically disclosed by the inventor."
2. Rule 131: To disqualify a commonly owned patent or published patent application as prior art:[12]
   "[P]atent owner may submit an oath or declaration to … establish invention of the subject matter of the rejected claim prior to the effective date of the reference or activity … ."
3. Rule 132: To provide evidence to traverse a rejection:[13]
   "When any claim … is rejected … any evidence submitted to traverse the rejection … on a basis not otherwise provided for must be by way of an oath or declaration under this section."

Our "Affidavit" regarding the '841 patent application was a "Rule 132 Affidavit" that presented additional experimental data demonstrating the positive impact on plating uniformity across an 18″ × 24″ panel with the subject combination. The experimental work supporting the "Rule 132 Affidavit" took approximately a year to complete and was conducted by an experienced research scientist who was not an inventor. In our opinion, this illustrates the importance of a team spanning numerous skill sets in order to move technology from concept to patentable invention.

On January 8, 2009, the USPTO issued a "Final Rejection" regarding the 10/804,841 patent application. The Final Rejection was based on that fact that the original claims were not commensurate in scope with the new evidence contained in the Rule 132 Affidavit.

The claims were amended to explicitly point out the subject combination of the porous polymeric cloth (128) and the shaped guides (136) (in Fig. 1) to redefine the boundaries of the "property" covered by the subject invention.[14] Specifically, as described in independent claim 1:[15]

> ***"[A] vertical solution flow that is uniform, parallel to and between the major surface of the workpiece and the parallel porous cloth of the anode chamber."***

On March 16, 2009, the USPTO issued a "Notice of Allowance" regarding the 10/804,841 patent application. We paid the issue fee on May 21, 2009 and the patent issued as US patent number 7,553,401 on June 30, 2009.

(continued on next page)

Table II. Types of continuing patent applications.

Type	Inventor Overlap	Disclosure in Parent	Claimed in Parent	Reason
Divisional	Yes — claim defined	Yes	Yes	Restriction requirement
Continuing	At least one common inventor	Yes	No	Applicant capture unclaimed embodiments
Continuation in Part	At least one common inventor	No	No	Applicant claim improvements after parent filing

Submission of Divisional Applications Based on Restriction/Election

On April 28, 2009, we filed a "Divisional" patent application 12/431,030 claiming priority to the 10/804,841 patent application. Note, a "Divisional" patent application must be filed **prior** to the issue date of the parent 10/804,841 patent application. The 12/431,030 "Divisional" patent application was published August 20, 2009, approximately four months after its filing date. Note, the publication is based on eighteen months from the earliest priority date, which for the case of this "Divisional" is the filing date of the 10/804,841 patent application. The four months from filing of the "Divisional" was the time the USPTO needed to get the 12/431,030 patent application in a publishable format.

Recall that the 10/804,841 patent application issued as US patent 7,553,401 on June 30, 2009, approximately two months **after** the 12/431,030 divisional patent application was filed.

In a general sense, once we overcame the objections of the USPTO examiner with the added supporting data in the "Rule 132 Affidavit", then the CIP and both "Divisional" patent applications issued with similar arguments. As the primary technical argument regarding the original 10/804,841 patent application has been summarized above, we simply provide the timeline related to these continuing patent applications herein.

On April 14, 2011, we filed a "Divisional" patent application 13/086,683 claiming priority to CIP patent application 11/836,903. Note, a "Divisional" patent application must be filed **prior** to the issue date of the parent 11/836,903 patent application. The 13/086,683 "Divisional" patent application was published September 11, 2011, approximately five months after its filing date. Note, the publication is based on eighteen months from the earliest priority date, which for the case of this "Divisional" is the filing date of the 11/836,903 patent application. The five months from filing of the "Divisional" was the time the USPTO needed to get the 13/086,683 patent application in a publishable format.

The 11/836,903 patent application which is a CIP of US patent number 7,553,401, issued as US patent number 7,947,161 on May 24, 2011. The issue date is approximately a month **after** the 13/086,683 Divisional patent application was filed.

The 13/086,683 patent application which is a Divisional of US patent number 7,947,161, issued as US patent number 8,226,804 on July 24, 2012.

The 12/431,030 patent application which is a Divisional of US patent number 7,553,401, issued as US patent number 8,329,006 on December 11, 2012.

Concluding Remarks

In this installment of our "Looking at Patent Law" series, we presented a case study of the conception and patenting of an electrochemical plating cell invention. The case study begins with an "Invention Disclosure" (ID) including the basic items required therein including 1) inventors; 2) title; 3) references; 4) funding source; 5) public disclosure if any; 6) problem-solution statement; and 7) detailed description. We particularly illustrated the value of the problem-solution statement with regards to drafting the patent drawings, detailed description and claims of the invention. We provided examples of patent drawings and their effectiveness in distinguishing the subject invention vis-à-vis the prior art. We described the patent application submission requirements to establish a filing date and the additional submission requirements to maintain the filing date. We introduced the requirement for an "Information Disclosure Statement" (IDS) and the associated "Duty of Candor" in interacting with the USPTO. We touched on the requirement to acknowledge federal funding sources. We discussed the eighteen month publication requirement of patent applications. We illustrated the "Restriction/Election" requirement and the resulting "Divisional" patent applications. We described how on-going research activities can lead to "Continuation-in-Part" (CIP) patent applications. In Table II, we present a description of the types of "continuing" patent applications. We introduced the use of a "Request for Continued Examination" (RCE) and the types of "Affidavits" relevant to prosecution of a patent application. We particularly emphasized the "Rule 132 Affidavit" used in the subject patent application. Finally we provided a timeline (Table III) for the filing and issuing of the patents based on our initial "Invention Disclosure." Our objective is that electrochemical and solid state scientists, engineers, and technologists are better prepared to interact with their patent counsel regarding their inventions.

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About the Authors

E. Jennings Taylor is the founder of Faraday Technology, Inc., a small business focused on developing innovative electrochemical processes and technologies based on pulse and pulse reverse electrolytic principles. Taylor leads Faraday's patent and commercialization strategy and has negotiated numerous via field of use licenses as well as patent sales. In addition to technical publications and presentations,

Table III. Timeline for the filing and issuing of patents based on the subject plating cell invention.

Patent Appl. No.	Filing Date	Patent No.	Issue Date	Type
10/804,841	March 19, 2004	7,553,401	June 30, 2009	
11/836,903	August 10, 2007	7,947,161	May 24, 2011	C-I-P (7,553,401)
12/431,030	April 28, 2009	8,329,006	December 11, 2012	Divisional (7,553,401)
13/086,683	April 14, 2011	8,226,804	July 24, 2012	Divisional (7,947,161)

Taylor is an inventor on 40 patents. Taylor is admitted to practice before the United States Patent & Trademark Office (USPTO) in patent cases as a patent agent (Registration No. 53,676) and is a member of the American Intellectual Property Law Association (AIPLA). Taylor has been a member of ECS for 38 years and is a fellow of ECS. He may be reached at jenningstaylor@faradaytechnology.com.
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Modeling the Viability of Polysulfide-Retaining Barriers for Li-S Batteries

Lithium-sulfur (Li-S) batteries are one of the most promising candidates for future "beyond Li-ion" high capacity energy-storage systems. However, a number of issues still need to be solved before widespread commercialization can occur. Polysulfide shuttle is the main reason why Li-S batteries have low coulombic efficiency and exhibit undesirable self-discharge. Many solutions have been proposed to reduce the effects of polysulfide shuttle such as electrode coatings, the addition of adsorbing inorganic materials and physical barriers in the form of membranes and interlayers. Researchers from the Paul Scherrer Institute have recently presented a model to evaluate the practicability of polysulfide barriers in terms of gravimetric and volumetric energy densities as well as cost. For practical applications comparing different battery chemistries solely in terms of their specific charge and theoretical voltage is not sufficient. The researchers discuss how a fair comparison requires all cell components, which contribute to the weight, volume and cost, to be considered. It is concluded that carbon-based interlayers may be a viable option for low-cost Li-S batteries if the consequential loss of gravimetric and volumetric energy density is acceptable for the particular application.

From: E. J. Berg and S. Trabesinger, J. Electrochem. Soc., ***165**, A5001 (2018).*

Au-Cu Alloys Prepared by Pulse Electrodeposition toward Applications as Movable Micro-Components in Electronic Devices

Au-Cu alloys, having high density, chemical stability, electrical conductivity, ductility, and high yield strength (σ_y) properties, are candidates for movable micro-components in micro-electro-mechanical systems (MEMS) devices. A research team in Japan investigated the micro-compression behavior of micro-pillars fabricated from thick Au-Cu films deposited by pulse current (PC) electrodeposition. The researchers varied the current density and time off (the time on, electrolyte solution composition, and temperature were kept constant) to deposit Au-Cu films in the 4-27% w_{Cu} range. Surface morphology and grain size, d_g, also were characterized as a function of PC conditions. Engineering stress-strain curves revealed high σ_y, 1.36 and 1.38 GPa, for the higher w_{Cu} alloy samples, 21.9 and 14.2 wt%, respectively, than for the lower w_{Cu} micro-pillars. However, the 21.9 wt% sample underwent brittle fracture. The 14.2 wt% micro-pillar had lower d_g of 4.68 nm, resulting in better grain boundary strengthening. Additionally, the relatively high solute concentration imparted greater solid solution strengthening to the alloy, improving σ_y over that of pure Au. The authors conclude that the PC deposition method affords a simple and versatile means of controlling Au-Cu alloys fabricated in MEMS devices.

From: H. Tang, C.-Y. Chen, T.-F. M. Chang, et al., J. Electrochem. Soc., ***165**, D58 (2018).*

Formation Mechanisms of Self-Organized Needles in Porous Silicon-Based Needle-Like Surfaces

Anodization of Si has been employed for creating porous silicon and for electropolishing of Si wafers. For the current-voltage conditions in the transition region between these two processes, needle-like structures are formed in lowly doped p-type Si in aqueous HF solutions. Researchers in Germany investigated in detail and modeled the instabilities in space and time occurring at the surface during anodic etching. Conditions spanned various current densities, wafer resistivity, electrolyte additives and etch times. The researchers found the morphology of the needles and surface had a strong dependence on current density. The clustered needle density and the length of these clustered needles increased with increasing current density. The diameter of and distance between these clustered needles decreased with increasing current density. Needle formation was characterized, and modeled, as a sequence of pore formation followed by resulting irregular islets remaining after adjacent pores widen to the point of contact and additional opening up between them. The authors combine the current burst and Zhang pore formation models to explain this process. Further definition of the needles via etching of the side walls and their adjacent pores is described by the Lehmann macro-pore formation model.

From: S. Keshavarzi, U. Mescheder, and H. Reinecke, J. Electrochem. Soc., ***165**, E108 (2018).*

Influence of the Bitline Length on the Resistance Consistency in Phase Change Memory Array

Nonvolatile memory based on phase change memory (PCM) consumes low power, operates at high speed, and is able to be fabricated with high storage density in conjunction with the complementary metal-oxide semiconductor (CMOS) process. The PCM device writes by passing coordinated electrical pulses to the PCM cells to change between the high-resistivity amorphous phase (Reset) and the low-resistivity crystalline phase (Set). Distinguishable resistances are required for accurate reading. As arrays become larger, effecting appropriate phase change at cells distant from the driving circuit becomes a challenge. Researchers in China investigated the resistance discrepancy amongst 8192 PCM cells (16 groups of 512) on a Bitline. Line resistance was considered the dominant factor amongst others such as parasitic capacitance and distribution capacitance and resistance. To counteract the resulting 40% lower resistance by the Reset operation in the 16th group of 512 PCM cells, a higher current (1.47 mA/100 ns compared to 1 mA/100 ns) was applied. Simulation modeling complemented experiments on the fabricated device that found the farthest PCM cell had been reduced ~30% in volume. Employing this approach, an increase in yield from 90% to 99.9% for the 64 Mb PCM test chip was achieved.

From: Y.-Y. Lu, D.-L. Cai, Y.-F. Chen, et al., ECS J. Solid State Sci. Technol., *7, Q33 (2018).*

Analysis of Near-Surface Metal Contamination by Photoluminescence Measurements

Molybdenum and tungsten contamination has a detrimental performance impact on silicon-based devices due to their low diffusivity values. Even small levels of contamination can affect device performance and thus it is becoming more important to detect any contaminants present early on. Current techniques sample too deep into the material and therefore cannot detect the molybdenum or tungsten contaminants which are located close to the surface. An international team of researchers have developed a new technique based on photoluminescence (PL) to probe a sample's surface for these near-surface metal contaminants. In this technique, a high-power above-gap laser is used to photoexcite the sample to produce PL light. A contaminant close to the surface acts as a recombination center which in turn affects the band-to-band PL intensity and therefore the carrier lifetime; this results in an associated decay due to higher concentrations of contaminants which can then be measured by the PL technique. Contamination in the region of ~10^{10} cm^{-2} contaminant dose has been easily detected using this method which is on par with the sensitivity of other conventional techniques which have extra difficulty probing at or near the surface.

From: M. L. Polignano, A. Galbiati, I. Mica, et al., ECS J. Solid State Sci. Technol., *7, R12 (2018).*

Tech Highlights was prepared by Colm Glynn of Analog Devices International, David McNulty of University College Cork, Ireland, and Donald Pile of Rolled-Ribbon Battery Company. Each article highlighted here is available free online. Go to the online version of Tech Highlights in each issue of Interface, *and click on the article summary to take you to the full-text version of the article.*

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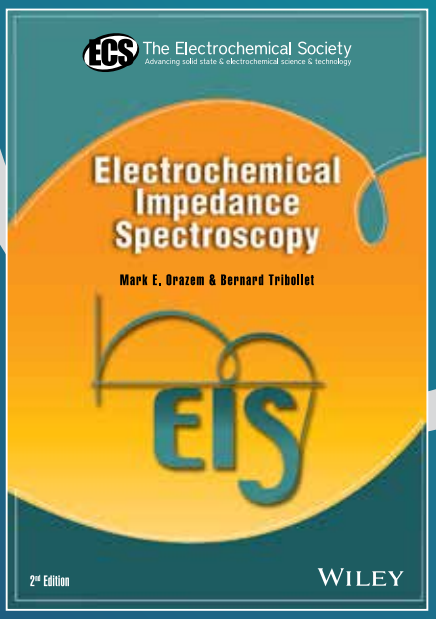

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UPD, SLRR, SEBALD: Abbreviations with Many Connotations

by Stanko R. Brankovic

Electrochemical deposition is a complex phenomenon that spans over different areas of chemistry and kinetics, thermodynamics, mechanics, metallurgy, and material science. It takes place at the solid/liquid and/or liquid/liquid interface, which makes the process somewhat unique and fascinating. Our knowledge in this area has significantly improved over the years, leading to the development of new methods and protocols with unprecedented levels of morphology control, composition, structure, and spatial resolution. Along these lines, in this issue of *Interface*, we focus our attention on several methods and phenomena that have attracted a growing interest in the past decades.

Underpotential deposition (UPD) is an enabling phenomenon that exploits the low energy of the metal ion precursors in solution to control the formation of single atomic layers via self-limiting processes. A monoatomic layer of metal is deposited on a conductive substrate at a potential more positive than the redox potential. UPD has been used to modify catalyst surfaces with metallic sub- or monolayers and as an analytical method to determine surface area. In some instances, UPD monolayers are used to enhance deposition kinetics, either serving as surfactants or as flux mediators. The successive deposition of atomic layers at underpotential forming a surface compound—also called electrochemical atomic layer deposition (EC-ALD)—has found wide application in the layer-by-layer growth of semiconductor superlattices.

Deposition via surface limited redox replacement (SLRR) of UPD monolayer involves UPD monolayer formation, followed by displacement of this layer with a full or partial monolayer of a more noble metal, through a cementation process (galvanic displacement). An analogous process, selective electrodesorption-based atomic layer deposition (SEBALD) consists of the formation of a sacrificial sulfur monolayer to induce UPD of late transition metals such as Fe, Co, and Ni in the form of monolayers or nanosized islands. Both processes are used extensively by practitioners in different areas to synthesize monolayer or nanocluster catalysts and ultrathin films with different compositions and applications.

The articles presented in the following text discuss the fundamentals and potential applications of these deposition methods. The journey starts with description of the fundamental relations between experimental conditions during SLRR of UPD monolayer and the resulting morphology of the deposit. The following article by Dimitrov et al. brings the example and a critical outlook to the thin film growth applications. As a second part of this story, the article by Vasiljevic delivers comprehensive insight into the SLRR of UPD monolayer for various catalyst synthesis applications. The final post in the journey is the article by Innocenti et al. showing an example of SEBALD for growth of high-quality Bi films.

As many researchers in this field have contributed greatly to the magnificent development of these methods, I am sure that interested practitioners can find many other articles in the literature with a wealth of information. Therefore, there is no doubt that new ideas and approaches involving SLRR and SEBALD are being researched, which leaves the guest editor of this issue with a strong impression that the best is yet to come.

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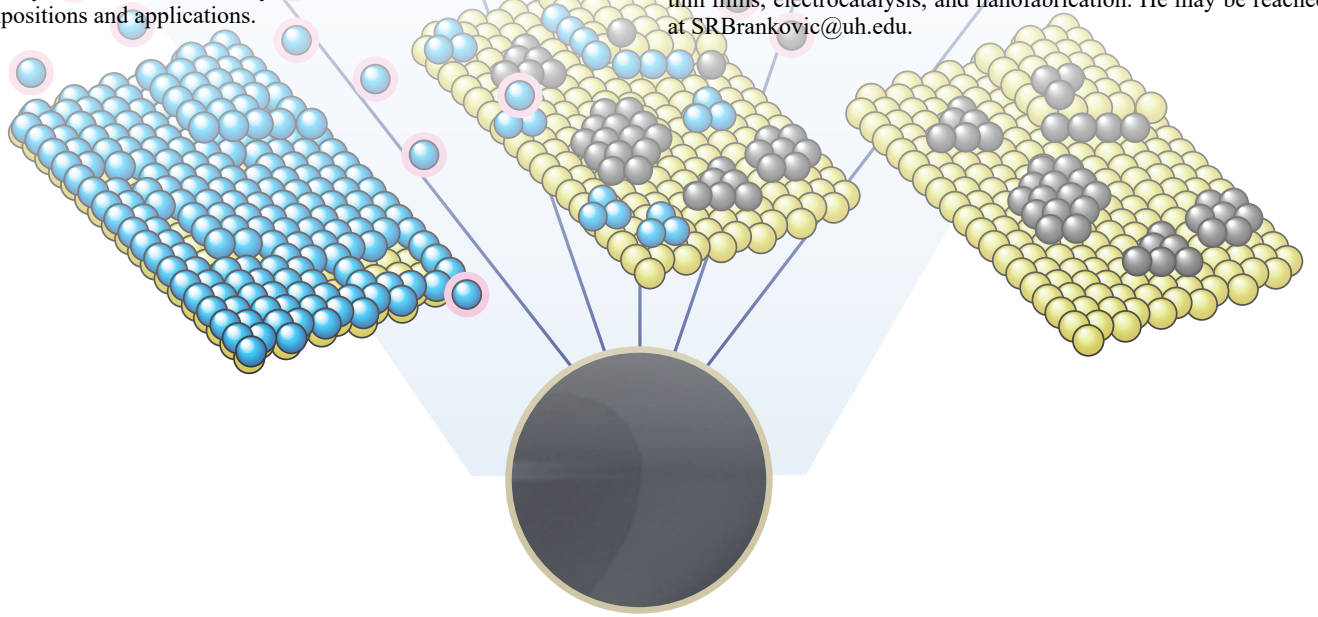
About the Guest Editor

Stanko R. Brankovic is a professor in the Department of Electrical and Computer Engineering and the Department of Chemical and Biomolecular Engineering at the University of Houston. His research is focused towards better understanding of the physical and chemical processes at the electrochemical interface and their use in producing materials and nanostructures with novel functionality and applications. The diverse and multidisciplinary nature of his research spans the areas of sensors, magnetic materials, thin films, electrocatalysis, and nanofabrication. He may be reached at SRBrankovic@uh.edu.



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Fundamentals of Metal Deposition via Surface Limited Redox Replacement of Underpotentially-Deposited Monolayer

by Stanko R. Brankovic

Deposition via surface limited redox replacement (SLRR) of underpotentially-deposited (UPD) monolayer (ML)[1] has gained many applications in the last two decades.[2-4] The caveat of this deposition method is the use of the M UPD ML as sacrificial material to reduce/deposit a more noble metal P (galvanic displacement). Over the years, several experimental protocols have been developed. The first basic protocol[1,5] involves formation of a UPD ML of M on the substrate S(h,k,l) (potential controlled step) and then subsequent immersion of M_{UPD}/S(h,k,l) in a separate solution where SLRR occurs and deposition of P takes place at open circuit (sample shuffling approach). The second protocol involves a similar routine but with a stagnant substrate; the solutions for M UPD ML formation and P deposition are exchanged in a single SLRR cycle[6] (solution shuffling approach). Finally, the latest developed protocol adopts a *one-solution, one-cell* experimental design.[7,8] In this case, the same solution serves for UPD ML formation and subsequent SLRR reaction at opencircuit potential. In a first potential-controlled step, co-deposition of UPD ML of M with small amount of P occurs, then the potential control is turned off (opencircuit step), allowing the SLRR reaction and deposition of P to proceed. The details of these three protocols have been frequently discussed in literature[4,5,9] and examples are presented also in this issue of *Interface*.

In many applications concerned with deposition of only a single monolayer of P or ultra-thin films such as core-shell catalyst synthesis for example[2,3,5] (P = Pt, Ru, Pd), the properties of deposited films are a direct function of their morphology.[10-15] Although the basic role of the UPD ML serving as a reducing agent for noble metal ions can be understood from fundamental electrochemical perception, successful control of the deposit morphology requires deeper insight. Specifically, the SLRR reaction stoichiometry, thermodynamics and kinetics and how these relate to the nucleation process[11,16] on the one hand and the experimental conditions[5,17] on the other. Therefore, identifying and understanding the fundamental relation between the experimental conditions and processes involved in deposition via SLRR reaction is mandatory if one is to claim full control over the deposit morphology. The aim of this article is to convey these relations using commonly adopted terminology and to point to some opportunities for future developments of this method.

Underpotential Deposition—The First Step and Enabling Phenomenon

Many electrochemical systems that include a noble metal electrode in solution with different metal ions exhibit the UPD phenomenon. It is diagnosed by the formation of one or two *wetting* monolayers (MLs) on the electrode surface at potentials that are more positive than the equilibrium potential defined by Nernst equation. In the 1960s and 1970s, extensive studies of many UPD systems were performed on single crystal and polycrystalline electrodes.[18,19] With the development of different in situ surface characterization methods during the 1980s and 1990s, many UPD systems were re-examined in detail, unraveling more information about the UPD process, its mechanisms and diversity.[20,21]

UPD represents a potential dependent adsorption with great sensitivity and selectivity towards the nature of the metal surface and its termination. The characteristic cyclic voltammetry features associated with the UPD process are demonstrated by one or more deposition/stripping peaks in the underpotential region observed during the potential sweep in the cathodic/anodic direction. The complexity of the voltammetry features arises from the existence of one or more UPD ML superstructures[22,23] and/or one or more UPD MLs formed.[24,25] An example of UPD cyclic voltammograms (CVs) is shown in Fig. 1 for two UPD systems commonly used in deposition via SLRR of UPD ML.

Over the years, different analytical models were developed to explain the UPD as a potential dependent adsorption process.[26-29] The adsorption behavior, in the most cases, is determined by the attractive interactions between the UPD metal and the substrate, and the repulsive interactions between the adatoms within the UPD ML. However, the effect of stored elastic energy in the UPD ML due to the epitaxial strain and the energetics of the anion co-adsorption were found to be important as well. In the quest for proper description of the UPD system one usually resorts to the analytical expression which best describes the underpotential vs. coverage relation, i.e., the UPD isotherm. The Burkenstain-Shwatterian (BS) isotherm is the most general one and offers sufficient depth for the interpretation for most UPD systems. It is formulated as follows:[30]

$$\Delta E = \Delta E^{0}_{\theta\to 0} - \frac{RT}{m\cdot F}\cdot\left[\ln\left(\frac{\theta}{1-\theta}\right) + f\theta + g\theta^{3/2}\right] \qquad (1)$$

Here the $\Delta E^{0}_{\theta\to 0}$ term represents the underpotential of the most positive stripping peak of the UPD adlayer where its coverage approaches zero. The term f is the Temkin parameter describing the attractive UPD ML-substrate interactions. The term g is the Frumkin parameter representing the lateral adatom interactions within the UPD ML. Examples of fits of the BS isotherm to θ vs. ΔE data for the two UPD systems in Fig. 1A are shown in Fig. 1B.

Stoichiometry of the Surface Limited Redox Replacement Reaction

The UPD ML coverage can be controlled effectively down to a fraction of a monolayer by proper choice of an underpotential (Fig. 1B). Accordingly, the same accuracy, for the coverage of metal P deposited via SLRR of the UPD M ML is expected. The amount/coverage of deposited P is controlled by the reaction stoichiometry, and the structure and coverage of the UPD ML of metal M. The most general formulation of the SLRR reaction is given by the following equation:[16]

$$\left(\theta_M\cdot\rho_M^{UPD}\right)\cdot M^{0}_{UPD}/S(h,k,l) + \left(\theta_M\cdot\rho_M^{UPD}\right)\cdot\left(\frac{m}{p}\right)P^{p+}_{solv} \Rightarrow \left(\theta_M\cdot\rho_M^{UPD}\right)\cdot M^{m+}_{solv} + \left(\theta_M\cdot\rho_M^{UPD}\right)\cdot\left(\frac{m}{p}\right)P^{0}_{s}/S(h,k,l) \qquad (2)$$

Here, m and p are the oxidation states of the UPD metal M and the more noble metal P. They are also the stoichiometry coefficients in the SLRR equation. Factors θ_M, and ρ_M^{UPD} are, respectively, the UPD

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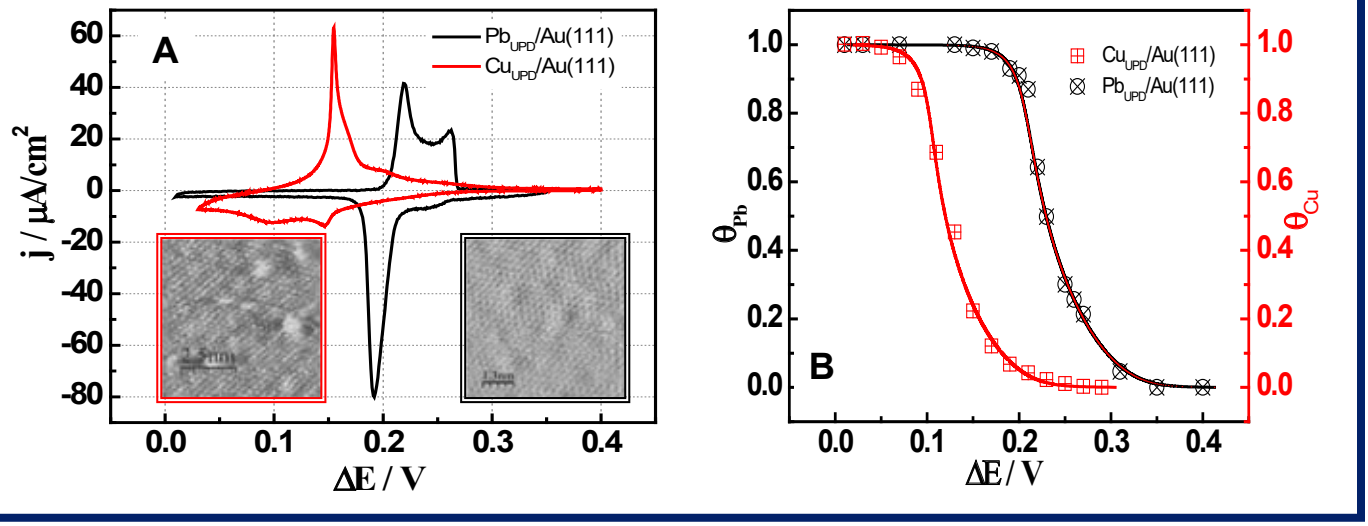

Fig. 1. *(A) Cyclic voltammograms for Pb UPD on Au(111) (black) and Cu UPD on Au(111) (red). Solution: 10^{-3} M Pb^{2+} (Cu^{2+}) + 0.1 M $HClO_4$, sweep rate 10 mV·s^{-1}. Insets show atomic resolution of full Cu UPD layer (red) and full Pb UPD layer (black) on Au(111). (B) Coverage θ versus ΔE dependence for Cu UPD on Au(111), (red) and Pb UPD on Au(111), (black). The coverage is estimated from charge stripping experiments. The full lines represent fits of the BS isotherm model to the coverage data (see text for more details).*

ML coverage and the packing density of M atoms in the full UPD ML with respect to the underlying substrate S(h,k,l). These parameters serve to accurately express the amount of deposited metal P in ML units with respect to the substrate S(h,k,l). In many reports, they are commonly omitted as the authors use consolidated SLRR equation defined only in terms of the stoichiometry coefficients. These presentations generally lack the full information about the expected deposit coverage in a single SLRR cycle. For example, if the metal P forms a 2D-monoatomically thick deposit, one can easily deduce, from Eq. 2, the expected P coverage with respect to the atomic areal density of the substrate. It is defined as:[16]

$$\theta_P = \theta_M \cdot \rho_M^{UPD}\left(\frac{m}{p}\right) \qquad (3)$$

Practitioners should be aware that the overall stoichiometry of the SLRR reaction also depends on specific experimental conditions favoring one over the other oxidation states of the metal M constituting the UPD ML. A typical example is copper which is stable either as the Cu^+ or Cu^{2+} ion. Direct ligand transfer from depositing noble metal ion complexed with halides ($\{PX_n\}^{(p-n)}$, P = Pt, Pd, Ru, X = Cl^-, Br^-…) to dissolving Cu ions could stabilize a $\{CuX_2\}^-$ complex where Cu has the +1 oxidation state.[16] This situation is generally applicable to experiments where the supporting electrolyte in the SLRR solution does not contain anions with complexing/stabilizing ability towards Cu^{2+} such as $\{ClO_4\}^-$ for example. Therefore, one should make sure to know the main complexing ligands at the interface when considering the stoichiometry of the SLRR of Cu UPD ML.

Driving Force for the SLRR Reaction and Nucleation Rate of Depositing Metal

The electrochemical driving force for SLRR reaction between the P^{p+} and M UPD ML is the positive difference between equilibrium potential of the bulk P and equilibrium potential of the M UPD ML at its coverage approaching zero limit, $\theta_{UPD} \rightarrow 0$.[1] This condition is defined as:

$$\Delta E_{SLRR} = \Delta E^0_{EMF} - \Delta E^0_{\theta\to 0} - \frac{RT}{F}\ln\frac{\left[a_{M^{m+}}\right]^m}{\left[a_{P^{p+}}\right]^p} > 0 \qquad (4)$$

Here, ΔE^0_{EMF} $\left(\Delta E^0_{EMF} = E^0_{P^{p+}/P} - E^0_{M^{m+}/M}\right)$ represents the electromotive force for the bulk M and P galvanic couple at standard conditions. The $\Delta E^0_{\theta\to 0}$ is the equilibrium underpotential of M UPD ML at the $\theta_{UPD} \rightarrow 0$ limit (UPD shift) at standard conditions ($a_{M^{m+}} = 1$, $a_{P^{p+}} = 1$, where *a* stand for activity). The logarithmic term provides a correction for the departure from standard conditions. In general, for most systems involving a noble metal ion-UPD metal ML, the condition described by Eq. 4 is always satisfied (Ag and Pd UPD MLs might be the only exceptions). It is important to recognize that ΔE_{SLRR} can be modified by adjusting the activities of M^{m+} and P^{p+} ions in the reaction solution, Eq. 4. Assuming that the ion concentrations are a good approximation for the activity of metal ions, it is a straightforward exercise to show that the nucleation overpotential and nucleation rate (J ~ exp(−*const*/$(\Delta E_{SLRR})^2$))[31]are effectively controlled by the metal ions concentration. Clearly, the link between the experimental

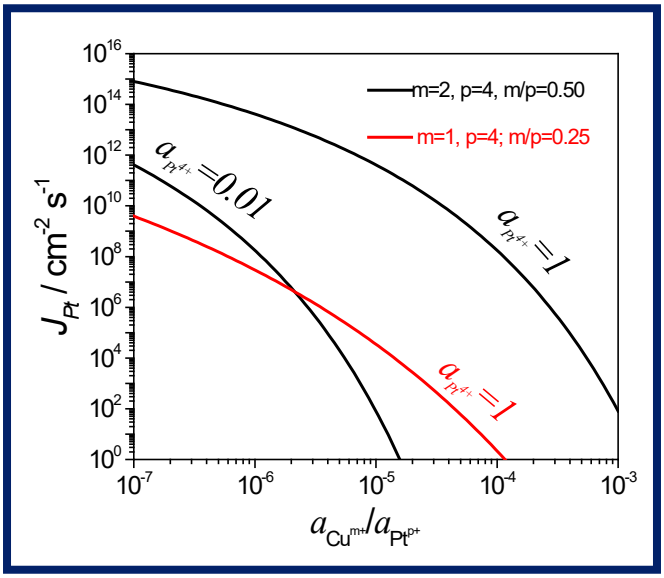

Fig. 2. *Estimates of the Pt nucleation rate versus $a_{Cu^{m+}}$ / $a_{Pt^{4+}}$ ratio. Estimates are made for Pt deposition via SLRR of Cu UPD ML. SLRR reactions:*
$2Cu^0_{UPD} + \{PtCl_6\}^{2-} = Pt^0 + 2Cu^{2+} + 6Cl^-$ (black).
$4Cu^0_{UPD} + \{PtCl_6\}^{2-} + 2Cl^- = 4\{CuCl_2\}^- + Pt^0$ (red).

conditions and nucleation behavior of the system is rooted in the dependence of ΔE_{SLRR} on the SLRR reaction stoichiometry and the metal ion concentrations in the reaction solution.

The special case for ΔE_{SLRR} is when there are no M^{m+} in the reaction solution. Then, the logarithmic term is very large and its contribution dominates the value of ΔE_{SLRR}. This leads to high nucleation rates of P and formation of very small 2D nuclei on the surface. This discussion is qualitatively illustrated in Fig. 2. Using classical nucleation theory,[31] the nucleation rate is approximately calculated for Pt deposition on Au(111) via SLRR of Cu UPD ML. For the two scenarios discussed previously (Cu^{+} vs. Cu^{2+}), the nucleation rate is shown as a function of $a_{Cu^{m+}} / a_{Pt^{4+}}$ ratio. One can see that a change in the experimental conditions leading to a 10× decrease in $a_{Cu^{m+}} / a_{Pt^{4+}}$ produces approximately a 10^3 – 10^5 times higher nucleation rate. A similar effect is achieved by 100× dilution of Pt^{4+} while keeping the same $a_{Cu^{m+}} / a_{Pt^{4+}}$ ratio. It has to be mentioned that the calculations in Fig. 2 are considered only as an illustration of the qualitative trend in nucleation rate induced by the changes in reaction stoichiometry (m/p ratio) and solution design ($a_{Cu^{m+}} / a_{Pt^{4+}}$). The conclusion that one takes from this discussion is that the SLRR reactions with larger m/p ratio and solutions with smaller $a_{M^{m+}} / a_{P^{p+}}$ ratio yield higher nucleation rates and thus a P deposits consisting of smaller clusters.

Reaction Kinetics vs. Nucleation Kinetics

Thermodynamics arguments formulate a correct framework for understanding the trends in deposit morphology dependence on experimental conditions of SLRR. Nevertheless, they are insufficient to elucidate all mechanistic details of the nucleation process. For this reason, other approaches were developed to establish a complete understanding of the phenomena controlling the deposition via SLRR of UPD ML. Following theoretical considerations from nucleation kinetics,[32,33] generalized results from recent work show that the nucleation density of P obtained during SLRR of UPD ML of metal M is well described by the following relation:[11]

$$n_P^{SLRR} = \alpha_0 \left(1 - \chi \cdot \theta_{o,M}\right) \cdot \left(\theta_{o,M}\right)^{N/3} \quad (5)$$

Here, n_P^{SLRR} is given in cm^{-2} units and α_0 is the numerical constant defined as $\alpha_0 = \left[\frac{m}{p} \cdot \frac{\Gamma_M^{UPD} K_{SLRR}}{D_P^S \cdot a^2}\right]^{1/3}$. K_{SLRR} is the SLRR reaction rate constant in s^{-1} units, Γ_M^{UPD} is the surface concentration of the full UPD ML in $mol \cdot cm^{-2}$ units, D_P^S is the surface diffusivity of P adatoms over the substrate S(h,k,l) in $cm^2 \cdot s^{-1}$ and a is the nearest neighbor distance on the surface (cm). The term χ is the numerical constant defined as $1-(n_P)$ where (n_P) stands for the nucleation probability of P on top of the M UPD ML.[11] $\theta_{o,M}$ represents the initial coverage of the UPD ML and the N is the SLRR reaction order in terms of the UPD ML as reactant. Equation 5 only applies for reaction orders where N > 0, i.e., for true SLRR reaction kinetics. When N > 1, the rate constant is defined as follows:[17]

$$K_{SLRR} = (N-1) \cdot k \cdot \left(C_P^{is}\right)^L \cdot \left(\Gamma_M^{UPD}\right)^{N-1} \quad (6)$$

Here, k represents the fundamental rate constant, C_P^{is} is the concentration of P^{p+} at the interface in $mol \cdot cm^{-2}$ units and L is the SLRR reaction order in terms of P^{p+} as reactant. For any practical consideration, C_P^{is} can be expressed as the product of the bulk concentration C_P^{∞}, $(mol \cdot dm^{-3})$ and the interface width $\xi \left(\approx 10^{-7} \text{ cm}, C_P^{is} = C_P^{\infty} \cdot \xi\right)$. For the case N = 1, the rate constant is defined as follows:[17]

$$K_{SLRR} = k\left(C_P^{is}\right)^L \quad (7)$$

The proper determination of the reaction order and rate constant during SLRR of UPD ML is a somewhat challenging task.[17,34]

To a first approximation, the value of N can be taken from the SLRR reaction stoichiometry assuming that it is an elementary red-ox process. However, a more proper methodology for the determination of the SLRR reaction kinetics parameters requires in situ measurements that monitor the UPD ML coverage during the reaction. One way to do this is by measuring the surface reflectivity during SLRR reaction and fitting the obtained data by an appropriate rate equation to extract the rate constant and reaction order.[34] Another way to do this is by measuring the open circuit potential (OCP) during the SLRR reaction.[17] This approach is somewhat easier to implement. It requires the derivation of an analytical model for the dependence of E vs. t during the SLRR reaction to fit the experimental OCP data and extract the parameters of the reaction kinetics.[17] The E versus t models are obtained by combining the appropriate rate equation[35] with a representative UPD adsorption isotherm, such as Eq. 1. Results from such an analysis are shown in Table I below.[36]

Equation 5 represents a bell-shape function whose maximum (n_P^{SLRR} = max) occurs for $\theta_{o,M} = N/(\chi(3+N)$, Fig. 3. n_P^{SLRR} is proportional to α_0. Hence, with proper choice of $\theta_{o,M}$ as well as by careful design of the SLRR reaction and experimental conditions governing α_0, it is possible to control n_P^{SLRR} and achieve the desired average cluster size of the P deposit $\left(\bar{S}_P = \theta_P / n_P^{SLRR} = (m/p) \cdot \theta_{o,M} \cdot \rho_M^{UPD} / n_P^{SLRR}\right)$[10,11].This is of particular importance for the catalysis community where finite size effects are shown to dominate the Pt ML catalyst activity.[10,15,37] Control of the nucleation density and the average cluster size in a single SLRR cycle is also of great interest for thin film growth applications. Homo- and hetero-epitaxial systems that exhibit 3D growth at room temperature due to kinetics limitation can be effectively forced to grow in 2D mode by enhancing the nucleation density and producing smaller nuclei during the growth process.[38]

To illustrate the arguments presented here, we focus on Fig. 3 where plots of Eq. 5 are presented using SLRR kinetics parameters from Table I. The case N = 4 is the starting point in the discussion (bold red). First, we address the effect of K_{SLRR} on n_P^{SLRR}. By definition, K_{SLRR} is proportional to the bulk concentration of P (Pt) ions, Eq. 6 and Eq. 7. A 100× dilution of $\{PtCl_6\}^{2-}$ ions, (from 10^{-3} M to 10^{-5} M $\{PtCl_6\}^{2-}$) results in a 40× decrease in K_{SLRR} (Table I). Considering that $\alpha_0 \sim (K_{SLRR})^{1/3}$, an approximately 3.5× lower nucleation rate is expected. The calculated functional relation between n_{Pt}^{SLRR} and $\theta_{o,Cu}$ for 10^{-5} M $\{PtCl_6\}^{2-}$ is shown in Fig. 3 as a green dashed line. The mathematical form of the relation does not change and evidently, higher concentration of $\{PtCl_6\}^{2-}$ would produce qualitatively the same effect but in the opposite direction, i.e., n_{Pt}^{SLRR} would increase 3.5×.

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Table I. Parameters for SLRR reaction kinetics extracted from OCP measurements.

SLRR Reaction	Solution, ω = 1000 rpm	K_{SLRR}, [s^{-1}]	N	m/p	Ref.
$Cu^0_{UPD} + \frac{m}{p}Pt^{p+}_{solv.} = Cu^{m+}_{solv.} + \frac{m}{p}Pt^0_s$	10^{-3} M $\{PtCl_6\}^{2-}$ + 0.1 M H_2SO_4	4.08 ± 0.07	2[a]	0.5	17
	10^{-3} M $\{PtCl_6\}^{2-}$ + 0.1 M $HClO_4$	3.61 ± 0.03	2[b], 4[a]	0.25	17
	10^{-5} M $\{PtCl_6\}^{2-}$ + 0.1 M $HClO_4$	0.089 ± 0.0008	2[b], 4[a]	0.25	17

[a]Reaction order is taken based on the value of stoichiometry coefficients.
[b]Reaction order determined from the fits of the reaction kinetics model to the open circuit transients obtained during SLRR reaction.

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Based on this discussion, one concludes that the nucleation density and nanocluster size is a strong function of the P^{p+} ($\{PtCl_6\}^{2-}$) concentration and the initial coverage of the UPD ML, $\theta_{o,M}$ ($\theta_{o,Cu}$).

The choice of supporting electrolyte in the SLRR reaction involving Cu UPD ML has a decisive effect on the oxidation state of Cu. In the case of 0.1 M $HClO_4$, Table I, the absence of solution complexing ability for Cu^{2+} makes the Cl^- liberated from $\{PtCl_6\}^{2-}$ the only ligand at the interface.[16] This leads to formation of the $\{CuCl_2\}^-$ complex with Cu being +1 oxidation state and m/p = 0.25. However, if the reaction solution has an abundance of sulfate ions, (for example: 0.1 M H_2SO_4) the Cu oxidation state in the SLRR reaction is +2. It means that the m/p ratio is 0.5. The reaction rate constant in this electrolyte is slightly higher too (K_{SLRR} = 4.08 s^{-1}, Table I). Both effects increase the value of α_0 by approximately 30% . The additional outcome is that the reaction order in the case of a 0.1 M H_2SO_4 electrolyte changes to N = 2.[17] This changes the qualitative shape of the n_{Pt}^{SLRR} versus $\theta_{o,Cu}$ curve and the position of the maximum shifts to $\theta_{o,Cu} \approx 0.4$. Therefore, for the same concentration of Pt ions in solution (10^{-3} M) but with a 0.1 M H_2SO_4 supporting electrolyte, roughly 30% higher n_{Pt}^{SLRR} values are expected in the $0 < \theta_{o,Cu} < 1$ range with qualitatively different n_{Pt}^{SLRR} dependence on $\theta_{o,Cu}$, (Fig. 3, blue dashed line). Following the same logic, further enhancement in nucleation density should be expected if the $\{PtCl_6\}^{2-}$ ion is replaced with $\{PtCl_4\}^{2-}$ yielding m/p = 1. In this case, α_0 is approximately 60% larger than the original one. In addition, one Pt ion reacts with one Cu UPD adatom and the reaction order takes N = 1.[17,36] Both changes make a major impact on the n_{Pt}^{SLRR} versus $\theta_{o,Cu}$ dependence even if the K_{SLRR} remains the same (Fig. 3, black line). The maximum value of n_{Pt}^{SLRR} increases almost 75% and further shifts toward the lower values of $\theta_{o,Cu}$ ($\theta_{o,Cu}$ = 0.23, for n_{Pt}^{SLRR} = max). The overall conclusion is that a larger m/p ratio produces a higher nucleation density and a deposit with smaller nanoclusters. The opposite is true when the reaction order is considered. The higher the SLRR reaction order, the lower the nucleation density is, i.e., a deposit with larger nanoclusters is expected.

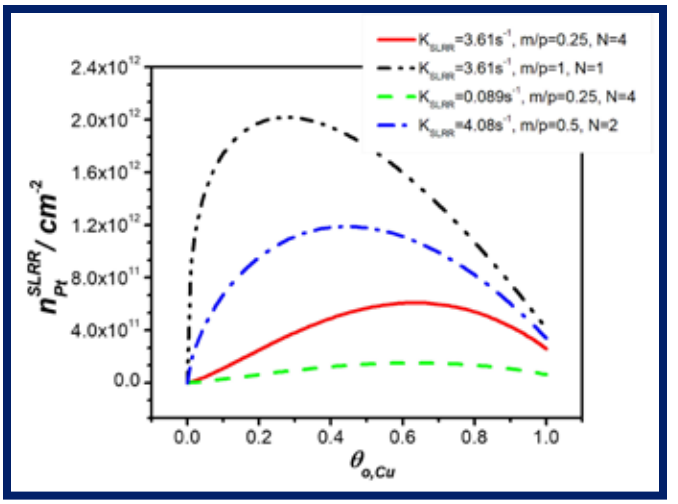

Fig. 3. *Model predictions (Eq. 5) for n_{Pt}^{SLRR} versus $\theta_{o,Cu}$ dependence on SLRR reaction kinetics parameters from Table I. Parameters of the model:*[11] D_{Pt}^{S} / $cm^2s^{-1} = 3.5 \times 10^{-8}$; $\chi = 0.9$; $\Gamma_{Cut}^{UPC}/cm^{-2} = 1.15 \times 10^{15}$; $a/cm = 0.408 \times 10^{-7}$.

An additional way to alter the values of K_{SLRR} and n_P^{SLRR} is by manipulating the experimental conditions that directly influence the fundamental rate constant k. Studies of the SLRR reaction kinetics during Au deposition via SLRR of Pb UPD ML using a *one-solution, one-cell* protocol show that k is linearly dependent on Pb^{2+} concentration, C_{Pb}^{∞}, Fig. 4A.[34] A higher concentration of Pb^{2+} leads to larger values of k. 100% increase in the value of k (or kξ) is observed for one order of magnitude increase in Pb^{2+} concentration. Considering the generalized notation adopted throughout the manuscript, we can state that experimental data in Fig. 4A indicate $k = f(C_M^{\infty})$. The k dependence on C_M^{∞} can be explained by looking into the intrinsic relations between the definitions for the fundamental rate constant,[39] $k \sim \exp(-\Delta G^{\#}/RT)$, the free energy of the activated complex,[40] $\Delta G^{\#} = (\Delta G_{SLRR} + \lambda)^2/4\lambda$ and ΔE_{SLRR}, Eq. 4.[1] After recalling

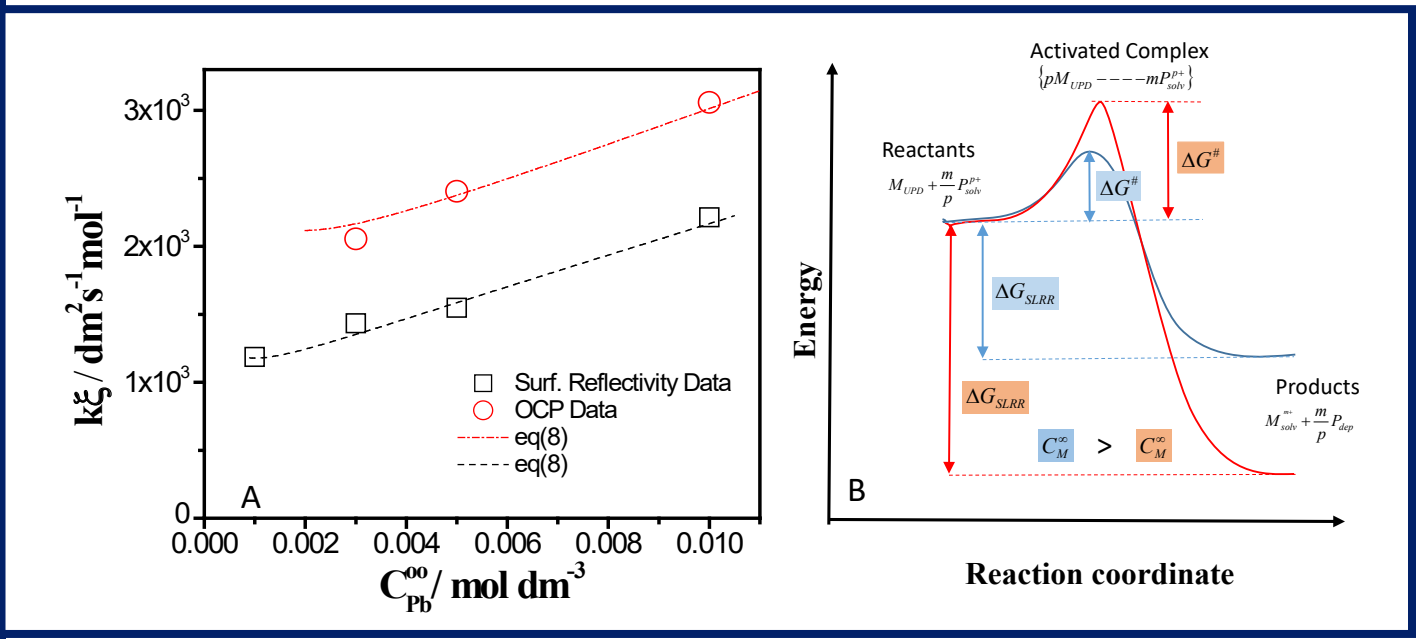

Fig. 4. *(A) Experimental data for the product of fundamental rate constant and interface width (kξ) as a function of Pb^{2+} concentration, C_{Pb}^{∞}, for SLRR reaction: $Pb_{UPD}^{0} + \left(\frac{2}{3}\right) Au_{solv}^{3+} \Rightarrow Pb_{solv}^{2+} + \left(\frac{2}{3}\right) Au_s^0$; surface reflectivity (black squares); OCP measurements (red circles); and dotted lines represent fits of Eq. 8. (B) Schematics illustrating change of ΔG_{SLRR} and $\Delta G^{\#}$ with increasing C_M^{∞}. Adopted from Ref. 34 with permission.*

the basic thermodynamic relation $\Delta G_{SLRR} = -\frac{m}{p} F \Delta E_{SLRR}$, and assuming that $a_{M^{m+}} \approx C_M^{\infty}$ and $a_{P^{p+}} \approx C_P^{\infty}$, one can show easily that the functional relation between k and C_M^{∞} is given by:

$$k \sim \exp\left(-\frac{\left(\frac{m}{p} F \cdot \left(\Delta E_{\theta\to 0}^{0} - \Delta E_{EMF}^{0} \right) - RT \ln \frac{\left[C_P^{\infty} \right]}{\left[C_M^{\infty} \right]} + \lambda \right)^2}{4\lambda \cdot RT} \right) \quad (8)$$

Here, λ represents the reorganization energy in J.mol^{-1} units while F and R are the Faraday and universal gas constants respectively. The fit of the functional defined by Eq. 8 to kξ versus C_{Pb}^{∞} data is plotted in Fig. 4A, dashed lines. We conclude that increasing the UPD metal ion concentration lowers the free energy for the SLRR reaction, which in turn leads to a lower free energy of the activated complex (energy barrier for SLRR reaction), and this leads to a larger value of the fundamental rate constant. A pictorial form of this conclusion is shown in Fig. 4B.

Additionally, Eq. 8 provides functional describing of the of C_P^{∞} effect on k. Significantly, an increase in C_P^{∞} leads to lower values of k, i.e., C_P^{∞} has an opposite effect on k than C_M^{∞}. However, per Eq. 6 and Eq. 7, the term $\left(C_P^{\infty}\right)^{\lambda}$ is multiplicand in the mathematical description of K_{SLRR}. These apparently conflicting effects of C_P^{∞} on the overall value of K_{SLRR} suggest a complex K_{SLRR} versus C_P^{∞} dependence. Yet, the experimental studies of SLRR kinetics during Au deposition via SLRR of UPD Pb ML show that K_{SLRR} is increasing monotonically with increasing values of C_P^{∞}.[34] Therefore, more experiments with diverse conditions are necessary for a better understanding of the C_P^{∞} effects on K_{SLRR}. As a conclusion, we should emphasize the fact that proper design of the metal ion concentrations in the reaction solution represents an extra "knob" to manipulate the nucleation density and to fine-tune the overall morphology of the deposit obtained by SLRR of UPD ML.

Recent studies that certainly deserve more experimental and theoretical attention demonstrate a large effect of the supporting electrolyte on the fundamental rate constant. Experimental data are shown in Fig. 5 for the SLRR reaction between Au^{3+} and Pb UPD ML on Au(111).[34] The results are intriguing since there is no obvious effect of the supporting electrolyte on reacting species neither is an obvious relation between the supporting electrolyte concentration and the definition of K_{SLRR} or k. Nevertheless, the k versus $C_{HClO_4}^{\infty}$ trend in Fig. 5 can be discussed by considering a basic postulate of the Debye-Huckel theory of electrolyte.[41] A higher $C_{HClO_4}^{\infty}$ in the solution influences the Debye length, λ_D, which is a distance at which the ion charge and Coulomb potential are completely screened by the surrounding ions in solution. For a symmetric supporting electrolyte such as $HClO_4$, the Debye length has $\lambda_D \sim \left(C_{HClO_4}^{\infty}\right)^{-0.5}$ dependence.

Therefore, more perchlorate ions in solution will reduce the value of the Debye length. This means that the effective Coulomb field surrounding a potentially reacting Au^{3+} ion near the surface is felt at shorter distance if the reaction solution contains more $HClO_4$. Because of that, the distance between Au^{3+} and Pb UPD adatoms necessary for effective electron transfer/tunneling has to be shorter. This leads to lower spatial probability of reactive encounter between Pb UPD adatoms and Au^{3+} ions and one could expect slower kinetics of the red-ox process and lower values of the rate constant in solution with higher $C_{HClO_4}^{\infty}$. Therefore, the proper design of the supporting electrolyte concentration in the reaction solution is an elegant way to control the SLRR reaction kinetics and nucleation density and thus to control the morphology of the deposit.

Conclusion and Future Prospects

Future prospects for metal deposition via SLRR of UPD ML are quite exciting. New ideas and approaches focusing on development of diverse protocols with even more possibilities for deposit morphology control are being researched. Along these efforts, one concept that certainly deserves more attention is metal deposition via SLRR of a

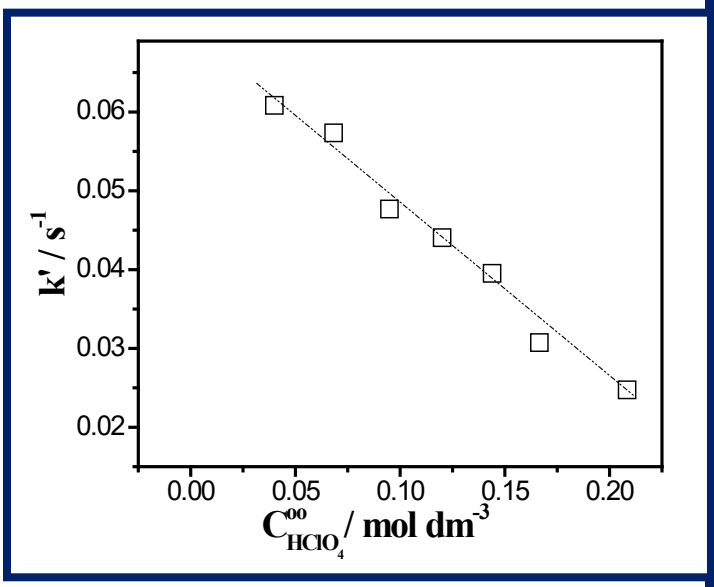

Fig. 5. *Rate constant values plotted as a function of supporting electrolyte concentration. Data obtained from surface reflectivity measurements. Adopted from Ref. 34 with permission.*

UPD ML guided by organic templates.[42] This concept is based on the spatial control of the nucleation probability using an organic phase which shows ordering on the electrode surface in the potential range of the SLRR reaction. The proof of this concept is shown in Fig. 6. The STM image of an organized layer consisting of PTCDI + melamine molecules[43] adsorbed on top of Cu_{UPD}/Au(111) and serving as a template is shown in Fig. 6A. The tri-fold symmetry and organization of the 2D organic phase is evident. The center to center spacing of the unit cells (cages) in the structures is approximately 0.9 nm while the diameter of the empty space within the cell is ~0.7 nm. After SLRR of Cu UPD ML by $\{PtCl_6\}^{2-}$ through the PTCDI + melamine layer, Pt is deposited on Au(111) forming islands/patches consisting of a well-organized population of Pt nanoclusters, Fig. 6B and 6C.[44] The effect of the organic template is obvious, Fig. 6B. The size and organization of Pt nanoclusters replicate the arrangement and symmetry of the organic template, Fig. 6C.

The discussions presented in this article highlight the current understanding of the fundamental relations governing the nucleation process during metal deposition via SLRR of UPD ML. They describe phenomenological links between the reaction solution design, choice of the UPD metal ML and SLRR reaction stoichiometry on the one hand and the SLRR reaction kinetics parameters, nucleation density,[11,16] and resulting morphology of the deposit[4,10] on the other. The general trend is that experimental conditions and solution design leading to SLRR reactions with faster kinetics yield higher nucleation density and deposits with smaller clusters for a given starting coverage of UPD ML. The experimental conditions promoting a larger m/p ratio and lower reaction order in terms of the $\theta_{o,M}$ do promote higher nucleation density and formation of deposits with smaller nanoclusters. These considerations are particularly important when one considers deposition via SLRR of UPD ML for catalyst ML synthesis application.

Design of the optimum experimental conditions for a desired catalyst ML morphology is a function of its application and intended use in a particular reaction. In the case where high activity of the catalyst ML is desired, the conditions promoting low nucleation density and formation of deposit ML morphology with larger nanocluster should be used. However, if poisoning of the catalyst by intermediates hinders the particular reaction kinetics, the synthesis of catalyst ML with modest activity might be beneficial to retain a good reaction yield and the desired reaction pathway.[37] In this case, the conditions promoting high nucleation density and small average size of nanoclusters should be chosen. The same is true if one pursues the

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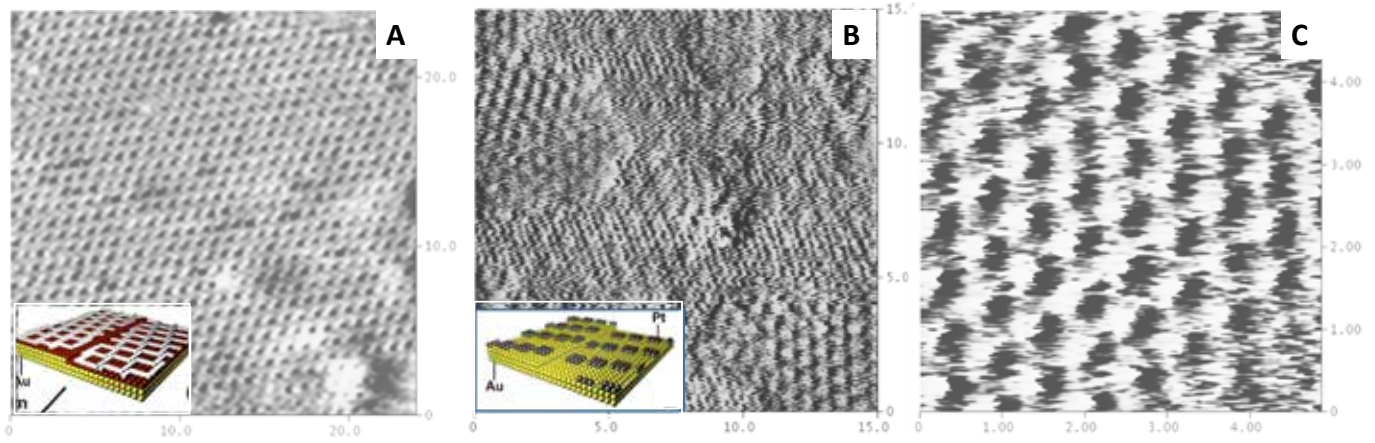

Figure 6. *STM images of: (A) PTCDI + Melamine layer adsorbed on Cu_{UPD}/Au(111), E = −0.V versus SCE in 0.1 M $HClO_4$, image size: 25 × 25* nm. *(B) Pt on Au(111) after SLRR of Cu UPD ML by Pt^{4+} through PTCDI + Melamine layer, image size: 15 × 15 nm. (C) Same as in B, image size 5 × 5 nm. Cartoons of the structures (bottom left) corresponding to the situation in image A and B.*

goal of depositing a high quality homo- and hetero-epitaxial thin films. In conclusion, the considerations presented in this article should be of broader significance for the catalysis and thin film communities as an effort in bridging the gap between the desired properties of metal deposit obtained by SLRR of UPD ML and the required conditions for its synthesis.

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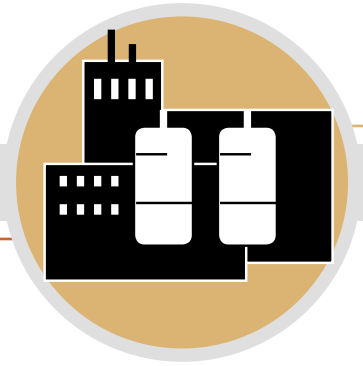

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Palladium Ultrathin Film Growth by Surface-Limited Redox Replacement of Cu and H UPD Monolayers: Approaches, Pros, Cons, and Comparison

by Nikolay Dimitrov, Innocent Achari, and Stephen Ambrozik

Palladium (Pd) is a Pt-group metal with unique properties relative to others within this group. It features high activity and remarkable selectivity in catalytic applications associated with pharmaceutical, agrochemical, and fine chemical industries.[1] In addition, it has a very high affinity for hydrogen (H), so that it can, not only, selectively and reversibly adsorb a monolayer of H, but it is also capable of absorbing quantities of this element as high as 900 times its volume under ambient conditions of temperature and pressure.[2] The absorbed H occupies the octahedral sites in the Pd *fcc* crystal lattice and forms a nonstoichiometric hydride compound, PdH_x in addition to the adsorbed hydrogen at the electrochemical interface.[3] Owing to the high affinity of Pd toward H and the very small size of the H atoms, they can freely and reversibly diffuse into, and out of, the Pd crystal lattice. Thus, depending on the pressure, Pd can be used to store H and thereby constitute a potential solution of the H-gas storage problem faced by hydrogen fuel cell powered vehicles.[4] This could ultimately facilitate said vehicles' commercialization. This high affinity toward H also makes Pd a good candidate for usage in catalytic scenarios associated with H sensing,[5] as well as a potent fuel cell catalyst[6] that could either replace Pt,[7] or be alloyed with Pt and/or other elements to drive these applications forward.

To date, Pt is utilized as the commercial standard for electrocatalysts in fuel cells but it is also known as an expensive rare metal and is less abundant relative to Pd. However, relative to Pt, the utilization of Pd in fuel cells does not provide significant monetary advantages, therefore minimizing its quantity while maximizing its utilization in relevant applications is one of the goals of state-of-the-art fundamental research and applied industrial developments. In practical realization, Pd or Pd-alloy ultrathin films, which have unique properties relative to the bulk counterparts, have been developed for application in H sensing, electrocatalysis, catalytic conversion, etc. Such ultrathin films grown on different substrates with strict structural and thickness control exhibit the said unique properties mostly owing to specific surface stress effects and/or the electronic interactions between the thin film atoms and those of the substrate.[8] These interactions often lead to both improved catalytic activity and enhanced durability of the accordingly synthesized catalyst and improved electronic and magnetic properties.[9] Such films can be grown for the purposes of heterogeneous catalysis on conductive (especially electrocatalysts) or nonconductive inert and inexpensive carriers.

Deposition of Pd Ultrathin Films and the SLRR Approach

The growth of thin metal films in a layer-by-layer mode is instrumental for the control of thickness, morphology, and continuity of the deposit. Moreover, to take advantage of unique catalytic properties owed to overlayer strain of ultra-thin films, the films must be epitaxial with respect to the substrate. Thin films of Pt-group metals, including Pd, have been deposited in quasi 2D growth mode to a thickness of tens of nanometers on various substrates by utilizing atomic layer deposition (ALD) techniques such as physical vapor deposition (PVD),[10] molecular beam epitaxy (MBE),[11] chemical vapor deposition (CVD),[12] metalorganic chemical vapor deposition (MOCVD),[13] magnetron sputtering,[14] and electrodeposition.[15] The latter approach is often preferred due to a lower level of operational complexity, low cost of the instrumentation and its maintenance, and finally, its functioning under ambient conditions. Unlike all deposition approaches requiring ultra-high vacuum (UHV) along with elevated temperature, the electrochemical based approaches normally only require oxygen evacuation for proper functioning.[16,17] As per other experimental requirements, the electrochemical deposition routines operate under applied potential enabling the reduction of ions of the metal or alloy thin film of interest thus producing a well-defined overlayer structure.

Bulk metal deposition at a constant potential negative to the equilibrium potential of the metal ion/complex of interest generally results in the preferential formation of 3D deposits either starting with nucleation and growth of 3D clusters or (at best) following the so-called Stranski-Krastanov transition[18] via the initial deposition of a few layers of 2D heteroepitaxial films which eventually transitions into the growth of 3D films. Normally, the bulk deposition routines allow for some control of amount of deposited metal or alloy but provide little or no control over the morphology of accordingly deposited films. More controlled electrodeposition can be realized by kinetic manipulation of the growth process through introducing a third-party mediating element that helps maintain the quasi 2D growth for a longer time of the process duration.[19] Among these approaches, the Surface Limited Redox Replacement (SLRR) that utilizes underpotentially deposited (UPD)[8] monolayer of sacrificial metal / element stands out as most widely applicable and highly efficient electrochemical deposition protocol for administering and control of a successive layer-by-layer growth of nearly atomically flat and remarkably conformal thin films of a variety of metals and alloys.[20] (**Ed. Note:** See companion article by Brankovic elsewhere in this issue.)

Realized initially by Brankovic, Adzic et al. for the electrodeposition of Ag, Pt, and Pd, and then furthered by this group for atomically platinizing catalysts for oxygen reduction[21], SLRR growth protocols (as shown schematically in Fig. 1) have been used to facilitate and control the layer-by-layer growth of the thin films in an electrochemical ALD fashion in many homo- and hetero-epitaxial systems summarized in a recent review.[20] Such protocols involve two-step cycles where the first step is to underpotentially deposit a sacrificial layer (SL) of a less noble element (Cu, H, Pb, Tl) on a carrier substrate followed by second step of replacing the SL atoms by a galvanic displacement reaction with the ions of the growing more noble element(s) such as Pd, Pt, Au, or Ag etc. The thickness of the growing thin film is quantitatively controlled as it is directly proportional to the number of the SLRR cycles applied in the growth process.

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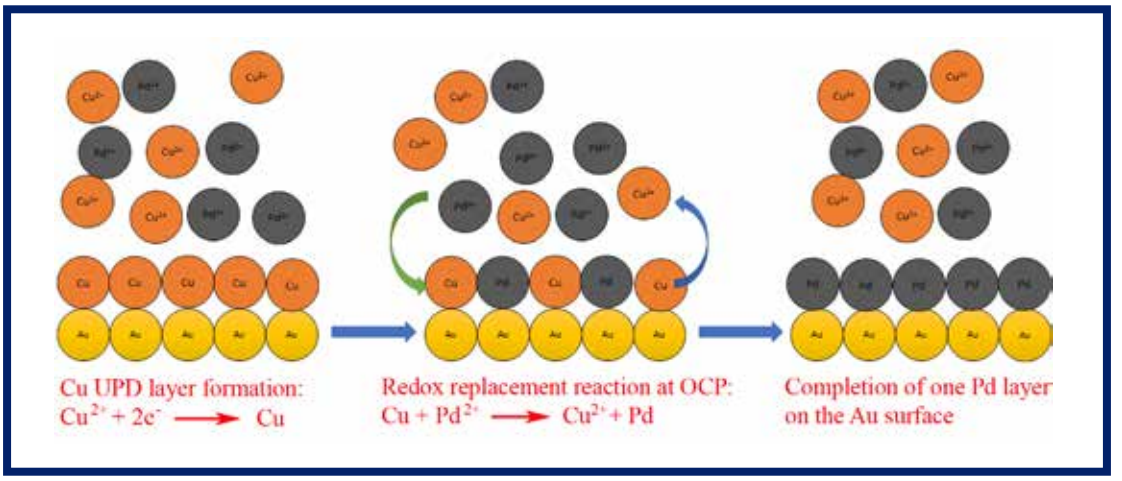

Fig. 1. *Cartoon showing the sequential steps of electrochemical ALD via SLRR of Cu UPD layer in a cycle employed for the deposition of Pd thin film on Au substrates.*

Thick, Smooth, and Uniform Pd Films Deposited by SLRR in a Flow-Cell

The state-of-the-art in electrochemical deposition of thin Pd films in quasi 2D growth mode involves the use of SLRR powered ALD realized in two conceptually and technically different setups that both enable the administration of successive SLRR cycles. These include the variant originally introduced by Stickney et al. using an automated flow-cell[22,23] and the more recently proposed by the present lead author (Dimitrov) et al. one-cell configuration.[24] The flow-cell approach involves successive, computer-controlled valve-system-distribution of separately stored electrolytes and blank rinsing solvents (Fig. 2) whereas the one-cell approach entails work in a single cell which contains all electrolyte components combined at appropriate concentrations.

The application of electrochemical ALD of Pd thin films on Pt and Au substrates by SLRR of a Cu UPD layer was pioneered by Stickney et al. in automated flow-cell.[9,23,25,26] The applied experimental routine involves pumping of a solution containing the sacrificial element ions into the cell where the working electrode (WE) is held at a potential that enables the formation of a Cu UPD monolayer. The WE is then held at OCP while a Pd(II) complex containing solution flows through the cell, allowing for the replacement of the Cu UPD layer with Pd. Finally, upon reaching a pre-designated "stop potential," the cell is rinsed with blank sulfuric acid solution to remove remnants of the Pd(II) complex and Cu^{2+} ions thus completing one SLRR cycle. The number of applied cycles depends on the targeted Pd-film thickness. While initially work on Pd SLRR deposition was done on Pt (111) substrates whereby up to eight perfectly epitaxial Pd layers were successfully deposited in classical Stranski-Krastanov transitional layout,[9] most of the developments and progress in flow-cell was made for Pd deposition on Au(poly) and (111)-textured thin-film substrates.[23] This work firstly came to determine that Cu was a more preferred sacrificial element than Pb for the production of

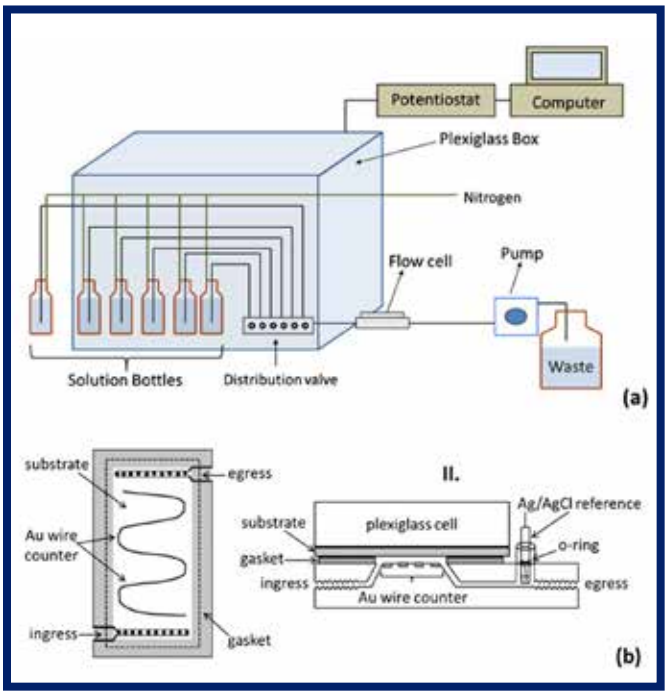

Fig. 2. *(a) An automated electrochemical flow cell system with (b) being the flow cell on (I) aerial view and (II) side view. (Reprinted by permission from Springer Nature; L. Sheridan, J. Czerwiniski, N. Jayaraju, D. Gebregziabiher, J. Stickney, D. Robinson, and M. Soriaga, "Electrochemical Atomic Layer Deposition (E-ALD) of Palladium Nanofilms by Surface Limited Redox Replacement (SLRR), with EDTA Complexation,"* Electrocatalysis. *Copyright 2012. Ref. 23.)*

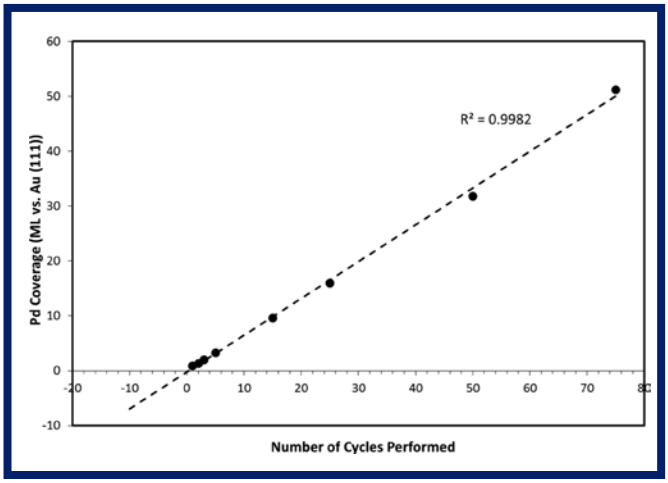

Fig. 3. *Plot illustrating the linear relationship between Pd coverage (i.e., film thickness) determined by stripping experiments and the number of SLRR cycles performed. The Pd solution composition was $[Cl^-]/[Pd(II)] = 500$. (Reprinted with permission from Ref. 25. Copyright 2013, American Chemical Society.)*

pure Pd films, since the latter resulted in more Pb incorporation into the accordingly deposited films even when Pd steady-state OCP was used as SLRR stop-potential. The Pb contamination has been attributed to the high stability of the Pb-Pd alloy formed to some extent during the SLRR cycle.[23]

A key issue in the use of a flow-cell for SLRR deposition of Pd was the uneven nature of the resulting film manifested by descending thickness gradient from the ingress to the egress point of the cell (see Fig. 1b).[23] This problem was also observed by authors on other systems and has been attributed to SLRR occurring in the flow cell at substantially higher rate relative to the time needed for a solution exchange, in turn leading to a dominant indirect local-cell exchange mechanism.[27,28] To slow down the rate of reaction of redox exchange between the Pd^{2+} ions and the Cu UPD, Pd was complexed with EDTA at a [EDTA]/[Pd(II)] ratio of 1 which improved the thickness uniformity of the growing conformal film but reduced substantially the exchange efficiency.[23] In a step further aimed at addressing the low exchange efficiency the authors experimented with excess of chloride ions as complexing agent and eventually obtained the best results at $[Cl^-]/[Pd^{2+}]$ ratio of 500. Using accordingly optimized conditions, Stickney's team not only minimized the displacement operating in a local-cell mode thus promoting conformal quasi 2D layer-by-layer growth across the substrate, but also managed to demonstrate reasonably high efficiency. The best results reported on accordingly performed Pd growth are shown in Fig. 3 that demonstrates the thickening of a conformal Pd film on Au(poly) with no roughness evolution in the course of 75 SLRR cycles at exchange efficiency of about 95%.[25]

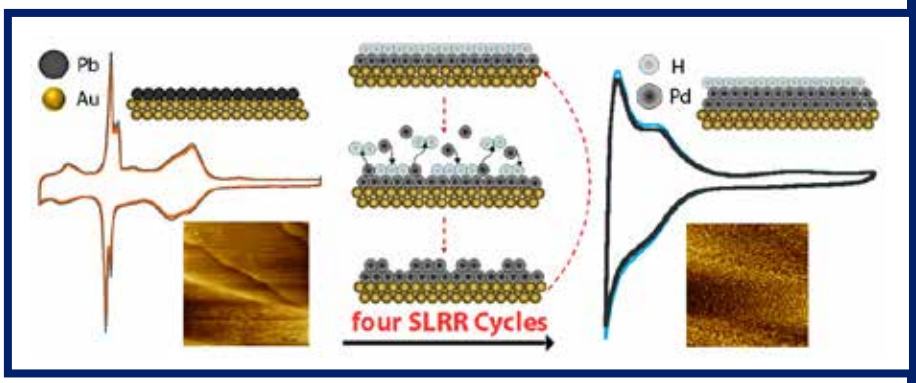

Fig. 4. *Schematic illustrating the growth of Pd films by SLRR of H UPD in one cell. The curves illustrate a CV characterization of the Au substrate (by Pb UPD) and the deposited Pd films (by H UPD). The STM images depict the surface quality of both the initial Au (111) substrate (left) and the Pd film deposited by four SLRR cycles (right). (Reprinted with permission from Ref. 29. Copyright 2017, American Chemical Society.)*

Thinner, Inexpensive, and Greener, Pd Ultrathin Films Deposited in One Cell

More recent work by Dimitrov et al. has been done on the deposition of Pd thin films by SLRR of both H UPD and Cu UPD layers in a one-cell configuration as an alternative to the automated flow cell.[29] The one-cell configuration entails working in a solution containing both sacrificial element ions and ions/complex of the growing metal(s) of interest in appropriate concentrations; the UPD forming ions (H^+ or Cu^{2+}) represented in one to two orders of magnitude higher concentration than that of the growing metal ions/complex (Pd(II)). The substantial concentration difference ensures virtually no Pd deposition upon the short (0.3 to 1.0 s) potential pulse aimed at formation of the H or Cu UPD sacrificial layer. After release of potential control, the WE is held at open circuit potential (OCP) so that the replacement of the Cu or H atoms by Pd(II) ions can be completed when the "spot potential" is reached thus closing the loop of the SLRR cycle. This can be repeated multiple times depending on the thickness needed for the target thin film.[30]

Using this protocol, Dimitrov et al. demonstrated the ability to deposit Pd ultrathin films on Au(poly) by SLRR of a H UPD layer.[29] As schematically presented in Fig. 4, the original Au substrate was characterized by Pb UPD CV curves whereas the thus grown Pd films assessed for surface roughness evolution by H UPD and Cu UPD. Analysis of the Pd deposit thickness evolution was performed by stripping experiments and modeling the progress of the SLRR deposition process. It was shown that the Pd film growth on Au starts with formation of Pd UPD layer that works as carrier of H UPD layer that in turn powers the SLRR cycle initiating the formation of a second Pd layer. After completion of the second Pd layer anticipated to happen after the third cycle [0.5 monolayers (ML) of Pd per H UPD ML], the progress of Pd film thickening can continue by SLRR of either adsorbed H_{UPD} atoms only (lower limiting case) or adsorbed and absorbed H_{UPD} atoms (afterwards) according to the equation below:

$$\Delta_{i+1} = 2 + 0.5 \times (i - 2) + 0.3 \times (\Delta_i - 2).$$

This equation[29] considers the number of deposited Pd MLs (Δ) after the third SLRR cycle, i.e., $i \geq 3$. Therefore, the first term (2) accounts for the number of deposited Pd MLs in the first 3 cycles, the second term, $(0.5 \times (i - 2))$ is associated with the contribution of only adsorbed H_{UPD} atoms, and the third term, $(0.3 \times (\Delta_i - 2))$ reflects the participation of absorbed H_{UPD} atoms in the replacement process. Thus, after SLRR cycle #4 ($i + 1 = 4$), $\Delta_4 = 2.5$ as adsorption only contributes to the SLRR cycle (the third term is 0), whereas $\Delta_5 = 3.15$ instead of 3.0, as 0.15 fraction of a ML is formed due to a contribution of absorbed H. To further elaborate in quantitative manner, Fig. 5 demonstrates calculated results by the proposed generic model are plotted along with those determined experimentally as a function of the number of applied SLRR cycles. It can be clearly seen that up to a total of 30 SLRR cycles the experimental results fit the model accounting for adsorbed + absorbed H_{UPD} atoms reasonably well. At more than 30 SLRR cycles a substantial thickness increase is observed, manifested by a significant departure of the experimentally obtained results from those theoretically calculated implying that a conformal Pd film with roughness of ~1.05 grows in quasi-2D mode for up to 30 SLRR cycles. A transition from 2D to 3D (likely dendritic) growth has been considered as the reason for a drastic increase of the roughness factor to about 1.60 in the SLRR range of 30 to 40 (Fig. 5). Transition from quasi 2D to dendritic growth has also been shown to occur in the SLRR and surfactant mediated growth of Au on Pt surfaces.[31] Overall, that growth mode transition could be enabled

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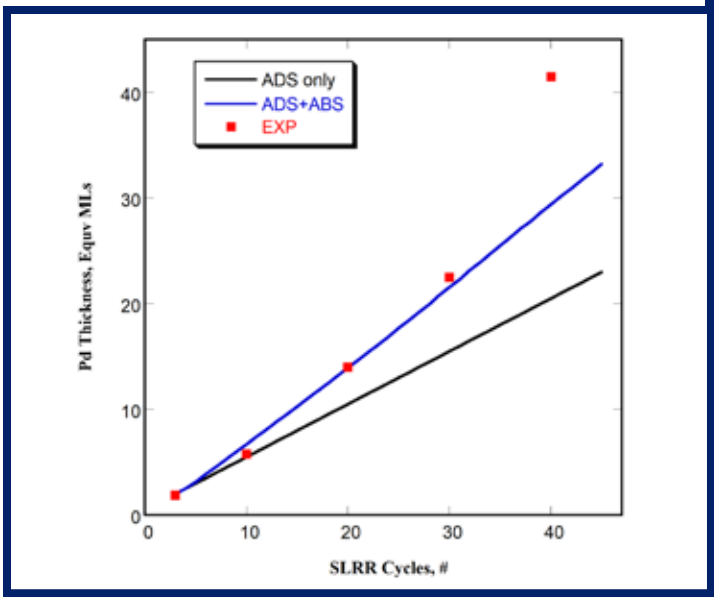

Fig. 5. *Calculated and experimentally obtained thicknesses of Pd ultrathin film (in #equivalent MLs) as a function of the number of SLRR cycles. (Reprinted with permission from Ref. 29. Copyright 2017, American Chemical Society.)*

by a gradual establishment of strictly diffusion limited growth that most likely occurs with the increasing number of SLRR cycles. In additional characterization experiments, in situ STM imaging shown only illustratively in Fig. 4 to demonstrate the morphological changes after application of four SLRR also provided additional evidence of relatively smooth and conformal Pd growth via H UPD. This quality is representative for up to 20 SLRR cycles.[29] Overall, the proposed strategy enables facile deposition of contamination-free, smooth and continuous Pd films of considerable thickness.

In another developmental effort, Dimitrov's team illustrated the application of E-ALD by SLRR in one-cell configuration for the growth of Pd thin films using Cu UPD as a sacrificial metal. Following previously described routines the growth of Pd films on Au was monitored by OCP transients while the roughness evolution and thickness of accordingly deposited Pd films were assessed by H UPD and Cu UPD cyclic voltammetry and stripping experiments, respectively. The uninterrupted SLRR growth in one-cell was optimized to yield smooth and continuous films of thickness up to 15 MLs at Pd^{2+} ion concentration of 0.3 mM and $[Cl^-]/[Pd(II)]$ ratios between 100 and 170. The thus deposited Pd films featured lower thickness (15-16 MLs) compared to those grown by SLRR of H UPD. Paralleling the latter case, after reaching that thickness, a transition to dendritic growth occurred owing to the previously mentioned establishment of mass-transport limitation at the growing interface. As a result of the hindered transport of the Pd^{2+} ions to the growing surface, a progressively formed concentration gradient (from zero on the electrode surface to the bulk Pd(II) concentration) serves to enhance the vertical growth of any 3D clusters nucleated in the initial deposition stages leading eventually to dendrite formation.[32,33]

In the general SLRR deposition protocol, the described sequential phenomenology promotes the transition to dendritic growth with every cycle. To minimize the propagation of this transition and to facilitate quasi-2D growth for as many SLRR cycles as thermodynamically possible, a modified SLRR protocol was implemented for Pd deposition in a single cell emphasizing: (i) an interruption of the successive cycle sequence at every four SLRR reaction events; and (ii) application of forced electrolyte convection during the break time. Results of Cu UPD CV characterization of surface roughness and evolution of the surface morphology imaged by STM are comparatively presented in Fig. 6 for both, uninterrupted (UI) and modified by "breaking (contact) and shaking (the electrolyte)" (BS) the SLRR deposition in one-cell configuration. The comparison reveals virtually no roughness increase even after 24 SLRR cycles of "break and shake" SLRR growth. This constitutes about two-fold thickness increase in comparison with the interrupted SLRR Pd deposition scheme suggesting that the cycle interruption and forced electrolyte convection facilitate the growth of thicker Pd films with minimal to no roughness.

The Choice Is up to the User

The presented snapshot of the state-of-the-art in the deposition of ultrathin Pd films using electrochemical ALD by SLRR not only summarizes the most recent limits of success in the growth of conformal, uniform, and smooth deposits but also puts forward some general drawbacks and/or limitations of most commonly used approaches for this type of deposition. Thus, a potential choice of approach to deposit Pd ultrathin films depends on the application purposes as well as on the desired film properties. For instance, if of interest is a thicker Pd film that is still continuous and uniform at thickness of 50-60 equivalent MLs, a better choice would be the flow-cell setup that once working under optimized conditions will guarantee the lack of mass-transport limitations and thus promote the deposition sustainability. Contrastingly, if the growth of cost-effective catalytic coating of Pd or Pd-based alloys of thickness in the range of 1 to 10 equivalent MLs is of interest, a better and more straightforward choice would be the one-cell setup that would provide remarkable simplicity, low cost, and better time management for the overall deposition matter. In the meantime, work on addressing and minimizing the effect of all discussed limitations is under way.

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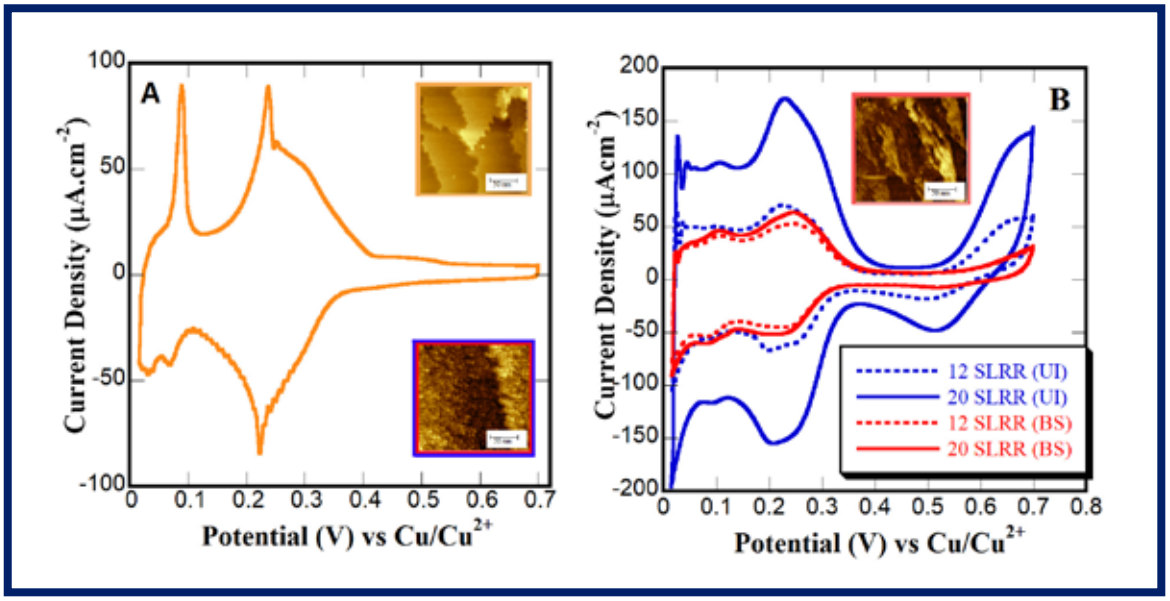

Fig. 6. *Plots illustrating the growth of Pd films by SLRR of Cu UPD in one cell configuration. The presented curves illustrate Cu UPD CV characterization of (A) initial Au surface and (B) accordingly deposited Pd films. The presented STM images depict the surface quality of both, the initial Au (111) substrate (left inset, up), the Pd film deposited by five SLRR cycles (representative for both UI and BS growth; left inset, down), and the Pd film deposited by 20 SLRR cycles (BS growth only; right inset).*

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Electrodeposition of Pt-Bimetallic Model Systems for Electrocatalysis and Electrochemical Surface Science

by Natasa Vasiljevic

Over the past few decades, low-temperature fuel cells have undergone rapid development delivering prototypes and commercially available cars with impressive performance.[1,2] The achievements and progress of the fuel cell research and development have been enthusiastically embraced by the transport industry boosting public and governmental interest and support.[3,4] Besides polymer electrolyte membrane fuel cells (PEM FCs) based on hydrogen fuel, the direct alcohol fuel cell (DAFC) based on liquid fuels, such as methanol, ethanol and formic acid (alcohol fuels) have been viewed as possible power systems for portable electronic devices.[5] In spite of the considerable progress, commercially competitive fuel cell cars and technology are still hindered by performance limitations and the high cost of Pt catalysts. Development of nanoscale bimetallic catalysts with low content of Pt and Pt-group metals exhibiting enhanced activity, and better stability than the pure metal has been pursued actively as the most promising strategy to make future advances.[1]

Pt-bimetallic systems comprise of nanoscale structures of Pt in contact with another metal. Some of the examples, shown in Figure 1, include Pt-nanoclusters (sub-ML) on top of another metal, strained Pt monolayers and ultrathin films (over layers on top of another metal or alloys), Pt-alloys and Pt-alloy overlayers (random alloys and intermetallics). Besides the low content, a combination of Pt with another metal at nanoscales often result in the catalysts with *superior activity compared to the single metal components*. The reduced dimensionality coupled by geometric (ensemble effect) and electronic (ligand) effects can substantially alter the Pt activity.

Real-world fuel cell catalysts (such as nanoparticles on carbon support) are complex and often it is hard to decouple different aspects that contribute to the catalytic activity and performance such as size, shape, and composition. For that reason catalytic reactions are best studied on well-defined single crystal surfaces, the so called *model systems* (Figure 1).[6] Single-crystal metal electrodes have a special place in the field of electrochemical surface science and electrocatalysis.[6] They have been essential for shaping our fundamental understanding of the processes and structure-reactivity relationship. The use of single-crystal vicinal surfaces enabled decoupling of electronics and surface structure effects resulting from the crystallographic orientation alone, and structural features such as terraces, steps, and kinks. Single crystal model systems have been essential for developing our understanding of the kinetics and mechanisms of electrocatalytic reactions providing an invaluable support for theoretical models and analysis (i.e., DFT, MD calculations).[7,8] Without model system it would have been impossible to establish links between the bulk surfaces and nanoscale effects of size and shape.[9]

Electrodeposition of Pt-Bimetallic Surfaces

Electrodeposition of electrocatalysts has an advantage in contrast to other chemical and physical, synthesis routes. Electrochemical routes are inexpensive and readily accessible; they are attractive because of their versatility, simplicity and easy scalability on electrodes of various shape and sizes ideal for a number of fundamental and practical studies. Moreover, they are an effective way of making clean surfaces, i.e., free of capping agents and organic molecules often used in the chemical synthesis methods, thus providing an ideal platform for studying electrocatalytic reactions on single crystals[10] as well as on mesoporous nanocomposite electrodes.[11]

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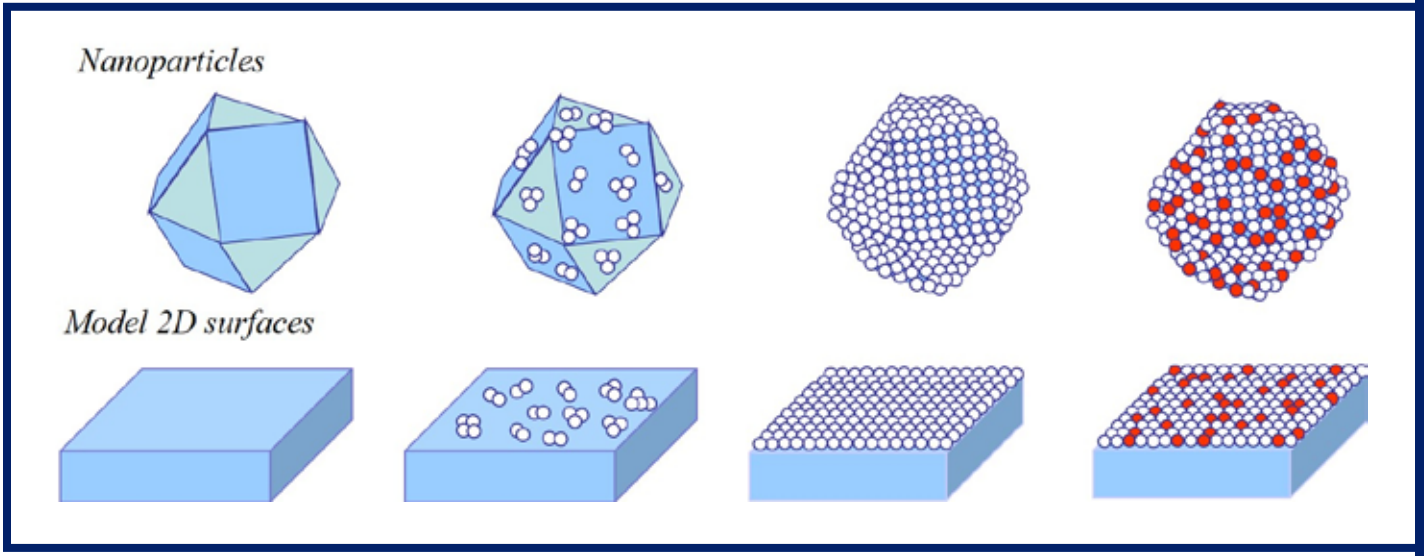

Fig. 1. *Schematics of different bimetallic system configurations presented in the form of nanoparticles (NP) (top row) and corresponding 2D analogues (bottom row). Examples from left to right include single metal, Pt-nanoclusters on metal surfaces, Pt-films (or core shell NP), Pt-alloys supported of different substrates.*

Controlled epitaxial deposition of Pt is a challenge. Due to the very high surface energy and low diffusivity, Pt growth, regardless of the method of deposition, is non-uniform and proceeds via 3D island formation (Volmer Weber growth).[12-14] The electrodeposition community has been actively pursuing different strategies and conditions for epitaxial films and alloy deposition, as reviewed next.

The SLRR Method

The surface limited redox replacement (SLRR) deposition method enabled for the first time successful epitaxial deposition of Pt films and nanoclusters with atomic scale control,[15-19] on to other metal surfaces. Very quickly the method has become one of the most exploited to design 2 dimensional and nanoparticle Pt-bimetallic systems.

The SLRR method has been outlined elsewhere in this issue and utilizes the galvanic replacement of an underpotentially deposited (UPD) epitaxial metal layer, such as Cu and Pb, by a more noble metal such as Pt. The electrochemical surface science studies of UPD processes on single crystal surfaces over four decades[20] provided a wealth of information about the epitaxial nature, thermodynamics and kinetics aspects of these and many other UPD processes. The UPD processes have been now used as fine tools for surface characterization (area, structure and composition) of complex systems,[21-25] as well as enablers to *grow and design* thin films and alloys.[15,18,26-32]

From the first demonstration of 2D deposition of a Pt monolayer, Cu UPD[15] has now become the most commonly used sacrificial layer to design highly active Pt-monolayer catalysts,[28,33] as well as functional nanoporous fuel cell electrodes.[34,35] Further demonstration of the SLRR controlled deposition of Pt films has been done using Pb UPD[18,19] as an excellent alternative for the comparative studies of the nature of UPD layer on the replacement kinetics, deposit structure and high deposition yield. Furthermore, the H UPD[36] based Pt deposition has been shown on a proof of concept level and quickly extended to other Pt- group metals such as Pd well known for its unique H-sorption behavior.[37,38] The coverage of deposited Pt in each SLRR cycle is generally defined by stoichiometry of the redox reaction, replacement reaction kinetics and structure of the UPD layer.[39,40]

Experimental Configurations

There are different experimental configurations by which SLRR protocol can be conducted: 1) by electrode immersion and transfer between the cells containing the UPD metal ions and the second one with Pt-ion complex for the replacement reaction;[15] 2) by exchanging the two solutions in the flow-cell set up;[31] and 3) by the controlled deposition in a single-cell configuration,[18] where growth of Pt films is maintained from the same solution containing both Pt and UPD-sacrificial metal ions[18] with concentrations and the potential control optimized to avoid co-deposition of Pt during UPD metal formation step and avoid UPD metal incorporation during the replacement step.

Each configuration has adavntages and disadvantages for the design of different Pt-bimetallic systems. The design of Pt-nanoclusters and monolayer catalysts (0 – 1 ML) can be best achieved by the immersion and transfer method with special care given to the control of the oxygen-free environment to prevent oxidation of UPD layer. Either by conducting deposition in a glove-box or using custom designed set-ups[41] a secure transfer of stable and uncompromised UPD covered electrode can be achieved.

For deposition of multi-layered thin films of Pt, the automated flow-cell and the single-cell configuration (***Ed. Note**: See also companion article by Dimitrov et al. in this issue.*) offer easier control, and handling, but they require careful optimization of the conditions and monitoring of the potential changes during process. For illustration, the single cell approach requires the metal ions concentrations and the control of the potential limits, to be optimized to maintain growth of high quality Pt, with minimum possible electrodeposition of Pt during UPD metal formation step and minimum possible UPD metal incorporation.[18] The single-cell approach illustrated in Fig. 2 requires controlled application of the elemental SLRR steps: (1) a potential step typically of few seconds duration to form UPD sacrificial layer at negative potential limit E_1 followed by (2) an open circuit potential (OCP) galvanic displacement by a more noble Pt ions monitored in time and terminated at the potential corresponding to a UPD-free surface of the growing film, E_2 (positive potential limit). Moreover, by limiting the potential of the replacement reaction to value E_2', $E_2'' < E_2$ can be exploited for deliberate incorporation of the UPD sacrificial metal and design of nanoalloys.[42]

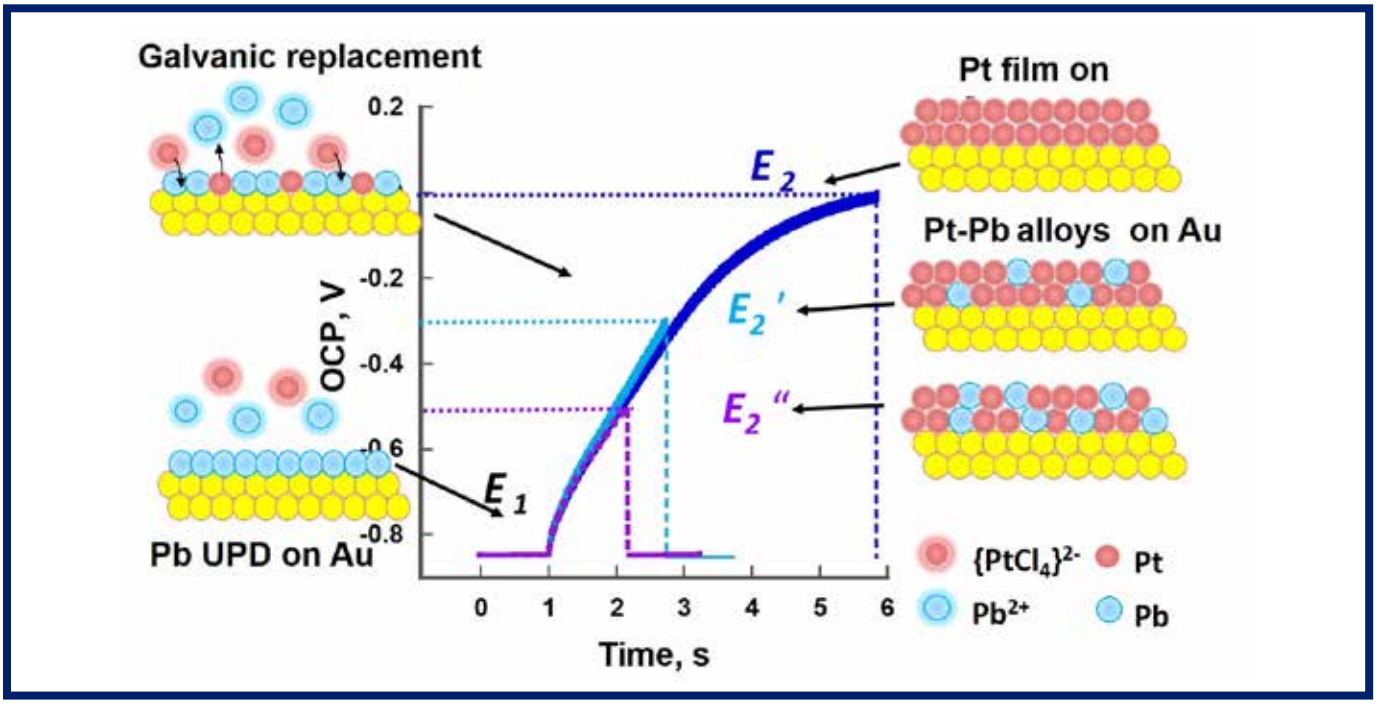

Fig. 2. *Schematics of the SLRR protocol of Pt and Pt Pb alloy deposition in the single-cell configuration using Pb UPD.*

Pt-Bimetallic Model Systems for Electrocatalysis

So far the SLRR method has been used in many fundamental studies to design and study various catalytic reactions. Separating the contributions of the two key mechanism of modification of the chemical properties of surfaces (geometric and ligand effects) is often very difficult because they usually occur together. Firstly, the activity of Pt can be altered by strain, i.e., by changing the average bond lengths between the Pt atoms in the supported ultra-thin layers on different substrates. Also, bonding interactions between the surface atoms of Pt and the substrate results in modification of the Pt electronic structure (ligand effect) therefore can change its surface catalytic properties. Here we would like to draw attention to a few systematic approaches oriented toward understanding of general trends in electrocatalysis by *systematic variations of the structure of the Pt surface using SLRR method*. Interested readers may also find more details and information in a recent review by Dimitrov.[43]

Pt films (overlayers) ▸ Epitaxial monolayers of Pt deposited via SLRR of Cu UPD on different single crystal surfaces such as Au(111), Rh(111), Pd(111), Ru(0001), and Ir(111)[28,44] have been used as model systems to explore the effect of strain on the kinetics of reactions such as the oxygen reduction reaction, methanol oxidation, ethanol oxidation (EOR), and formic acid oxidation. The established experimental trends were used in combination with DFT calculations to rationalize to what extent changes in the average bond length of Pt-Pt (strained on the substrates with different lattice spacing) affect the kinetics rate and/or selectivity of the complex reactions with different pathways.

Another way to explore the effect of strain on Pt electrocatalytic properties is to vary the thickness of Pt films. Repeated application of SLRR cycles using UPD layers of Cu or Pb have been shown to produce epitaxial films of controlled thickness but with different roughness dependant on the stoichiometry and kinetics of the redox replacement reaction.[18,45] For example, the studies of thickness dependant CO electrooxidation showed that besides strain in the layer, the morphology and roughness of the deposited Pt films play an important role in the potential shift, i.e., the strength of CO adsorption.[45,46]

Pt-nanoclusters (sub-ML) ▸ Two dimensional Pt nanoclusters at sub-ML coverage ($\theta \leq 1$ *ML*) on different substrates are ideal for studies of coverage dependant electrocatalytic behaviour. A recent study of Pt sub-ML on Au(111) grown by SLRR of Cu UPD showed that the kinetics of hydrogen oxidation reaction (HOR)[47] is dependent on the size of Pt clusters (smaller clusters being less active for HOR), Fig. 3. The results were rationalized by average active strain in Pt nanoclusters that has two contributions: the tensile strain due to epitaxial misfit (4%) and the compressive strain due to the clusters finite size. Agreement with the DFT-derived model of the size-dependent strain indicates that the morphology/size of Pt-nanoclusters can be exploited to fine tune Pt activity on different substrates. The coverage dependant studies of CO electrooxoidatoon and the EOR of Pt on Au-poly and Au(*hkl*) stepped surfaces also confirmed the dominant role of the structure and morphology of Pt-nanoclusters on the overall activity and product distribution of the EOR.[48,49]

Pt nano alloys ▸ Nanoalloys are even more challenging systems as the effects of the surface structure and chemical composition equally shape Pt electrocatalytic behaviour. Studies on single crystal surfaces of Pt alloys and Pt- intermetallics[50,51] have been extremely valuable but they are limited. Alloy single crystal surfaces are not easily grown and in some cases not available. The SLRR based deposition is one of the most promising pathways to controllably grow model 2D nanoalloy systems and study their properties. This is one of the least explored applications of SLRR method but one that could potentially have high impact.

So far three different approaches have been explored to grow nanoalloy films: 1) the galvanic replacement of a UPD metal later in the solution with both Pt and alloying metal mixed in a desired concentration ratio[52,53] (examples include Pb UPD based growth of and $Pt_{0.8}X_{0.2}$ monolayers on Pd(111) surface where X = Ir, Ru, Rh, Pd, Au, Re, or Os); 2) the alternation of the replacement cycles of Pb UPD between separate solutions of Pt and Ru using flow-cell set up[54] (alloys of different compositions 70:30, 82:28, and 50:50 were grown by controlling the number of alternating replacement cycles in Pt and Ru solutions); and 3) controlled incorporation of the sacrificial Pb UPD metal during Pt deposition to form PtPb alloys (up to 10% Pb composition) by controlling the potential of the replacement step. In the last case of PtPb alloys it has been shown that Pb has a strong screening effect on the adsorption of both H and CO. The changes in alloy composition cause a negative shift in the potential of the peaks of CO oxidation (weaker CO bond) that scales with the increase of Pb content. The results suggest electronic and bifunctional effects of incorporated Pb on the electrochemical behaviour of Pt.

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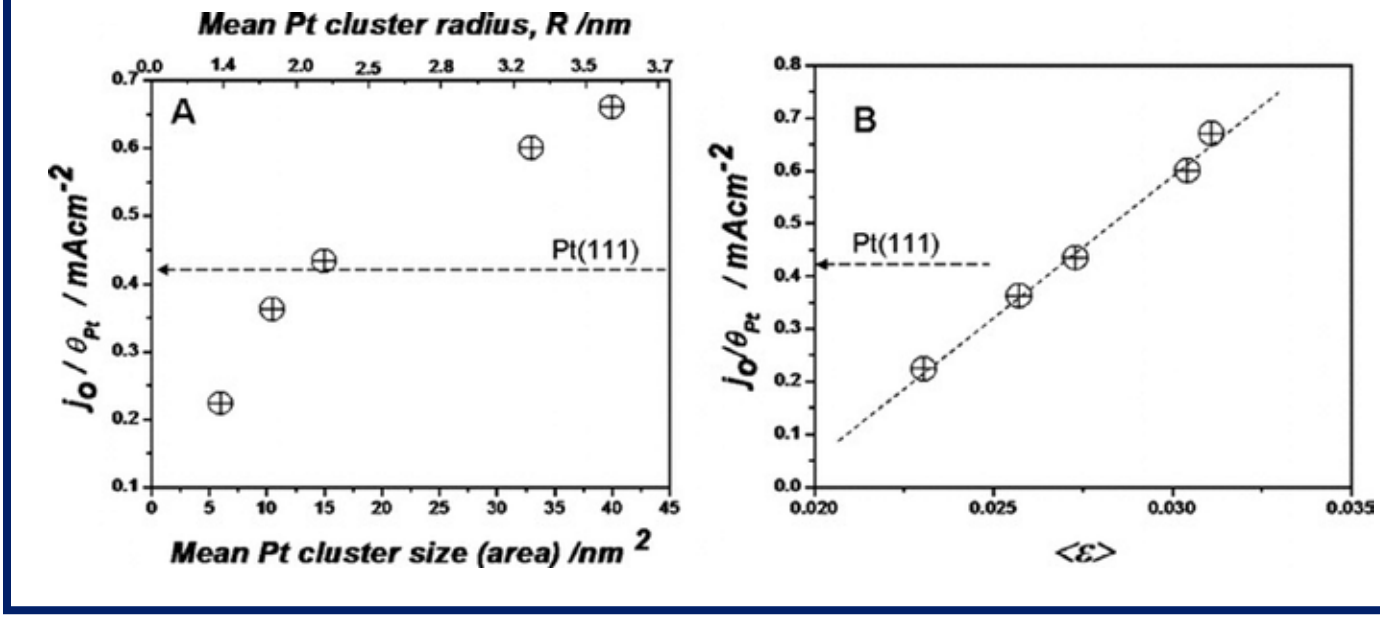

Fig. 3. *Normalized exchange current density for HOR on Pt sub ML on Au (111) as a function of: a mean size of Pt clusters population and B) average active strain calculated for Pt clusters with size corresponding to the mean of Pt clusters' population for each Pt sub-ML coverage on Au(111). Reprinted by permission from Springer Nature and Copyright Clearance Centre: Springer, Ref [47]. Copyright (2012).*

What Is in the Future?

The SLRR based approaches will undoubtedly play an important role in the future of fuel cell develoment and electrocatalysis in general. Control of the structure, thickness and composition on atomic scales provides an excellent platform for model studies on different types of bimetallic systems. In combination with theoretical modelling, the systematic design and studies of various systems will enable the development of more powerful and stable catalysts with tailored electrocatalytic properties. It can also contribute to the understanding of other equally important aspects of the ideal catalysts such as durability. In this vein, recent studies have shown that SLRR grown films and structures are ideal systems to study Pt-dissolution during different catalytic reactions.[55,56]

In this article the focus was on Pt-electrocatalyts for fuel cell applications as the SLRR method has made the biggest impact in this area. The potential and challenges, of extending the approach to the design of other (both noble and transition) bimetallic systems of interest, are exciting. Some of the active areas of research include improving the activity and selectivity of bimetallic catalysts for carbon dioxide electrochemical reduction, environmental and water cleaning, and sensing. Design of multilayers and 2D nanoalloys (particularly those with no bulk counterparts) with controlled composition and distribution of components, can open new avenues of interest beyond the field of electrocatalysis such as nanophotonics, corrosion and microelectronics. The future is bright indeed.

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Carl Hering was one of the founding members of ECS. President of the Society from 1906-1907, he served continuously on the Society's Board of Directors until his death on May 10, 1926. Dr. Hering not only left a legacy of commitment to the Society, but, through a bequest to ECS, he also left a financial legacy. His planned gift continues to support the Society to this day, and for this reason we have created this planned giving circle in his honor.

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Selective Electrodesorption-Based Atomic Layer Deposition (SEBALD) of Bismuth under Morphological Control

by Walter Giurlani, Andrea Giaccherini, Emanuele Salvietti, Maurizio Passaponti, Andrea Comparini, Vittorio Morandi, Fabiola Liscio, Massimiliano Cavallini, and Massimo Innocenti

The development of next-generation electronics is very dependent on the discovery of materials with exceptional surface-state spin and valley properties. Bismuth has most of the characteristics required for technological development in this field. Thin films of this element have shown nontrivial topology[1-3] enabling their definition as a topological insulator and a distribution of spin states and valleys in the band diagram that are suitable for both spintronics and valleytronics applications.[4] In some cases, these properties depend on the quantum confinement of the related particles or quasi-particles; hence they can be tuned by varying the thickness in the ultrathin film range.[5] Finally, thin films of Bi can be processed by electrochemical lithographic methods.[6]

Bismuth ultrathin films can be obtained by techniques that require vapor phase with different degrees of vacuum (e.g., PVD and CVD).[7-9] These methods are efficient for producing flat polycrystalline thin films of Bi. Similarly, Bi thin films were electrodeposited from an aqueous solution containing organic additives with multiple morphologies and textures according to the different surface effect promoted by these substances.[10] These studies have demonstrated that Bi thin films are among the wide range of technologically interesting coatings that cannot be easily obtained from aqueous solutions without interference from metal oxide growth. In most cases, these processes lead to films with uncontrolled morphology.

Introduction to SEBALD

To avoid these limitations, we explored the possibility of using electrochemical atomic layer deposition (E-ALD) to deposit highly ordered ultrathin films from diluted aqueous solutions at room temperature and pressure. In the present context, we use E-ALD for the growth of metal chalcogenide films. Underpotential deposition (UPD) of metal chalcogenide is possible due to the energy gain involved in the formation of the corresponding chalcogenide, so that an adlayer of metal can be deposited at an underpotential on a chalcogenide adlayer covering the electrode surface. The combination between the alternation of solutions containing precursor elements that form this type of compound and UPD is the basis of E-ALD. Repetition of the basic cycle of depositions leads to the growth of semiconductor materials whose thickness increases with the number of cycles, up to the ultrathin film range. Then, after selective electrodesorption of the chalcogen layer, the resulting film is constituted by a confined layer of metal, which reorganizes its shape in ordered crystalline domains. Therefore, the selective desorption of the chalcogen leaves an increasingly higher amount of metals with the number of cycles.

The combination of E-ALD with this second stage leads to a process called selective electrodesorption-based atomic layer deposition (SEBALD), which is depicted by the scheme in Fig. 1. SEBALD was successfully used to grow Cd with a control level not achievable in overpotential deposition through the application of Faraday's laws (even when deposition was limited to very low overpotentials)[11] and to obtain Co/Fe catalytic clusters.[12] In what follows, we show that with the SEBALD protocol it is possible to obtain the growth of a high-quality bismuth ultrathin film on the Ag (111) surface. In this way, we have overcome most of the problems derived from the electrochemical properties of bismuth at the solid-water electrified interface.

SEBALD of Bismuth Thin Films

As often happens in E-ALD,[13] deposition during the first step plays a crucial role for the growth of the following layers. The first phase of SEBALD consisted of the deposition of $(Se/Bi)_n$ on Ag, followed by the removal of selenium (Fig. 1). For this reason, the deposition conditions and the stability of the two elements were investigated first.

The deposition of Se is a well-known process described in literature.[14,15] A selenide solution was used, and silver working electrode potential was set at −0.90 V versus Ag/AgCl sat. KCl

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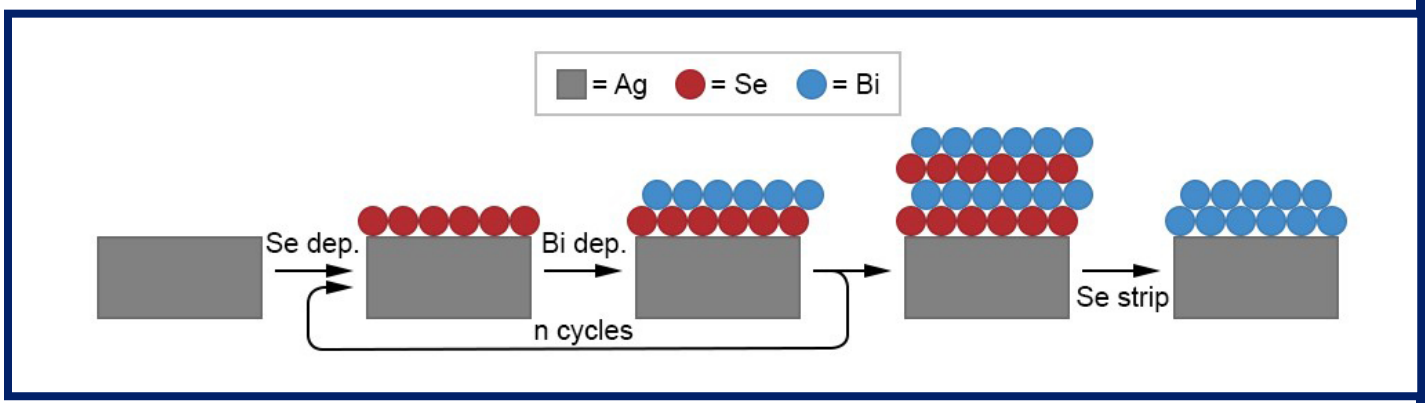

Fig. 1. *Schematic operations of a SEBALD alternating a chalcogenide layer to a metal one. In our study, the chalcogenide is represented by selenium while bismuth is the metal.*

reference electrode for one minute. Then, to remove the excess bulk selenium deposited, leaving only the UPD layer on silver, the working electrode was immersed in ammonia buffer solution for another minute at the same potential value. The bismuth settles to more positive potentials than selenium; therefore it is crucial for a correct E-ALD to verify the stability of Se with an anodic scan, and the results show that it does not get oxidized. Once we had ensured the stability of the Se UPD layer, we proceeded with the UPD of bismuth. The thermodynamic possibility of this deposition is justified by the presence of a cathodic peak (−0.40 – −0.50 V) slightly before the massive deposition one (over −0.50 V) in a cyclic voltammetry scan of a bismuth (III) solution (inset image in Fig. 2). After that, a conventional UPD study was carried out to evaluate the amount of metal deposited in function of the deposition potential and time.[16] The optimal UPD condition to deposit bismuth on selenium consists of keeping the potential fixed at −0.43 V for one minute in the presence of the bismuth solution and then washing the sample with ammonia buffer solution.

After having optimized the UPD conditions of both the elements, the first step of SEBALD was performed by sequential automatic alternate deposition for multiple cycles, obtaining a deposit of increasing thickness. After the deposition process, SEBALD was completed by setting the working electrode potential at −2.0 V and washing the cell in the buffer solution, in order to remove all the selenium previously deposited. Anodic stripping of the remaining bismuth confirmed its growth over the number of cycles performed (Fig. 2). For the very first cycles, a typical rapid growth, due to interaction phenomena confined to the nanoscale, is present. After the fifth deposition cycle, the trend becomes linear.

A 50-cycles final bismuth deposit was morphologically characterized, revealing that this simple SEBALD process, performed at room conditions, allows obtainment of a highly ordered and crystalline deposit difficult to obtain with other techniques. From the SEM image (Fig. 3A), we can observe how the bismuth deposit obtained by SEBALD has reorganized into its typical crystalline shape,[17] hard to obtain with direct bulk deposition. The EDX (Fig. 3B) data confirm the presence of bismuth metal on the silver electrode without any traces of selenium, diagnostic of a proper SEBALD. AFM measurements (Fig. 3C) give useful information on the surface topology: the estimated RMS roughness is only 5.06 nm; moreover the image shows an overview of the sample.

Finally, the quality of the Bi thin film was quantified by XRD. The specular scan reported in Fig. 4 shows the peak of the substrate (Ag (111)) and, more importantly, peaks of Bi thin film corresponding to (102) and (204) crystalline planes. This observation indicates the growth of high-crystalline films with [102] texturing.

Conclusions and Outlook

The development of next-generation electronic devices demands specific materials that often are not simple to synthesize in the required way. SEBALD opens up the possibility of employing electrochemical processes to build, one by one, monolayers of highly pure and ordered structures. The SEBALD methodology constitutes an efficient approach to overcome the limitations of electrodepositing bismuth layers from aqueous solution. This is done by exploiting the SLRs of bismuth and selenium on Ag (111), characterized conclusively by means of electrochemical methods. The UPD experiments proved the occurrence of a SLR leading to the growth of a Bi_{ad} on Se. On this basis, multiple E-ALD cycles could be performed to grow the Bi_2Se_3 compound. Subsequent selective desorption of selenium concludes the SEBALD process and allows obtainment of the bismuth ultrathin film.

We were able to grow extremely ordered bismuth layers with exquisite control on film thickness, as proven by the topography and morphology of the resulting ultrathin films. This process is a very promising candidate for the growth of metal ultrathin films and constitutes an easy way to obtain an ordered bismuth ultrathin film of controlled thickness under room temperature and pressure. The films obtained by SEBALD are highly crystalline and oriented; moreover they are characterized by low roughness. All these properties are promising for ultimate application in new-generation electronic devices.

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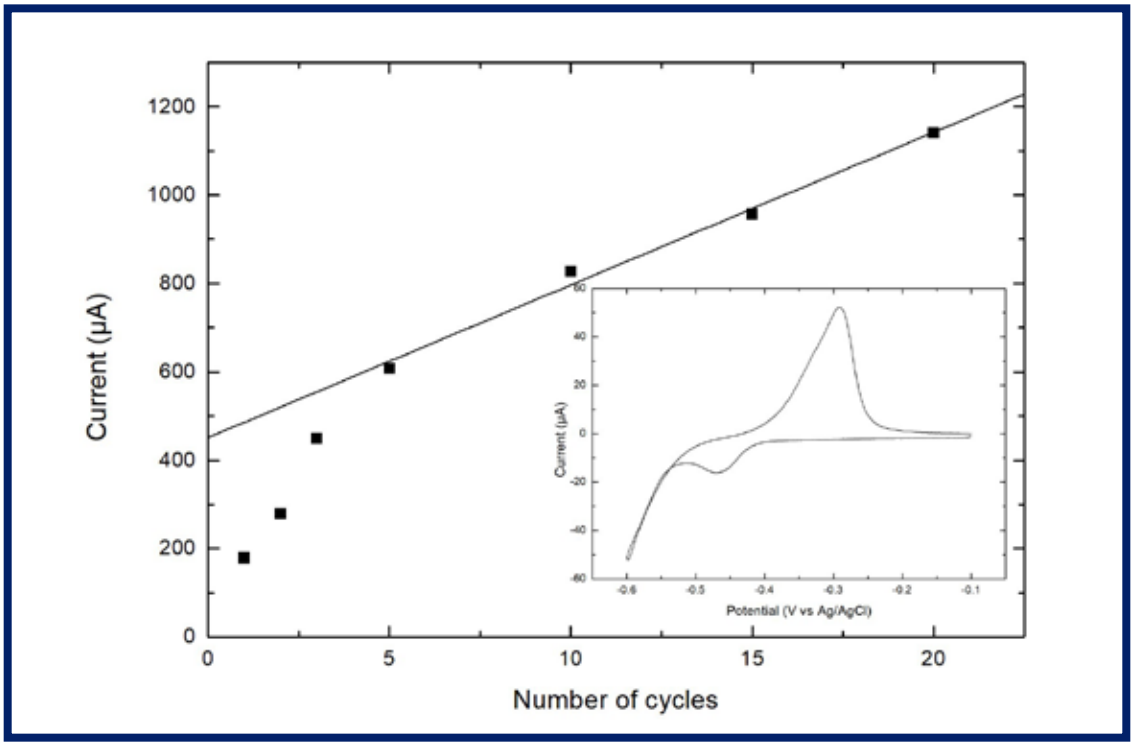

Fig. 2. *Deposit growth according to the number of deposition cycles. After the first five cycles, the deposition rate becomes linear. Inset shows the cyclic voltammetry of bismuth solution on Ag/Se in which is evident the cathodic UPD peak of the metal.*

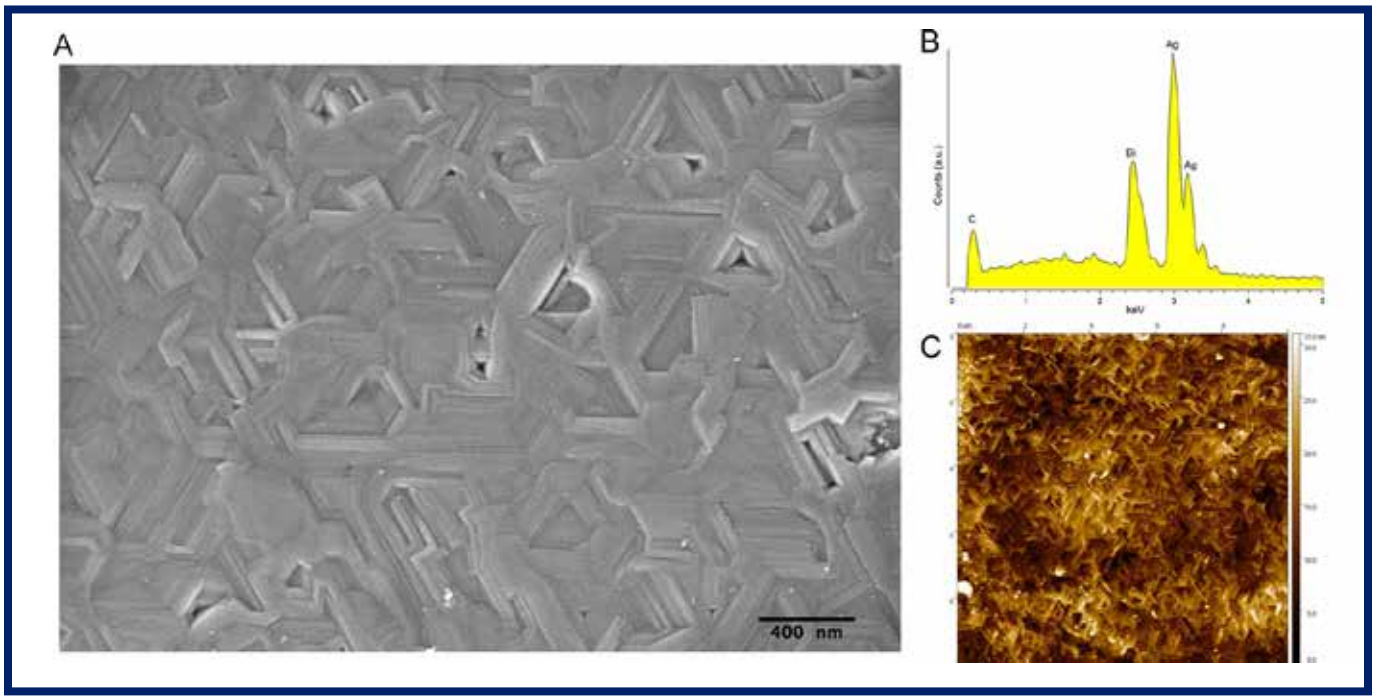

Fig. 3. *A) Secondary electrons SEM image of the 50-layers bismuth sample, showing the shape and morphology of the deposit. B) EDX spectrum collected on the same area, with an accelerating voltage of 10 kV that confirms the absence of selenium. C) AFM image of the same sample.*

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Walter Giurlani is a PhD student of chemistry at the University of Florence. Prior to this he earned both a BS and MS in chemistry at the same university, working on the electrochemistry of electrocatalysis, energy production, and the storage of fuel cells. He is part of the Applied Electrochemistry Group of the University of Florence Department of Chemistry. Currently he is focusing his studies on the electrodeposition and characterization of interesting materials for industrial application and next-generation technological devices. He is also collaborating with galvanic industries in R&D on the development of new deposition methods and quality control protocols for different practical applications. He may be reached at walter.giurlani@unifi.it.

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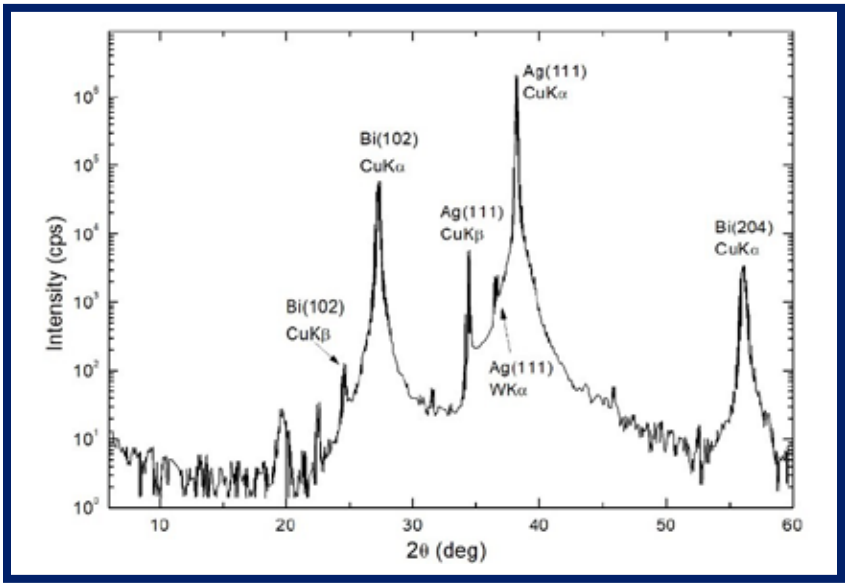

Fig. 4. *XRD measurement of the 50-layers bismuth sample to prove the crystallinity of the deposit.*

Andrea Giaccherini received his MS in chemistry in 2014 and his PhD in chemical sciences in 2018 from the University of Florence. His PhD research was focused on the characterization of ultrathin films of compound semiconductors grown by means of electrochemical atomic layer deposition (E-ALD). He is now serving as a postdoc at the University of Florence in the Department of Earth Sciences on a project aimed at finding new solvothermal synthesis of nanostructured quaternary sulfides for photovoltaics applications. He continues to collaborate with the Department of Chemistry of the University of Florence on the characterization of new compound semiconductors deposited by means of E-ALD. He may be reached at andrea.giaccherini@unifi.it.

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Detroit Section

In the 2017-2018 academic year, the **ECS Detroit Section** has held regular meetings serving southeastern Michigan members largely from the Detroit area. Section members are primarily from the automotive and battery industries, but are also from local universities, including the University of Michigan, Michigan State University, Wayne State University, Oakland University, and Kettering University.

The section meetings occur on campus at Lawrence Technological University in Southfield, MI. Below are a few of the events from the previous year.

- September 27, 2017: Tom Guarr of MSU Bioeconomy Institute spoke to 22 attendees on "Durable Organic Redox Systems for Practical Energy Storage Applications."
- October 24, 2017: Alvaro Masias of Ford Motor Company spoke to 24 attendees on "Improving Battery Prognostics Through High Precision Testing."
- November 28, 2017: Levi Thompson of the University of Michigan spoke to 38 attendees on "Non-Aqueous Redox Flow Batteries for Grid-Scale Energy Storage."
- January 16, 2018: Balasubramanian Lakshmanan of General Motors spoke to 35 attendees on "Recent Technical and Commercial Developments in Fuel Cells and Its Impact on Transportation Applications."
- February 15, 2018: John Warner of Ener1 spoke to 31 attendees on the "World Battery Market for Hybrid and Electric Bus Applications."
- March 22, 2018: John Camardese of XALT Energy spoke to 29 attendees on "Material Advancements for Lithium-Ion Batteries, the Hype versus Reality."
- April 25, 2018: Peter Gibson of LG Chem spoke on "Global Markets for Stationary Energy Storage."

Georgia Section

The **ECS Georgia Section** held its local conference at the Georgia Institute of Technology on April 27, 2018. The meeting was organized by Marta Hatzell, Paul Kohl, Jung Fang, and Seung Woo Lee. The event started with a reception and an invited seminar entitled "Electrochemically Instrumenting Organs on a Chip," given by David Cliffel, Cornelius Vanderbilt Professor and Chair, Department of Chemistry, Vanderbilt University. It was followed by a group lunch for the audience and a student poster session. Finally, three student poster awards were presented at the award ceremony: Garrett Huang (first place, Georgia Tech), Shan Xiong (second place, Georgia Tech), and Srinivas Hanasoge (third place, Georgia Tech).

Attendees gathered at Georgia Tech Manufacturing Institute during the 2018 ECS Georgia Section local conference.

Korea Section

On April 5, 2018, the **ECS Korea Section** hosted a ceremony recognizing the Korea Section Student Award at the Changwon Exhibition Convention Center in Korea, an event that took place concurrently with the Korean Electrochemical Society's spring meeting.

Hieu Quang Pham received the 2018 student award with a cash prize of $500 from the Society. During the KECS spring meeting, Pham presented the results of his research, which had been conducted with his adviser Seung-Wan Song. His presentation was titled "Development of Multi-Functional Binder for Li-Rich Layered Oxide Cathode of High-Energy Li-ion Batteries." Pham reported rationally designed fluorinated polyimide as a novel high-voltage (4.7 V) binder for high-capacity $Li_{1.13}Mn_{0.463}Ni_{0.203}Co_{0.203}O_2$ cathode in a 55 °C full-cell with graphite anode and conventional electrolyte without any electrolyte additive.

Pham is a PhD candidate in the Department of Chemical Engineering and Applied Chemistry at Chungnam National University in the Republic of Korea. His current research interests focus on the development of high-voltage electrolyte materials and binders for high-capacity Li-rich layered oxide cathodes of Li-ion batteries as well as high-voltage interfacial phenomena and electrochemical reaction mechanisms for performance enhancement.

The section will present the next award at its 2019 spring symposium.

Hieu Quang Pham *gave a presentation on the "Development of Multi-Functional Binder for Li-Rich Layered Oxide Cathode of High-Energy Li-ion Batteries."*

Hieu Quang Pham *(right) received the 2018 ECS Korea Section Student Award from KECS President* **Won Il Cho** *(left).*

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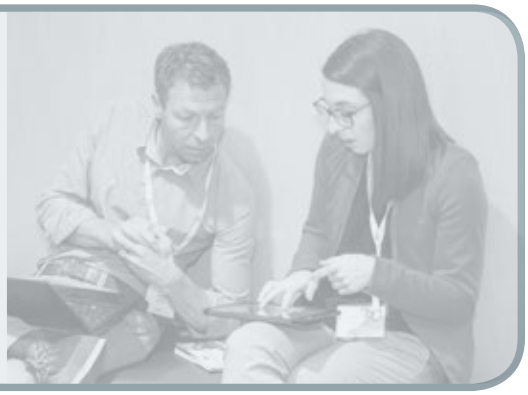

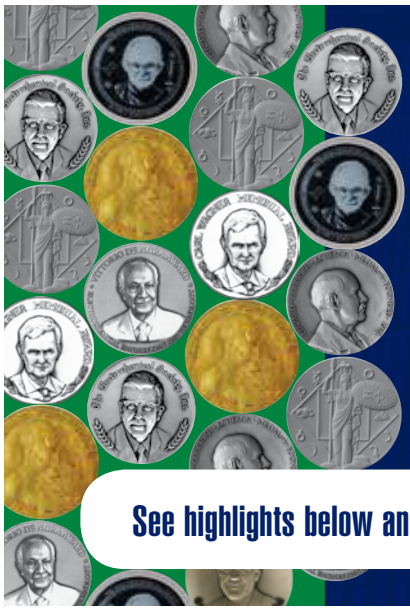

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ECS distinguishes outstanding technical achievements in electrochemistry, solid state science and technology, and recognizes exceptional service to the Society through the **Honors & Awards Program**. Recognition opportunities exist in the following categories: Society Awards, Division Awards, Student Awards, and Section Awards.

ECS recognizes that today's emerging scientists are the next generation of leaders in our field and offers competitive **Fellowships** and **Grants** to allow students and young professionals to make discoveries and shape our science long into the future.

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Society Awards

The **ECS Carl Wagner Memorial Award** was established in 1980 to recognize mid-career achievement and excellence in research areas of interest of the Society, and significant contributions in the teaching or guidance of students or colleagues in education, industry, or government. The award consists of a silver medal, a wall plaque, Society life membership, complimentary meeting registration, and travel assistance of up to $1,000.

Materials are due by October 1, 2018.

The **ECS Olin Palladium Award** was established in 1950 to recognize distinguished contributions to the fields of electrochemical or corrosion science. The award consists of a palladium medal, a wall plaque, a $7,500 prize, Society life membership, and complimentary meeting registration.

Materials are due by October 1, 2018.

Division Awards

The **ECS Energy Technology Division Research Award** was established in 1992 to encourage excellence in energy-related research. The award consists of a framed certificate, a $2,000 prize, and membership in the Energy Technology Division for as long as the recipient is an ECS member.

Materials are due by September 1, 2018.

The **ECS Energy Technology Division Supramaniam Srinivasan Young Investigator Award** was established in 2011 to recognize and reward an outstanding young researcher in the field of energy technology. The award consists of a framed certificate, a $1,000 prize, and complimentary meeting registration.

Materials are due by September 1, 2018.

The **ECS Nanocarbons Division Richard E. Smalley Research Award** was established in 2006 to encourage excellence in fullerenes, nanotubes, and carbon nanostructures research. The award is intended to recognize, in a broad sense, those persons who have made outstanding contributions to the understanding and applications of fullerenes. The award consists of a framed certificate, a $1,000 prize, and assistance up to a maximum of $1,500 to facilitate attendance of the meeting at which the award is to be presented.

Materials are due by September 1, 2018.

The **ECS Physical and Analytical Electrochemistry Division David C. Grahame Award** was established in 1981 to encourage excellence in physical electrochemistry research and to stimulate publication of high-quality research papers in ECS journals. The award consists of a framed certificate and a $1,500 prize.

Materials are due by October 1, 2018.

The **ECS Corrosion Division Herbert H. Uhlig Award** was established in 1972 to recognize excellence in corrosion research and outstanding technical contributions to the field of corrosion science and technology. The award consists of a framed certificate, a $1,500 prize, and possible travel assistance.

Materials are due by December 15, 2018.

The **ECS High Temperature Materials Division J. Bruce Wagner, Jr. Award** was established in 1998 to recognize a young Society member who has demonstrated exceptional promise for a successful career in science and/or technology in the field of high temperature materials. The award consists of an appropriately worded scroll and the sum of $1,000. The recipient may receive (if required) complimentary registration and up to $1,000 in financial assistance toward travel expenses for attendance of the Society meeting at which the award is to be presented.

Materials are due by January 1, 2019.

(continued from previous page)

Section Awards

The **ECS Europe Section Heinz Gerischer Award** was established in 2001 to recognize an individual or a small group of individuals (no more than three) who have made an outstanding contribution to the science of semiconductor electrochemistry and photoelectrochemistry including the underlying areas of physical and materials chemistry of significance to this field. The award consists of a framed certificate, a EUR 2,000 prize and, if required, financial assistance for unreimbursed travel expenses incurred to receive the award, not to exceed EUR 1,000.

Materials are due by September 30, 2018.

Student Awards

The **ECS Corrosion Division Morris Cohen Graduate Student Award** was established in 1991 to recognize and reward outstanding graduate research in the field of corrosion science and/or engineering. The award consists of a certificate and the sum of $1,000. The award, for outstanding master's or PhD work, is open to graduate students who have successfully completed all the requirements for their degrees, as testified to by the students' advisers, within a period of two years prior to the nomination submission deadline.

Materials are due by December 15, 2018.

The **ECS Energy Technology Division Graduate Student Award sponsored by Bio-Logic** was established in 2012 to recognize promising young engineers and scientists in fields pertaining to this division. The award consists of a framed certificate, a $1,000 prize, complimentary student meeting registration, and complimentary admission to the ETD business meeting.

Materials are due by September 1, 2018.

The **ECS Georgia Section Outstanding Student Achievement Award** was established in 2011 to recognize academic accomplishments in any area of science or engineering in which electrochemical and/or solid state science and technology is the central consideration. The award consists of a $500 prize.

Materials are due by August 15, 2018.

The **ECS Industrial Electrochemistry and Electrochemical Engineering Division H. H. Dow Memorial Student Achievement Award** was established in 1990 to recognize promising young engineers and scientists in the field of electrochemical engineering and applied electrochemistry. The award consists of a framed certificate and a $1,000 prize to be used for expenses associated with the recipient's education or research project.

Materials are due by September 15, 2018.

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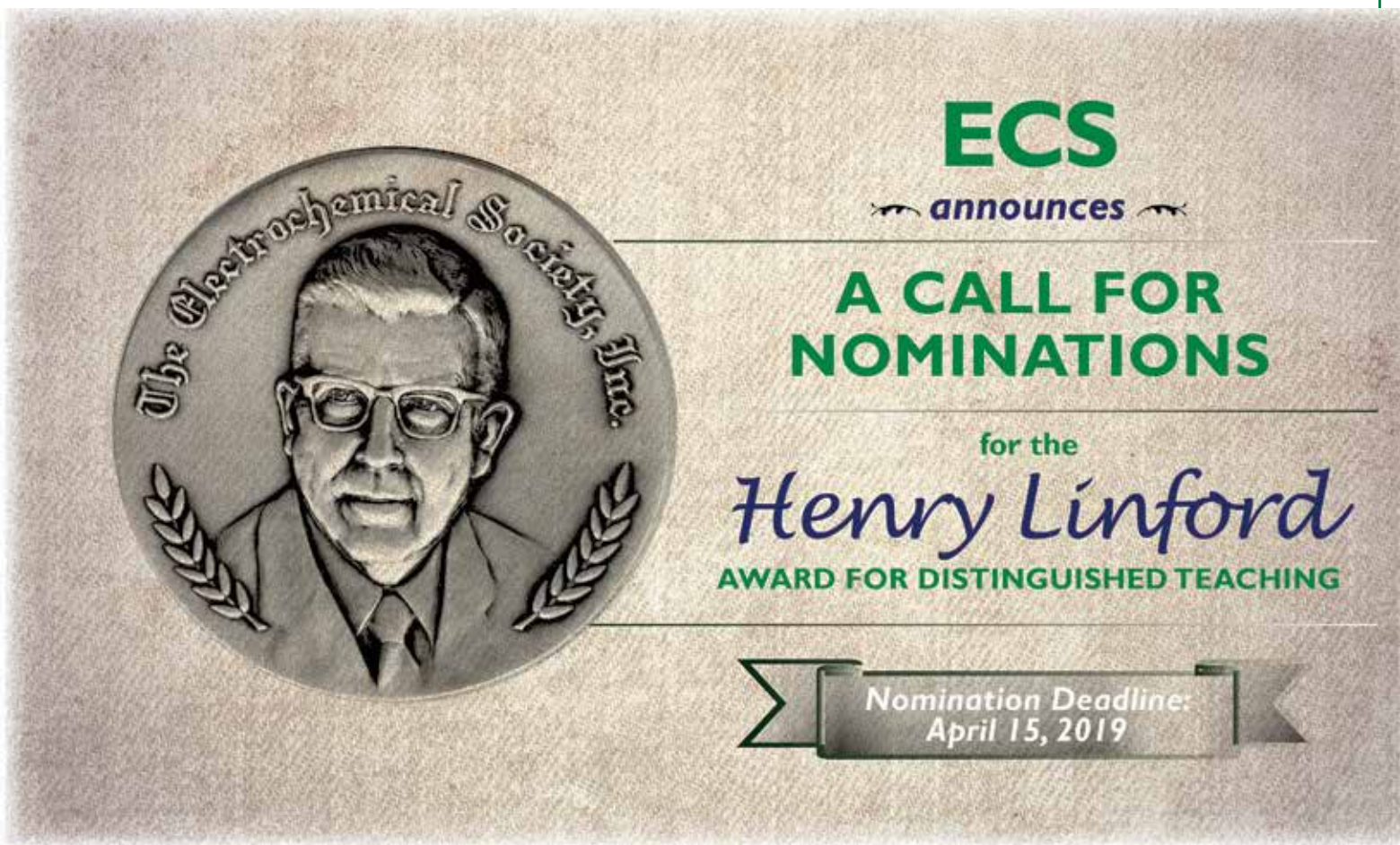

The **ECS Industrial Electrochemistry and Electrochemical Engineering Division Student Achievement Award** was established in 1989 to recognize promising young engineers and scientists in the field of electrochemical engineering and to encourage the recipients to initiate careers in this field. The award consists of a framed certificate and a $1,000 prize.

Materials are due by September 15, 2018.

The **ECS Korea Section Student Award** was established in 2005 to recognize academic accomplishments in any area of science or engineering in which electrochemical and/or solid state science and technology is the central consideration. The award consists of a $500 prize and is presented at a designated Korea Section meeting. At that time, the recipient may be requested to speak on a subject of major interest to him/her in the field of electrochemical and/or solid state science and technology.

Materials are due by September 30, 2018.

ECS INTRODUCES

the 2018 Winner of the ECS Canada Section Electrochemical Award: *Ashok Vijh*

Ashok Vijh is maître-de-recherche at the Institut de recherche d'Hydro-Québec and, concurrently, an invited professor at the National Institute of Scientific Research of the Université du Québec.

Vijh is an electrochemist of international stature who has published over 380 refereed papers and 7 books on various areas of interfacial electrochemistry. His original and extensive research contributions have advanced the following areas: the conversion and storage of energy (electrocatalysis, fuel cells, batteries, photoelectrochemical cells, and hydrogen economy), corrosion, and oxidation of metals. Particularly noteworthy is his seminal work on the mechanisms of a large number of electrode reactions involving surface films—based on his theoretical insights on *demetallized* surfaces where solid state properties of passive layers (including those on the battery electrodes, now so-called *solid-electrolyte interphases*) control the kinetics of charge transfer. His pathbreaking work on electrochemical reactions across metal/plasma, metal polymer, and metal/dielectric interfaces, as well as the electrochemical treatment of cancerous tumors is of extraordinary originality.

Vijh's distinctions are many. He is a fellow of the following: the Royal Society of Chemistry, the Institute of Physics, the American Physical Society, and the Institute of Electrical and Electronics Engineers. His academy memberships include: the Royal Society of Canada, where he served as president from 2005 to 2007; the World Academy of Sciences; the European Academy of Sciences, Arts and Letters; and the Indian National Science Academy.

He was the youngest winner of the I. W. Killam Memorial Prize of the Canada Council (1987)—the highest Canadian prize in any field of science. He was the first physical scientist to become a Knight of the National Order of Quebec in 1987 and was promoted to the rank of officer in 2008. He was decorated as an Officer of the Order of Canada in 1990. He received the Golden Jubilee Medal (2002) and the Diamond Jubilee Medal (2012) from Her Majesty Queen Elizabeth II. In 2017, he was made a Knight of the Order of Montreal.

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Questions? Contact OA@electrochem.org

NEW MEMBERS

ECS is proud to announce the following new members for January, February, and March 2018.

Members

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Fabien Besnard, Charlotte, NC, USA
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Ping Chen, Dalian, China
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Po-Ya Chuang, Merced, CA, USA
Woon Jin Chung, Cheonan, South Korea
Finn Deckert, Kirkel, SL, Germany
Pravas Deria, Carbondale, IL, USA
Edmund Dickinson, Teddington, UK
Xochitl Dominguez-Benetton, Mol, Belgium
Ban Dong, Chicago, IL, USA
Mateusz Donten, Kehlen, Luxembourg
Yueying Fan, Morgantown, WV, USA
Zhenxing Feng, Corvallis, OR, USA
Lin Gan, Shenzhen, China
Michael Gerhardt, Berkeley, CA, USA
Livia Giordano, Auburndale, MA, USA
Jorge Gonzalez-Sanchez, Campeche, Campeche, Mexico
Padma Gopalan, Madison, WI, USA
Reuven Gordon, Victoria, BC, Canada
Sergio Granados-Focil, Worcester, MA, USA
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Eric Hostetler, Lebanon, OR, USA
Michael Hughes, Northampton, PA, USA
James Hurst, Oxford, MI, USA
Haiping Jia, Richland, WA, USA
Yan-Xia Jiang, Xiamen, China
Sadia Kabir, Golden, CO, USA
Yongmook Kang, Seoul, South Korea
Yu Katayama, Ube, Yamaguchi, Japan
Shrikant Kawale, London, London, UK
Isaiah Kellogg, Union, MO, USA
Jungseung Kim, Lebanon, OR, USA
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Daniel Kissel, Brookfield, IL, USA
Jesse Ko, Arlington, VA, USA
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Gregory Korshin, Seattle, WA, USA
Darshan Kundaliya, Beverly, MA, USA
Oleg Kuznetsov, Columbus, OH, USA
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Bin Liu, Manhattan, KS, USA
Jenifer Locke, Columbus, OH, USA
Marc Madou, Irvine, CA, USA
Claudia Marcela Bazan, Montreal, QC, Canada
Joshua Maurer, Troy, NY, USA
Eric McCalla, Montreal, QC, Canada
James McKone, Pittsburgh, PA, USA
Eric Meshot, Livermore, CA, USA
Giuseppe Milano, Yamagata-shi, Yamagata, Japan
Elisa Miller-Link, Lakewood, CO, USA
Gregory Moore, Groton, CT, USA
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Chanho Pak, Gwangju, South Korea
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Su-Yuan Xie, Xiamen, PR, China
Lijun Yang, Burnaby, BC, Canada
Lifeng Zhang, Xi'an, China
Linghong Zhang, Lemont, IL, USA
Jing Zhao, Storrs, CT, USA
Yun Zhao, Newark, DE, USA
Ilya Zharov, Salt Lake City, UT, USA
Nan Zheng, Fayetteville, AR, USA

Student Members

Richard Aadahl, Charlottesville, VA, USA
Fatemeh Abbasi, Guelph, ON, Canada
Fahimah Abd Lah Halim, Kanazawa, Ishikawa, Japan
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Jada Adams, New Orleans, LA, USA
Viacheslav Agafonov, Seattle, WA, USA
Jinhyeok Ahn, Ansan, South Korea
Ali Alshanoon, Manassas, VA, USA
Rakan Altarawneh, St. John's, NL, Canada
Erik Anderson, Atlanta, GA, USA
Chalita Aphirakaramwong, Wangchan, Thailand
Jared Arabit, Buena Park, CA, USA
Alina Arslanova, Leuven, Flanders, Belgium
Kalin Baca, Albuquerque, NM, USA
Mehrdad Balandeh, Los Angeles, CA, USA
Pete Barnes, Boise, ID, USA
Jack Beane, Liverpool, Merseyside, UK
Melissa Becker, Rochester, NY, USA
Jon Bender, Austin, TX, USA

NEW MEMBERS

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Samuel Castro Pardo, Houston, TX, USA
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Utibe-Eno Charles-Granville, Charlottesville, VA, USA
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Hung-Yu Chen, Hsinchu City, Taiwan, Taiwan
Miao Chen, Yonezawa, Yamagata, Japan
Shuai Chen, Guelph, ON, Canada
Ting Chen, Fukuoka, Fukuoka, Japan
Che Chiu, Taipei, Taiwan
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Yun-Jung Chung, Taoyuan, Taiwan, Taiwan
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Venkatesh Subramanian Manikandan, Guelph, ON, Canada
Scohy Marion, Saint Martin d'Heres Cedex, France
Tim Marshall, Philadelphia, PA, USA

(continued on next page)

NEW MEMBERS

(continued from previous page)

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Michael Strand, Stanford, CA, USA
Callie Stuart, Clemson, SC, USA
Zihang Su, Cleveland, OH, USA
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He Sun, Yonezawa, Yamagata, Japan
Yunkai Sun, Charlottesville, VA, USA
Tse-Yu Tai, Hsinchu, Taiwan, Taiwan
Natsumi Takaya, Sendai, Miyagi, Japan
Greg Tatar, Kalispell, MT, USA
Linnette Teo, Seattle, WA, USA
Antony Raj Thiruppathi, Guelph, ON, Canada
Seamus Thomson, Sydney, New South Wales, Australia
Sophia Tiano, Westford, MA, USA
Yi-Hsin Ting, Hsinchu, Taiwan, Taiwan
Mineyoshi Tomie, Noda, Chiba, Japan
Nam Tran, New Orleans, LA, USA
Ngoc Tham Tran, Brisbane, Queensland, Australia
Wendy Tran, Edmonton, AB, Canada
Yuki Tsuda, Yamagata-shi, Yamagata, Japan
Kyota Uda, Yonezawa, Japan
Can Uzundal, Ankara, Turkey
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Mary Vijila, Ernakulam, KL, India
Julija Vinckeviciute, Goleta, CA, USA
Ruiyu Wang, Philadelphia, PA, USA
Shaofei Wang, Rochester, NY, USA
Shin Wang, Hsinchu, Taiwan, Taiwan
Ting-Yi Wang, Taipei, Taiwan, Taiwan
Zhiyang Wang, Bloomington, IN, USA
Jon Weller, Phoenix, AZ, USA
Benjamin Whitman, Cleveland, OH, USA
Cedrik Wiberg, Mölndal, Sweden
Anna Winiwarter, Kgs. Lyngby, Denmark
Min-Ci Wu, Hsinchu, Taiwan
Xinxin Xiao, Limerick, Ireland
B?o xiong, Hamilton, ON, Canada
Stephanie Xiong, Placentia, CA, USA
Xinzhao Xu, London, London, UK
Jiancheng Yang, Gainesville, FL, USA
Tzu-Chin Yang, Taipei, Taiwan, Taiwan
Yuxiang Yao, Toronto, ON, Canada
Dai Yifan, Cleveland Heights, OH, USA
Jae Young Yoo, Daejeon, South Korea
Ji Mun Yoo, Woodridge, IL, USA
Seungho Yu, Ann Arbor, MI, USA
Xiaoyun Yu, Palo Alto, CA, USA
Nina Zensen, Ulm, BW, Germany
Qiang Zhang, Kami, Japan
Xiaoxuan Zhang, Union City, CA, USA
Xueli Zheng, Palo Alto, CA, USA
Shan Zhu, Bethlehem, PA, USA
Yufeng Zhu, Cleveland, OH, USA

Member Anniversaries

It is with great pleasure that we recognize the following ECS members who have reached their 30, 40, 50, and 60 year anniversaries with the Society in 2018.
Congratulations to all!

60 Years

David S. Newman
S. A. Prussin
Arthur M. Wilson
Petr Zuman

50 Years

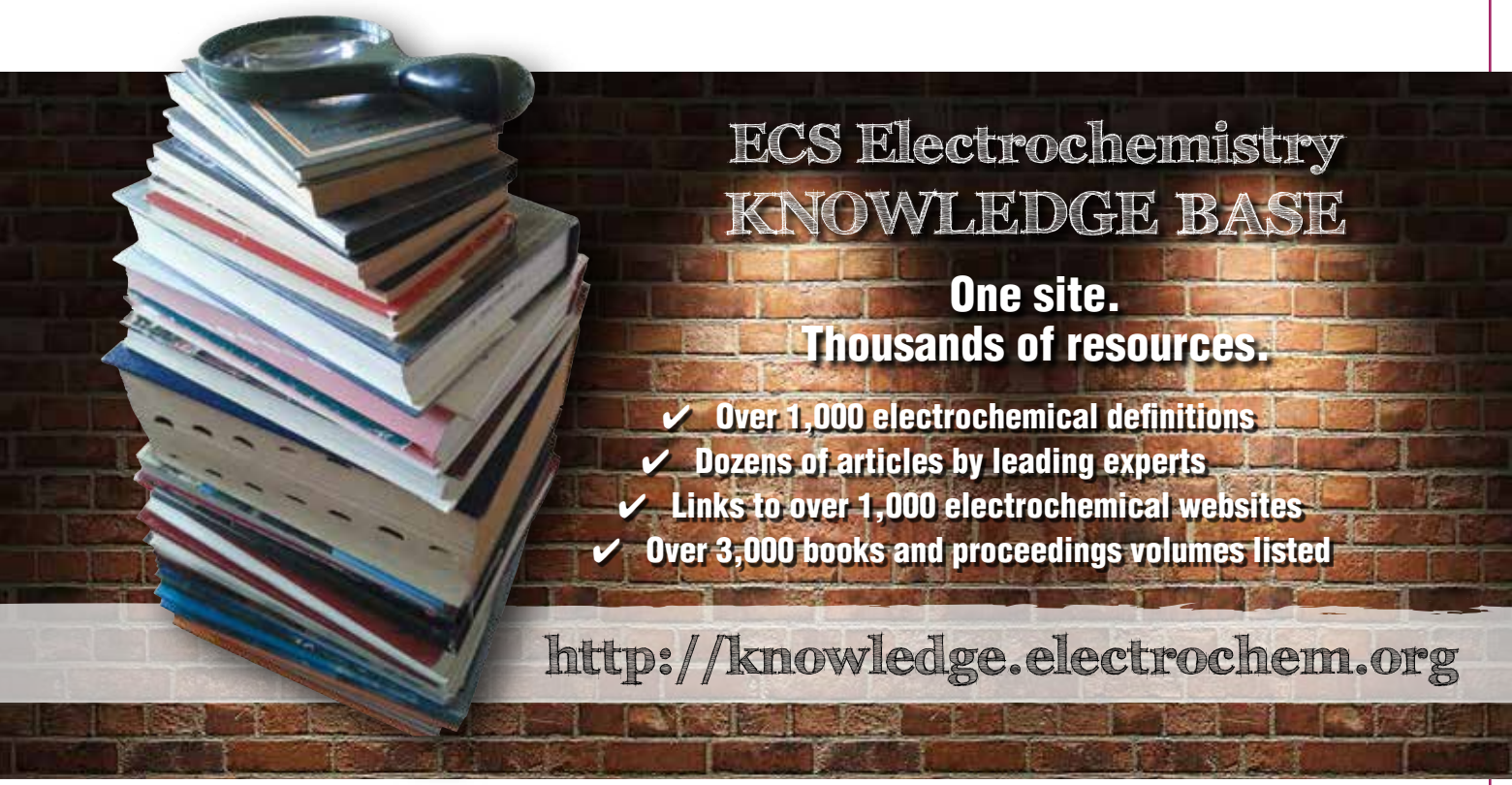
Eric W. Brooman
John S. Dunning
George H. Fraser
George W. Luckey
Robert E. Palmer
Frank Parsen
Howard W. Pickering
Allan H. Reed
Ashok K. Vijh
Hiry B. West
Jerry M. Woodall

40 Years

Lionel P. Adda
Albert S. Bergendahl
Andrew B. Bocarsly
Sid Clouser
Geoffrey John Dudley
Wolfgang R. Fahrner
Hisashi Harada
Kurt R. Hebert
Raji Heyrovska
Curtis F. Holmes
Rudolf Holze
Harold W. Korb
Michael Krumpelt
Thomas F. La Gess
Robert Charles McDonald
Leroy J. Miller
Sudhan S. Misra
Joseph R. Monkowski
Timothy A. Moore
Colin W. Oloman
Tetsuo Osa
Detchko Pavlov
Michael R. Polcari
Robert F. Savinell
Robert Spotnitz
Hans-Henning Strehblow
Micha Tomkiewicz
Michael S. Waite
Arthur Yelon

30 Years

Derryl D. J. Allman
Jeffrey Stuart Buchanan
Stephanie Watts Butler
Kwong-Yu Chan
Alison J. Davenport
Hugh C. De Long
Peter C. Foller
Jeffrey C. Gelpey
Hossein Ghezel-Ayagh
Andrew N. Jansen
David Kaplin
G. H. Kelsall
Chi-Woo Lee
Andrei Leonida
Azzam N. Mansour
Mohammad R. Mirabedini
Katsuhiko Naoi
Demetrius Papapanayiotou
Michael F. Pyszczek
Jimmie L. Russell
Alberto A. Sagues
Michael J. Sailor
Yuichi Sato
Eric M. Stuve
Francis L. Tanzella
D. Morgan Tench
Markku V. Tilli
Bernard Tribollet
Young-Chung Wang
Xiaoge Zhang



ECS 2018 Summer Fellowships

This year marks the 90th anniversary of ECS providing summer fellowships to assist students in continuing their graduate and postdoctoral work in a field of interest to the Society. Each awardee receives up to $5,000 to support their research efforts. Congratulations to the following five summer fellowship recipients. We look forward to reading their reports in this year's winter issue of *Interface*.

2018 Colin Garfield Fink Fellowship Recipient

Haegyeom Kim received a BSc degree from the Department of Materials Science and Engineering in Hanyang University, a MSc degree on graphene-based hybrid electrodes for lithium rechargeable batteries from the Korea Advanced Institute of Science and Technology, and a PhD degree on graphite derivatives for Li and Na rechargeable batteries at Seoul National University. Now, he serves as a postdoctoral researcher in Prof. Gerbrand Ceder's group at Lawrence Berkeley National Laboratory. His current research interest lies in the design and development of novel electrode materials for Li-, Na-, and K-ion batteries as well as the investigation on underlying energy storage mechanisms within. To date, he has published more than 50 papers in peer-reviewed journals, including 27 first-authored papers. According to Google Scholar, his papers have been cited over 4,000 times and his H-index is 33. His accomplishments have been recognized by the ECS Battery Division Postdoctoral Associate Research Award, ECS Energy Technology Division Graduate Student Award, ECS Student Award of the Korea Section, ECS Battery Division and ECS Energy Technology Division, travel grants, the Best Graduate Thesis Award of Seoul National University, and a Korea Global PhD Fellowship. For his summer fellowship, he will investigate how intercalating ion species affect electrochemical properties of electrode materials in the rechargeable battery system.

2018 Edward G. Weston Fellowship Recipient

Aashutosh N. Mistry has been pursuing his doctoral studies with Prof. Partha P. Mukherjee at Purdue University. His present research focuses on the mesoscale understanding of transport phenomena in lithium batteries. He investigates the physicochemical interactions taking place in electrodes, how microstructure affects these processes and the role of this coupling at an observable scale. His research and academic achievements have been recognized in the form of various awards and fellowships throughout his student career. He is the recipient of the Purdue College of Engineering Outstanding Research Award 2018 and Lambert Graduate Teaching Fellowship at Purdue University.

2018 F. M. Becket Fellowship Recipient

Xinyou Ke is a PhD candidate in the Department of Mechanical and Aerospace Engineering at Case Western Reserve University under the supervision of Dr. Robert F. Savinell, Dr. Joseph M. Prahl, and Dr. Jesse S. Wainright. He has focused on understanding the fundamentals involved in high performance flow batteries with flow field and stack designs, and electronic conduction mechanisms of slurry or semi-solid electrodes used for electrochemical flow capacitors and flow batteries through both modeling and experimental approaches. To date, he has authored and coauthored 10 peer-reviewed journal articles and has been awarded several scholarships and certificates for his contributions to research, academic records, and professional services. He served as the treasurer of the ECS Case Western Reserve University Student Chapter during 2016-2017.

2018 Joseph W. Richards Fellowship Recipient

Yi Peng is pursuing his PhD degree at the University of California-Santa Cruz (UCSC) under the supervision of Prof. Shaowei Chen. In 2017, he won the John and Grace Wang Award in Physical Chemistry from UCSC and a STEM Chateaubriand Fellowship from the Embassy of France, and is carrying out collaborative research in spring 2018 in Prof. Pierre Millet's laboratory in Universite Paris-Sud in France. His research interests include surface functionalization and engineering of metal/semiconductor nanoparticles, their charge-transfer dynamics, and single atom catalysis for electrochemical energy conversion and storage such as oxygen reduction, hydrogen evolution, and CO_2 reduction reactions. Thus far, he has authored 26 peer-reviewed publications and one U.S. patent.

2018 H. H. Uhlig Fellowship Recipient

Jeffrey Henderson is a third year PhD candidate at the University of Western Ontario with Dr. David W. Shoesmith and Dr. James J. Noël serving as his advisors. Henderson focuses his attention on the corrosion behavior of Ni-Cr-Mo alloys while under aggressive conditions. During his graduate studies, he has received a total of six honors and awards including the prestigious Alexander Graham Bell Canada Graduate Scholarship given by the Natural Sciences and Engineering Research Council of Canada. As a recipient of this year's ECS summer fellowship, Henderson will travel to Chimie ParisTech in Paris, France, where he will work alongside Dr. Kevin Ogle and Dr. Philippe Marcus to better understand the corrosion behavior and oxide properties of commercially available Ni-based Hastelloy materials.

2018 Summer Fellowship Committee

ECS thanks the 2018 Summer Fellowship Committee for its time and effort in selecting this year's recipients:

Vimal Chaitanya, Committee Chair
Director, Energy Research Lab
New Mexico State University, USA

Peter Mascher
Professor and William Sinclair Chair in Optoelectronics
McMaster University, Canada

David Hall
Postdoctoral Researcher
Dalhousie University, Canada

Kalpathy Sundaram
Professor & Graduate Coordinator
University of Central Florida, USA

Auburn University Student Chapter

The **ECS Auburn University Student Chapter** is comprised of a multidisciplinary group of student members from the materials engineering, chemical engineering, chemistry, and electrical engineering departments. Chapter members were surveyed on their interests and indicated a strong interest in industry. The chapter organized a professional development lecture, a plant tour focused on sustainability, three invited talks, and two student member talks. The theme of the chapter's activities focused on global sustainability challenges.

Dr. Jeffrey Fergus, Dr. Xinyu Zhang, and Dr. Byron Farnum shared their research and perspectives on solid oxide fuel cells, chemical vapor sensors using conducting polymers and carbon nanotubes, and inorganic nanomaterials and molecules for renewable energy conversion and storage.

Dr. Dale Watson provided a professional development workshop on job searching techniques and preparing for a career in electrochemistry.

On March 23, 2018, the chapter enjoyed a tour of InterfaceFLOR, the world's largest manufacturer of commercial carpet tile. InterfaceFLOR's initiative Mission Zero promises to eliminate the organization's negative environmental impacts by 2020.

Chapter members are actively involved in presentations and discussions on MXene 3D materials in energy storage application. The members want to make contributions to global sustainability.

ECS Auburn University Student Chapter members visited InterfaceFLOR, the world's largest manufacturer of commercial carpet tile.

Members of the ECS Auburn University Student Chapter with Emre Kayali, who presented his work on the electrochemical performance of 2D Mxenes.

2019 Summer Fellowships Dates

Application opens – September 2019

Application deadline – January 15, 2019

Brno University of Technology Student Chapter

The **ECS Brno University of Technology Student Chapter** has enjoyed a number of successes since the beginning of the year. The chapter successfully recruited another member, Kamil Jaššo, who shares an interest in post-lithium systems; more specifically, his work is focused on lithium-sulfur systems.

The chapter also hosted José Francisco Dos Santos from Federal University Santa Catarina. Dos Santos visited through the support of the international project UNIGOU, organized by the Institute of Czech-Brazilian Academic Cooperation. Dos Santos was with the department from January 15 to March 31, 2018. His work was focused on aprotic sodium-ion systems. His task was to lay on solid-liquid synthesis of sodium titanate electrode material (NaxTiyOz) for negative electrode in sodium-ion cell. The chapter looks forward to future collaborations with him.

The chapter is also preparing for the arrival of Dr. Mariela Ortiz from National Technological University in La Plata, Argentina. She is an expert on energy storage and renewable energy sources along with electrochemical energy sources such as Li-ion and Li-sulfur batteries. The chapter anticipates that Dr. Ortiz will be with the department for the upcoming year.

Additionally, the chapter is planning to participate in the 19th International Conference on Advanced Batteries, Accumulators and Fuel Cells (conference webpage: www.aba-brno.cz) that is held in Brno. ABAF is an ECS-sponsored meeting. Its meeting proceedings will be published in a special volume of *ECS Transactions*.

The chapter's members will continue to participate in international meetings focused on lithium-ion systems organized by the International Society of Electrochemistry, like the one held in Japan from April 15 to 18, 2018.

The chapter will soon host its own meeting, which will be held in Blansko, Czech Republic, July 17-18, 2018. The meeting will be focused on batteries, energy storage systems, and renewable energy.

Case Western Reserve University Student Chapter

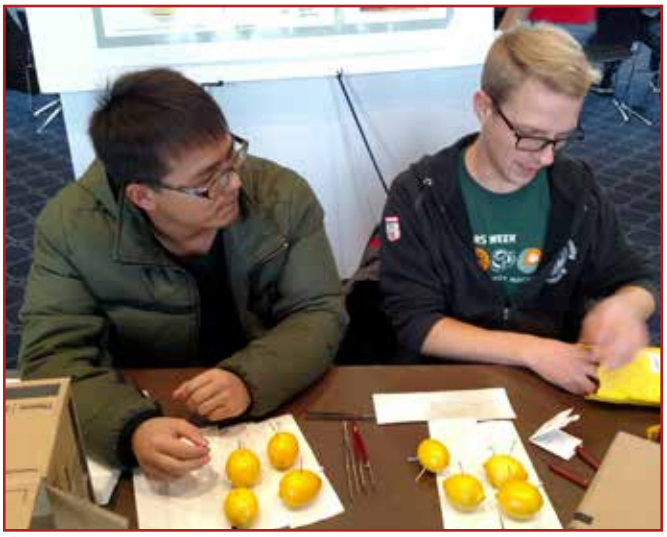
The **ECS Case Western Reserve University Student Chapter** established a service outreach team, and in February 2018, the chapter partnered with the Chemical Engineering Graduate Student Organization to volunteer at the university's annual engineering carnival event. Participation involved showing interactive science concepts to students in second to eighth grade. The chapter and ChEGSO showed these prospective scientists two different experiments: an electrochemical lemon battery and a Cartesian diver. When the children's LED light illuminated, their faces simultaneously lit up with wonder and curiosity.

The chapter also brought outside speakers to campus and had them showcase their research. Its speakers included Dr. Daniel Scherson, Dr. Anne Co from The Ohio State University, and Dr. Yanhai Du from Kent State University. The chapter partnered with the Graduate Materials Society and brought in Dr. Gerald Frankel from The Ohio State University. The speakers' seminars ranged from topics on the technical details of their research as a professor to what it is like running a startup.

The chapter continues to grow its service outreach team as well as its partnerships with other on-campus organizations by bringing together students and faculty from other on-campus organizations and by helping tie in professional, personal, and service development for its students and affiliates.

Dr. Anne Co *presented her work on electrocatalysis to the chapter.*

Dr. Daniel Scherson *(left) met with members of the ECS Case Western Reserve University Student Chapter during the social hour after his presentation.*



Xinyou Ke *(left) and* **Jason Pickering** *(right), the chapter's service outreach team lead, set up a lemon battery experiment for the children attending the Case Western Reserve University Engineering Carnival Fair.*

Calgary Student Chapter

The **ECS Calgary Student Chapter** organized an afternoon workshop on advanced electrochemical impedance spectroscopy (EIS) at the end of October 2017. The instructor for this workshop was Dr. Mark Orazem, a distinguished professor of chemical engineering at the University of Florida, an adjunct professor at the Beijing University of Chemical Technology, and a highly respected expert in EIS. This workshop reviewed the basics of impedance measurements and then focused on how to develop models for interpreting impedance data. In addition, equivalent circuits, kinetic models, diffusion impedance, and constant phase elements were covered during the workshop. The workshop was very successful, with over 40 attendees from the Department of Chemistry and a number of departments within the Schulich School of Engineering at the University of Calgary, as well as a few students from the University of Alberta in Edmonton. This event also served to attract a number of new members to the Calgary Student Chapter.

Dr. Mark Orazem *introduced a resource for electrochemical impedance spectroscopy at the start of the ECS Calgary Student Chapter's workshop.*

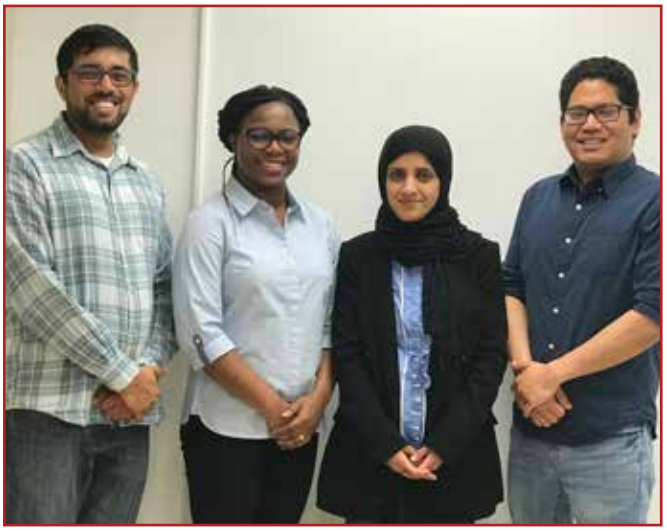
A portion of the attendees of the chapter's advanced impedance workshop in Calgary, Alberta, Canada.

Oklahoma Student Chapter

The **ECS Oklahoma Student Chapter** was established in 2017 with six members and three co-advisors from local institutions: Dr. Sadagopan Krishnan and Dr. Barry K. Lavine from Oklahoma State University and Dr. Gabriel LeBlanc from the University of Tulsa.

The chapter participated in National Lab Day 2017, a nationwide initiative to foster ongoing collaboration among volunteers, students, and educators. The chapter demonstrated single-drop electrochemical analysis at the event.

This year, to expand the chapter membership, the new executive committee organized an orientation and membership recruitment session on April 2, 2018, at Oklahoma State University. The president of the chapter, Gayan Premaratne, presented an overview of ECS, details on student chapters, and the benefits associated with ECS membership. Plans were also discussed on the activities to be conducted for the fiscal year to improve intellectual and professional development of the members. The chapter aims to hold monthly chalkboard talks, an invited seminar on a focused area of electrochemistry, and live electrochemistry demonstrations at public events in Oklahoma. The event recruited 12 enthusiastic graduate students who are driven to be involved in the activities of ECS and learn insights on electrochemistry.



Executive committee of the ECS Oklahoma Student Chapter (left to right): **Gayan Premaratne**, *president,* **Isio Sota-Uba**, *secretary,* **Zainab Al Mubarak**, *vice president, and* **Jinesh Niroula**, *treasurer.*

Lewis University Student Chapter

Throughout the 2017 fall and 2018 spring semesters, the **ECS Lewis University Student Chapter** traveled and hosted demonstrations and community outreach events at various high schools, elementary schools, and community centers to promote STEM awareness. The demos allowed students and members of the community of all backgrounds, ages, and interest levels to participate in hands-on activities and learn about concepts such as polymerization, metal complexation, and surfactant interactions. These events truly stimulate an interest in science among students and parents due to their applications in everyday life.

The chapter hosted its first annual water filtration competition, called Shipwrecked, which allowed students from community high schools to remediate synthetic wastewater. Students had the ability to improve skills in critical thinking, problem solving, and team building. Water quality specialists came to judge the competition, evaluating the designs based on innovation, efficiency, and repeatability. An Elkay-sponsored water filtration system was presented to the winning school of the competition.

Furthermore, in order to give back to the community, the chapter hosted its first Pedal for Pi-Day event, called Pedal for Preemies. In honor of the Lewis University volleyball coach's premature daughter, a stationary bike was pedaled over the course of 26 hours by volunteers, resulting in a total of 939,574 revolutions of pis generated by the rotation of the bike wheel. Donations amounting to a total of $5,000 were raised and presented to the Loyola neonatal intensive care unit. This event brought math and science together while also emphasizing the importance of giving back to the community.

In addition to participating in community outreach, members have had the opportunity to present their work at numerous conferences, such as the Lewis University Celebration of Scholarship Symposium, an ECS meeting, the American Chemical Society Regional Conference, and the Associated Colleges of the Chicago Area Symposium. In the coming semesters, the chapter is looking forward to hosting more community outreach events, offering tutoring hours, and continuing to promote STEM.

The ECS Lewis University Student Chapter at the White Oak Library STEM Fest on March 3, 2018.

Look Out!

We want to hear from you!

Students are an important part of the ECS family and the future of the electrochemistry and solid state science community . . .

Send your news and a **few good pictures** to Shannon Reed, director of membership services, at **Shannon.Reed@electrochem.org.**

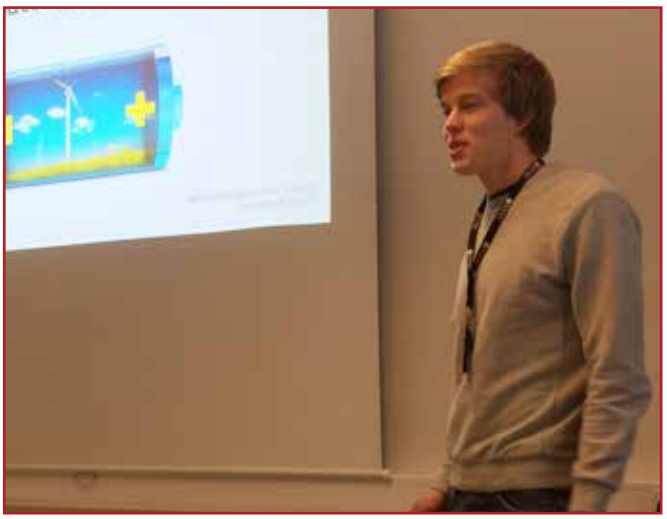
We'll spread the word around the Society. Plus, your student chapter may also be featured in an upcoming issue of *Interface*!

www.electrochem.org/student-center

Norwegian University of Science and Technology Student Chapter

The **ECS Norwegian University of Science and Technology Student Chapter** in Trondheim, Norway, is always looking to recruit new members. On March 1, 2018, the student chapter held a recruitment seminar inviting both students looking for a master's thesis project as well as those currently writing their thesis. After a variety of presentations on different topics related to electrochemistry, the lively discussion was continued over dinner with professors dazzling the minds of young, enthusiastic prospective researchers.

Kristian Thorbjørnsen *presented on the electrochemical energy group.*



Henning Kaland *presented on the battery group.*

Ohio University Student Chapter

On March 6, 2018, the **ECS Ohio University Student Chapter** organized an outreach event for the Margaret Boyd Scholars of Ohio University. The event allowed 20 undergraduate students to visit the Center for Electrochemical Engineering Research over two days to become familiar with highlighted research going on in the center, such as ammonia synthesis, ammonia and urea electrolysis for wastewater treatment, coal electrolysis, lithium-ion batteries, and transmission electron microscopy and its application in electrochemistry and fuel cell technology. At the end of the outreach program, the students were trained to run fuel cell cars that operated on hydrogen fuel cells.

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Members of the ECS Ohio University Student Chapter with the Margaret Boyd Scholars of Ohio University and **Dr. Gerardine Botte** *(front row, second from right).*

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They also had the opportunity to race their cars a calculated distance. The students shared their thoughts with Dr. Gerardine Botte on how this outreach caught their attention and how useful electrochemistry can be in real world. The outreach also provided chapter members an opportunity to mentor and teach young minds and support science education in schools around the country.

On April 2, 2018, the chapter hosted Dr. Viola Birss, professor of chemistry at the University of Calgary, Canada. Dr. Birss graciously accepted the chapter's invitation and presented a talk during the Russ College of Engineering's weekly chemical and biomolecular engineering seminar. The audience was a mixture of undergraduate students, graduate students, and faculty. The title of the lecture was "Novel Electrode and Catalyst Support Materials for Reversible Fuel Cell Applications." Dr. Birss joined the chapter committee over lunch for an informal discussion in which she imparted her cognizance in electrochemistry. Later that evening, Dr. Birss joined the members of CEER, other students from the Department of Chemical and Biomolecular Engineering, and students from the Department of Chemistry for a friendly discussion session, which centered mostly upon her experiences as well as future career options in the field of electrochemistry, and provided members new perspectives on the field.

From left to right: Mehrdad Abbasi, Ali Yazdani, Ashwin Ramanujam, Alamgir Haque, Dr. Madhivanan Muthuvel, Dr. Gerardine Botte, Bertnard Neyhause, Dr. Viola Birss, Benjamin Sheets, Behnaz Jafari, Amy Linderberger, Raziyeh Ghahremani, Payman Sharifi, Bahareh Baheri, Andrew Kasick, Xiang Lyu, *and* Mohiedin Bagheri.

University of Iowa Student Chapter

In the months leading up to April 8, 2018, members of the **ECS University of Iowa Student Chapter** worked collaboratively with faculty from the Chemistry Department and the School of Music at the University of Iowa to develop the chemical element of a musical production titled *Musical Chemistry* orchestrated by Prof. Jean-François Charles. This project allowed members to bridge the gap between the physical sciences and fine arts. The production featured a water clock, rijke tubes, a soxhlet extraction, several chemiluminescent reactions, and fluorescent compounds. The chapter was happy to work as chemical consultants in regard to what reactions would work and the chemical safety required. In the end, luminol and fluorescein prevailed as the primary sources of chemiluminescence and fluorescence under UV light. Members of the chapter also hosted chemical demonstrations prior to the show on April 8, demonstrating how common household items (e.g., tonic water, detergent, etc.) have additives that cause them to fluoresce under UV light. In addition to working as consultants and doing demonstrations prior to the show, members assisted in writing the show's program, which included information on the physics and chemistry observed in the show. The club worked to make the information accessible to the general public in order to spread the joys of chemistry.

From left to right: Sidney DeBie, Michaella Raglione, Daniel Parr, *and* Kasun Dadallagei *with the water clock used in the* Musical Chemistry *production at the University of Iowa.*

University of Kentucky Student Chapter

The **ECS University of Kentucky Student Chapter** hosted Prof. Martin Maldovan from Georgia Institute of Technology on March 30, 2018. His seminar titled "New Approaches for Thermal Transport Control in Nanomaterials and Metamaterials" gave insights into manipulations of thermal energy transfer using wave interference and thermal band gaps. Prof. Maldovan also visited Prof. Y. T. Cheng's Energy, Nanomechanics, and Surfaces Research Laboratory at the University of Kentucky and discussed energy-related topics with the group. Prof. Maldovan's seminar was a campus-wide event attended by faculty and students from both the College of Engineering and the College of Arts & Sciences at the University of Kentucky.

University of Texas at Austin Student Chapter

The **ECS University of Texas at Austin Student Chapter** hosted two chalk talks for the 2017-2018 academic year. The first talk, on October 26, 2017, was presented by Dr. Charuksha Walgama, who discussed "Voltage Driven Drug Metabolism by Wired Human Liver Enzyme." In the talk, he explored how electrochemistry can be used in biocatalysts to have drugs react with liver cells to produce metabolites. The second talk was presented on March 2, 2018, by Matthew Boyer, who is a fourth-year PhD candidate in the McKetta Department of Chemical Engineering. He presented his talk on "A Computational Approach to Li-ion Battery Interfaces," which elucidated SEI layer Li-ion transport characteristics through modeling of ethyl carbonate and diethyl carbonate SEI layers on electrodes.

On March 3, 2018, the chapter participated in the annual Explore UT event, where students, parents, teachers, and community members from across Texas come to participate and learn about research happening at UT Austin. Explore UT seeks to get the community interested in education and motivate them to pursue higher education. The chapter discussed the science behind clean energy by demonstrating a fuel cell car and modeling layered Li-ion battery structures in cell phones and electric vehicles. The chapter looks forward to continuing these activities and hopes to expand its involvement inside and outside the university while planning potential collaborations with other student chapters.

University of Washington Student Chapter

During its winter quarter proceedings, the **ECS University of Washington Student Chapter** focused on supporting the holistic development of its student members. Specifically, the chapter organized several opportunities for students to expand their understanding of the foundations of electrochemistry, engage in community outreach, and learn skills relevant to their professional development.

To foster academic growth, senior members organized and led various educational seminars. First, an Introduction to Electrochemistry series aimed at new members explored the field's foundations. This spanned the topics of thermodynamics, kinetics, transport, and a formal discussion of electrostatic effects in electrochemical cells. Second, a series of short talks highlighted technologies influenced by electrochemistry, including simulations of neural interfaces, water purification, and the processing of rare earth ores. Third, a survey of characterization techniques began with presentations on cyclic voltammetry and electrochemical impedance spectroscopy. Following this theme, talks on electron microscopies and X-ray absorption spectroscopies are scheduled for later in the spring. In addition to the student-led events, the chapter continued its Coffee Talk series with visiting faculty on December 4, 2017, by welcoming Prof. Elizabeth J. Biddinger from the City College of New York. Prof. Biddinger communicated some of her past and present research, suggested several useful electrochemistry resources for the annual Coffee & Electrochemistry book series the chapter hosts each summer, and facilitated a discussion regarding opportunities for community involvement. The meeting summary can be found on the chapter's official website.

On December 14, 2017, the chapter hosted a workshop geared toward helping students establish an online presence by creating and maintaining websites showcasing their professional achievements. The event was led by Neal Dawson-Elli, an ECS@UW member, and reached over 30 individuals, including nonmembers not in regular attendance. Discussions for a second installment are underway. Another professional development event, the chapter's annual Industry Panel, is scheduled for this spring. Last year's inaugural Industry Panel was a huge success, connecting over 50 graduate students with panelists from Boeing, UniEnergy Technologies, PolyDrop, Intellectual Ventures Labs, and Microsoft.

This winter, the chapter participated in the 6th Annual Enumclaw Interactive STEM Expo hosted by the Enumclaw School District and the Enumclaw Schools Foundation. Each year, the event draws volunteers from myriad technology organizations to provide a truly unique experience for the local youth. The expo involved over 70 exhibits, each with an engaging demonstration of science specific to the host organization's expertise. The chapter elected to present the popular hand battery experiment (as outlined by the Royal Society of Chemistry), an endeavor that proved highly successful. In this

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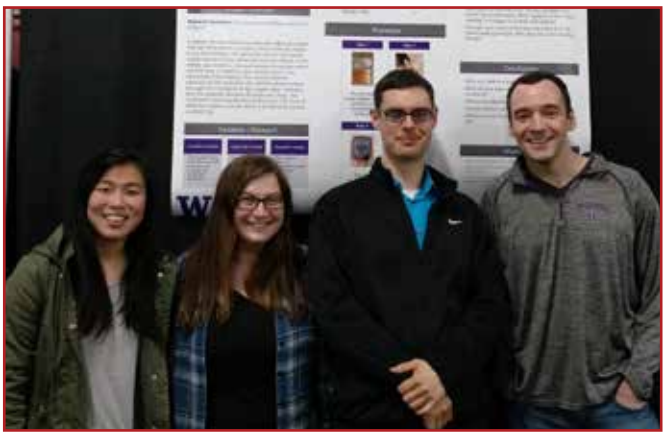

ECS volunteers at the Enumclaw Interactive STEM Expo (left to right): **Linnette Teo**, **Erica Eggleton**, **Keith Steele**, *and* **Evan Jahrman**.

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demonstration, participants were invited to form a mock battery by placing each of their hands on two dissimilar metals connected by an ammeter. The experiment not only permitted aspiring scientists to investigate variations on the basic premise, but initiated several fun, organic moments such as family members linking hands to increase the resistance in the circuit. The event served as an exciting opportunity to engage with children and present science in a positive light.

The chapter is committed to continuing this theme of civic outreach and will participate in next quarter's UW Discovery Days, in which the chapter traditionally features an electrodeposition experiment, Enginearrings, which reached more than 800 K-12 students last year.

ECS University of Washington Student Chapter members with **Prof. Elizabeth J. Biddinger** *(fifth from right) from the City College of New York following an installment of the chapter's Coffee Talk series.*

University of Maryland Student Chapter

On April 14, 2018, the **ECS University of Maryland Student Chapter** gathered at the National Mall in Washington, DC, for the second annual March for Science. With science skeptics holding high-up positions in government, it is important for scientists, engineers, and STEM advocates to urge evidence-based policy. Last spring, tens of thousands of scientists and engineers marched because government agencies such as the Department of Energy and the Environmental Protection Agency were being threatened by major budget cuts and complete abolishment, respectively. This year, many government agencies are still being threatened; this could hamper numerous funding opportunities, including those for electrochemical and solid state sciences. By participating in the March for Science, the chapter hopes to support and publicize evidence-based studies and to improve scientific literacy and policy in the United States.

The ECS University of Maryland Student Chapter participated in the second annual March for Science in Washington, DC. **Griffin Godbey** *(left), vice president, and* **Steven Lacey** *(right), president, showed their support near the main stage with #FreetheScience T-shirts and a handmade sign.*

University of Virginia Student Chapter

The **ECS University of Virginia Student Chapter** organized a seminar given by Dr. David Green on March 2, 2018. His seminar "Development of Experiment and Theory to Detect, Predict, and Visualize Ligand Phase Separation on Metal Nanoparticles" introduced a way to drive vital innovation in the realm of nanoparticle surface engineering, which has applications in a broad range of fields, including personalized medicine and energy conversion. The seminar was attended by faculty and students from the Department of Materials Science and Engineering, the Department of Chemical Engineering, as well as the Department of Chemistry.

The chapter will continue to support ECS in promoting quick and efficient ways for students to learn and exchange information in the field of electrochemistry, as well as in reaching out to and benefiting the community in Charlottesville, VA.

Dr. David Green *provided a seminar that was hosted by the ECS University of Virginia Student Chapter.*

The volunteers from the NanoDays outreach to Murray Elementary School in Charlottesville, VA (left to right): **Hongxu Dong**, **Chao Liu**, **Wade Jensen**, **Will Blade**, **Prof. Jerry Floro**, **Nate Kabat**, **Jonathan Skelton**, *and* **Katie Lutton**.

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ECS STUDENT PROGRAMS

Awarded Student Membership

Our divisions offer free memberships to full-time students. You can re-apply to receive an awarded student membership for up to four years!

Student Chapter Membership

Apply for a free student membership for those involved in active ECS student chapters. You must apply or re-apply each year for a student chapter membership.

Check out **www.electrochem.org/student-center** for qualifications!

Biannual Meeting Travel Grants

Many ECS divisions offer funding to undergraduates, graduate students, postdocs, and young professionals that are presenting research at ECS biannual meetings.

Visit **www.electrochem.org/travel-grants** to learn more!

Summer Fellowships

Apply for a $5,000 summer fellowship with ECS! The annual deadline for applications is January 15.

Review candidate qualifications at **www.electrochem.org/summer-fellowships**.

Student Chapters

There are more than 75 student chapters worldwide. ECS offers funding to support chapter events!

Find the guidelines for starting a student chapter at **www.electrochem.org/student-center**.

Make the Connection

The ECS Career Expo gives students the opportunity to meet with interested employers and advance their job search with various career services.

More information at **www.electrochem.org/career-expo**.

Enhance Your Resume

ECS equips our student members to be successful when starting their careers. The professional development workshops provide attendees with skills not often learned in the classroom.

View offerings on **www.electrochem.org/education**.

Call for Papers

235th ECS Meeting

May 26-May 31, 2019

Dallas, TX

Sheraton Dallas

Abstract Submission Deadline: Friday, December 14, 2018

For more information, please contact
Abstracts@electrochem.org

MEETING INFORMATION

General Information

The 235th ECS Meeting will be held in Dallas, Texas, USA from May 26-31, 2019 at the Sheraton Dallas Hotel. This international conference will bring together scientists, engineers, and researchers from academia, industry, and government laboratories to share results and discuss issues on related topics through a variety of formats, such as oral presentations, poster sessions, panel discussions, tutorial sessions, short courses, professional development workshops, a career fair, and exhibits. The unique blend of electrochemical and solid state science and technology at an ECS Meeting provides an opportunity and forum to learn and exchange information on the latest scientific and technical developments in a variety of interdisciplinary areas.

Abstract Submission

To give an oral or poster presentation at the 235th ECS Meeting, you must submit an original meeting abstract for consideration via the ECS website, https://ecs.confex.com/ecs/235/cfp.cgi **no later than December 14, 2018**. Faxed, e-mailed, and/or late abstracts will not be accepted. Meeting abstracts should explicitly state objectives, new results, and conclusions or significance of the work.

Once the submission deadline has passed, the symposium organizers will evaluate all abstracts for content and relevance to the symposium topic, and will schedule all acceptable submissions as either oral or poster presentations.

In February 2019, Letters of Acceptance/Invitation will be sent via email to the corresponding author of all accepted abstracts, notifying them of the date, time, and location of their presentation. Regardless of whether you requested a poster or an oral presentation, it is the symposium organizers' discretion to decide how and when it is scheduled. For abstract submission questions, contact abstracts@electrochem.org.

Paper Presentation

Oral presentations must be in English; LCD projectors and laptops will be provided for all oral presentations. **Presenting authors MUST bring their presentation on a USB flash drive to be used with the dedicated laptop that will be in each technical session room.** Speakers requiring additional equipment must make written request to meetings@electrochem.org at least one month prior to the meeting so that appropriate arrangements may be worked out, subject to availability, and at the expense of the author.

Poster presentations must be displayed in English, on a board approximately 3 feet 10 inches high by 3 feet 10 inches wide (1.17 meters high by 1.17 meters wide), corresponding to their abstract number and day of presentation in the final program.

Meeting Publications

ECS Meeting Abstracts—All meeting abstracts will be published in the ECS Digital Library (www.ecsdl.org), copyrighted by ECS, and all abstracts become the property of ECS upon presentation.

ECS Transactions— Select symposia will be publishing their proceedings in *ECS Transactions* (ECST). Authors presenting in these symposia are strongly encouraged to submit a full-text manuscript based on their presentation. Issues of ECST will be available for sale at the meeting, through the ECS Digital Library, and through the ECS Online Store. Please see each individual symposium listing in this Call for Papers to determine if your symposium will be publishing an ECST issue. Please visit the ECST website (www.ecst.ecsdl.org) for additional information, including overall guidelines, author and editor instructions, a downloadable manuscript template, and more.

ECSarXiv – All authors are encouraged to submit their full-text manuscripts, posters, slides, or data sets to ECS's new preprint service, ECSarXiv. For more information on this new offering, please visit http://www.electrochem.org/ecsarxiv. Please note that submission to ECSarXiv does not preclude submission to ECST or ECS Journals.

ECS Journals–Authors presenting papers at ECS meetings, and submitting to ECST or ECSarXiv, are also encouraged to submit to the Society's technical journals: *Journal of The Electrochemical Society* and *ECS Journal of Solid State Science and Technology*. Although there is no hard deadline for the submission of these papers, it is considered that six months from the date of the symposium is sufficient time to revise a paper to meet the stricter criteria of the journals. Author instructions are available from http://www.electrochem.org/submit.

Short Courses

Three short courses will be offered on Sunday, May 26, 2019 from 0900-1630h. Short courses require advanced registration and may be cancelled if enrollment is under 10 registrants in the respective course. The following short courses are scheduled: 1) Advanced Impedance Spectroscopy, 2) Fundamentals of Electrochemistry: Basic Theory and Thermodynamic Methods and 3) Lithium-Ion Battery Safety and Reliability Analysis. Registration opens February 2019.

Technical Exhibit

The 235th ECS Meeting will include a Technical Exhibit, featuring presentations and displays by dozens of manufacturers of instruments, materials, systems, publications, and software of interest to meeting attendees. Coffee breaks are scheduled in the exhibit hall along with evening poster sessions.

Interested in exhibiting at the meeting with your company? Exhibitor opportunities include unparalleled benefits and provide an extraordinary chance to present your scientific products and services to key constituents from around the world. Exhibit opportunities can be combined with sponsorship items and are customized to suit your needs. Please contact sponsorship@electrochem.org for further details.

Meeting Registration

All participants—including presenters and invited speakers—are required to pay the appropriate registration fees. Hotel and meeting registration information will be posted on the ECS website as it becomes available. **The deadline for discounted early-bird registration is April 22, 2019.**

Hotel Reservations

The 235th ECS Meeting will be held at the Sheraton Dallas Hotel. Please refer to the meeting website for the most up-to date information on hotel availability and information about the blocks of rooms where special rates have been reserved for participants attending the meeting. The hotel block will be open until **April 22, 2019 or until it sells out.**

Letter of Invitation

In February 2019, Letters of Invitation will be sent via email to the corresponding author of all accepted abstracts, notifying them of the date, time, and location of their presentation. Anyone else requiring an official letter of invitation should email abstracts@electrochem.org; such letters will not imply any financial responsibility of ECS.

Financial Assistance

ECS divisions and sections offer travel grants to students, postdoctoral researchers, and young professionals to attend ECS biannual meetings. Applications are available beginning November 1, 2019 at www.electrochem.org/travel-grants and must be received no later than the submission deadline of Monday, February 25, 2019. Additional financial assistance is very limited and generally governed by symposium organizers. Individuals may inquire directly to organizers of the symposium in which they are presenting to see if funding is available.

For general travel grant questions, please contact travelgrant@electrochem.org.

Sponsorship Opportunities

ECS biannual meetings offer a wonderful opportunity to market your organization through sponsorship. Sponsorship allows exposure to key industry decision makers, the development of collaborative partnerships, and potential business leads. ECS welcomes support in the form of general sponsorship at various levels. Sponsors will be recognized by level in the Meeting Program, meeting signage, and on the ECS website. In addition, sponsorships are available for the plenary, meeting keepsakes and other special events. In addition, ECS offers specific symposium sponsorship. By sponsoring a symposium your company can help offset travel expenses, registration fees, complimentary proceedings, and/or host receptions for invited speakers, researchers, and students. Advertising opportunities for the Meeting Program as well as in *Interface* magazine are also available. Please contact sponsorship@electrochem.org for further details.

Contact Information

If you have any questions or require additional information, contact ECS.

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SYMPOSIUM TOPICS & DEADLINES

A— Batteries and Energy Storage

A01—Battery and Energy Technology Joint General Session
A02—Lithium Ion Batteries and Beyond
A03—Large Scale Energy Storage 10
A04—Battery Student Slam 3
A05—Battery Characterization
A06—Battery Safety and Failure Modes

B— Carbon Nanostructures and Devices

B01—Carbon Nanostructures for Energy Conversion and Storage
B02—Carbon Nanostructures in Medicine and Biology
B03—Carbon Nanotubes - From Fundamentals to Devices
B04—Nano in Latin America
B05—Fullerenes - Endohedral Fullerenes and Molecular Carbon
B06—2D Layered Materials from Fundamental Science to Applications
B07—Light Energy Conversion with Metal Halide Perovskites, Semiconductor Nanostructures, and Inorganic/Organic Hybrid Materials
B08—Porphyrins, Phthalocyanines, and Supramolecular Assemblies
B09—Nano for Industry

C— Corrosion Science and Technology

C01—Corrosion General Session

D— Dielectric Science and Materials

D01—Chemical Mechanical Polishing 15
D02—Low Cost Photovoltaic Materials and Devices for Clean Energy

E— Electrochemical/Electroless Deposition

E01—Electrodeposition for Advanced Node Interconnect Metallization Beyond Copper

F— Electrochemical Engineering

F01—Industrial Electrochemistry and Electrochemical Engineering General Session
F02—Tutorial on Industrial Electrochemistry
F03—Characterization of Porous Materials 8
F04—Multiscale Modeling, Simulation and Design 3: Enhancing Understanding, and Extracting Knowledge from Data

G—Electronic Materials and Processing

G01—Silicon Compatible Emerging Materials, Processes, and Technologies for Advanced CMOS and Post-CMOS Applications 9
G02—Processes at the Semiconductor Solution Interface 8
G03—Organic Semiconductor Materials, Devices, and Processing 7

H—Electronic and Photonic Devices and Systems

H01—Wide Bandgap Semiconductor Materials and Devices 20
H02—Solid-state Electronics and Photonics in Biology and Medicine 6
H03—Wearable and Flexible Electronic and Photonic Technologies 2

I—Fuel Cells, Electrolyzers, and Energy Conversion

I01—Hydrogen or Oxygen Evolution Catalysis for Water Electrolysis 5
I02—Materials for Low Temperature Electrochemical Systems 5
I03—Renewable Fuels via Artificial Photosynthesis or Heterocatalysis 4
I04—Energy Conversion Systems Based on Nitrogen 2
I05—Heterogeneous Functional Materials for Energy Conversion and Storage 2
I06—An Invited Symposium on Advances and Perspectives on Modern Polymer Electrolyte Fuel Cells – In Honor of Shimshon Gottesfeld

K— Organic and Bioelectrochemistry

K01—Bioelectrochemistry: From Nature-Inspired Electrochemical Systems to Electrochemical Biosensors
K02—Electron-Transfer Activation in Organic and Biological Systems
K03—Young Investigators in Organic and Biological Electrochemistry

L—Physical and Analytical Electrochemistry, Electrocatalysis, and Photoelectrochemistry

L01—Physical and Analytical Electrochemistry, Electrocatalysis, and Photoelectrochemistry General Session and Grahame Award Symposium
L02— Impedance Technologies, Diagnostics, and Sensing Applications 5
L03—Computational Electrochemistry 5
L04—Polyoxometallates and Nanostructured Metal Oxides in Efficient Electrocatalysis, Energy Conversion, and Charge Storage
L05—Spectroelectrochemistry 4
L06—Supramolecular Materials

M—Sensors

M01—Sensors, Actuators, and Microsystems General Session
M02—Semiconductor Electrochemistry and Photoelectrochemistry in Honor of Krishnan Rajeshwar
M03—Sensors for Precision Medicine

Z—General

Z01—General Student Poster Session
Z02—Sustainable Materials and Manufacturing 3
Z03—Nanoscale Electrochemical Imaging and Detection

IMPORTANT DATES AND DEADLINES

Meeting Abstract submission opens	August 2018
Meeting Abstracts submission deadline	December 14, 2018
Notification to Corresponding Authors of abstract acceptance or rejection	February 11, 2019
Technical Program published online	February 2019
Meeting registration opens	February 2019
ECS *Transactions* submission site opens for *enhanced* issues	February 15, 2019
Travel Grant application deadline	February 25, 2019
ECS *Transactions* submission deadline for *enhanced* issues	March 15, 2019
Meeting Sponsor and Exhibitor deadline (for inclusion in printed materials)	March 15, 2019
Travel Grant approval notification	March 8, 2019
Hotel and Early Bird meeting registration deadlines	April 22, 2019
Release date for ECST *enhanced* issues	May 17, 2019
235th ECS Meeting – Dallas, TX	May 26-31, 2019

WHY JOIN ECS?

VISIBILITY

Involved members get noticed! Join a committee and enhance your leadership skills.

NETWORK

It's not just who you know, it's who others know! Networking is powerful!

DISCOUNTS

Members receive exclusive pricing on meeting registrations, publications, and professional development opportunities.

CAREER

Utilize the ECS network to advance your career!

CREDIBILITY

Formed in 1902 – become a part of this highly respected community.

GROWTH

Educational programming is growing to support our membership.

ECS

"Our community is more than just academics and subject matter. It's family."

– Jim Fenton, Secretary of The Electrochemical Society

Join online: www.electrochem.org/join

2017 ANNUAL REPORT

"The ECS community is a place to go when you have that question that you can't get an answer to."

Johna Leddy
ECS president 2017-2018

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www.electrochem.org

DISCOVER YOUR COMMUNITY

> "No one interested in electrochemistry can belong to such a society and participate in its work, without receiving from it many times more than the small share he contributes."
>
> – Joseph Richards, first Society president

In 2017, ECS celebrated its 115th anniversary. Over a century ago, our founders set out to create a place where researchers could discover their community.

We recalled the principles expressed by Joseph Richards, the Society's first president, in the introduction to the Society's first meeting *Transactions*. Richards wanted to bring electrochemists into personal contact with each other, disseminate the research, stimulate original thought and discussions, and encourage electrochemical work worldwide "by publishing the news of what is being done here."

It is a great matter of pride to say ECS has been vigorously carrying out this mission for 115 years. We will continue to advocate for our community and its work for years to come by supporting the next generation of scientists and publishing high-quality peer-reviewed research with broad implications for fundamental science, advanced technologies, energy, and sustainability.

We had great success in 2017. Published ECS journal articles now number over 50,000. The ECS Digital Library has grown to contain over 141,000 articles and abstracts. New member and student member applications are on the rise, and we added a new section in Singapore, our first new section in over 20 years.

The Society fully embraced open science by sponsoring events like OpenCon and ECS Data Sciences Hack Day. We are proud to report that more than 35% of the ECS journal articles published since 2014 were published open access after critical review. And we know that open access enhances visibility and citation of ECS content.

In August of 2017, coauthor of this letter and ECS Executive Director Roque Calvo established an agreement with the ECS Board of Directors to conclude his time with the Society. Roque has served as an outstanding steward of the Society for over 37 years, advancing the Society through revolutionary upheaval in publications and communications technologies as well as effectively managing the rampant growth and interest in electrochemical and solid state science and technology.

Roque took the Society from print to digital, created an international audience for its programs and meetings, promoted open science, expanded the ECS Honors & Awards program, and encouraged student participation by instituting student chapters and adding more travel grants and fellowships.

The Society, its members, and the other coauthor of this letter applaud Roque for his outstanding contributions and unwavering commitment to advance The Electrochemical Society and its mission.

In honor of Roque's devotion to ECS, the Society has established the Roque Calvo Next Generation Scholarship Fund, which is dedicated to provide students and early-career researchers opportunity to participate in biannual ECS meetings. Learn more about the fund and make a donation in honor of Roque at www.electrochem.org/next-gen.

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President 2017-2018
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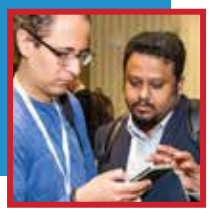

PUBLICATIONS

The enduring success of ECS publications is the result of dynamic, concentrated efforts in content procurement, dissemination, and enhancement. In 2017, these efforts elevated ECS publications to new heights.

The year 2017 saw ECS take huge strides in the areas of content acquisition and dissemination.

- From 2016 to 2017, the total number of journal articles published increased 16.7%.
- In 2017, the total amount of published journal articles surpassed 50,000. By the year's end, over 35% of the journal content published since 2014 was open access.
- By the conclusion of 2017, the ECS Digital Library contained over 141,000 articles and abstracts.
- The year 2017 was record-setting in terms of content access; over 3.5M articles and abstracts were downloaded.
- Announced in 2017, the 2016 journal impact factors for the *Journal of The Electrochemical Society* and the *ECS Journal of Solid State Science and Technology* both rose 8% (JES: 3.259, JSS: 1.787). JES ranked #2 in Materials Science, Coatings and Films and #9 in Electrochemistry with a cited half-life of greater than 10 years—the highest value awarded by Journal Citation Reports.

These accomplishments are owed in large part to the strength of ECS subscriptions, which remain the predominate method for dissemination of Society research. They are also products of ECS's continual efforts to expand and enhance the influence of its publications, which in 2017 included participation in the Society's first-ever *Free the Science* Week, International Open Access Week 2017, and endeavors to refine the journal manuscript submission system.

Over
35%
open access journal content published since 2014

Over
141,000
articles and abstracts

ECS Digital Library total content

Over
50,000
total published ECS journal articles

MEETINGS

4,262
attendees at the 2017 biannual meetings

Though it is doubtful that our founders ever envisioned that 115 years of ECS meetings lay ahead, we did our best to honor their legacy in 2017 with gatherings around the world!

For the 231st ECS Meeting, almost 2,000 attendees convened in New Orleans, LA, in order to meet, connect, present, and learn. They took part in the technical presentations, exhibits, short courses, and the plenary by Way Kuo, president of the City University of Hong Kong.

The 232nd ECS Meeting was in National Harbor, MD. Over 2,400 delegates converged near the nation's capital for a week of presentations, networking, and professional development. In addition to a plenary talk by Nobel Prize winner Steven Chu, ECS held the 7th International Electrochemical Energy Summit, consisting of the symposia Energy-Water Nexus, The Brain and Electrochemistry, and Sensors for Food Safety, Quality, and Security.

In July, ECS ran the 15th International Symposium on Solid Oxide Fuel Cells in Hollywood, FL. Attendees heard over 400 talks, attended an afternoon workshop on SOFC use in data centers and other embedded energy applications, and kicked up their heels at the traditional banquet!

Also in July, ECS co-organized the First International Semiconductor Conference for Global Challenges with the Chinese Physical Society, where 84 speakers gathered in Nanjing, China, to discuss how semiconductor technology can help address global challenges.

Finally, in December, ECS co-organized a joint symposium on Electrochemistry for Energy and the Environment (ECEE) in Shanghai, China, with the Chinese Electrochemical Society, where 40 leading researchers gave talks in the areas of batteries, fuel cells, and CO_2 reduction.

Though we may not know where the next 115 years will take us, you can be sure we'll be looking for a space to hold a meeting!

43%
first time attendees at the 2017 biannual meetings

4,459
presentations at the 2017 biannual meetings

MEMBERSHIP & EDUCATION

In 2017, the Society experienced a 7.6% increase in new member and student member applications. The increase in membership applications is attributed to the new online membership wizard launched in 2017. This feature allows people to join ECS instantly.

ECS provided almost $56,000 in biannual meeting travel grants through division funding in 2017. More than 300 travel grant applications were received. ECS divisions approved 44% of the biannual meeting travel grant applicants.

Student chapters continue to experience growth. In all, five new student chapters were chartered, bringing the number of student chapters to 69 worldwide.

The Society also charted a new section in 2017—the ECS Singapore Section. This is the first new section in almost 20 years.

ECS and the Toyota Research Institute of North America renewed their partnership agreement for the ECS Toyota Young Investigator Fellowship that supports young researchers working in the area of green energy technology. Since 2014, nine recipients were awarded $495,144 through the Toyota Young Investigator Fellowship; this includes the $150,000 awarded to three recipients in 2017.

ECS also offered four new professional development workshops at the 2017 biannual meetings. Education and professional development remain a focus in equipping our members with the tools they desire to succeed.

8,202
members

2,574
student members

$150,000
awarded for three ECS Toyota Young Investigator Fellowships

$20,000
awarded for four ECS summer fellowships

7.6%
increase in new membership applications

HONORS & AWARDS

"The encouragement from ECS is like a light on the academic path for me and other young scholars."

-Peng Sun, winner of the ECS Bruce Deal & Andy Grove Young Author Award

Peng Sun, postdoctoral research fellow at the University of Michigan, receives the ECS Bruce Deal & Andy Grove Young Author Award from ECS President Johna Leddy.

This is the story of a category of the ECS Honors & Awards program that is a big deal, but goes under the radar. Allow us to explain.

ECS young author awards are quite special as they are the only two among the 50-plus within the recognition program that are based specifically on the quality of articles that were published in ECS journals. As the second-oldest Society award, the ECS Norman Hackerman Young Author Award was established in 1928 and acknowledges the best paper published in the *Journal of The Electrochemical Society* by a young author or young coauthors. When the Society initiated the *ECS Journal of Solid State Science and Technology*, it created the Bruce Deal & Andy Grove Young Author Award to follow form. For both awards, there is a rigorous review process of articles that were published in the preceding volume year. The reward is lucrative: a hefty cash prize and travel stipend to attend the ECS biannual meeting for recognition.

Winning our young author awards proves to be a precursor to great careers in our sciences, both professionally and as volunteers in our Society's history. Winners have included past presidents such as Larry Faulkner, Barry MacDougall, and legends Stanley Whittingham and John Newman. So congratulations to those who were recognized as amazing young authors and scientists in 2017 as we acknowledge that this is just the beginning of great things to come!

OPEN SCIENCE

"Open science is building openness from the beginning and having an environment that fosters collaboration, so you have open notebooks and open data. It promotes equity among scientists and really supports collaboration."

— Ashley Farley, open access program associate at the Bill & Melinda Gates Foundation, during ECS OpenCon

The *Free the Science* initiative aims to move ECS toward an open science model that creates greater transparency from research design to sharing data and conclusions. ECS firmly believes that more sharing means more progress, because more minds will discover information to help move technology and solutions forward.

To give the ECS community even more exposure to open science, ECS hosted its first-ever satellite **OpenCon** event during the ECS fall meeting. This event—the first from a scholarly society—featured the leading vocal advocates in the open science movement. The event examined the intersection of advances in research infrastructure, the researcher experience, funder mandates and policies, as well as the global shift that is happening in traditional scholarly communications.

The Society's first foray into building a data sciences and open source community for electrochemistry and solid state science took place at the ECS fall meeting, with the **ECS Data Sciences Hack Day.** Dataset sharing and open source software have transformed many big data areas such as astronomy, particle physics, synchrotron science, protein and genomic sciences, as well as computational sciences. There is a fast-growing demand for turning big data into actionable information.

In the **open access** arena, efforts continued in 2017 to build support for more openness in ECS content, and opening up citations is one way to make content more accessible. ECS has joined the Initiative for Open Citations and is now making the references in its journal articles completely open.

The ECS Plus program, a subscription plan that includes access to the entire ECS Digital Library *plus* unlimited article credits, continued to grow, and by the end of 2017, there were 27 libraries and consortia that took advantage of this opportunity, almost double the 2016 number.

For the third year, ECS opened up the entire ECS Digital Library for International Open Access Week. ECS also promoted the power of openness during *Free the Science* Week in April. During these weeks, content from the ECS Digital Library was downloaded 32% more than the average amount downloaded in other months when the content was closed.

DONORS

Thank you to all the individuals and organizations that made either unrestricted or program gifts to ECS during 2017. With their support ECS is able to honor leaders in its fields, support travel grants, create innovative programs, and build the *Free the Science* fund.

Special thanks

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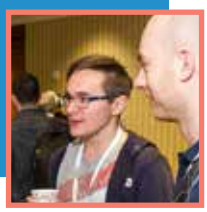

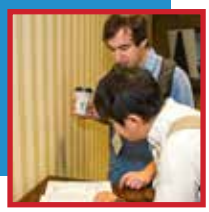

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S. K. Rangarajan

Thank you to all of our supporters. If there is a mistake in our listings, please contact development@electrochem.org and we will issue a correction.

FINANCIALS

STATEMENT OF ACTIVITIES

Year Ended December 31, 2017

	2017
REVENUE	
Total Operating Revenue	$7,725,014
EXPENSE	
Program Services	5,641,652
Rental Operations	512,972
Fundraising	409,644
General & Administrative	699,751
Total Expense	7,264,019
TOTAL INCREASE IN NET ASSETS FROM OPERATIONS	460,995
Net change in fair value of investments	1,078,557
INCREASE IN NET ASSETS	$1,539,552

STATEMENT OF FINANCIAL POSITION

Year Ended December 31, 2017

	2017
ASSETS	
Cash, Investments and other	$15,308,935
Property & Equipment	4,064,275
Total Assets	$19,373,210
LIABILITIES AND NET ASSETS	
Liabilities	$2,322,726
Net Assets	17,050,484
Total Liabilities and Net Assets	$19,373,210

MISSION

The mission of ECS is to advance and disseminate knowledge in the fields of electrochemical and solid state science and technology, and allied subjects. To encourage research, discussion, and critical assessment, the Society holds meetings, publishes scientific papers, fosters training and education of scientists and engineers, and cooperates with other organizations to promote science and technology in the public interest.

ECS envisions a future where our published peer-reviewed research will be completely open access, an initiative that we call *Free the Science.* ECS is leading the way as a steward of scientific knowledge in our technical domains and accelerating scientific discovery and innovation by promoting openness and increased accessibility of research, the scientific process, and data.

To support our bold vision for open access you can make a gift directly to the *Free the Science* campaign or to any ECS program area that contributes to the overall financial position of the organization:

- Awards
- Specific collections in the ECS Digital Library
- Meeting symposia
- ECS Fund, an unrestricted fund supporting the greatest needs of the organization as determined by leadership
- Roque Calvo Next Generation Scholarship Fund

Visit **www.electrochem.org** or **www.freethescience.org** to donate online or send an email to development@electrochem.org to discuss ways to give, including planned giving and IRA charitable rollovers.

Other ways to contribute to ECS include membership, exhibiting, sponsoring, advertising, and submitting abstracts to our meetings or articles to our journals.

Together, our Society can share solutions for the benefit of our global society. ***Thank you.***

CONTACT ECS

The Electrochemical Society
65 South Main Street, Building D
Pennington, NJ 08534-2839, USA
609.737.1902

2017

BY THE NUMBERS
BY THE COMMUNITY

What follows are the statistics that chart the progress of ECS and the names of our community members who are making ECS work.

Thank you!

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(as of December 31, 2017)

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(as of December 31, 2017)

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EDITORIAL BOARDS

(as of December 31, 2017)

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FINANCE

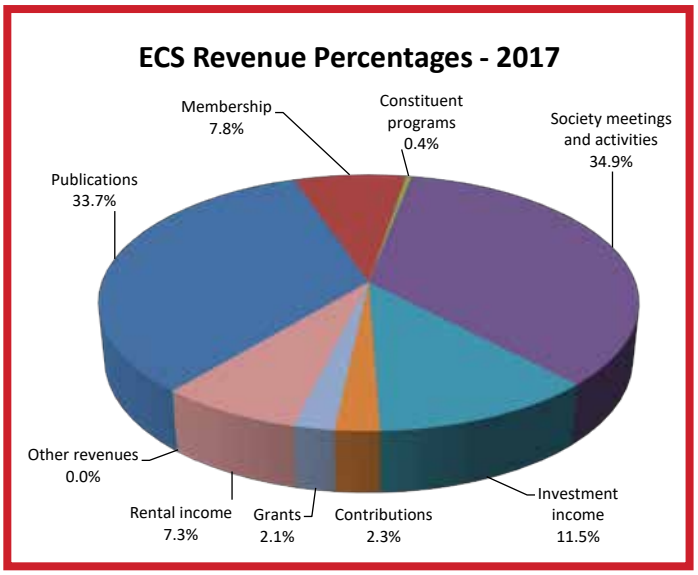
We are pleased to present the audited financial statements of ECS for the year ending December 31, 2017. These reports indicate that our financial health continues to be strong and that we continue to work towards the Society's objectives of contributing to the advancement of electrochemical and solid state science through the dissemination of technical content.

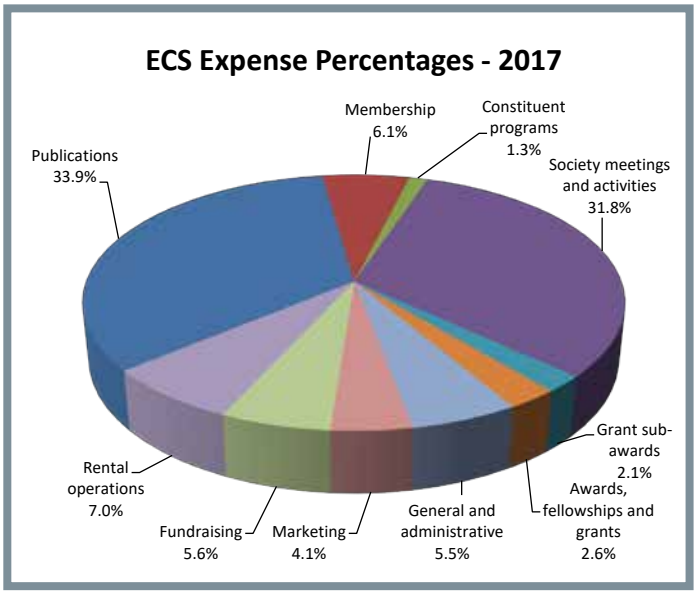
For the year ended December 31, 2017, net assets increased by $1.54 million. The increase was a result of operating revenues, which exceeded the budget, totaling $7.72 million, plus the net increase in the fair value of investments of $1.08 million less expenses of $7.26 million. The revenue performance against the budget was largely due to the increases in the market value of the investment portfolio, supplemented by positive performance in the publications, membership, and meetings areas.

The total operating expenses remained virtually flat compared to the prior year, primarily due to decreased meetings, general and administrative, marketing, and fundraising costs, partially offset by increases in publications and membership costs compared to the previous year. Membership and publications costs increased as a result of organizational structure and personnel changes in 2017.

The Society's *Statement of Financial Position* reflects assets of $19.4 million. Of these total assets, 76.7% are either custodial or endowment funds. Growth in these funds is important because it is clear that there will be pressure to generate financial support through investment and contribution revenues. Changes in the scientific publishing industry have inspired the Society's *Free the Science* open access initiative, the goal of which is to make ECS content free to publish and free to access. Digital library subscription revenue, over time, will begin to decline. In anticipation of a declining subscription revenue model, ECS continues to look for opportunities to generate additional revenues and operating margins from both traditional and new revenue sources. Our broader financial goal is to avoid the use of the endowment funds to cover operating expenses for as long as possible, enabling the funds to maintain future growth.

From an operational perspective, 2017 was an outstanding year for ECS, largely due to the strong performance of the investment portfolio and the positive financial performance of many of our program areas. We anticipate the continued need for program growth and growth in our investment portfolio to fund advances in our programs, the broader dissemination of our content, and the open access initiative. The Society's current financial strength will aid in this growth.





NOTE: Marketing expense depicted above does not include marketing expenses for program-specific purposes. Those are included in the individual program areas.

E. Jennings Taylor
Treasurer

Tim Gamberzky
Chief Operating Officer

NOTE: The Electrochemical Society is a nonprofit international association of scientists and engineers chartered as a tax-exempt organization under Section 501(c)(3) of the United States Internal Revenue Code. The Board of Directors engages the services of an independent auditor to assure that the Society maintains an effective system of financial management, and operates under its nonprofit charter. The Board of Directors received an unmodified or clean opinion from their independent auditors, *Horvath & Giacin, P.C.* for the fiscal year ending December 31, 2017.

To obtain a complete copy of the Audit Financial Statements, interested parties can email their request to **paul.grote@electrochem.org**.

FINANCIAL SUMMARY

CONSOLIDATED STATEMENT OF FINANCIAL POSITION (For the year ended December 31, 2017)

ASSETS	2017
Cash and cash equivalents	$1,491,540
Accounts receivable, net	33,385
Prepaid expenses, deposits and other assets	338,035
Investments in marketable securities	13,380,408
Custodial account investments	423
Deferred rent	65,144
Investments in real estate:	
Land	1,603,427
Buildings, less accumulated depreciation of $943,337	2,460,848
Intangible assets	-
Total assets	**$19,373,210**
Liabilities and Net Assets	
Liabilities	
Accounts payable and accrued expenses	$432,168
Deferred revenue	1,641,330
Custodial account liability	424
Security deposits	38,248
Deferred compensation	210,556
Net Assets	
Unrestricted	15,408,075
Temporarily restricted	683,341
Permanently restricted	959,068
Total net assets	17,050,484
Total liabilities and net assets	**$19,373,210**

CONSOLIDATED STATEMENT OF CHANGES IN NET ASSETS (For the year ended December 31, 2017)

Revenues	
Publications	$2,599,315
Membership	606,331
Constituent programs	29,595
Society meetings and activities	2,697,400
Investment income	889,603
Contributions	176,421
Grants	160,000
Rental income	564,674
Other revenues	1,675
Total Revenues	**7,725,014**
Expenses	
Program services	
Publications	$2,460,962
Membership	442,494
Constituent programs	91,705
Society meetings and activities	2,307,847
Grant sub-awards	150,000
Awards, fellowships and grants	188,644
Total Program Services Expenses	**5,641,652**
Supporting services	
General and administrative	401,332
Marketing	298,419
Fundraising	409,644
Rental operations	512,972
Total Supporting Services Expenses	**1,622,367**
Total Expenses	**7,264,019**
Increase in net assets from operations	460,995
Net change in fair value of investments	1,078,557
Change in net assets	1,539,552
Net assets, beginning of year	15,510,932
Net assets, end of year	**$17,050,484**

These financial statements are a condensed version of the audited statements of ECS for the year ending December 31, 2017. ECS will be pleased to provide complete copies along with all footnotes and the unqualified report of our auditors upon request.

NOTES TO FINANCIAL STATEMENTS

1 - Summary of Significant Accounting Policies

The consolidated financial statements include the accounts of The Electrochemical Society, Inc. (the Society) and its Divisions, Groups and Sections and ECS Holdings, LLC, (the LLC). All intercompany balances and transactions have been eliminated in consolidation. The consolidated financial statements are prepared on the accrual basis of accounting. Revenue, other than contributions, is recognized when earned and expense is recognized when the obligation is incurred.

The consolidated financial statements have been prepared to focus on the Society and its subsidiaries as a whole, and to present balances and transactions according to the existence or absence of donor-imposed restrictions. Accordingly, net assets and changes therein are classified as follows: Unrestricted net assets – net assets not subject to donor-imposed stipulations; Temporarily restricted net assets – net assets subject to donor-imposed stipulations that will be met by actions of the Society and/or by the passage of time; Permanently restricted net assets (endowment funds) – net assets subject to donor-imposed stipulations that they be maintained permanently by the Society.

2 - Income Tax Status and Income Taxes

ECS and its Divisions, Groups, and Sections qualify as a tax-exempt organization described under Section 501(c)(3) of the Internal Revenue Code and all of its income, except income generated through the advertising included in its publications, is exempt from Federal income taxes.

As a single-member limited liability company, the LLC is treated as a "disregarded entity" for income tax purposes and, as such, its financial activity is reported in conjunction with the Federal income tax filings of ECS. The Society has adopted the accounting pronouncement that provides guidance on uncertain tax positions. The Society has no unrecognized tax benefits at December 31, 2017.

3 - Investments

Investments in equities and fixed income instruments are reported at fair market value, and investment in real estate is reported at cost. Investment income and realized and unrealized net gains and losses on investments of permanently restricted net assets are reported as follows: as increases or decreases in temporarily restricted net assets if the terms of the gift impose restrictions on the use of the income and/or net gains; as increases or decreases in unrestricted net assets in all other cases. Cost, market value and unrealized appreciation (depreciation) at December 31, 2017 are summarized as follows:

	Cost	Fair Market Value	Unrealized Appreciation (Depreciation)
Stocks and mutual funds	$ 8,016,495	$10,501,491	$ 2,484,996
Corporate and U.S. bonds	2,086,447	2,183,241	96,794
Real estate	5,007,611	5,007,611	--
Real Estate Trust	250,000	348,895	98,895
Other Investments	298,329	347,204	48,875
Total	$15,658,882	$18,388,442	$ 2,729,560

4 - Endowment Funds

The Society's endowment funds consist of several funds established to support awards, as well as an educational endowment fund and a Free the Science fund. The endowment funds include both donor-restricted funds and funds designated by the Board of Directors to function as endowments. As required by generally accepted accounting principles (GAAP), net assets associated with endowment funds are classified based on the existence or absence of donor-imposed restrictions.

The Society's policy requires the preservation of the fair value of the original gift as of the gift date of the donor-restricted endowment funds absent explicit donor stipulations to the contrary. As a result, the Society classifies as permanently restricted net assets the original value of gifts donated to the permanent endowment and the original value of subsequent gifts to the permanent endowment. The remaining portion of the donor-restricted endowment fund that is not classified in permanently restricted net assets is classified as temporarily restricted net assets until those amounts are appropriated for expenditure by the Society.

5 - ECS Holdings, LLC

ECS Holdings LLC was chartered in 1998 to manage the real estate assets of the Society. Current real estate holdings include five buildings at Howe Commons in Pennington, NJ valued at a cost of $5,007,611. The Society occupies one of the buildings and the other four are classified as an investment. The LLC leases office space in these four buildings to various tenants under operating lease arrangements expiring through 2023. Rental income under the aforementioned leases totaled $564,674 (excluding intercompany rentals of $91,416) for the year ended December 31, 2017.

Report of the ECS Audit Committee

The ECS Audit Committee provides oversight of The Electrochemical Society's financial reporting process on behalf of the Board of Directors. Management (ECS Staff Directors and Officers) is responsible for the financial statements and the financial reporting process, including the system of internal control. In fulfilling its oversight responsibilities, the Committee discussed the financial statements in the annual report with management, including a discussion of quality, not just the acceptability, of the accounting principles; the reasonableness of significant judgments; and the clarity of disclosures in the financial statements.

The members of the Audit Committee in 2017 were Krishnan Rajeshwar (Chair), E. Jennings Taylor, Johna Leddy, Yue Kuo and Stuart Swirson.

The ECS Audit Committee discussed with the independent auditors the overall scope and plans for their respective audits. The Committee meets with the independent auditors with and without management present, to discuss the results of their examinations, their evaluations of the Society's internal control, compliance with laws and regulations, and the overall quality of the Society's financial reporting.

Based on the discussions referenced above, the ECS Audit Committee recommended for acceptance to the Board of Directors the audited financial statements for the year ended December 31, 2017 and the Board unanimously approved.

ECS MEMBERSHIP STATISTICS

As of October 1, 2017

TABLE I. ECS MEMBERSHIP BY CLASS

Category	2011	2012	2013	2014	2015*	2016**	2017	2017-2016 # Change	2017-2016 % Change
Members-Good Standing	4731	4657	4253	4260	3889	3536	3311	-225	-6.36
Members-Expired	N/A	N/A	N/A	N/A	393	382	364	-18	-4.71
Members-Lapsed	N/A	N/A	N/A	N/A	1235	1035	787	-248	-23.96
Member Representatives-Good Standing	112	134	175	219	269	316	282	-34	-10.76
Member Representatives-Expired	N/A	N/A	N/A	N/A	16	7	2	-5	-71.43
Member Representatives-Lapsed	N/A	N/A	N/A	N/A	10	18	29	11	61.11
Retired Members	N/A	N/A	N/A	N/A	N/A	6	19	13	216.67
Life Members (Paid Life + Award Life)	52	64	101	105	117	131	127	-4	-3.05
Emeritus Members	289	288	283	296	299	330	336	6	1.82
Honorary Members	23	22	25	27	22	23	21	-2	-8.70
Subtotal Members in Good Standing	5207	5165	4837	4907	4596	4342	3814	-528	-12.16
Total Delinquent (Expired + Lapsed)	1236	1302	1225	1143	1654	1442	1578	136	9.43
Total Members	**6443**	**6467**	**6062**	**6050**	**6250**	**5784**	**5346**	**-438**	**-7.57**
Student Members-Good Standing	1427	1502	1438	1497	1519	1625	1532	-93	-5.72
Student Members-Expired	N/A	N/A	N/A	N/A	228	270	280	10	3.70
Student Members-Lapsed	N/A	N/A	N/A	N/A	858	798	762	-36	-4.51
Total Student Members Delinquent (Expired + Lapsed)	825	847	775	760	1086	1068	1042	-26	-2.43
Total Students Members	2252	2349	2213	2257	2605	2693	2574	-119	-4.42
Total Individual Members	**8695**	**8816**	**8275**	**8307**	**8855**	**8477**	**8202**	**-275**	**-3.24**
Automatic Renewal Enrollment	N/A	N/A	N/A	N/A	N/A	176	248	72	40.91

**Number represents a recategorization in 2015 of good standing, expired & lapsed members.*
***Membership numbers no longer include free memberships from ECS meetings.*

TABLE II. ECS MEMBERSHIP BY SECTION

(data does not include member representatives)

Section	2011	2012	2013	2014**	2015*	2016**	2017	2017-2016 # Change	2017-2016 % Change
Arizona	109	98	102	N/A	89	67	47	-20	-29.85
Brazil	65	66	47	N/A	27	26	16	-10	-38.46
Canada	381	382	371	N/A	256	217	195	-22	-10.14
Chicago	182	180	155	N/A	215	137	108	-29	-21.17
Chile	N/A	10	13	N/A	7	8	7	-1	-12.50
China	81	86	78	N/A	64	72	91	19	26.39
Cleveland	123	124	106	N/A	74	83	59	-24	-28.92
Detroit	118	116	96	N/A	94	56	49	-7	-12.50
Europe	1105	1108	1041	N/A	1005	768	630	-138	-17.97
Georgia	171	179	133	N/A	136	87	60	-27	-31.03
India	58	59	59	N/A	70	49	38	-11	-22.45
Israel	39	39	27	N/A	31	19	18	-1	-5.26
Japan	771	775	756	N/A	636	553	510	-43	-7.78
Korea	243	253	205	N/A	146	75	48	-27	-36.00
Mexico	31	30	30	N/A	49	37	26	-11	-29.73
National Capital	159	154	162	N/A	147	103	105	2	1.94
New England	381	360	292	N/A	217	168	128	-40	-23.81
Pittsburgh	87	80	58	N/A	66	43	49	6	13.95
San Francisco	413	416	376	N/A	244	198	145	-53	-26.77
Singapore	N/A	N/A	N/A	N/A	N/A	N/A	5	5	-
Taiwan	122	123	87	N/A	64	68	62	-6	-8.82
Texas	144	146	142	N/A	122	112	129	17	15.18
Twin Cities	74	76	53	N/A	47	40	37	-3	-7.50

TABLE III. ECS MEMBERSHIP BY DIVISION

(data does not include member representatives)

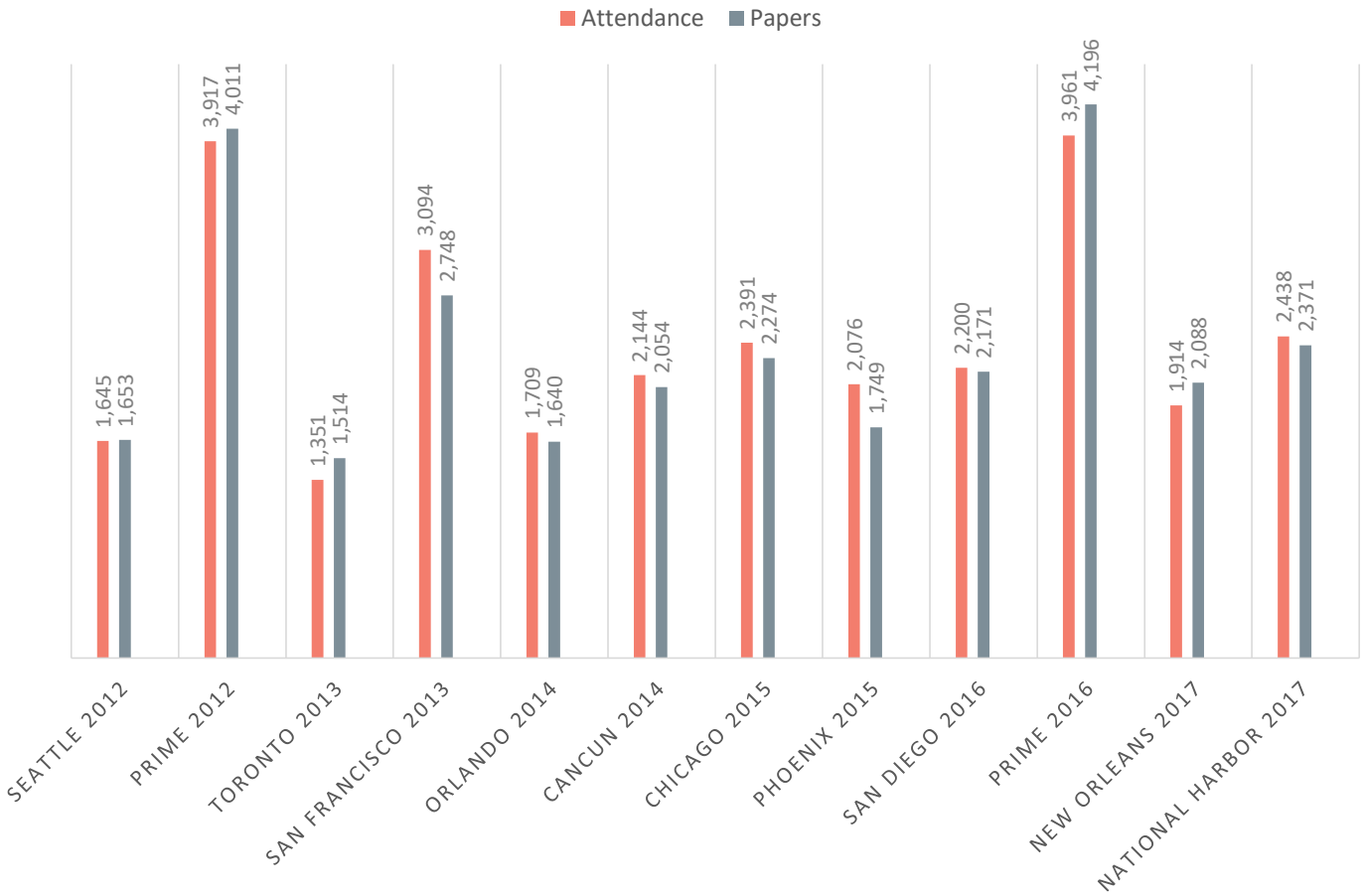
Division	2011	2012	2013	2014	2015*	2016**	2017	2017-2016 # Change	2017-2016 % Change
Battery	1668	1709	1987	1824	1701	1605	1545	-60	-3.74
Dielectric Science & Technology	319	275	256	235	204	194	171	-23	-11.86
Electrodeposition	483	448	464	445	392	365	338	-27	-7.40
Electronics & Phontonics	679	550	581	556	511	502	433	-69	-13.75
Energy Technology	1220	1194	1122	1025	995	930	858	-72	-7.74
Nanocarbons Division	176	160	183	177	154	171	152	-19	-11.11
High Temperature Materials	184	218	212	202	218	184	174	-10	-5.43
Industrial Electrochemistry & Electrochemical Eng	307	290	303	282	286	257	248	-9	-3.50
Luminescence & Display Materials	111	97	94	90	64	68	59	-9	-13.24
Organic & Biological Electrochemistry	184	176	180	166	161	150	139	-11	-7.33
Physical & Analytical Electrochemistry	618	564	609	561	560	545	492	-53	-9.72
Sensor	229	217	233	218	225	212	203	-9	-4.25

TABLE IV. ECS MEMBERSHIP BY OCCUPATION

(data does not include member representatives or student members)

Occupation	2011	2012	2013	2014	2015*	2016**	2017	2017-2016 # Change	2017-2016 % Change
Academic	2434	2362	2206	2346	2227	2151	1990	-161	-7.48
Industry	2094	2123	1902	1900	1724	1288	1089	-199	-15.45
Government	387	377	377	435	360	309	315	6	1.94
Retired	109	110	111	117	119	137	203	66	48.18
Other	N/A	N/A	N/A	N/A	121	33	38	5	15.15

MEETING STATISTICS



231ST ECS MEETING, NEW ORLEANS ABSTRACTS BY THE NUMBERS

All presentations	
Award Talks (Society and Division)	20
Invited & Keynote talks	439
Oral Presentations	1,254
Posters	375
Total Presentations	**2,088**
Student Presentations	
Total Student Presentations	615
Total Countries	
Number of Countries Represented	58
Attendees	
Total Attendance	**1,914**
New Attendees	829
Percentage of New Attendees	43%

232ND ECS MEETING, NATIONAL HARBOR ABSTRACTS BY THE NUMBERS

All presentations	
Award Talks (Society and Division)	15
Invited & Keynote talks	531
Oral Presentations	1,259
Posters	566
Total Presentations	**2,371**
Student Presentations	
Total Student Presentations	644
Total Countries	
Number of Countries Represented	54
Attendees	
Total Attendance	**2,438**
New Attendees	1,006
Percentage of New Attendees	43%

ECS STUDENT CHAPTERS

Student Chapter Name	Year Chartered	Faculty Advisor(s)
Aalborg University	2017	Daniel-Ioan Stroe Maciej Swierczynski
Auburn University	2007	Majid Beidaghi
Belgium Student Chapter	2015	Philippe M. Vereecken Stefan De Gendt
Boston Student Chapter	2009	Eugene Smotkin
British Columbia University	2013	Dan Bizzotto
Brno University of Technology	2006	Jiri Vondrak
California State University-Fullerton	2012	John L. Haan
Case Western Reserve University	2005	Robert F. Savinell
Central Illinois Student Chapter	2008	Andrzej Wieckowski
Clemson University	2014	Stephen E. Creager
Colorado School of Mines	2012	Andy M. Herring
Drexel University	2012	Yury Gogotsi Ekaterina A. Pomerantseva
Georgia Institute of Technology	2008	Seung Woo Lee
Hong Kong University of Science and Technology	2016	Francesco Ciucci Minhua Shao
Illinois Institute of Technology	2015	Wei Chen Adam Hock
Indiana University	2012	Dennis Peters Lane A. Baker
Kerala, India at CUSAT Student Chapter	2008	Madambi K. Jayaraj
Lahore, Pakistan Student Chapter	2008	Inam Ul Haque
Lewis University	2015	Jason Keleher
Louisiana State University	2016	Christopher G. Arges
Missouri University of Science and Technology	2017	Amitava Choudhury Jay A. Switzer Manashi Nath
Montana State University	2013	Ryan W. Anderson Paul E. Gannon
Montreal Student Chapter	2010	Steen B. Schougaard
Munich Student Chapter	2015	Hubert Gasteiger
New Mexico State University	2015	Vimal H. Chaitanya Hongmei Luo
North Florida Student Chapter	2014	Pedro Moss
Norwegian University of Science and Technology	2014	Ann Mari Svensson
Ohio State University	2006	Anne C. Co
Ohio University	2011	Gerardine Gabriela Botte
Oklahoma Student Chapter	2017	Sadagopan Krishnan
Rensselaer Polytechnic Institute	2013	David J. Duquette Daniel J. Lewis
Research Triangle Student Chapter	2013	Jeffrey Glass
South Brazil Student Chapter	2010	Luís F. P. Dick
SRM University	2013	Ranjit Thapa Bhalchandra Anand Kakade
Tel Aviv University	2009	Eliezer Gileadi Yosi Shacham-Diamand
Texas A&M University	2016	Yue Kuo
Tyndall National Institute	2012	Alan O'Riordan
UK Northwest Student Chapter	2015	Laurence J. Hardwick
University of Alabama	2016	Shanlin Pan
University of Calgary	2011	Viola Ingrid Birss
University of California–Berkeley	2014	Bryan D. McCloskey
University of California–Los Angeles	2015	Sarah H. Tolbert

Chapter Name	Year Chartered	Faculty Advisor(s)
University of California–Riverside	2011	Alexander A. Balandin
University of California–San Diego	2014	Shirley Meng
University of Central Florida	2000	Kalpathy B. Sundaram
University of Cincinnati	2007	Marc Cahay
University of Florida	2005	Erin Patrick
University of Houston	2016	Yan Yao
University of Illinois at Chicago	2016	Sanjay Kumar Behura Brian P. Chaplin
University of Iowa	2014	Johna Leddy
University of Kansas	2016	Trung Van Nguyen
University of Kentucky	2014	Doo Young Kim
University of Maryland	2011	Eric D. Wachsman
University of Nevada-Reno	2014	Dev Chidambaram
University of New Mexico	2017	Fernando H. Garzon Plamen B. Atanassov
University of Oxford	2016	Charles W. Monroe Kylie A. Vincent
University of Pittsburgh	2014	Prashant N. Kumta Spandan Maiti
University of South Carolina	2010	William Mustain
University of St. Andrews	2015	John T. S. Irvine
University of Tartu	2013	Kaido Tammeveski
University of Texas at Austin	2006	Arumugam Manthiram
University of Texas at Dallas	2012	Moon J. Kim
University of Toronto	2016	Donald W. Kirk
University of Utah	2015	Shelley D. Minteer
University of Virginia	2006	Giovanni Zangari
University of Washington	2016	Daniel T. Schwartz Venkat R. Subramanian Stuart B. Adler
University of Western Ontario	2017	Jungsook Clara Wren Zhifeng Ding James J. Noel D. W. Shoesmith
Valley of the Sun (Central Arizona)	2013	Candace Kay Chan

ECS SECTIONS

Arizona Section	Candace Kay Chan, *Chair*	Japan Section	Hiroshi Iwai, *Chair*
Brazil Section	Ernesto Pereira, *Chair*	Korea Section	Yung-Eun Sung, *Chair*
Canada Section	Christa Brosseau, *Chair*	Mexico Section	Ignacio Gonzalez, *Chair*
Chicago Section	Alan Zdunek, *Chair*	National Capital Section	Eric D. Wachsman, *Chair*
Chile Section	Jose H. Zagal, *Chair*	New England Section	Sanjeev Mukerjee, *Chair*
China Section	Yong Yao Xia, *Chair*	Pittsburgh Section	Clifford W. Walton, *Chair*
Cleveland Section	Heidi B. Martin, *Chair*	San Francisco Section	Yarik Syzdek, *Chair*
Detroit Section	Srikanth Arisetty, *Chair*	Singapore Section	Qingui Yan, *Chair*
Europe Section	Petr Vaný́sek, *Chair*	Taiwan Section	Bing-Joe Hwang, *Chair*
Georgia Section	Seung Woo Lee, *Chair*	Texas Section	Jeremy P. Meyers, *Chair*
India Section	Vijayamohanan K. Pillai, *Chair*	Twin Cities Section	Peter Zhang, *Chair*
Israel Section	Daniel Mandler, *Chair*		

ECS HONOR ROLL

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L. H. Baekeland 1909-1910
W. H. Walker 1910-1911
W. R. Whitney 1911-1912
W. L. Miller 1912-1913
E. F. Roeber 1913-1914
F. A. Lidbury 1914-1915
L. Addicks 1915-1916
F. A. J. FitzGerald 1916-1917
C. G. Fink 1917-1918
F. J. Tone 1918-1919
W. D. Bancroft 1919-1920
W. S. Landis 1920-1921
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A. T. Hinckley 1923-1924
H. C. Parmelee 1924-1925
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W. Blum 1926-1927
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L. Kahlenberg 1930-1931
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L. I. Gilbertson 1964-1965
E. B. Yeager 1965-1966
H. J. Read 1966-1967
H. C. Gatos 1967-1968
I. E. Campbell 1968-1969
N. C. Cahoon 1969-1970
C. W. Tobias 1970-1971
C. V. King 1971-1972
T. D. McKinley 1972-1973
N. B. Hannay 1973-1974
D. A. Vermilyea 1974-1975
T. R. Beck 1975-1976
M. J. Pryor 1976-1977
D. N. Bennion 1977-1978
D. R. Turner 1978-1979
J. B. Berkowitz 1979-1980
E. M. Pell 1980-1981
R. J. Brodd 1981-1982
F. J. Strieter 1982-1983
J. B. Wagner, Jr. 1983-1984
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R. E. Enstrom 1986-1987
F. G. Will 1987-1988
B. E. Deal 1988-1989
E. J. Cairns 1989-1990
J. M. Woodall 1990-1991
L. R. Faulkner 1991-1992
W. L. Worrell 1992-1993
R. P. Frankenthal 1993-1994
J. A. Amick 1994-1995
K. R. Bullock 1995-1996
D. W. Hess 1996-1997
B. Miller 1997-1998
G. M. Blom 1998-1999
D. E. Hall 1999-2000
C. M. Osburn 2000-2001
J. Talbot 2001-2002
K. Spear 2002-2003
B. Scrosati 2003-2004
R. Susko 2004-2005
W. Smyrl 2005-2006
Mark Allendorf 2006-2007
Barry MacDougall 2007-2008
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Paul Natishan 2009-2010
William D. Brown 2010-2011
Esther S. Takeuchi 2011-2012
Fernando Garzon 2012-2013
Tetsuya Osaka 2013-2014
Paul Kohl 2014-2015
Daniel Scherson 2015-2016
Krishnan Rajeshwar 2016-2017

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J. A. Amick 1984-1988
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E. G. Enck 1961-1964
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R. H. Cherry 1967-1973
F. J. Strieter 1973-1976
J. L. Griffin 1976-1982
J. Kruger 1982-1986
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R. E. White 1990-1994
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W. D. Brown 1998-2002
P. Fedkiw 2002-2006
J. Susko 2006-2010
Christina Bock 2010-2014
E. J. Taylor 2014-2018

Edward Goodrich Acheson Award

E. G. Acheson....1929
E. F. Northrup....1931
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F. J. Tone....1935
F. M. Becket....1937
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C. F. Burgess....1942
W. Blum....1944
H. J. Creighton....1946
D. A. MacInnes....1948
G. W. Vinal....1950
J. W. Marden....1952
G. W. Heise....1954
R. M. Burns....1956
W. J. Kroll....1958
H. B. Linford....1960
C. L. Faust....1962
E. A. Gulbransen....1964
W. C. Vosburgh....1966
F. L. LaQue....1968
S. Ruben....1970
C. W. Tobias....1972
C. V. King....1974
N. B. Hannay....1976
D. A. Vermilyea....1978
E. B. Yeager....1980
H. C. Gatos....1982
N. Hackerman....1984
E. M. Pell....1986
H. H. Uhlig....1988
T. R. Beck....1990
D. R. Turner....1992
J. B. Wagner, Jr.....1994
R. C. Alkire....1996
J. M. Woodall....1998
L. R. Faulkner....2000
B. Deal....2002
W. L. Worrell....2004
V. de Nora....2006
Robert P. Frankenthal....2008
John Newman....2010
Dennis Hess....2012
Ralph J. Brodd....2014
Barry Miller....2016

Olin Palladium Award

(formerly the Palladium Medal Award, 1951-1977)

C. W. Wagner....1951
N. H. Furman....1953
U. R. Evans....1955
K. F. Bonhoeffer....1957
A. N. Frumkin....1959
H. H. Uhlig....1961
N. Hackerman....1965
P. Delahay....1967
T. P. Hoar....1969
L. Brewer....1971
V. G. Levich....1973
M. J. N. Pourbaix....1975
H. Gerischer....1977
R. Parsons....1979
I. M. Kolthoff....1981
M. Cohen....1983
M. Fleischmann....1985
A. J. Bard....1987
B. E. Conway....1989
J. Newman....1991
J.-M. Savéant....1993
J. Kruger....1995
R. W. Murray....1997
J. B. Goodenough....1999
N. Sato....2001
E. Gileadi....2003
R. Rapp....2005
Sergio Trasatti....2007
Dieter M. Kolb....2009
Koji Hashimoto....2011
Ralph White....2013
Digby Macdonald....2015
Philippe Marcus....2017

Gordon E. Moore Medal for Outstanding Achievement in Solid-State Science and Technology

(formerly the Solid State Science & Technology Award, 1973-2005)

W. G. Pfann....1973
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G. L. Pearson....1981
N. Holonyak, Jr.....1983
J. M. Woodall....1985
A. Y. Cho....1987
J. F. Gibbons....1989
J. D. Plummer....1991
B. E. Deal....1993
W. L. Worrell....1995
K. E. Spear....1997
I. Akasaki....1999
A. Reisman....2001
R. B. Fair....2003
D. Hess....2005
Tak H. Ning....2007
C. Grant Willson....2009
Stephen Pearton....2011
Fan Ren....2013
Yue Kuo....2015
Paul Kohl....2017

Vittorio de Nora Award in Electrochemical Engineering and Technology

(formerly the Electrochemical Science and Technology Award, 1974-1977)

A. Brenner....1974
R. B. MacMullin....1976
F. T. Bacon....1978
H. B. Beer....1980
J. C. Schumacher....1982
D. E. Danly....1984
K. Kordesch....1986
A. Heller....1988
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F. Mansfeld....2006
John S. Newman....2008
Derek Pletcher....2010
Bruno Scrosati....2012
Chad Mirkin....2014
Ralph White....2016

Carl Wagner Memorial Award

A. J. Bard....1981
G. C. Wood....1983

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Carl Wagner Memorial Award *(continued)*

R. C. Alkire 1985
R. W. Murray 1987
W. L. Worrell 1989
D. D. Macdonald 1991
J. Jorné 1993
B. R. MacDougall 1995
M. J. Weaver 1997
C. R. Martin 1999
P. A. Kohl 2001
R. M. Crooks 2003
J. Hupp 2005
Philip N. Bartlett 2007
Henry S. White 2009
Peter Bruce 2011
Marc T. M. Koper 2013
Martin Winter 2015
Eric Wachsman 2017

Henry B. Linford Award for Distinguished Teaching

C. W. Tobias 1982
B. E. Conway 1984
A. J. Bard 1986
L. Brewer 1988
J. Newman 1990
K. Nobe 1992
J. O'M. Bockris 1994
T. C. Franklin 1996
R. A. Rapp 1998
G. Stoner 2000
D. Peters 2002
R. M. Latanision 2004
D. Pletcher 2006
Eliezer Gileadi 2008
Daniel T. Schwartz 2010
Mark E. Orazem 2012
Dennis Hess 2014
John Scully 2016

Charles W. Tobias Young Investor Award

Stuart B. Adler 2004
Hock Min Ng 2006
Yang Shao-Horn 2008
Thomas J. Schmidt 2010
Bryan S. Pivovar 2012
Bilge Yildiz 2012
Adam Weber 2014
Y. Shirley Meng 2016

Allen J. Bard Award

Henry White 2015
Doron Aurbach 2017

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James C. Acheson 1990
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Bertram Schwartz 1991
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R. S. Karpiuk 1996
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Jefferson Cole 2001
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John S. Newman 2007
Jerry M. Woodall 2007
Allen J. Bard 2013
John B. Goodenough 2013
Adam Heller 2015
Dennis Hess 2016

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Glenn W. Cullen 1990
Theodore I. Kamins 1990
Paul C. Milner 1990
Edward H. Nicollian 1990
Robert A. Osteryoung 1990
Arnold Reisman 1990
Lubomyr T. Romankiw 1990
Geraldine C. Schwartz 1990
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Bruce E. Deal 1991
Werner Kern 1991
William A. Pliskin 1991
Charles W. Tobias 1991
Rolf Weil 1991
Richard C. Alkire 1992
Vittorio de Nora 1992
Jerome Kruger 1992
Barry Miller 1992
Dennis R. Turner 1992
Jerry M. Woodall 1992
Richard P. Buck 1993
Larry. R. Faulkner 1993

Dennis W. Hess 1993
Vik J. Kapoor 1993
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Carlton M. Osburn 1993
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Der-Tau Chin 1996
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Venkataraman Swaminathan 1996
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Denis Noel Buckley 1997
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Michel J. Froment 1997
Koji Hashimoto 1997
Chung-Chiun Liu 1997
Edward McCafferty 1997
Theodore D. Moustakas 1997
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Huk Y. Cheh 1998
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Dennis H. Evans 1998
Fumio Hine 1998
Dennis C. Johnson 1998
Zoltan Nagy 1998
Katsumi Niki 1998
Jun-ichi Nishizawa 1998
Fan Ren 1998
Antonio J. Ricco 1998
David A. Shores 1998
William H. Smyrl 1998
George Thompson 1998
Eric Brooman 1999
Stanley Bruckenstein 1999
Kathryn Bullock 1999
Shimshon Gottesfeld 1999
Yue Kuo 1999
Dieter Landolt 1999
Jerzy Ruzyllo 1999
Norio Sato 1999
Ralph White 1999
William Yen 1999
Cammy Abernathy 2000
Kuzhikalail M. Abraham 2000
John C. Angus 2000
W. Ronald Fawcett 2000
David S. Ginley 2000
Yasuhiko Ito 2000
Howard Huff 2000
Robert F. Savinell 2000
Roger Staehle 2000
Charles W. Struck 2000
Sergio Trasatti 2000
Dieter M. Kolb 2001
David J. Lockwood 2001
James McBreen 2001
Patrick J. Moran 2001
Shohei Nakahara 2001
William E. O'Grady 2001
Supramanian Srinivasan 2001
Mark Allendorf 2002
William Brown 2002
Cor Claeys 2002
Martin Kendig 2002
Kim Kinoshita 2002
Paul Kohl 2002
Zempachi Ogumi 2002
Tetsuya Osaka 2002
Krishnan Rajeshwar 2002
Israel Rubinstein 2002
Sigeru Torii 2002
Toshio Shibata 2002
Sorin Cristoloveanu 2002
David Duquette 2003
Peter Fedkiw 2003
Charles Hussey 2003
Richard McCreery 2003
Frank McLarnon 2003
Robin Susko 2003
Darrel Untereker 2003
Osamu Yamamoto 2003
G. T. Burstein 2004
C. Clayton 2004
G. Davis 2004
M. J. Deen 2004
S. Fonash 2004
M. Meyyappan 2004
J. F. Rusling 2004
M. Seo 2004
M. Shur 2004
J. Simonet 2004
M. Stratmann 2004
J. Talbot 2004
M. S. Whittingham 2004
R. Adzic 2005
J. Davidson 2005
T. Hattori 2005
J. P. Leburton 2005
P. Marcus 2005
C. Martin 2005
P. Natishan 2005
D. Pletcher 2005
B. Scrosati 2005
J. Scully 2005
R. Singh 2005
H. H. Strehblow 2005
M. Williams 2005
A. Baca 2006
S. Bandyopadhyay 2006
T. Fahidy 2006
G. Frankel 2006
C. Jagadish 2006
N. Koshida 2006
J. Lessard 2006
H. Massoud 2006
H. Yokokawa 2006
B. MacDougall 2006
M. Orazem 2006
D. Misra 2006
A. Virkar 2006
A. Wieckowski 2006
Simon S. Ang 2007
Viola Birss 2007
Marc Cahay 2007
James M. Fenton 2007
Dennis G. Peters 2007
Daniel A. Scherson 2007
Eric D. Wachsman 2007
Doron Aurbach 2008
Albert J. Fry 2008
Fernando Garzon 2008
Yury Gogotsi 2008
Curtis F. Holmes 2008
Prashant V. Kamat 2008
Patrik Schmuki 2008
Gery R. Stafford 2008
Joseph R. Stetter 2008
John Stickney 2008
Thomas Thundat 2008
Vladimir Bagotsky 2009
Ugo Bertocci 2009
Manfred Engelhardt 2009
Tom Fuller 2009
Peter Hesketh 2009
Uziel Landau 2009
Dolf Landheer 2009
Thomas P. Moffat 2009
Ikuzo Nishiguchi 2009
Kohei Uosaki 2009

ECS HONOR ROLL

Fellows *(continued)*

Rudolph G. Buchheit....2010
Francis D'Souza....2010
Toshio Fuchigami....2010
Michel Houssa....2010
Robert G. Kelly....2010
Roger C. Newman....2010
Peter N. Pintauro....2010
Peter C. Searson....2010
David Shoesmith....2010
Bernard Tribollet....2010
John W. Weidner....2010
David J. Young....2010
Hugh C. DeLong....2011
Hubert Gasteiger....2011
Arumugam Manthiram....2011
Ashok Kumar Shukla....2011
Paul C. Trulove....2011
Karim Zaghib....2011
Giovanni Zangari....2011
Thomas A. Zawodzinski....2011
Jeffrey R. Dahn....2012
Stefan DeGendt....2012
Hariklia Deligianni....2012
Andrew Gewirth....2012
Meilin Liu....2012
Junichi Murota....2012
Sri Narayan....2012
Trung Van Nguyen....2012
Winston Revie....2012
Daniel Schwartz....2012
Esther Takeuchi....2012
Mark Verbrugge....2012
Petr Vaníysek....2012
Bruce Weisman....2012
Hector Abruña....2013
Nancy Dudney....2013
Gary Hunter....2013
Jiri Janata....2013
Johna Leddy....2013
Shelley Minteer....2013
Sanjeev Mukerjee....2013
Elizabeth Opila....2013
Jan Robert Selman....2013
Kalpathy Sundaram....2013
Enrico Traversa....2013
Martin Winter....2013
George E. Blomgren....2014
Gerardine Botte....2014
Ralph J. Brodd....2014
Yasuhiro Fukunaka....2014
Jay W. Grate....2014
Dirk Guldi....2014
Bruce Parkinson....2014
Fred Roozeboom....2014
Alvin Salkind....2014
Sudipta Seal....2014
Michael Thackeray....2014
Tooru Tsuru....2014
Harry Tuller....2014
Jose Zagal....2014
Piotr Zelenay....2014
Simon Deleonibus....2015
Raymond Gorte....2015
Ellen Ivers-Tiffeé....2015
Deborah Jones....2015
Robert Kostecki....2015
Mogens Mogensen....2015
Kailash Mishra....2015
Emanuel Peled....2015
E. Jennings Taylor....2015
John Turner....2015
Steven Visco....2015
Nick Birbilis....2016
John Goodenough....2016
Masahiro Watanabe....2016
Hiroshi Imahori....2016
Alan C. West....2016
Eddy Simoen....2016
Bryan Chin....2016
Ram S. Katiyar....2016
Bor Yann Liaw....2016
Jeffrey Fergus....2016
Peter Mascher....2016
A. Robert Hillman....2016
Jürgen Fleig....2016
Christian Amatore....2017
Khalil Amine....2017
Plamen Atanassov....2017
Scott Barnett....2017
Christina Bock....2017
Marca Doeff....2017
Mario Ferreira....2017
Clare Grey....2017
Robert Huggins....2017
Christopher Johnson....2017
Joachim Maier....2017
Rangachary Mukundan....2017
Tae-Yeon Seong....2017
Yang Shao-Horn....2017
Nianqiang Wu....2017

Edward G. Weston Summer Fellowship

(formerly the Edward G. Weston Fellowship, 1930-1945)

E. B. Sanigar....1930
K. Solliner....1931
M. E. Fogle....1932
R. D. Blue....1933
P. A. Jacquet....1934
M. A. Coler....1935
H. B. Linford....1936
G. L. Putnam....1937
V. de Nora....1938
W. P. Ruemmier....1940
R. E. Black....1941
W. E. Roake....1942
R. D. Misch....1947
M. T. Simnad....1948
R. L. Brubaker....1961
D. Yohe....1962
H. O. Daley, Jr.....1963
M. D. Hawley....1964
T. G. McCord....1965
J. D. McLean....1966
K. B. Prater....1967
K. Doblhofer....1968
L. R. Faulkner....1969
W. J. Horkans....1970
W. J. Horkans....1971
W. J. Bover....1972
B. J. Alexander....1973
S. S. Fratoni, Jr.....1974
M. Suchanski....1975
R. J. Nowak....1976
P. A. Kohl....1977
C. D. Jaeger....1978
L. Bottomley....1979
G. L. McIntire....1980
J. Pemberton....1981
M. E. Kordesch....1982
R. G. Tompson....1983
P. M. Kovach....1984
J. N. Harb....1985
S. E. Creager....1986
X. Zhang....1987
C. Amass....1988
R. J. Phillips....1989
J. E. Franke....1990
S. R. Snyder....1991
P. Pantano....1992
G. J. Edens....1993
B. Idriss....1994
D. Bizzotto....1995
L. A. Lyon....1996
C. Claypool....1997
B. Bath....1998
A. C. Templeton....1999
P. W. Wuelfing....2000
K. Balss....2001
T. Hu....2002
J. Mauzeroll....2003
J. Seegmiller....2004
E. Blair....2005
F. Laforge....2006
Aleix G. Güell....2007
Matthew J. Banholzer....2008
Shulei Chou....2009
Binh-Minh Nguyen....2010
Abrin Schmucker....2011
Sujat Sen....2012
Philippe Dauphin Ducharme....2013
Tuncay Ozel....2014
Gen Chen....2015
Soo Kim....2016
Lushan Zhou....2017

Colin Garfield Fink Summer Fellowship

P. Brown....1962
W. G. Lemmermann....1963
W. G. Stevens....1964
J. P. Carney....1965
S. Piekarski....1966
B. S. Pons....1967
R. E. Bonewitz....1968
L. Papouchado....1969
R. G. Reed....1970
R. Fike....1971
D. L. McAllister....1972
R. R. Chance....1973
P. I. Lee....1974
J. B. Flanagan....1975
J. S. Hammond....1976
P. D. Tyma....1977
S. M. Wilhelm....1978
J. D. Porter....1979
R. S. Glass....1980
E. E. Bancroft....1981
T. D. Cabeika....1982
B. L. Wheeler....1983
E. T. T. Jones....1984
D. A. Van Galen....1985
J. S. Hanson....1986
P. Gao....1987
D. T. Schwartz....1988
A. E. Russell....1989
J. Xue....1990
C. K. Rhee....1991
M. J. Shane....1992
C. M. Pharr....1993
J. M. Lauerhaus....1994
S. M. Hendrickson....1995
J. C. Hutchinson....1996
P. V. A. Pamidi....1997
G. S. Hwang....1998
W. Baker....1999
A. Crown....2000
R. Maus....2001
S. Peper....2002
M. Alpuche-Aviles....2003
A. Mugweru....2004
G. Lica....2005
A. Martinson....2006
Prabeer Barpanda....2007
Sau Yen Chew....2008
Hyea Kim....2009
Brian Adams....2010
Tae-Ho Shin....2011
Devika Sil....2012
Gabriel G. Rodríguez-Calero....2013
Christena K. Nash....2014
Hadi Khani....2015
Yelena Gorlin....2016

Joseph W. Richards Summer Fellowship

V. E. Hauser, Jr....1960
M. J. Schaer....1961
R. E. Visco....1961
A. K. Postma....1962
C. C. Liu....1963
M. J. Vasile....1964
M. J. Vasile....1965
C. C. Liu....1966
B. N. Baron....1967
L. P. Zajicek, Jr....1968
K. R. Bullock....1969
S. H. Cadle....1970
J. W. Webb....1971
C. P. Keszthelyi....1972
M. Shabrang....1973
D. H. Karweik....1974
T. P. DeAngelis....1975
D. L. Feke....1976
H. Faulkner....1977
D. M. Novak....1978
B. R. Karas....1979
R. M. Cohen....1980
R. N. Dominey....1981
R. M. Ianniello....1982
D. F. Tessier....1983
N. T. Sleszynski....1984
C. M. Lieber....1985
J. L. Valdes....1986
R. Q. Bligh....1987
D. W. Conrad....1988
S. A. Schofield....1989
J. A. Roberts....1990
M. S. Freund....1991
L. Gao....1992
H. Gasteiger....1993
J. Schoer....1994
S. Morin....1995
N. Madigan....1996
S. Petrovic....1997
J. J. Sumner....1998
A. Wijayawardhana....1999
B. Liu....2000
C. Noble....2001
C. B. France....2002
P. Ramadass....2003
J. Carroll....2004
K. Salaita....2005
J. Breger....2006
Sadagopan Krishnan....2007
Meng Jiang....2008
Haizhou Liu....2009
Mohammad Rez Khajavi....2010
Jeyavel Velmurugan....2011
Balazs Berkes....2012
Yongjin Lee....2013
Andrey Gunawan....2014
Mohammad Mahdi Hasani-Sadrabadi....2015
Charuksha T. Walgama....2016
Zakaria Y. Al Balushi....2017

Frederick M. Becket Summer Fellowship

(formerly the F. M. Becket Memorial Award 1962-1999)

R. B. Johnson....1962
J. K. Johnstone....1964
K. Lehman....1966
H. K. Bowen....1967
T. E. Parker....1971
G. M. Crosbie....1973
N. A. Godshall....1975
J. D. Hodge....1977
W. Cheng....1979
P. Davies....1981
P. A. Barron....1983
G. J. Miller....1985
M. Rosenbluth....1987
J. D. Cotton....1989
J. Philliber....1991
P. Agarwal....1993
H. C. Slade....1995
K. S. Weil....1997
G. S. Hwang....1999
J. Parrish....2001
S. Wasileski....2002
E. Clark....2003
F. Deng....2004
S. Harrison....2005
Y. Yang....2006
Michael Orthner....2007
Marcos Jose Leitos Santos....2008
Steve Rhieu....2009
James Whitaker....2011
Celeste Morris....2012
Carlo Santoro....2013
Brandy Kinkead....2014
Raphaële Clément....2015
Muhammad Boota....2016
Siddesh Umapathi....2017

Herbert H.Uhlig Summer Fellowship

Natalia Shustova....2008
Venkatasubramanian Viswanathan....2009
Swetha Puchakayala....2011
Julia van Drunen....2012
Junsi Gu....2013
Hadi Tavassol....2014
Alexander Pak....2015
Michael Metzger....2016
Debasmita Dwibedi....2017

Energy Research Summer Fellowship

(supported by the U.S. Department of Energy)

M. R. Deakin....1985
P. B. Johnson....1985
D. A. La Hurd....1985
S. E. Morris....1985
D. P. Wilkinson....1985
D. G. Frank....1986
K.-C. Ho....1986

ECS HONOR ROLL

Energy Research Summer Fellowship
(continued)

R. G. Kelly 1986
I.-H. Yeo 1986
J. Kwak 1986
L. C. Dash 1987
S. A. Naftel 1987
T. R. Nolen 1987
D. Schwartz 1987
T. H. Wong 1987
S. D. Fritts 1988
D. A. Koos 1988
D. A. Hazlebeck 1988
M. O. Schloh 1988
S. S. Perine 1988
J. E. Baur 1989
C.-P. Chen 1989
D. W. Eng 1989
R. L. McCarley 1989
C. J. Murphy 1989
C. K. Nguyen 1990
I.-H. Oh 1990
T. G. Strein 1990
J. W. Weidner 1990
S. E. Gilbert 1990
C. S. Johnson 1991
H. Huang 1991
D. R. Lawson 1991
B. D. Pendley 1991
C. C. Streinz 1991
P. A. Connick 1992
A. C. Hillier 1992
D. L. Taylor 1992
K. K. Lian 1992
T. T. Nadasdi 1992
D. G. Jensen 1993
J. C. Bart 1993
G. Seshadri 1993
J. A. Poirier 1993
K. W. Vogt 1993
Z. Shi 1994
C.-C. Hsueh 1994
V. A. Adamian 1994
K. M. Maness 1994
K. M. Richard 1994
Y.-E. Sung 1995
J. C. Conboy 1995
L. A. Zook 1995
W. R. Everett 1995
H. Zhang 1995
S. Grabtchak 1996
J.-B. Green 1996
S. Motupally 1996
C. Nasr 1996
S. Nayak 1996
K. Hu 1997
M. E. Williams 1997
A. Zolfaghari 1997
C. R. Horne 1997
G. K. Jennings 1997
M. Zhao 1998
S. Sriramulu 1998
J. Ritchie 1998
M. A. Elhamid 1998
S. Zou 1998
K. Cooper 2000
K. Grant 2000
D. Hansen 2000
J. F. Hicks 2000
Z. Liu 2000

Oronzio de Nora Industrial Electrochemistry Fellowship

N. Mano 2004
N. Mano 2005
N. Mano 2006
Vijayasekaran Boovaragavan 2007
Vijayasekaran Boovaragavan 2008
Vijayasekaran Boovaragavan 2009
Wenjing (Angela) Zhang 2010

Norman Hackerman Young Author Award

(formerly the Young Authors Prize, 1929-1988)

W. C. Gardiner 1929
D. K. Alpern 1930
F. L. Jones 1931
F. W. Godsey, Jr. 1932
B. L. Bailey 1933
J. R. Heard, Jr. 1934
U. B. Thomas, Jr. 1935
W. A. Johnson 1936
R. S. Soanes 1937
N. B. Nichols 1938
G. A. Moore 1939
J. S. Mackay 1940
E. Adler 1941
S. Speil 1942
W. G. Berl 1943
J. P. Coyle 1944
A. E. Hardy 1945
N. A. Nielsen 1946
H. Leidheiser, Jr. 1947
M. A. Streicher 1948
J. C. Griess, Jr. 1949
G. W. Murphy 1950
J. T. Byrne 1951
W. E. Kuhn 1952
J. Halpern 1953
M. J. Pryor 1954
M. Stern 1955
R. S. Cooper 1956
P. Ruetschi 1957
M. Stern 1958
F. A. Posey 1959
A. C. Makrides 1960
J. D. Newson 1961
M. J. Dignam 1962
J. A. Cunningham 1963
R. E. Westerman 1964
R. E. Visco 1965
J. Newman 1966
H. W. Pickering 1967
G. G. Charette 1968
G. Dryhurst 1969
J. Newman 1969
W. R. Parrish 1969
A. J. Appleby 1970
D. C. Johnson 1970
D.-T. Chin 1971
M. S. Whittingham 1971
M. A. Hopper 1972
F. Kuhn-Kuhnenfeld 1972
M. J. Bowden 1973
L. Thompson 1973
D. Simonsson 1973
S. H. Cadle 1974
A. D. Dalvi 1974
L. R. Faulkner 1975
S. Solmi 1975
P. Negrini 1975
B. MacDougall 1976
S. K. Ubhayakar 1976
C. W. Manke 1977
W. J. Horkans 1977
A. G. Gonzalez 1978
C. H. Tsang 1978
D. A. Antoniadis 1978
D. Y. Wang 1979
C. W. Magee 1979
E. Takayama 1980
H. Reller 1980
W. J. P. Van Enckevort 1981
M. W. M. Graef 1981
C. Y. Chao 1981
L. F. Lin 1981
D. W. Sittari 1982
T. P. Chow 1982
P. G. Pickup 1983
K. F. Jensen 1983
D. B. Graves 1983
N. A. Godshall 1984
E. K. Broadbent 1984
J. C. Farmer 1985
G. S. Oehrlein 1985
J. Richer 1986
T. Tanaka 1986
C. P. Wilde 1987
P. N. Bartlett 1987
J. Maier 1987
J. A. Bardwell 1988
C.-J. Han 1988
A. E. Husser 1989
D. H. Craston 1989
J. M. Rosamilia 1989
J. H. Comfort 1989
M. W. Verbrugge 1990

C. J. Giunta 1990
T. J. Mountziaris....1991
J. V. Cole 1991
D. W. Suggs 1991
B. W. Gregory....1991
D. B. Bonham....1992
E. S. Aydil....1992
P. P. Apte 1993
A. West 1993
H. A. Gasteiger 1994
F. R. Myers 1994
R. Vidal 1995
G. D. Papasouliotis....1995
J. H. Nordlien 1996
J. Lee 1996
A. K. Padhi 1997
S. M. Han 1997
A. D. Robertson 1998
Y. Shao-Horn....1998
S. R. Kaluri....1998
A. Bautista....1999
P. A. O'Neil 1999
R. T. Leah....2000
J. W. Klaus 2000
J. F. Whitacre 2001
P. Feichtinger....2001
T. J. Pricer....2002
P. S. Lee 2002
K. Jambunathan 2003
S. Noda 2003
M. Miyamoto....2003
R. Akolkar 2004
Y.-K. Hong....2004
S. Borini 2005
M. Kunimatsu....2005
Mathieu Bervas 2006
Pradeep Dixit....2006
Steffen Eccarius 2007
A. T. J. van Niftrik....2007
Kevin Ralston....2008
Eu Jin Tan 2008
Yudi Setiawan 2008
Paul Albertus....2009
Louis Hutin 2009
Gijs Dingemans....2010
Erik Langereis 2010
Stephen E. Potts 2010
Xingbao Zhu....2010
Igor Volov 2011
Claudia Fleischmann 2011
Sebastien Couet 2011
Koen Schouteden....2011
Philipp Hönicke....2011
Kiersten Horning....2012
Sykes Mason 2012
Balavinayagam Ramalingam 2012
Rahul Malik....2013
Aziz Abdellahi....2013
Nathaniel D. Leonard....2014
Trevor M. Braun 2015
Mark Burgess....2016
Kenneth Hernandez-Burgos 2016
Raymond Smith 2017

Bruce Deal & Andy Grove Young Author Award

Konstantinos Spyrou....2013
Pengfei Guo 2014
Ran Cheng 2014
Wei Wang....2014
Kohei Shima....2015
Peng Sun 2016
Shihyun Ahn 2017

ECS General Society Student Poster Session Awards

F. Forouzan....1993
D. L. Taylor....1993
L. Abraham 1994
A. J. Aldykiewicz 1994
A. Dalmia 1994
M. Murthy 1994
R. Munkundan 1995
A. E. Thomas....1995
C. E. Ramberg....1995
W. Wang 1995
S. Chen 1996
K. Kowal....1996
C. Leger 1997
E. Potteau....1997
K. Bera 1998
E. Dickenson 1998
G. Q. Lu....1998
M. W. Riley....1998
J. Pearton....1999
A. Templeson 1999
N. Baydokhi....2000
A. Pismenny....2000
A. Besing....2001
V. Sochnikov 2001
S. Dimovski....2002
P. Maitra....2002
H. Ohtsuka 2002
T. Wiley 2002
P. Kavanagh....2003
B. Monahan....2003
O. Rabin....2003
P. Scopece....2003
K. Yasuda 2003
M. Guan 2004
K. Kanaizuka....2004
A. Oide 2004
R. M. Todi 2004
W. J. Cheong....2005
J. Chmiola....2005
S. Chrisanti 2005
C. Drake 2005
D. L. Gonzalez-Parra 2006
Naoko Kamiura 2006
T. Takeyasu....2006
Arun Vijayakumar....2006
Naoaki Hashimoto....2007
Daisuke Kikutani 2007
Toyoki Okumura....2007
Gholamreza Rostamikia 2007
Arun Vijayakumar....2007
Rajwant Singh Bedi....2008
Bryan K. Boggs 2008
John Chmiola....2008
Yuta Ishigami 2008
J. S. O'Brien....2008
Tyler Osborn 2008
Ralf Peipmann....2008
Philippe Perret 2008
Kenji Takada....2008
Vinit Todi....2008
Natalia B. Shustova 2008
Joshua Snyder 2008
Tomomasa Sugiyama....2008
Anasuya Adibhatla....2009
Magdalena Gizowska....2009
Frederik Golks....2009
Karina Kangas....2009
Kiera A. Kurak 2009
Manale Maalouf....2009
Debasish Mohanty 2009
Natalia Shustova 2009
Joko Sutrisno....2009
Jaroslaw Syzdek 2009
Alex Avekians....2010
Shayna Brocato....2010
Pablo de la Iglesia....2010
Christian Desilets 2010
Ayesha Maria Hashambhoy....2010
Carolin Lau....2010
Raja S. Mannam....2010
Joshua P. McClure 2010
Sarvesh Pasem 2010
Robert Sacci 2010
Misato Tashiro 2010
Jesse Benck....2011
Benjamin Caire....2011
Zhebo Chen....2011
Damilola Daramola....2011
Kirsten Marie Jensen 2011
Javed Khan 2011
Simon Lux....2011
Ashley Maes....2011
Lingchong Mai 2011
Francis Richey....2011
Neil Spinner 2011
Melissa Vandiver....2011
Georgi Bodurov....2012
Aurelien Etiemble 2012
Kiersten Horning 2012
Yoon Jang Kim....2012
Prabhu Doss Mani 2012
K. Sykes Mason 2012
Seungha Oh 2012
Michael Siedlik....2012
Bong Seob Yang....2012
Yoshinobu Adachi 2012

ECS HONOR ROLL

ECS General Society Student Poster Session Awards
(continued)

Kwi Nam Han 2012
Takashi Hasegawa....2012
Cheng Ai Li....2012
Shigeta Yagyu 2012
Michal Osiak 2013
Andrew J. Naylor....2013
Danielle Smiley 2013
Mohammed Boota....2013
Kelsey B. Hatzall....2013
Christopher R. Dennison....2013
Tobias Placke 2013
Buido Schmuelling....2013
Richard Kloepsch....2013
Olga Fromm 2013
Sergej Rothermel 2013
Paul Meister 2013
Kristy Jost....2013
John McDonough 2013
Takashi Tsuda....2013
Masanari Hashimoto 2013
Axel Gambou-Bosca....2014
Miguel Angel Arellano Gonzalez 2014
Andrew Durney 2014
Elizabeth Hotvedt 2014
Andrew R. Akbashev 2014
Jorge Ivan Aldana-Gonzalez 2014
Heather Barkholtz....2015
Subrahmanyam Goriparti 2015
Daiki Ito....2015
Jonathan Kucharyson 2015
Maria Lukatskaya 2015
Kenta Machida 2015
Rajankumar Patel....2015
Xiaoxing Xia 2015
Mallory Fuhst....2016
Shota Matsumura 2016
Hiyori Sakata....2016
Masahiro Kato....2016
Futaba Yamamoto 2016
Masha Lotfi Marchoubeh 2016
Leanne Mathurin 2016
Isaac Taylor....2016
Haitham Kalil....2016
Katrina Vuong and Laurie Clare....2017
Emily Gullette, Natalie Handson, Emily Klutz, and Meredith Hammer....2017
Oliver Harris....2017
Josie Duncan and Mary Heustess 2017
Saad Intikhab 2017
Sungyup Jung....2017
Mariko Kadowaki....2017
Abubakar Khaleed 2017
Yubin Liu....2017
Phuong Tu Mai....2017
Travis Omasta 2017
Hiroki Shiikuma....2017
Sanjana Das and Stephanie Silic 2017

ECS Sponsored Meeting Student Poster Award Winners

Simposio Brasileiro de Electroquimica e Eletroanalitica (SIBEE)

L. M. Nunes 2009
Felipe Ibanhi Pires....2011
V. Dos Santos....2013

China Semiconductor Technology International Conference (CSTIC)

C. Santini 2009
L. Ma....2010
M. B. Gonzalez 2011
Chien Chi Chen....2012
Tao Deng 2013
Meng Lin....2014
Jin Jisong 2015
Xiaofei Wu....2015
Yanfen Xiao 2015
Alberto V. de Oliveira 2016
Jie Cheng 2016

SImposio Brasileiro de Extroquimica e Electroanalitica (XXI SIBEE)

Marilya Palmeira Galdino da Silva....2017
Filipe Soares da Cruz....2017
Thais Tasso Guaraldo....2017

Euro CVD Award

A. Szkudlarek 2011

IC4N: From Nanoparticles and Nanomaterials to Nanodevices and Nanosystems

M. Gharbi....2009
H. N. Green 2011
Mariana Sendova 2013
Brian DiMarco 2016

Sociedad Mexicana de Electroquímica (SMEQ) and ECS Mexican Section Meeting

A. Mendez-Albores....2008
L. S. Hernandez-Munoz....2009
C. Avila-Gonzalez....2010
D. C. Martinez-Casillas 2011
Lidia G. Trujano-Ortiz 2012
Paola Yamela De la Cruz-Guzmán 2013
Maria Dámaris Cortez Diaz....2015
Gibran Hernandez-Moreno....2016

ECS Toyota Young Investigator Fellowship Awards

Patrick Cappillino 2015
David Go 2015
Yogesh Surendranath....2015
Elizabeth Biddinger 2016
Joaquin Rodriguez Lopez....2016
Joshua Snyder 2016
Ahmet Kusoglu 2017
Julie Renner....2017
Shuhui Sun 2017

Turner Book Prize

S. Speil....1942
W. G. Berl....1943
J. P. Coyle 1944
J. T. Waber 1945
B. Cartwright....1946
A. E. Hardy 1947
M. A. Streicher 1948
R. E. Hoeckelman....1949
P. Delahay 1950
K. H. Stern 1951
C. C. Templeton....1951
P. T. Gilbert....1952
R. B. Holden....1953
D. A. Vermilyea 1954
J. G. Jewell....1955
J. H. Westbrook 1956
A. C. Makrides....1957
J. P. Pemsler 1958
R. G. Carlson....1959
R. E. Meyer 1960
P. C. Milner....1960
H. Freitag 1961
P. J. Boddy 1962
E. J. Cairns....1963
M. Weinstein 1963
R. W. Bartlett....1964
E. M. Hofer....1965
C. S. Tedmon, Jr.....1966
F. P. Kober 1967
J. M. Hale....1968

Leadership Circle Awards

Legacy Level

Dow Chemical Co., Central Research, received 2011
Olin Chlor Alkali Products Division, received 2011
Occidental Chemical Corp., received 2013
Energizer, received 2015

Medallion Level

Occidental Chemical Corp., received 2007
Atotech USA, Inc., received 2009
Energizer, received 2009

Diamond Level

General Electric Co., Corporate Research & Development, received 2011
General Motors Research Laboratories, received 2001
Rayovac, received 2002
Duracell, received 2006
IBM Corporation, received 2006

Gold Level

Toshiba Corp., Research & Development Center, received 1998
Siltronic AG, received 1998
Osram Sylvania, Inc., Chemical & Metallurgical Division, received 1999
Sandia National Laboratories, received 2000
International Lead Zinc Research Organization, Inc., received 2003

Medtronic, Inc., Energy and Component Center, received 2004
Toyota Central Research and Development Labs, Inc., received 2004
Yuasa Corp, received 2004
Princeton Applied Research/Solartron Analytical, received 2005
Saft Batteries, received 2006
CSIRO Minerals, received 2007
Industrie de Nora, received 2007
Ballard Power Systems, Inc., received 2008
ECO Energy Conversion, received 2008
Varta Automotive GmbH, Advanced Battery Division, received 2008
Leclanche S. A., received 2009
Max-Planck-Institut für Festkörperforschung, received 2009
Giner, Inc., received 2010
Greatbatch, Inc., received 2010
TIMCAL Graphite and Carbon Ltd., received 2011
3M Company, received 2014
Princeton Applied Research/Solartron Analytical, received 2016

Silver Level

Eltech Systems Corp., received 1992
Tronox LLC, received 1994
Japan Storage Battery Co., Ltd., received 1997
3M Company, received 1998
E. I. Du Pont de Nemours & Co., Inc., HD Microsystems, received 1998
Solartron Instruments, received 1999
Central Electrochemical Research Institute, received 2002
TDK Corp., R&D Center, received 2002
Valence Technology, received 2002
DAISO, Co., Ltd., received 2003
Panasonic Corp., received 2003
C. Uyemura & Co., Ltd., Central Research Lab, received 2005
Electrosynthesis Co., Inc., received 2005
FMC Corporation, Active Oxidants Division, received 2005
Nacional de Grafite, LTDA, received 2005
Permelec Electrode, Ltd., received 2005
PPG Industries, Inc., Chemicals Group Technical Center, received 2005
Scribner Associates, Inc., received 2005
Technic Inc., received 2005
Advance Research Chemicals, Inc., received 2007
Yeager Center for Electrochemical Sciences at CWRU, received 2007
PEC North America, received 2009
Quallion, LLC, received 2009
UTC Power, received 2009
Broddarp of Nevada, received 2010
Teledyne Energy Systems, Inc., received 2010
OM Group, Inc., received 2012
Evonik Degussa GmbH, received 2013
Permascand AB, received 2013
Lawrence Berkeley National Lab, received 2014
ZSW, received 2014
Faraday Technology, Inc., received 2016
Metrohm USA, received 2016
Pine Research Instrumentation, received 2016

Bronze Level

Hach Company, Radiometer Analytical Division, received 2002
De Nora Technologie Elettrochimiche S.r.L., received 2003
BAE Systems Battery Technology Center, received 2005
Agilent Laboratories, received 2008
Evonik Degussa GmbH, received 2008
Samsung SDI, received 2008
GAIA-Akkumulatorenwerke GmbH, received 2009
Permascand AB, received 2009
ZSW Center for Solar Energy & Hydrogen Research, received 2009
Coolohm, Inc., received 2010
ElectroChem, Inc., received 2010
Faraday Technology, Inc., received 2010
Johnson Matthey, received 2010
Metrohm USA, received 2010
Pine Research Instrumentation, received 2010
Sanyo Electric Co. Ltd., received 2011
Nissan Motor Co. Ltd., received 2011
Hydro-Québec, received 2011
Bio-Logic USA/Bio-Logic SAS, received 2012
ENEOS CELLTECH Co. Ltd., received 2012
Fortu Research GmbH, received 2012
Gamry Instruments, received 2012
Rockwood Lithium, received 2012
Asahi Kasei E-Materials Corp., received 2014
Gelest, Inc., received 2014
Honda R+D Co. Ltd., received 2014
Next Energy EWE-Forschungszentrum, received 2014
Los Alamos National Laboratory, received 2015
Toyota Research Institute of North America, received 2015

Battery Division Student Research Award

J. R. Waggoner 1980
K. E. Yee 1980
W. A. van Schalkwijk 1981
C. Y. Mak 1986
T. I. Evans 1987
C. C. Streinz 1988
J. Weidner 1989
M. G. Lee 1990
E. J. Podlaha 1991
G. E. Gray 1992
D. Qu 1993
P. De Vidts 1994
S. Motupally 1995
J. Xu 1996
Y. Shao-Horn 1997
I. Courtney 1998
G.E. Rousse 1999
V. Srinivasan 2000
M. Zhao 2001
V. Subramaniam 2001
L. Fransson 2002
K.-W. Park 2003
A. Weber 2004
C. Delacourt 2005
K. Kang 2006
Feng Jiao 2007
Nonglak Meethong 2009
Yi-Chun Lu 2010
Christopher Fell 2011
Yuhui Chen 2012
Mohammed Ati 2013
Martin Ebner 2014
Matteo Bianchini 2015
Billur Deniz Polat Karahan 2016
Lin Ma 2017

Battery Division Research Award

J. J. Lander 1958
D. M. Smyth 1959
T. P. Dirkse 1962
F. G. Will 1964
J. Burbank 1966
C. P. Wales 1966
D. Tuomi 1968
Y. Okinaka 1970
A. C. Simon 1972
S. M. Caulder 1972
J. McBreen 1974
T. Katan 1976
S. Szpak 1976
A. Heller 1978
K. R. Bullock 1980
R. A. Huggins 1982
D. Pavlov 1984
G. H. J. Broers 1985
J. L. Devitt 1986
D. H. McClelland 1986
J. P. Gabano 1987
M. Armand 1988
J. Jorne 1989
A. N. Dey 1990
R. E. White 1991
D. N. Bennion 1992
E. Peled 1993
K. M. Abraham 1995
J. Dahn 1996
B. Scrosati 1997
C. Delmas 1999
J. B. Bates 2000
S. Wittingham 2002
K. Kinoshita 2003
J. Newman 2004
G. Ceder 2004
M. Thackeray 2005

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Battery Division Research Award
(continued)

T. Ohzuku 2006
Clare P. Grey 2007
Peter G. Bruce 2008
Linda Nazar 2009
Dominique Guyomard 2010
Yang-Kook Sun 2011
Stefano Passerini 2012
Doron Aurbach 2013
Arumugam Manthiram 2014
Martin Winter 2015
Yang Shao-Horn 2016
Nobuyuki Imanishi 2016
Ryoji Kanno 2017

Battery Division Technology Award

Y. Nishi 1994
K. Ozawa 1994
E. S. Takeuchi 1995
S. Gilman 1996
J.-M. Tarascon 1997
G. E. Blomgren 1998
A. Yoshino 1999
H. Y. Cheh 2000
B. B. Owens 2001
D. Wilkinson 2002
M. Winter 2002
J. Yamaki 2003
M. Yoshio 2003
M. Ue 2004
D. Aurbach 2005
P. Novak 2005
K. Lee 2006
Michel Broussely 2007
Hiroshi Inoue 2008
Satoshi Mizutani 2008
Eiji Endoh 2009
Khalil Amine 2010
Jeffrey Dahn 2011
Yet-Ming Chiang 2012
Karim Zaghib 2013
Feng Wu 2014
Ashok Shukla 2015
Dominique Guyomard 2016
Jun Liu 2017

Battery Division Postdoctoral Associate Research Award Sponsored by MTI Corporation and the Jiang Family Foundation

Yelena Gorlin 2016
Liumin Suo 2016
Haegyeom Kim 2017
Kimberly See 2017

Corrosion Division H. H. Uhlig Award

(formerly the Outstanding Achievement Award of the Corrosion Division 1973-1983)

M. Cohen 1973
D. A. Vermilyea 1975
J. Kruger 1977
M. J. Pryor 1979
T. R. Beck 1981
N. Sato 1983
P. Kofstad 1985
H. W. Pickering 1987
R. P. Frankenthal 1989
H. Leidheiser 1991
H. Isaacs 1993
W. H. Smyrl 1995
M. J. Graham 1997
K. Hashimoto 1999
D. Macdonald 2001
F. Mansfeld 2002
C. Leygraf 2003
R. Newman 2004
P. Marcus 2005
G. T. Burstein 2006
Edward McCafferty 2007
Martin Stratmann 2008
John R. Scully 2009
Gerald S. Frankel 2010
Patrik Schmuki 2011
Hans-Henning Strehblow 2012
Mário Ferreira 2013
Paul Natishan 2014
David Shoesmith 2015
Robert G. Kelly 2016
Herman Terryn 2017

Corrosion Division Morris Cohen Graduate Student Award

(formerly the Corrosion Division Award for Summer Study 1986-1988)

S. D. Scarberry 1986
C. C. Streinz 1987
R. Bianco 1988
M. A. Harper 1992
R. G. Buchheit 1993
J.-F. Yan 1994
B. V. Cockeram 1995
I. Odnevall 1996
D. G. Kolman 1997
C. S. Brossia 1998
M. Verhoff 1999
S. Yu 2000
S. F. Nitodas 2001
K. Cooper 2002
T. Ramgopal 2003
Q. Meng 2004
D. Chidambaram 2005
H. Tsuchiya 2006
Magnus Johnson 2007
Christopher D. Taylor 2008
Mariano Iannuzzi 2009
Pouria Ghods 2010
Hongbo Cong 2011
Mariano Kappes 2012
Quentin Van Overmeere 2013
Yolanda Hedberg 2014
Eric Schindelholz 2015
Saman Hosseinpour 2016
Mohsen Esmaily 2017

Dielectric Science and Technology Division Thomas D. Callinan Award

J. A. Davies 1968
J. P. S. Pringle 1968
G. M. Sessler 1970
J. E. West 1970
C. A. Mead 1971
W. Kern 1972
J. R. Szedon 1973
C. M. Osburn 1975
T. W. Hickmott 1976
J. R. Ligenza 1977
R. Williams 1978
R. J. Kriegler 1979
B. E. Deal 1982
L. Young 1983
A. K. Sinha 1985
A. C. Adams 1986
S. P. Murarka 1987
R. B. Comizzoli 1988
E. A. Irene 1988
R. A. Levy 1989
M. H. Woods 1990
V. J. Kapoor 1991
S. I. Raider 1992
D. W. Hess 1993
Y.-H. Wong 1994
K. L. Mittal 1995
W. D. Brown 1996
J. P. Dismukes 1997
R. Singh 1998
A. Rohatgi 1999
K. Saraswat 2000
P. Ho 2001
J. Deen 2002
S. K. Banerjee 2003
A. G. Revesz 2003
S. Fonash 2004
Paul A. Kohl 2008
Tsu-Jae King Liu 2011
Durgamadhab (Durga) Misra 2013
Kalpathy Sundaram 2015
Hiroshi Iwai 2017

Electrodeposition Division Early Career Investigator Award

Yihua Liu 2016
Jiahua Zhu 2017

Electrodeposition Division Research Award

W. Weil....1980
Y. Okinaka 1981
E. B. Budevski 1982
R. C. Alkire 1983
L. T. Romankiw 1984
R. J. von Gutfeld 1984
J. W. Dini....1985
H. R. Johnson 1985
H. Leidheiser....1986
J. P. Hoare....1987
H. Y. Cheh 1988
D. S. Lashmore 1989
S. Nakahara....1990
T. C. Franklin 1991
R. E. White 1992
P. C. Andricacos 1993
M. J. Froment....1994
D. Landolt 1995
T. Osaka 1996
M. Schlesinger 1997
Madhav Datta....1998
R. Winand 1999
H. Honma....2000
D. Kolb 2002
J. Switzer 2003
J. Dukovic 2004
P. Bartlett....2005
T. P. Moffat 2006
Ibro Tabakovic....2007
Olaf Magnussen 2008
John Stickney 2009
Takayuki Homma....2010
Philippe Allongue 2011
Hariklia Deligianni 2012
Daniel Lincot 2013
Alan C. West....2014
Daniel Schwartz 2015
Stephen Maldonado 2016
Stanko Brankovic 2017

Electronics and Photonics Division Award

F. A. Trumbore....1970
F. C. Palilla....1971
M. B. Panish....1972
W. A. Pliskin....1973
B. E. Deal 1974
H. M. Manasevit 1975
M. G. Craford 1976
A. Y. Cho 1977
C. M. Wolfe 1978
E. Sirtl 1979
J. M. Woodall....1980
G. A. Rozgonyi 1981
G. W. Cullen 1982
D. W. Shaw 1983
A. Reisman....1984
S-M. Hu 1985
E. H. Nicollian....1986
B. Schwartz....1987
K. E. Bean....1988
T. Kamins 1989
D. M. Brown....1990
C. M. Osburn....1991
G. S. Oehrlein....1992
B. S. Meyerson....1993
G. K. Celler 1994
L. C. Kimerling 1995
H. Huff 1996
A. F. Tasch 1997
U. M. Gösele 1999
S. N. G. Chu 2000
S. P. Murarka....2001
S. Cristoloveanu....2002
T. Ohmi 2003
C. Claeys 2004
S. Pearton 2005
H. Massoud....2006
Yue Kuo 2007
Fan Ren....2008
Eicke R. Weber....2009
Lih J. Chen....2010
M. Jamal Deen 2011
Chennupati Jagadish 2012
Durgamadhab (Durga) Misra 2013
Albert Baca....2014
Cammy Abernathy....2015
Michael Shur....2016
D. Noel Buckley....2017

Energy Technology Division Research Award

M. W. Verbrugge 1994
S. Srinivasan....1996
H. R. Kunz....1998
A. W. Czanderna....1999
R. Selman 2001
I. Uchida....2001
A. Nozik....2003
K. Kinoshita....2004
K. Kanamura 2005
S. Licht....2006
Radoslav Adzic....2007
Yang Kook Sun....2007
Tom Fuller 2008
Krishnan Rajeshwar 2009
Jai Prakash 2009
John Weidner....2010
Karim Zaghib....2010
Claude Levy-Clément 2011
Piotr Zelenay 2013
James Fenton....2014
Rodney Borup 2015
Thomas Zawodzinski 2016
Hubert Gasteiger 2017

Energy Technology Division Srinivasan Young Investigator Award

Vijay Ramani 2012
Adam Weber 2012
Stefan Freunberger 2013
Minhua Shao....2014
William Mustain 2015
Prabeer Barpanda 2016
Ahmet Kusoglu 2017

Energy Technology Division Graduate Student Award *sponsored by Bio-Logic*

Thomas Dursch....2014
James Radich 2014
Scott Cushing 2015
Haegyeom Kim....2015
Matthew Genovese 2016
Antoni Forner-Cuenca 2017

High Temperature Materials Division Outstanding Achievement Award

J. B. Wagner, Jr. 1986
W. L. Worrell 1988
R. A. Rapp....1990
H. Schmalzried....1992
S. C. Singhal 1994
C. G. Vayenas....1996
C. Bernard....2001
H. Yokokawa 2002
K. Spear 2004
A. Virkar 2006
David J. Young....2008
Harry L. Tuller 2010
Eric Wachsman 2012
Janusz Nowotny....2014
Harlan Anderson 2016

High Temperature Materials Division J. B. Wagner, Jr. Young Investigator Award

S. Mohney....1999
S. M. Haile 2001
M. Swihart 2003

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High Temperature Materials Division J. B. Wagner, Jr. Young Investigator Award *(continued)*

R. Mukundan 2005
Xiao-Dong Zhou 2007
Juan Claudio Nino 2009
Toshiaki Matsui 2011
Paul Gannon 2013
Sean Bishop 2015
Cortney Kreller 2017

Industrial Electrochemistry and Electrochemical Engineering Division New Electrochemical Technology (NET) Award

Asahi Glass Company 1999
DeNora Tecnologie 2005
E-Tek 2005
Bayer Material Science AG 2005
Ballard Power Systems 2007
FuelCell Energy 2009
U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, and Electro Tech CP 2011
UTC Power 2013
Matthew Ward Brodt 2014
Proton OnSite 2015

Industrial Electrochemistry and Electrochemical Engineering Division H. H. Dow Memorial Student Achievement Award

R. Bakshi 1991
G. J. Yusem 1992
J. A. Poirier 1993
S. Siu 1994
M. Vreeke 1995
A. E. Thomas 1996
S. A. Leith 1997
P. Soo 1998
S. Sriramulu 1999
K. M. Jeerage 2000
A. L. Prieto 2001
W. He 2002
J. Zhang 2003
S. Basker 2004
V. Ramani 2005
N. Jalani 2006
Brenda L. Garcia-Diaz 2007
Sunil Roy 2008
Prabeer Barpanda 2009
Brandon Bartling 2010
Long Cai 2011
Meng Li 2012
Young Woo-Lee 2013
Matthew Ward Brodt 2014
Santosh Vijapu 2015
Muhammad Boota 2017

Industrial Electrochemistry and Electrochemical Engineering Division Student Achievement Award

Y.-E. Sung 1995
J. K. N. Mbindyo 1996
C. A. Smith 1997
J. A. Drake 1998
R. Lowrey 1999
C. Arvin 2000
B. Djurfors 2001
V. Subramanian 2002
P. M. Gomadam 2003
I. AlNashef 2004
V. Sethuraman 2006
Minhua Shao 2007
Vinten Dewikar 2008
Paul Albertus 2009
Satheesh Sambandam 2010
Venkatasailanathan Ramadesigan 2011
Rainer Kungas 2012
Wei Yan 2013
Christopher Arges 2013
Paul Northrop 2014
Venkata Raviteja Yarlagadda 2014
Vedasri Vedharathinam 2014
Mohammad Mahdi Hasani-Sadrabadi 2015
Regis P. Dowd, Jr. 2016
Bahareh Alsadat Tavakoli Mehrabadi 2017

Luminescence and Display Materials Division Centennial Award

A. Meijerink 2004
A. Srivastava 2004
H. Guedel 2006
David J. Lockwood 2010
Hajime Yamamoto 2012
Baldassare Di Bartolo 2016

Nanocarbons Division Richard E. Smalley Research Award

Sumio Ijima 2008
Phaedon Avouris 2009
Robert Haddon 2011
Nazario Martín 2013
Dirk Guldi 2015
Shunichi Fukuzumi 2017

SES Research Young Investigator Award of the Nanocarbons Division

Nikhil Koratkar 2009
Mark C. Hersam 2010
Aurelio Mateo-Alonso 2012
Jiayan Luo 2016

Organic and Biological Electrochemistry Division Manuel Baizer Memorial Award

T. Shono 1994
H. Lund 1996
H. Schäfer 1998
S. Torii 1998
J. Simonet 2000
J. Utley 2000
J. M. Savéant 2002
M. Tokuda 2004
D. Evans 2004
I. Nishiguchi 2006
Albert Fry 2008
Toshio Fuchigami 2010
Dennis Peters 2012
Jun-Ichi Yoshida 2014
Kevin Moeller 2016

Physical and Analytical Electrochemistry Division David C. Grahame Award

F. C. Anson 1983
J. Newman 1985
A. Heller 1987
M. J. Weaver 1989
B. Miller 1991
A. T. Hubbard 1993
R. M. Wightman 1995
D. M. Kolb 1997
P. N. Ross, Jr. 1999
D. A. Scherson 2001
A. Wieckowski 2003
H. White 2005
Joseph T. Hupp 2007
Héctor D. Abruña 2009
Masatoshi Osawa 2011
Richard L. McCreery 2013
Hubert Gasteiger 2015
Viola Birss 2017

Physical and Analytical Electrochemistry Division Max Bredig Award in Molten Salt Chemistry

M. Blander 1987
G. P. Smith 1990
R. A. Osteryoung 1992
G. Mamantov 1994
N. Bjerrum 1996
H. A. Øye 1998
Y. Ito 1999
G. N. Papatheodorou 2002
M. Gaune-Escard 2004
J. Wilkes 2006
Bernard Gilbert 2008
C. Austen Angell 2010
Derek Fray 2012
Charles Hussey 2014
Masayoshi Watanabe 2016

Sensor Division Outstanding Achievement Award

J. Janata 1994
R. P. Buck 1996
I. Lundström 1998
A. J. Ricco 2000
M. Aizawa 2002
N. Yamazoe 2004
W. Heineman 2006
Chung-Chiun Liu 2008
Thomas Thundat 2010
Sheikh Ali Akbar 2012
Peter Hesketh 2014
Rangachary Mukundan 2016

Sensor Division Student Paper Award

Jeffrey Kirsch 2012
Kazuaki Edagawa 2012

Gwendolyn B. Wood Section Excellence Award

Metropolitan New York Section 1975-1976
Columbus Section 1976-1977
Chicago Section 1979-1980
Chicago Section 1980-1981
Chicago Section 1981-1982
Southern Wisconsin Section 1982-1983
Southern Wisconsin Section 1983-1984
Southern Wisconsin Section 1984-1985
National Capital Section 1985-1986
North Texas Section 1986-1987
Southern Wisconsin Section 1987-1988
Chicago Section 1988-1989
Southern Wisconsin Section 1989-1990
North Texas Section 1990-1991
Southern Wisconsin Section 1991-1992
Southern Wisconsin Section 1992-1993
New England Section 1993-1994
National Capital Section 1994-1995
National Capital Section 1995-1996
National Capital Section 1996-1997
Canadian Section and National Capital Section 1997-1998
Chicago Section 1998-1999
New England Section 1999-2000
National Capital and New England Section 2000-2001
National Capital Section 2001-2002
National Capital Section 2002-2003
San Francisco Section 2003-2004
San Francisco Section 2004-2005
San Francisco Section 2005-2006

Canada Section Electrochemical Award

E. J. Casey 1982
Brian E. Conway 1986
L. Young 1990
S. Flengas 1994
Jacek Lipkowski 1998
Jean Lessard 2002
Jeffrey R. Dahn 2006
David Shoesmith 2010

Canada Section R. C. Jacobsen Award

George Fraser 1988
Barry MacDougall 1990
Louis Brossard 1994
Ernest E. Criddle 2002
Sharon G. Roscoe 2006
Jacek Lipkowski 2010

Canada Section W. Lash Miller Award

J. L. Ord 1969
J. E. Desnoyers 1971
A. K. Vijh 1973
W. R. Fawcett 1975
W. A. Adams, A. J. Spring Thorpe 1977
Barry MacDougall 1979
David W. Shoesmith 1981
A. Belanger 1983
Viola I. Birss 1985
S. Das Gupta 1987
K. Tomantscher, D. Leaist 1989
Jennifer Bardwell 1991
Jeff Dahn 1993
Alireza Zolfaghari-Hesari 1999
Daniel Bizzotto 2001
Jamie Noel 2003
Aicheng Chen 2009
Hua-Zhong (Hogan) Yu 2011
Not Awarded 2013
Federico Rosei 2015
Yurij Mozharivskyj 2017

Canada Section Student Award

Jean St-Pierre 1988
Gessie Brisard 1989
James Hinatsu 1990
Gregory Jerkiewicz 1991
Hubert Dumont 1992
Meijie Zhang 1993
Dan Bizzoto 1994
Sylvie Morin 1995
Alexandre Brolo 1996
Aicheng Chen 1997
Ian A. Courtney 1998
Dany Brouillette 1999
Shiyuan Qian 1999
Bryan Park 2000
Luc Beaulieu 2001
Vlad Zamliny 2002
Sandra Rifai 2003
Amy Lloyd 2004
M. Toupin 2006
Thamara Laredo 2007
Arash Shahryari 2008
Mohamed Naser 2009
Mohammed Naser 2010
Ahmad Ghahremaninezhad 2011
Karen Chan 2012
Drew Higgins 2013
Leah Ellis 2017

Cleveland Section Ernest B. Yeager Electrochemistry Award

B. Miller 2004
Richard McCreery 2006
Uziel Landau 2008
Jacek Lipkowski 2010
Gerald Frankel 2012

Europe Section Heinz Gerischer Award

Akira Fujishima 2003
Michael Graetzel 2005
Allen J. Bard 2007
Rüdiger Memming 2009
Helmut Tributsch 2011
Arthur Nozik 2013
Adam Heller 2015
Kazuhito Hashimoto 2017

Europe Section Alessandra Volta Award

M. Armand 2000
J.-M. Tarascon 2002
R. G. Compton 2004
Bruno Scrosati 2006
Not Awarded 2010
Jean-Noël Chazalviel 2012
Phillip Bartlett 2014
Christian Amatore 2016

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Georgia Section Student Award

Matthew Lynch....2012
Kara Evanoff....2013
Johanna Karolina Stark....2014

India Section S. K. R. Graduate Student Award

S. Anantharaj....2017

Korea Section Student Award

Ho-Suk Ryu....2006
Jae-Hwan Oh....2007
Sung Ki Cho....2008
Cheol-Min Park....2009
Ji-Hyung Han....2010
Young Woo Lee....2011
Not Awarded....2012
Seong Min Bak....2013
Haegyeom Kim....2014
Minah Lee....2015
Changshi Jo....2016
Hye Won Jeong....2017

National Capital Section William Blum Award

W. Blum....1958
S. Schuldiner....1960
D. N. Craig....1962
A. Brenner....1964
J. Kruger....1966
J. Burbank....1969
K. H. Stern....1972
B. F. Brown....1974
A. C. Simon....1976
R. T. Foley....1978
R. de Levine....1980
E. McCafferty....1982
R. L. Jones....1984
Ugo Bertocci....1986
P. J. Moran....1988
M. H. Peterson....1990
D. S. Lashmore....1992
J. R. Scully....1994
Paul M. Natishan....1996
G. D. Davis....1998
W. E. O'Grady....2000
Thomas P. Moffat....2002
J. L. Hudson....2004

National Capital Section Robert T. Foley Award

R. T. Foley....1989
W. J. Hamer....1991
G. E. Stoner....1993
P. J. Moran....1995
P. M. Natishan....1997
J. Kruger....1999
R. G. Kelly....2001

San Francisco Section Daniel Cubicciotti Student Award

L. J. Oblonsky....1995
Y. Ma....1996
C. Wade....1997
C. R. Horne....1998
M. Tucker....1999
L. V. Protsailo....2000
H. Visser....2001
D. Wheeler....2002
J. Hollingsworth....2003
E. Guyer....2004
D. Steingert....2005
Sarah Stewart....2006
James Wilcox....2007
Susan Ambrose....2008
Que Anh Nguyen....Honorable Mention 2008
Yuan Yang....Honorable Mention 2008
Paul Albertus....2009
Andrew Lee....Honorable Mention 2009
Mark Oliver....Honorable Mention 2009
Venkat Viswanathan....2010
Yi Wei Chen....Honorable Mention 2010
Thomas Conry....Honorable Mention 2010
Maureen Tang....2011
Yi Wei Chen....Honorable Mention 2011
Thomas Conry....Honorable Mention 2011
Allison Engstrom....2012
Matthew McDowell....Honorable Mention 2012
Xiongwu Kang....Honorable Mention 2012
Daniel Cohen....2013
Mallory Hammock....Honorable Mention 2013
Anthony Ferrese....Honorable Mention 2013
Nian Liu....2014
Isaac Markus....Honorable Mention 2014
Alan Berger....Honorable Mention 2014
Karthish Manthiram....2015
Christina Li....Honorable Mention 2015
Lei Cheng....Honorable Mention 2015
Yiyang Li....2016
William Nguyen....Honorable Mention 2016
Katherine Harry....Honorable Mention 2016
Andrew Scheuermann....Honorable Mention 2016
Tianyu Liu....2017
Colin Burke....Honorable Mention 2017
Limei Chen....Honorable Mention 2017

Outstanding Student Chapter Award

University of Maryland....2013
Ohio University....Chapter of Excellence 2013
University of Texas at Austin....Chapter of Excellence 2013
University of Texas at Austin....2014
University of Maryland....Chapter of Excellence 2014
Valley of the Sun (Central Arizona)....Chapter of Excellence 2014
Indiana University....2015
University of Virginia....Chapter of Excellence 2015
University of Maryland....Chapter of Excellence 2015
University of South Carolina....2016
University of Kentucky....Chapter of Excellence 2016
University of Maryland....Chapter of Excellence 2016
University of Maryland....2017
Munich Student Chapter....Chapter of Excellence 2017
University of Washington....Chapter of Excellence 2017

Future ECS Meetings

AiMES 2018

CANCUN, MEXICO
September 30-October 4, 2018
Moon Palace Resort

AiMES 2018
AMERICAS INTERNATIONAL MEETING ON ELECTROCHEMISTRY AND SOLID STATE SCIENCE

235th ECS Meeting

DALLAS, TX
May 26-May 31, 2019
Sheraton Dallas

2019

236th ECS Meeting

ATLANTA, GA
October 13-17, 2019
Hilton Atlanta

2019

237th ECS Meeting

with the 18th International Meeting on Chemical Sensors (IMCS 2020)

MONTREAL, CANADA
May 10-15, 2020
Palais des congress de Montreal

2020

ECS www.electrochem.org/meetings

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