Cornell University
College of Human Ecology
Fiber Science & Apparel Design

CIFFI
Cornell Institute of Fashion and Fiber Innovation

THE FIBER SOCIETY

75th Anniversary · 1941 – 2016

Advancing Scientific Knowledge Pertaining to Fibers and Fibrous Materials

The Fiber Society 2016 Fall Meeting and Technical Conference

The Fiber Society—75 Years in the Making

October 10–12, 2016

Conference Co-chairs

Dr. Margaret Frey and Dr. Juan Hinestroza
College of Human Ecology
Cornell University

Venue

Cornell University
Ithaca, New York, USA

Program

Sunday, October 9

1:00 PM–5:00 PM	Governing Council Meeting
5:00 PM–7:00 PM	Early-bird Registration and Reception *(Human Ecology Building Atrium)*

Monday, October 10
Morning

7:00 Registration and Breakfast: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), G71

8:00 Welcome and Opening Remarks *Margaret Frey and Juan Hinestroza, Cornell University, Co-chairs*
Alan Mathios, The Rebecca Q. and James C. Morgan Dean of the College of Human Ecology
Kostya Kornev, President, The Fiber Society

8:20 Keynote Speaker: Uli Wiesner, Spencer T. Olin Professor of Engineering, Materials Science and Engineering, Cornell University, *Self-assembly–based Functional Nanomaterials and Fibers*

9:00 Break

MARTHA VAN RENSSELAER HALL (MVR), G71

Session: Knit Modeling

Session Chair: Antonios Kontsos, Drexel University

9:10 *Physics-based Modeling of Knitted Textile Behavior* – Antonios Kontsos, Drexel University
9:30 *3D Modeling of Knittable Structures with Stitch Meshes* – Cem Yuksel, University of Utah
9:50 *Modeling Methodologies for Knitted Shape Memory Alloy Textiles* – Julianna Abel, University of Minnesota
10:10 *Modeling of Knitted Structures at Fiber/Filament Level: Tasks and Some Possible Solutions* – Yordan Kyosev, Hochschule Niederrhein
10:30 Break
10:40 *Efficient Simulation of Fabric at the Yarn Level* – Gabriel Cirio, URJC Madrid
11:00 *Nonintrusive Determination of Fibre Segment Orientation Distribution of Primary Nonwoven Structures* – Muhammad Tausif, University of Leeds
11:20 *Fiber Segment Orientation and Crossing in Nonwovens from X-ray Micro-computed Tomographic Data* – Steven Keller, Miami University
11:40 *open*

12:00 Lunch: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), G73

Session: Green Materials and Natural Fibers

Session Chair: Anil Netravali, Cornell University

9:10 *Manufacturing Cellulose and Chitin Fibres Using Ionic Liquids as Environmentally Benign Solvents* – Sameer Rahatekar, University of Bristol
9:30 *Fiber Orientation Control in Cellulose Nanofiber-reinforced Green Nanocomposites* – Hitoshi Takagi, Tokushima University
9:50 *Development and Characterization of Biobased Polymers and Natural Fiber Composites* – Mahesh Hosur, Tuskegee University
10:10 *open*
10:30 Break
10:40 *Cellulose Nanofiber Extraction from Grasses by Kitchen Blender and Ultrasonication* – Antonio Nakagaito, Tokushima Unversity
11:00 *Fully Bio-based Self-healing Composites Using Microcapsules* – Joo Ran Kim, Cornell University
11:20 *Biologically Derived Nanofibers for Novel Functions* – You-Lo Hsieh, University of California Davis
11:40 *open*

12:00 Lunch: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), 157

Session: Modeling Smart Textiles and Processes

Session Chair: Chunhui Xiang, Iowa State University

9:10 *Foldable Textile-based Devices Using Conductive Fibers* – Matsumi Kimura, Shinshu University

9:30 *Dielectric Soft Textile Polymers with Smart Functions: Electro-mechanical, Mechano-electric, Electro-*optical – Toshihiro Hirai

9:50 *Adaptive Washing Strategy for Overflow Rinsing* – Warren Jasper/Melih Gunay, North Carolina State University/Akdeniz University

10:10 *open*

10:30 Break

10:40 *Influence of the Wear of Carbon Nanotubes Grafted on Carbon* Fibers – Glaire Guignier, ENSISA

11:00 *Capillary Race in Fibrous Constructs* – Dahua Shou, Cornell University

11:20 *open*

12:00 Lunch: College of Human Ecology (CHE) Commons

Afternoon

MARTHA VAN RENSSELAER HALL (MVR), G71

Session: Graduate Student Paper Competition

Session Chair: Juan Hinestroza, Graduate Student Paper Competition Chair

1:00 Kerianne Dobosz, University of Massachusetts Amherst – *Electrospun Nanofiber Morphology Enhances the Flux and Antifouling Performance of Ultrafiltration Membranes*

1:25 Maike Quandt, EMPA – *Continuous Melt-extrusion of Touch-sensitive Polymer Optical Fibers*

1:50 Larissa Shepherd, Cornell University – *Increasing Stability of Biotin Functionalized Electrospun Fibers for Biosensor Applications*

2:15 Break

MARTHA VAN RENSSELAER HALL (MVR), G71

Session: Architecture

Session Chair: Jenny Sabin, Cornell University

2:30 *The Weaver and the Navvy*: A Concrete/Textile Collaboration* – Ruth Morrow, Queen's University

2:50 *Couture Construction* – Ruth Morrow/Trish Belford, Queen's University/Ulster University

3:10 *Thermally Resistant Membrane Enclosures* – Jonathan Knowles, Rhode Island School of Design

3:30 *Predictability and Pattern Logic in Textile Architecture* – Martin Tamke, Royal Danish Academy of Fine Arts

3:50 Break

Session: Metrology

Session Chair: Warren Jasper, North Carolina State University

4:00 *Evaluating Sources of Variability in Forensic Fiber Trace Evidence* – Julie Bitter, National Institute of Standards and Technology

4:20 *Forensic Files: So How Much Blood Was That?* – Stephen Michielsen, North Carolina State University

4:40 *Characterization of Micron-sized, Bicomponent Islands-in-Sea Fibers Using Various AFM Techniques* – Marion Schelling, Cornell University

5:00 *Characterization of Mechanical Properties of Micro- and Nanofiabers Using Magnetic Probes* – Kostya Kornev, Clemson University

5:20 *Raman Spectroscopy and Chemometrics Applied to Recycled Polyethylene Terephthalate* – Edmir Silva, Unifi

6:00 **Banquet: College of Human Ecology (CHE) Commons**
Awards Ceremony
Speaker: Dr. Karl Pillemer, Cornell University, *Lessons for Living from the Oldest (and Wisest) Americans*

MARTHA VAN RENSSELAER HALL (MVR), G73

Session: Green Materials and Natural Fibers *cont'd*

Session Chair: Anil Netravali, Cornell University

2:30 *In Situ and Real-time Studies of Cellulose Nanocryatals Orientational Order During Solution Shearing by X-ray Scattering* – Lina Sanchez-Botero

2:50 *Nanocellulose Functional Coatings on Fabric Surface* – Sergiy Minko, University of Georgia

3:10 *Impacts of Molecular Size and Affinity of Chemicals in Crosslinking Cotton Fabrics with Polycarboxylic Acids* – Gang Sun

3:30 *Gel Spinning of Lignin-reinforced Fibers* – Ericka Ford, North Carolina State University

3:50 Break

4:00 *Study of the Wetting Behavior of Micrometer-sized Natural and 3D Printed Natural-like Fibers* – Carlos Fuentes, KU Leuven

4:20 *Creep of Barkcloth-reinforced Laminar Epoxy Biocomposites* – Samson Rwariire, Technical University of Liberec

4:40 *Functionalization of Cotton Fiber by Partial Etherification and Self-assembly of Polyoxometalate Encaptulated in $Cu_3(BTC)_2$ Metal-Organic Framework* – Laura Lange, Invista

5:00 *"No Waste": The Development of Sustainable Knitted Clothes Made from PLA Fibers* – Ellen Bendt, Niederrhein University

5:20 *open*

6:00 **Banquet: College of Human Ecology (CHE) Commons**
Awards Ceremony
Speaker: Dr. Karl Pillemer, Cornell University, *Lessons for Living from the Oldest (and Wisest) Americans*

MARTHA VAN RENSSELAER HALL (MVR), 157

Session: Modeling Smart Textiles and Processes *cont'd*

Session Chair: Janice R. Gerde, US Customs and Border Protection

2:30 *Mathematical Modeling and Experimental Analysis of Dynamic Yarn Path in the Superconducting Magnetic Bearing-based Ring Spinning Machine* – Mahmud Hossain, Technische Universität Dresden

2:50 *Effect of Rotor Spinning Parameters on Trash Removal Proficiency* – Huiting Lin, Donghua University

3:10 *Modeling the Dynamic Behavior of Drafting Process* – Baolong Ma, Donghua University

3:30 *Heat Transfer Simulation of Fabrics with Heterogeneous Model* – Shen Hua, Kyoto Institute of *Technology*

3:50 Break

4:00 *Non-local Self-similarity Fabric Defect Detection* – Wai Keung Wong, Hong Kong Polytechnic University

4:20 *Analysis of Electrospinning Bending Region to Determine Fiber Diameter for Non-aqueous Solutions: Evaporation and Water Absorption* – Yunshen Cai, Boston University

4:40 *Finite Element Analysis of Effects of the Mesoscale Material Properties on the Mechanical Response of Woven Fabrics* – Ozan Erol, University of Delaware

5:00 *Determination of Relative Importance for Raw Material of Yarn Using Hybrid GA-TOPSIS Model* – Subhasis Das, Government College of Engineering and Textile

5:20 *open*

6:00 **Banquet: College of Human Ecology (CHE) Commons**
Awards Ceremony
Speaker: Dr. Karl Pillemer, Cornell University, *Lessons for Living from the Oldest (and Wisest) Americans*

Tuesday, October 11
Morning

8:00 Registration and Breakfast: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), G71

8:20: Keynote Speaker: Kavita Bala, Computer Science Department, Cornell University, *Modeling and Rendering Virtual Fabrics*

9:00 Break

MARTHA VAN RENSSELAER HALL (MVR), G71

Session: Fibrous Materials for Biomedical Applications

Session Chair: Minglin Ma, Cornell University

9:10 *Microfabrication with Cotton Candy: Fibers as Sacrificial Templates for Fluidic Systems* – Leon Bellan, Vanderbilt University

9:30 *Electrostatically Flocked Chitosan Fiber Scaffolds* – Robert Tonndorf, Technische Universität Dresden

9:50 *Hybrid Electrospun Chisotan-Phospholipids Nanofibers as a Platform for Biomedical Applications* – Ana Mendes, Technical University of Denmark

10:10 *Growth of Spinal Cord Explants on Electrospun Polyethylenimine-blended Nanofibers* – Reva Street, Drexel University

10:30 Break

10:40 *Put Electrospun Nanofibers to Work for Biomedical Research* – Jingwei Xie, University of Nebraska Medical Center

11:00 *Hybrid Textile for Heart Valve Prosthesis: In Vitro Assessment of Various Construction Designs* – Amna Amri, ENSISA

11:20 *Multicomponent Fibers Tailored for Medical Textiles* – Rudolf Hufenus, Empa

11:40 *Adhering Zwitterions to Electrospun Nanofiber Mats Using Bioglue* – Jessica Schiffman, University of Massachusetts Amherst

12:00 Lunch: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), G73

Session: Nanofibers

Session Chair: Yong Joo, Cornell University

9:10 *New Method for Characterization of Oriented Nanofibers* – Neda Shah Hosseini, ENSISA

9:30 *Study of Mechanical Properties of Electrospun PA-6 Nanowebs and Electrospun PA-6/B Composite as Substitution Membrane for Congenital Diaphragmatic Hernia Treatment* – Elham Mohsenzadeh, ENSISA

9:50 *Separation and Modeling of Oil-in-Water Emulsions Stabilized by Different Types of Surfactants Using Electrospun Fiber Membranes* – Yi-Min Lin, Massachusetts Institute of Technology

10:10 *open*

10:30 Break

10:40 *Investigation the Long-term Behavior of PAN Nanofiber Yarns* – Kolos Molnár, Budapest University of Technology

11:00 *From the Synthesis of Polymers to the Fabrication of Smart Nanofibers* – Edurne González, Cornell University

11:20 *open*

11:40 *open*

12:00 Lunch: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), 157

Session: Fiber Formation, Structure, and Properties

Session Chair: Philip Brown, Clemson University

9:10 *Bi-component Fibers for Temperature Adaptive Thermal Insulation* – Stephen Fossey, U.S. Army Natick Soldier RD&E Center

9:30 *Braided Structure with Negative Poisson's Ratio* – Hong Hu, Hong Kong Polytechnic University

9:50 *Investigation of Nanoyarn Preparation by Modified Electrospinning Setup* – Ariana Levitt, Drexel University

10:10 *New Styrenic Block Copolymers for Elastic Nonwoven and Fiber Applications* – Kuitian Tan, Kraton Performance Polymers

10:30 Break

10:40 *Overview of HIB Process for Making High-performance Fibers* – Mesbah Najafi, North Carolina State University

11:00 *Electrospinning Polyelectrolyte Complex Coacervates into Fiber Mats* – Xiangxi Meng, University of Massachusetts Amherst

11:20 *Slip-effect Functional Air Filter for Efficient Purification of PM2.5* – Xinglei Zhao, Donghua University

11:40 *High-performance Electrospun Polyethylene Fibers by Gel-Electrospinning* – Jay Hoon Park, Massachusetts Institute of Technology

12:00 Lunch: College of Human Ecology (CHE) Commons

Afternoon

MARTHA VAN RENSSELAER HALL (MVR), G71

Session: Clothing and Textile Comfort

Session Chair: Jintu Fan, Cornell University

1:00 *A Novel Female Sweating Thermal Manikin for Thermal Comfort Evaluation* – Jintu Fan, Cornell University

1:20 *Engineering Design of Knitted Fabrics for Optimal Thermo-physiological Comfort as Well as UV Protection* – Anindya Ghosh, Government College of Engineering and Textile Technology

1:40 *Chemical Protective Clothing Comfort Performance Study: Comfort and Textile Material Fundamental Properties* – Chunhui Xiang, Iowa State University

2:00 *Investigation of Value-added Component for Denim Fabrics Based on the Tactile Sensation* – Sachiko Sukigara, Kyoto Institute of Technology

2:20 *Preliminary Results of an Anthropometric Study with Brazilian Women in Portugal Using the Kinect Body Image System* – Miguel Carvalho/Carla Capelass, University of Minho

2:40 *A Comparative Analysis for Water Absorption and Transport Test Measurement for Fabrics* – Ka Po Maggie Tang, Cornell University

3:00 Break

3:10 *Study of the Thermal Comfort of Mattress Using Supine Thermal Manikin* – Lun Lou, Cornell University

3:30 *Children's Apparel for Medical Accommodations: Designed for Use with Pump, Catheter, or Port* – Jessica Estrada, Sam Houston State University

3:50 *Anthropometric Data Collection of Portuguese Children with Overweight and Obesity* – Miguel Carvalho, University of Minho

4:10 *Recovering Hydrophilicity of Wrinkle-free Cotton Fabric via Nanoparticle Treatment* – Lihong Lao, Cornell University

4:30 *open*

4:50 *open*

5:20-6:00 Fiber Society Annual Business Meeting, MVR G71: *Open to Fiber Society Members Only.*

6:00-7:30 Poster Session and Reception: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), G73

Session: Nanofibers and Energy

Session Chair: Yong Joo, Cornell University

1:00 *Ultralight Nanofiber-assembled Cellular Aerogels with Superelasticity and Multifunctionality* – Gang Sun/Yang Si, University of California Davis

1:20 *Facile Synthesis of Highly Carboxylated Electrospun Nanofibrous Membranes for Efficient Protein Adsorption* – Qiuxia Fu, Donghua University

1:40 *Superwetting Hierarchical Porous Silica Nanofibrous Membranes for Oil/Water Microemulsion Separation* – Jichao Zhang, Donghua University

2:00 *Electrospun Carbon Nanofibers for Electrochemical Biosensing and Energy Storage* – Xianwen Mao, Massachusetts Institute of Technology

2:20 *Synthesis of Lithium Ion-Sieve Nanoparticles and Evaluation of Li^+ Adsorption* – Kelsey Dean, Colorado State University

2:40 *open*

3:00 Break

3:10 *Polyacrylonitrile/Polymer-derived Ceramic Co-continuous Nanofiber Membranes via Room-curable Organopolysilazane for Improved Lithium Ion Battery Performance* – Soshana Smith, Axium Nano LLC

3:30 *Freestanding Nanofiber Electrodes for Supercapacitors and Batteries* – Vibha Kalra, Drexel University

3:50 *Electrospun Polyacrylonitrile/Polystyrene Nanofibrous Membranes Applied in Protein Through Hydrophobic Force* – Lihuan Wang, Donghua University

4:10 *In Situ Synthesis of Flexible Hierarchical TiO_2 Nanofibrous Membranes with Enhanced Photocatalytic Activity* – Xiaohui Wu, Donghua University

4:30 *open*

4:50 *open*

5:20-6:00 Fiber Society Annual Business Meeting, MVR G71: *Open to Fiber Society Members Only.*

6:00-7:30 Poster Session and Reception: College of Human Ecology (CHE) Commons

MARTHA VAN RENSSELAER HALL (MVR), 157

Session: Fiber Formation, Structure, and Properties *cont'd Session*

Chair: Philip Brown, Clemson University

1:00 *Thermoplastic Coating of Glass Fibres in the Nozzle Drawing Process* – Robert Brüll, RWTH Aachen University

1:20 *Invention (Recognition) of High-modulus, Low-shrinkage Tire Cord: A Model for the Development of Fiber Structure and Properties* – Michael Jaffe, New Jersey Innovation Institute

1:40 *Influence of Molecular Orientation on Crystallization Behavior of Poly(ethylene terephthalate) Measured by Fast Scanning DSC* – Takeshi Kikutani, Tokyo Institute of Technology

2:00 *Touch-spinning and Magnetospinning of Nano- and Microfibers* – Darya Asheghali, University of Georgia

2:20 *Effect of Crystal Orientation on Cellulose Nanocrystals/Polyvinyl Alcohol-Nanocomposite Fibers Produced by Dry Spinning* – Shikha Shrestha, Purdue University

2:40 *Studies in Strain-induced Polymer Crystallization: Joys of Uncovering Simple Relationships in Complex Systems* – David Salem, South Dakota School of Mines and Technology

3:00 Break

3:10 *Synergistic Reinforcement of Regenerated Silk Fibroin Fiber with Graphene Oxide/Titanium Dioxide Hybrid Filler* – Yaopeng Zhang, Donghua University

3:30 *open*

Session: The Fiber Society—A History
Session Chair: Michael Ellison, Clemson University

3:50 *Early Fiber Society History Recap and Continuation to 1960s* – Michael Ellison, Clemson University
4:10 *The Textile Research Institute and the Fiber Society: Foundations of Fiber Science Research in the United States* – David Salem, South Dakota School of Mines and Technology
4:30 *TRI, the Fiber Society, and the Gordon Conferences* – Bhuvenesh Goswami, Clemson University
4:50 *Highlights and Personal Recollections, 2001–2007* – Subhash Batra, North Carolina State University

5:20-6:00 Fiber Society Annual Business Meeting, MVR G71: *Open to Fiber Society Members Only.*

6:00-7:30 Poster Session and Reception: College of Human Ecology (CHE) Commons

Wednesday, October 12

NOTE LOCATION CHANGE: Nevin Center, Cornell Plantations

8:00 Breakfast: Ten Eyck Room

TEN EYCK ROOM

8:20: Keynote Speaker: Susan Ashdown, Helen G. Canoyer Professor, Fiber Science and Apparel Design, Cornell University, *Why Ready-to-Wear Clothing is Not Ready to Wear: The "Wicked" Design Problem of Clothing Fit*

9:00 Break

TEN EYCK ROOM
Session: Costume, Fashion, and History
Session Chair: Denise Green, Cornell University

9:10 *Kalamkari Revamping: Traditional vs Conventional Pretreatment Processes* – Geetal Mahajan, Institute of Chemical Technology
9:30 *Assessing Fastness Properties of Kalamkari Painted Fabric* – Ritika Jhunjhunwala, Sophia Shree B.K. Somani Memorial Polytechnic
9:50 *Interdisciplinary Product Development: Leveraging Fiber and Material Development in Technical Apparel* – Linsey Griffin, University of Minnesota
10:10 *Production of Material Culture in Guatemala* – Amanda Denham, Cornell University
10:30 Break

Session: Technical Apparel
Session Chair: Huiju Park, Cornell University

10:40 *Female Breast Shape Classification Based on Analysis of CAESAR 3D Body Scan Data* – Jie Pei, Cornell University
11:00 *Adaptive Clothing and Its Application for Female Breast Cancer Patients with Lymphedema* – Grace Jun, Parsons School of Design
11:20 *Degradation Mechanisms in Unidirectional UHMWPE Soft Ballistic Inserts* – Zois Tsinas, University of Maryland
11:40 *Comparison of Stretch and Recovery Properties of Polyester and Polyamide Knitted Fabrics for Compression Sportswear* – Jawairia Umar Khan, University Agriculture Faisalabad

Conference Concludes

Afternoon Tour of the Cornell Science & Apparel Design Facilities (sign-up required)

1:00 p.m. at the Human Ecology Building, T Level; hosted by Prof. Jintu Fan and Company

Poster Session

Tuesday, October 11, 6:00–7:30 p.m., College of Human Ecology (CHE) Commons

Presenter	Title
Yue Yuan	*Analysis of Water Contact Area on a Superhydrophobic Web*
Laurence Schacher	*Simple Method of Feather Keratin Extraction and Development of Nanofibers from Feather Waste*
Olga Urbanek	*Charge-assisted Tailoring and Its Effect on Surface Modification of Chitosan Nanofibers*
James Plaia	*Rope Recoil: Analysis and Control Strategy*
Youngjoo Chae	*Toward Accurate Color Prediction of Woven Fabrics: Three-dimensional Structural Modeling*
Chunhui Xiang	*Color and Colorfastness of Nanosilver-treated Cotton by UV Photo Reduction and Chemical Silver Plating Methods*
Larissa Shepherd	*The Physical Aging of Electrospun PLA/PLA-b-PEG Fibers*
Chelsea Knittel	*Crosslinked Poly(vinyl alcohol) Nanofibers and Textiles*
Mesbah Najafi	*Properties of High-tenacity PTT Yarns*
Nelyan López Pérez	*Degradation of High-performance Polymeric Fibers: Effects of Sonication, Humidity, and Temperature*
Rachael Granberry	*Fabric-based Soft Actuators for a Soft Robotic Glove*
Sanggu Kim	*Design and Feasibility of Two-way Actuating SMA Device for Smart Wear*
Elisa Mayerberger	*Electrospinning of Novel Chitosan-MXene Fiber Composite for Antibacterial Bandage Applications*
Edurne González	*Synthesis, Characterization, and Electrospinning of P(VCL-co-MMA) Biocompatible and Thermoresponsive Polymers*
Margaret Frey	*Electro-optical and Thermal Responsiveness of Liquid Crystal Fiber Arrays*
Vanessa Sanchez	*A Functional Apparel Approach for Soft Exosuit Design*
Eric Beaudette	*Development of New Hockey Gear for Enhanced Neck Laceration Protection*
Robert Brüll	*Using Commingled Yarns Made from Nanomodified Polypropylene and Glass Fibres for Microwave-based Heat Pressing*
Raha Saremi	*Surface Modification of Nanofibrillated Cellulose and Nanocrystalline Cellulose for Textile Coating and Dyeing*
Ben Greenspan	*Development and Testing of a Stitched Stretch Sensor for Measuring Human Movement*
Erik Zavrel	*Sleepwear with Lateralized Thermal Properties for the Treatment of Sleep Disturbance in Women*

Min Xiao	*NMR Study of Wrinkle-free Cotton Fabrics Treated with Polypropylene Glycol-di-epoxide and 1,2,3,4-butanetetracarboxylic Acid*
Marion Schelling	*Characterization of Micron-sized, Bicomponent Islands-in-Sea Fibers Using IR-AFM*
Lina Sanchez-Botero	*Synthesis of α-MnO2 Nanocrystals Using Natural Extracts of Vitis Vinifera Stems and Malus Domestica "Cortland" Apple Peels*
Inhwan Kim	*Characteristics of PU Nanoweb Treated with Ag Nanowire Solution and Exploration as a Strain Sensor*
Hyunsook Kim	*A Comparison of Garment Sleeve Patterns for Korean Women*
Fangfang Weng	*Attachment of Donor-Acceptor Stenhouse Adducts Photochromic Compounds onto Cotton Fabrics*
Namrata Patil	*From Bio-waste to Green Composite Using Non-edible Starch and Modified Sisal Fibers*
Kolos Molnar	*Electrospinning of Polyisobutylene-based Thermoplastic Elastomers and Characterization of the Electrospun Fibers*
Ghazal Shoorideh	*Water-based Electrospinning as a Facile and Scalable Method to Directly Deposit PVA-Silicon-Graphene Nanoribbon Nanofibers for High-performance Li-ion Batteries*
Yeji Choi	*Wear Trials of Knit T-shirts With and Without a Phase Change Material*
Simge Uzun	*In-situ X-ray Study of the Deformation Mechanisms of Nonwoven Aramids*
Goeun Sim	*Hydrophobization of Cotton Fabrics via Silica Nanocoatings*

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Keynote Speakers

Self-assembly–based Functional Nanomaterials and Fibers

Uli Wiesner

Materials Science and Engineering, Cornell University, Ithaca, New York, USA

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Polymer self-assembly provides access to complex, multi-component hybrid materials and fibers with unprecedented control over composition, structure, and order down to the nanoscale. This talk will give examples for the rational design of novel functional polymer hybrids inspired by biological examples. These materials are often based on the self-assembly of block copolymers as structure directing molecules for polymer-inorganic hybrid materials and fibers. Experimental results will be compared to theoretical predictions to provide physical insights into formation principles. The aim of the described work is to understand the underlying fundamental chemical, thermodynamic and kinetic formation principles enabling generalization of results over a wide class of materials systems. Examples will cover the formation of hierarchical structures at equilibrium as well as via processes far away from equilibrium.

Modeling and Rendering Virtual Fabrics

Kavita Bala

Computer Science Department, Cornell University, Ithaca, NY, USA

kb@cs.cornell.edu

What makes silk look like silk? And different from velvet? Accurately predicting the appearance of fabrics is increasingly important in virtual prototyping, textile and industrial design, and e-commerce. We introduce micro-appearance fabric models that explicitly model a fabric's microgeometry, combined with light scattering models to represent fabric appearance. I will describe how we use micro-CT scans to acquire a fabric's microgeometry and fit procedural models to these datasets to get easy-to-edit fabric appearance models. Combined with image measurements to find the optical parameters of fabric and rendering algorithms that accurately simulate light scattering, we are able to create the most detailed and accurate visualizations of virtual fabrics to date.

Why Ready-to-Wear Clothing is Not Ready to Wear: The "Wicked" Design Problem of Clothing Fit

Susan P. Ashdown
Cornell University
spa4@cornell.edu

The fit of clothing is consistently cited by consumers as the largest problem they have with apparel purchases. The most common method of providing clothing to fit the population, for both fashion and functional apparel, is the system of Ready-To-Wear (RTW) sizing. Consumers expect to be able to go to a rack or website and choose a garment in a size that fits them. But was RTW sizing ever intended to fit 'off the rack'? We will look at the origin of this sizing system in the 18th century, how it developed, the way it is manifested today, and its critical flaws.

Now, in the 21st century, how should we address the challenge of designing a product for a extensive variety of body sizes and proportions; a product that provides functionality and fits intimately in physical, physiological, psychological space; a product that must accommodate a moving body; a product made of an almost unlimited variety of complex soft and hard materials with countless functional properties; a product made in a world of limited resources for a population that expects access to constant new fashion trends? This 'wicked' design problem exists for each consumer and for each piece of clothing purchased.

Technology has some possible answers to this design problem. However many start-up businesses that have attempted to address clothing fit issues in the last 20 years have failed, including automated size selection systems, mass customization initiatives, and automated pattern generation for custom clothing. Some emerging new technologies will be presented that could help improve the fit of apparel, including 3D scanning using an iPad and virtual fit. Reasons why these new technologies hold promise for the future will be discussed.

Knit Modeling

Physics-based Modeling of Knitted Textile Behavior

Dani Liu[1,5], Daniel Christe[1,5], Bahareh Shakibajahromi[2,5], Chelsea Knittel[3,4,5], David Breen[2,5]
Genevieve Dion[3,5], Antonios Kontsos[1,5]

[1]Theoretical & Applied Mechanics Group, Department of Mechanical Engineering & Mechanics, Drexel University
[2]Department of Computer Science, Drexel University
[3]Shima Seiki Haute Tech Lab, Department of Design, Drexel University
[4]Department of Materials Science & Engineering, Drexel University
[5]Center for Functional Fabrics, Drexel University

akontsos@coe.drexel.edu

Knitted textiles are hierarchically structured materials. Compared to other materials such as fiber-reinforced composites or metals, knitting provides control over the manufacturing process and is capable of creating a variety of multiscale structures using a broad range of input materials. While the manufacturing capability of computer-controlled knitting machines is high, lack of predictive design and simulation capabilities hinders progress towards certification and deployment of garment devices, which are envisioned as tailorable material platforms for such advanced applications as sensing and communication. This talk is focused on the deformation and kinematical characteristics of the mechanical behavior of knitted textiles. The connection between local geometry and global performance at the mesoscale where the material microstructure is directly taken into account is investigated. The internal structure of knitted textiles is parametrically described by the use of a small number of morphological features. An approach to use such features as inputs to a mathematical model that is then used to create digital representations of knitted textiles is presented. Such representations are subsequently used as inputs to a finite element modeling procedure in which the interactions between internal yarns are modeled, first, by tie constraints followed by a direct way to account for contact and friction. A net force/moment in the out-of-plane direction is discovered, which contributes to a characteristic out-of-plane motion for all investigated sizes. Such results are finally placed in a design context that explains the dominance of the structure over the mechanical behavior of knitted textiles, which can be extended to other cases of architectured materials.

3D Modeling of Knittable Structures with Stitch Meshes

Kui Wu, Cem Yuksel
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Knitting is a popular technique for clothing and it also allows generating structures with intrinsic 3D shapes. Yet, designing a 3D knitted structure requires a 3D modeling interface that can represent 3D connections between stitches that form the surface of the knitted structure. The recent stitch mesh modeling approach [Yuksel et al. 2012] provides a compelling interface for modeling knitted structures using a 3D polygonal mesh as a canvas for defining the stitches. This approach allows designing knitted structures with arbitrary 3D surface shapes and knitting patterns. However, the original stitch mesh structure is designed for computer graphics purposes only, so it does not necessarily produce an output that is knittable in reality and it is limited in terms of the knitted structures it can represent.

We augment the stitch mesh structure so that the stitch mesh modeling framework can be used for designing actually knittable structures. To achieve this we overcome two important limitations of the original stitch mesh structure. We first introduce a shift path defined by connecting neighboring wale edges of the stitch mesh. The shift path connects the consecutive rows of the stitch mesh and breaks the non-realistic closed loops of the original stitch mesh structure. Our algorithm automatically determines what portion of the stitch mesh surface is converted to a knittable form by the chosen shift path that is selected by the user.

We also introduce a new stitch mesh face type that is needed for representing short rows, which is crucial for creating interesting shapes, such as the heels of a typical sock. Like all other stitch mesh faces, this new face type also has two wale edges, but unlike the other face types, these two wale edges are connected to each other in the same direction giving it a triangular shape.

The improvements we introduce are vital for producing general and knittable structures from stitch meshes. Our new 3D modeling interface allows designing knitted structures with arbitrary surface shapes and the augmented stitch mesh structures contains the stitch information needed for reproducing these structures either by hand or knitting machines.

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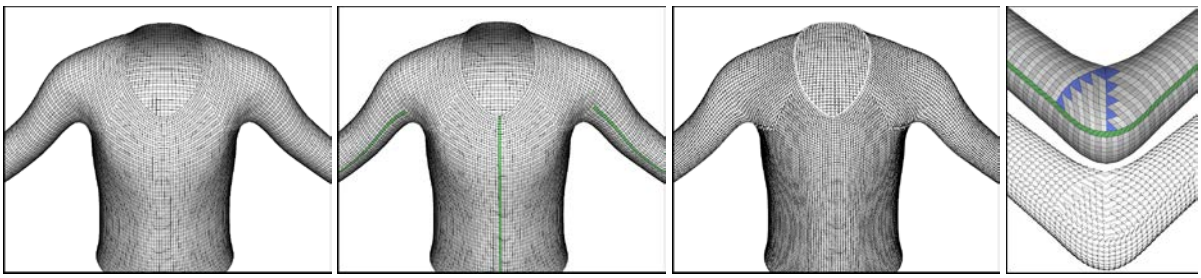

(a) Stitch mesh model (b) Stitch mesh with shift path (c) Yarn model (d) Short Rows

Figure 1: An example knitted garment model showing (a) the original stitch mesh model that represents the 3D surface and the knitting pattern, (b) the stitch mesh model with the shift paths (marked in green) that connects neighboring rows, (c) the initial yarn-level model (before relaxation) directly generated from the stitch mesh, which represents the topological connections of the knittable structure, and (d) an example model showing the short rows with the new triangle shaped faces (marked in blue) placed at the ends of the short rows, and the knittable yarn-level model generated from the stitch mesh.

Modeling Methodologies for Knitted Shape Memory Alloy Textiles

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Shape Memory Alloy (SMA) knitted textiles have the potential to meet emerging needs for diverse engineering applications such as morphing aircraft, deployable space structures, biomedical and rehabilitative devices, robotic manipulators, and wearable technology. Shape Memory Alloys are a type of smart material that can undergo large recoverable material strains (2-8%) as a result of a solid-st phase transformation. During the knitting manufacturing process, extension, bending, torsion, and buckling deformations are induced in the SMA wire while forming a network of interlacing loops. The tortuous loop geometry of the knit structure results in actuators capable of complex, three-dimensional distributed actuation motions (contraction, scrolling, coiling, arching, accordioning, etc.). Before these unique actuators can be integrated into applications, predictive capabilities are required to connect the important geometric design parameters to the kinematic and kinetic performance of the textile actuator. This research introduces three modeling methodologies that provide low to high fidelity predictive capabilities of SMA knitted textiles. The first modeling methodology, segment modeling, uses a linear-elastic two-state material model and a linear spring geometric model. The four step segment modeling approach identifies the unit cell and the primary deformation mode, segments the unit cell, enumerates simple spring models across the unit cell, and predicts the force-deflection of the unit cell. The segment modeling approach provides a low fidelity design model that can be used for inverse design. The second modeling methodology, analytical modeling, uses a linear-elastic two-state material model and a non-linear geometric model. The analytical modeling approach establishes geometric relations and force-equilibrium for the unit cell, develops differential equations using Euler-Bernoulli and Elastica Theory, establishes kinematic and kinetic relationships, and then solves for the actuation performance. The analytical modeling approach captures the kinematic and kinetic performance of basic SMA knit geometries. The third modeling methodology, finite element modeling, uses a nonlinear SMA material model and a non-linear geometric model. The finite element modeling approach enables partial material phase transformations and improves the handling of friction between interlacing adjacent loops to provide high fidelity results. This research establishes the predictive capabilities to design, analyze, and synthesize complex shape change actuators.

Modeling of Knitted Structures at Fiber/Filament Level: Tasks and Some Possible Solutions

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Warp and weft knitted structures are used in large number of the application areas because of their good elasticity, flexibility, air permeability and other specific properties. The engineering design of these structures is in more complicated in comparison to the design of the woven structures, because of the large variety of combinations of the structural elements, the flexibility of the yarns and the three dimensional form of the loops. There are several works, dedicated on the creation of models of plain loops and other structural elements with use of analytical or computational algorithms, but the largest part of these seems still to remains more area of researchers and high tech laboratories. The reason for this is in the complexity of the geometrical structures and the sensibility of the algorithms and larger computational time needed to get good enough results.

This paper gives a short overview about some ways for yarn level modelling of warp and weft knitted structures and concentrates after that on some issues about the modelling at the fiber or filament level. The endless filaments are more used in the area of warp knitting. For weft knitting staple fiber yarns with low density and larger deformability in lateral direction are used, which request separate models.

As presented in Fig.1 the filaments in the warp knitted loops are placed not homogenously along the loop and their distribution depends strongly on the boundary conditions around the crossing points. The “rowing” or “multifilament yarn” has different forms of the cross section – as for instance area A is wider and more flat than area C, which is well compacted, but different than and B. Such structure cannot be modelled accurately using solid tube with constant cross section as presented on Fig 2. The modelled loop will have different porosity and different dimension the loops compared to the real structure. One of the ways to overcome this problem is the modelling of all or large part of the filaments (Fig.5). Such process is very computationally intensive. One possible solution is the two step modelling – first relaxation at the yarn level (Fig. 4), then generating the volume with filaments and then relaxation at the filament level.

Another problem is the principal difficulty to get correct orientation of the loops with pure geometrical models. Figure 3 presents a loop of tricot structure, modelled pure geometrically, but the configuration will become closer to the reality after it is relaxed applying forces and contact calculations as presented on Figure 4. This means that even for the generation of the (initial) geometry of knitted structures, algorithms like time integration or force relaxation have to be used. After receiving the relaxed state, these algorithms can be used for simulation of the mechanical behavior, but the industrials normally would like to get first impression of the fabrics quickly, without the need of setting large number of mechanical data and simulation settings.

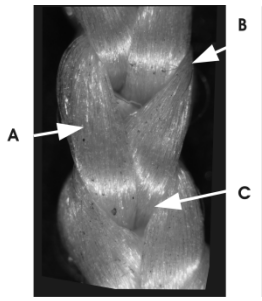

Fig 1. Loop of multifilament yarns

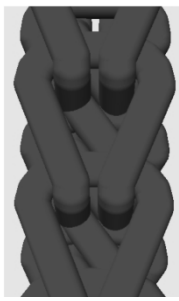
Fig 2. Modelling as a solid tube

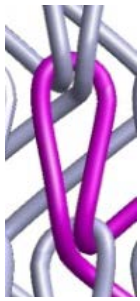
Fig. 3. Geometrical model of tricot loop

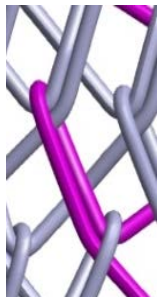
Fig. 4. Relaxed loop from fig. 3

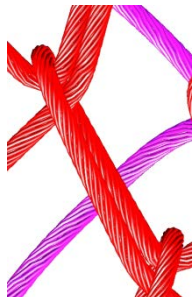
Fig. 5. Relaxed loop with multifilament twisted yarns

Efficient Simulation of Fabric at the Yarn Level

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The vast majority of garments are made of a yarn structure, either knitted or woven, and the large-scale mechanics of cloth are dictated by the fine-scale behavior of yarns, their mechanical properties, arrangement, and contact interactions. The computation of cloth mechanics at the yarn level appears as a computationally complex and costly process at first sight, due to the need to resolve many fine-scale contact interactions between yarns. For instance, in a plain weave fabric the number of contacts is quadratic in the number of yarns. Modeling even low yarn-density fabrics soon leads to an explosion in the number of degrees of freedom and contacts, and common fabrics may contain in the order of 100 yarns/inch.

We present instead a novel fabric model that enables efficient yarn-level simulation, introducing a compact representation of yarn geometry and kinematics, and capturing the essential deformation modes of yarn crossings, loops, stitches, and stacks, with a minimum cost. The key aspect of our model is a discretization focused on yarn contacts, consisting in the 3D position of the yarn-yarn contact plus two additional degrees of freedom to capture yarn sliding. Inter-yarn contact is therefore persistent and handled implicitly, and we avoid altogether the computation of collision detection and collision response between crossing yarns. Based on our discretization, we formulate force models for low-level yarn mechanics, including stretch and bending forces of individual yarns. But, most importantly, our novel discretization enables simple formulations of inter-yarn contact forces, in particular sliding friction at yarn contacts and contact between adjacent yarns.

Our approach is suited for both woven and knitted fabrics. We demonstrate the efficiency of our method on simulations of full garments with millions of degrees of freedom (Fig. 1), with a computational cost of less than an hour per second of simulation on a desktop computer. Interesting effects, such as fine-scale plasticity effects (detailed tearing, snags, loose yarn ends) (Fig. 2) or the influence of the fabric pattern on large-scale draping behavior (Fig. 3) are obtained naturally thanks to yarn-level mechanics.

Figure 1: Yarn-level simulation of a shirt with over 2000 yarns.

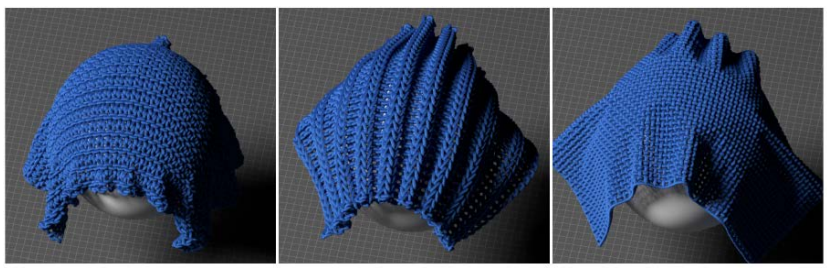

Figure 2: Three different fabrics (knitted Garter, knitted Rib and plain weave) with different draping behavior.

Figure 3: Plasticity examples. A snag (left) and tearing (right).

Nonintrusive Determination of Fibre Segment Orientation Distribution of Primary Nonwoven Structures

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The geometric arrangement of fibres and fibre-fibre bonding forms the structure of nonwoven fabrics, and the structure forms the link between demonstrated properties and fundamental elements of the fibrous assembly. The subject of fibre orientation in textile materials has mostly been addressed in two dimensions (XY) and the third dimension (Z) of the structure cannot be neglected as orientations in the thickness contribute to the physical behaviour of such fibrous assemblies. The fibre segments were defined by spherical coordinates (θ , φ); where θ and φ is for in-plane and out-of-plane fibre orientations, respectively. X-ray microtomography (Figure 1) is a nonintrusive technique, compared to digital volumetric imaging, for acquisition of 3D images and datasets from a nonwoven sample. The orientation of fibre segments in three dimensions are important and current study aims to calculate 3D FOD of nonwoven samples.

Three primary dry-laid structures, air-, cross- and parallel-laid hydroentangled fabrics were scanned employing a micro-focused X-ray microtomography and investigated for computation of the 3D FOD. A customised software was developed to calculate local orientation vectors from 3D datasets by following Eberhardt and Clarke's (2002) algorithm. The results were compared by physical testing (zero span tensile testing for θ and z-directional tensile testing, ZTS, for φ) and gave good agreement. Parallel-laid and air-laid (Figure 2) samples depicted their characteristic shapes whereas the cross-laid sample appeared closer to a transverse oriented web due to the small lapping angle during cross-lapping. The results of Phi for parallel-, cross- and air-laid samples showed that most of the fibres were aligned in-plane with very few fibres in the z-direction (thickness). Air-laid webs exhibited better mechanical properties, compared to parallel- and cross-laid webs, owing to its inherently random structure. The out-of-plane fibre segment deflections (φ = ±61-90°) were compared with their respective ZTS. There is evidence that through-thickness deflections are responsible for higher ZTS in mechanically-bonded fibrous assemblies.

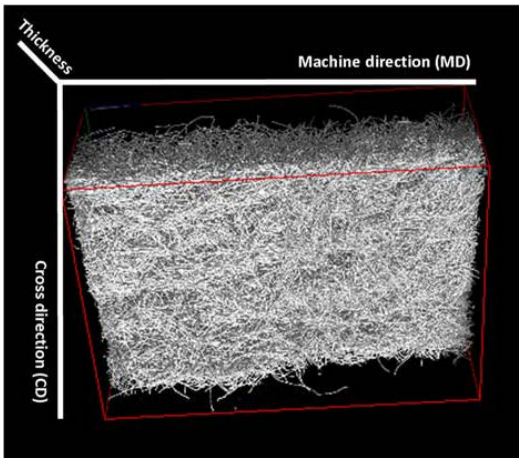

Figure 1: An exemplar reconstruction of X-ray computed microtomography (XMT) image for parallel-laid sample

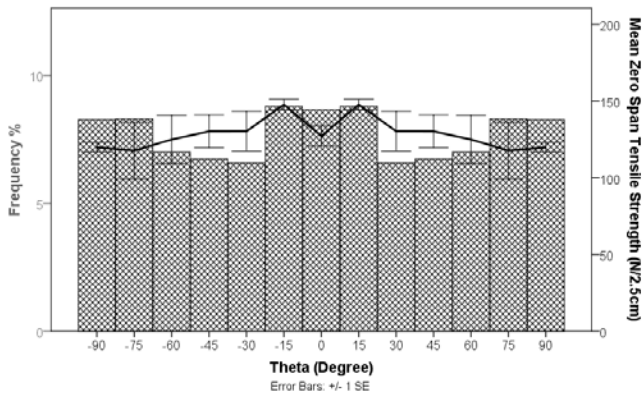

Figure 2: Zero span tensile strength of air-laid sample and Frequency % histogram of Theta(θ) computed from 3D XMT datasets

Fiber Segment Orientation and Crossings in Nonwovens from X-ray Micro-computed Tomographic Data

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The orientation of free fiber segments and the extent of interfiber bonding are key elements of the mechanical strength and deformability of fibrous structures. The direct determination of fiber orientation is elusive so that methods such as the ratio of MD/CD tensile strength, ultrasonic tensile stiffness orientation or 2D image analysis are used to estimate the mean fiber orientation. Characterization of interfiber bonding is even more difficult to determine accurately. The introduction of X-ray micro-computed tomography (XRμCT) or 3D X-ray microscopy has enabled the visualization of the internal structural of fibrous webs, from which detailed analyses of fiber distribution and position, as well as contact points can be identified. The purpose of this investigation was to provide analytical methods to quantify the local 3D orientation of fiber segments between bonds, and the number of fiber crossings where bonds may occur, for low density nonwoven fibrous structures.

XRμCT data sets were obtained using an Xradia MicroXCT-200 for various nonwoven samples selected from the INDA Reference Sampler. The analytical method involved the determination of the moment of inertia for a spherical region about each solid voxel contained within the data set. Using a method of principal component analysis, the three angles and three eigenvalues that define the orientation and prolateness of the ellipsoid for each voxel were determined, as shown in Figure 1.

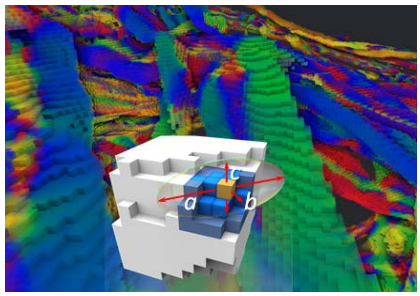

Figure 1. Inertial ellipsoid determined for spherical region around each voxel in the XRμCT data set.

For low density nonwovens with relatively uniform fiber cross sections, such as spun bond, the analytical method produces well defined fiber segment orientation that can be used to characterize regional orientation such as machine direction fiber alignment or out-of-plane waviness, creping or embossments, cf. Figure 2. The method fails to provide fiber orientation in regions proximate to fiber crossings where the inertial ellipsoid becomes oblate. However, by testing the characteristics of the ellipsoid using the eigenvalues, the number of crossings can be determined for a given region, which can be seen in Figure 3. The method is ideal for comparing mean fiber orientation in different regions of the structure, determining the extent layered vs. felted structure through the Z-direction, or characterizing structural features such as embossments

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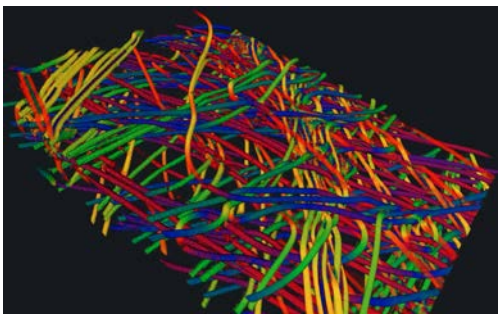

Figure 2. In-plane orientation shown in color

Figure 3. Fiber crossings identified by ellipsoid shape

Green Materials and Natural Fibers

Manufacturing Cellulose and Chitin Fibres Using Ionic Liquids as Environmentally Benign Solvents

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Cellulose and Chitin are the most abundant polymer in world, however their large scale utilization in regenerated fibres manufacturing is limited by lack of a simple and environmentally benign method for their dissolution and processing. We have developed method to dissolve and fibre spin cellulose and chitin using ionic liquids as benign solvents. The cellulose fibres spun from the low molecular weight source show high degree of cellulose chain alignment with cellulose II type of crystal structure. The regenerated cellulose fibres showed relatively good mechanical properties with modulus similar to that of soft wood. The dissolution of chitin was more difficult than cellulose, however using appropriate dissolution and fibre spinning conditions we were able to dissolve and fibre spin chitin fibres. The mechanical properties of chitin fibres were relatively lower than cellulose fibres. The development simple and environmentally benign method of the fibres spinning these two most abundant natural polymers will allow us to carry out their large scale utilization in engineering and biomedical applications.

Fiber Orientation Control in Cellulose Nanofiber-reinforced Green Nanocomposites

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Recently cellulose nanofiber has attracted researchers' attention, because they are biomass-derived strengthening fibers and also their mechanical performance seems to be high enough to use as reinforcement; for example, their tensile strength is 2-3 GPa and Young's modulus is 140 GPa. However, the mechanical properties of polymer nanocomposites (i.e. green nanocomposites) reinforced by the cellulose nanofiber are much lower than expected. There are several reasons for such poor mechanical performance. In this study, we intended to improve the mechanical properties of the green nanocomposites by controlling the orientation of cellulose nanofiber.

In this study we tried to control the cellulose nanofiber orientation by two different approaches; namely unidirectional freezing method and multiple mechanical extension method. In the unidirectional freezing method, water suspension with cellulose nanofiber was directionally solidified into a chilling bath at a controlled speed. The fiber orientation of cellulose nanofiber was aligned with the help of the unidirectional growth of the ice. In addition, the effect of the fiber content on the strength was investigated for the purpose of further strengthening of the unidirectional cellulose nanocomposite. On the other hand, in the multiple mechanical extension method, the alignment of cellulose nanofiber in polymeric matrix can be controlled by applying multiple mechanical extension (2-10 times). The effectiveness of the fiber alignment control has been successfully demonstrated experimentally, namely tensile strength and Young's modulus of the cellulose nanofiber reinforced composites after multiple mechanical extension treatment increased by 78% and by 36% respectively as compared with those of the untreated ones.

ACKNOWLEDGMENT: This work was financially supported by Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number 15K14148 and 16H01790.

Development and Characterization of Biobased Polymers and Natural Fiber Composites

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Global warming, environment concerns, depletion of petroleum resources have led researchers to develop materials that are abundant in nature, biodegradable, low-cost, and competitive in properties with existing synthetic non-biodegradable materials. In view of this, we have recently investigated synthesis of a phenolic resin system utilizing lignin extracted from different plants. In another study, we have fabricated fully biodegradable jute fiber reinforced Poly (3-hydroxybutyrate-co-3-hydroxyvalerate)-(PHBV) nanocomposites were prepared by adding 1-3 wt. % grafted halloysite nanotubes (HNTs).

Resole phenolic resins were prepared using lignin from flax and alfalfa fibers as well as a commercial source as partial replacement for phenol. Control resole phenol formaldehyde resin was synthesized using phenol and paraformaldehyde with a base catalyst. Phenol was reacted with paraformaldehyde at 75-80 °C for one hour, placed in an oven with vacuum at 65 °C for 30 minutes, and then cured. Resins with lignin extracted from plants were synthesized in similar fashion using different ratios of phenol-lignin. All resins were subjected to thermogravimetric analysis (TGA) to observe thermal stability and degradation properties. Each system degraded in three temperature regions from 100-300 °C, 300-600 °C, and above 600 °C. Introducing lignin in the resin formulation decreased thermal stability leading to lower decomposition temperatures and reduced char yield.

Thin films of PHBV nanocomposites were prepared by adding 1-3 wt. % grafted halloysite nanotubes (HNTs). Jute-PHBV bio-nanocomposites were then fabricated using these films and alkali/silane treated jute fibers through compression molding. The effect of treatment of jute fiber and HNTs, and the change in their morphology were investigated using Fourier transform infrared spectroscopy, X-ray diffraction, scanning and transmission electron microscopy. Flexural and thermomechanical properties were determined using 3-point bend test and dynamic mechanical analysis. Results showed fiber bundle de-fibrillation with rougher fiber surface, and grafting of coupling agent on both fiber and HNTs. As a result, the flexural and thermomechanical properties of these Jute-PHBV bio-nanocomposites increased significantly in comparison to untreated jute-PHBV composites.

Details of these studies will be presented. These works were supported through NSF-EPSCoR (grant # 1168862) and NSF-CREST (grant # 1137681) funding.

Cellulose Nanofiber Extraction from Grasses by Kitchen Blender and Ultrasonication

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Cellulose is a biopolymer photosynthesized from carbon dioxide and water, driven by sunlight energy. This substance is naturally produced in massive amounts and naturally decomposed in a perfectly sustainable process. Cellulose is mostly found in the cell wall of plant cells, in which the smallest element is known as nanofibers. These tiny fibrils have a diameter of a few tens of nanometers, and are made up of a bundle of long cellulose molecular chains arranged in a semi-crystalline structure. The tensile modulus and strength are comparable to those of aramid fibers, and cellulosic fibers have the ability to interact with each other by hydrogen bonds in well dispersed systems, increasing the reinforcing effect in composites over systems in which the stress transfer occurs only between matrix and reinforcing phase.

In general cellulose nanofibers have been extracted from wood, but non-wood plants like those of the Gamineae family (grass, cereals, reed, bamboo) are also potential sources. Agricultural residues have been long used in papermaking and grass contains less lignin than wood, requiring smaller amounts of pulping and bleaching chemicals in the pulping process. Extraction of nanofibers is mostly based on mechanical nanofibrillation processes but still relying on expensive devices, with high energy demand but low production yields. Kitchen blender has been considered an affordable means of nanofibrillation as it is an appliance intended to disrupt parenchyma cells to extract nutrients from edible plants. As fibers are also plant cells, the impact with the blender blades would be able to break up the cell walls and ultimately produce nanofibrillation. Ultrasonication is another approach of fiber disruption through cavitation in fiber suspensions, offering the possibility of continuous nanofibrillation.

Here we discuss the extraction of nanofibers from agricultural residue fibers by blending and ultrasonication. Due to the worldwide availability, lower cost, and lower lignin content, we focus on the extraction of cellulose nanofibers from grass straw. The extracted nanofibers showed morphology similar to that of commercially available cellulose nanofibers, while paper-like sheets made from these nanofibers were slightly stronger than the commercial nanofiber counterparts.

ACKNOWLEDGMENT: This work was supported by JSPS KAKENHI Grant Number 15K04624.

Fully Bio-based Self-Healing Composites Using Microcapsules

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Light weight fiber reinforced composites have been replacing heavier metals in many applications. However, most commercial fiber reinforced composites use fibers and resins derived from petroleum. These composites have two critical problems. First, the petroleum is non-sustainable and will last for only 50-60 years. Second, their disposal is difficult and not environment friendly. 'Green' composites derived from plants can eliminate both these concerns. One of the best resin used in green composites is from soy protein. It is sustainable, inexpensive and biodegradable. However, soy protein based resins are brittle, especially when crosslinked.

All composites, when under stress, develop microcracks which propagate with time and result in their premature failure. This paper discusses the development of self-healing soy protein isolate (SPI)-based green thermoset resins and their composites using poly(d,l-lactide-*co*-glycolide)(PLGA) microcapsules containing SPI, as crack healant. The SPI–PLGA microcapsules were prepared using a water-in-oil-in-water double-emulsion solvent evaporation technique.

Self-healing efficiencies of SPI resin and microfibrillated cellulose (MFC) reinforced SPI composite containing SPI-loaded SPI-PLGA microcapsule were characterized using mode I fracture toughness test. The SPI resin containing 15 wt% microcapsules showed self-healing efficiency of 48%. It was observed that the SPI released from SPI–PLGA microcapsules present in the resin within the microcracks could react with the glutaraldehyde and bridged the two fracture surfaces. MFC reinforced SPI composites 15 wt% microcapsules showed 27% healing efficiency. It was lower than the pure SPI resin because of the inherent high tensile strength of MFC.

The paper will demonstrate how microcracks get healed through the crosslinking reactions in thermoset SPI resin and MFC reinforced composites. The self-healing protein-based green resins can extend their useful life and, thus, expand the use of green composites in many applications. The method developed here can be easily used to self-heal other proteins and their composites.

Biologically Derived Nanofibers for Novel Functions

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Nature produces a wide range of materials including natural fibers that have served critical functions for humans for millenniums. Many biopolymers in forms other than fibers are also potential precursors for new fibers and advanced fibrous products. In this presentation, innovative approaches to generate nanofibers, micro- and meso-porous fibers and super-high specific fibrous materials from cellulose, proteins and lignins from the waste streams of our food system will be illustrated. Diverse efficient ways to derive 1D nano-arrays of highly crystalline nanocellulose in varied geometries and surface chemistries will be presented. These nanocellulose domains have shown to be effective dispersing and emulsifying agents for oil-water emulsions[1,2], coagulants for microbes[3] as well as templates for nanoparticles and nanoprisms[4]. Ways to assemble nanocellulose into new structures and functional materials such as highly crystalline nanofibers[5], super-absorbent hydrogels and amphiphilic aerogels[6] will also be demonstrated for applications, such as nano-composites, oil recovery and separation, water purification, etc. Lignins, the most abundant heterogeneous phenopropanoid macromolecules from plants, have several unique structural features that make them idea multi-functional binding, complexing and reducing agents[7]: the hydroxyl groups are capable of polar interaction whereas the phenyl rings interact hydrophobically. In addition, lignins are known to exhibit anti-microbial and UV-absorbing capabilities. The rich carbon contents in lignins also make them excellent precursors for carbon fibers. Activated carbon nanofibers have been fabricated by electrospinning and simultaneous activation and carbonation. Such micro-porous and meso-porous carbon fibers have been made into super-capacitors and solid acid catalysts to exhibit excellent electric and catalytic performances in electrical energy storage[8] and catalysis[9] applications.

ACKNOWLEDGMENT
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In Situ and Real-time Studies of Cellulose Nanocrystals Orientational Order During Solution Shearing by X-ray Scattering

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We investigated the influence of solution concentration, shear-cast velocity and solvent evaporation rate on the ordering of cellulose nanocrystals by synchrotron-based wide-angle X-ray scattering analysis. The oriented films were prepared from aqueous suspensions of cellulose nanocrystals using two concentrations of CNC/water suspension (7wt% and 9wt%.). Structural characterization of the dry films was carried out by use of polarized optical microscopy (POM) and scanning electron microscopy (SEM). In addition, a rheological study of the suspension was performed. The results show that the orientation pattern of CNCs in the films was significantly affected by shear velocity, concentration and evaporation temperature. To interpret the orientation patterns, the orientation parameter of the longitudinal axis of CNC was quantified by WAXD intensity measurements. The results presented here may help the optimization of processability conditions where the alignment of CNCs is key, such as in the development of new materials and nanocomposites.

KEYWORDS: Cellulose Nanocrystal, Orientation, Shear Cast, WAXS

Nanocellulose Functional Coatings on Fabric Surface

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Textile industry has been traditionally associated with environment pollutions and consumption of larger volumes of water. The most of waste water contaminated with salts and dyes is generated in the traditional textile dyeing technology. An increasing public concern in environmental issues has prompted the development of sustainable textile dyeing technologies that would reduce the generation of wastewater as well as the use of toxic chemicals and subsequently satisfy regulatory and legal requirements. This concerns are not only limited to textile dyeing processes and they extend over various methods of fabric surface functionalization and modification. Emerging areas of advanced functional and smart textiles are referred to the development of fibers and fabrics that provide a range of properties from barrier materials to electronic devices that could be approached through surface functionalization of fabric. At the same time, emerging novel advanced textiles are seen as sustainable and biodegradable materials with a minimal environmental impact.

This presentation considers unique characteristics of nanocellulose (NC) such as a large specific surface area, strong affinity to cellulosic surfaces, and the reactive surface arising from abundant hydroxyl groups for various add-on functionalities bound to conventional textiles provided by NC hydrogels as functional coating materials. NC hydrogels produced by high-pressure homogenization could be deposited on cotton fabrics by padding, draining or printing methods. We demonstrate that a thin layer of NC (up to c.a. 5 μm) coated on conventional cotton fabrics is used as a carrier as well as a binder for dyes, nanoparticles, nanowires, capsules, and reactive molecules; and a protective layer for functional fabrics in laundering. The efficient uptake and attachment of reactive molecules and functional particles is attributed to the large surface area of NC fibers compared to cotton fibers (1000 vs 10-20 m2/g) while binding of nanoparticulates is achieved due to arresting of nanoparticles in a tiny network created by the NC coating.

ACKNOWLEDGMENT: The authors acknowledge the support of Walmart Foundation, University of Georgia, and University of Liverpool.

Impacts of Molecular Size and Affinity of Chemicals in Crosslinking Cotton Fabrics with Polycarboxylic Acids

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Polycarboxylic acids are considered as potential crosslinking agents of cellulose to improve wrinkle resistant performance of cotton fabrics. Both aliphatic and aromatic polycarboxylic acids, such as 1,2,3,4-Butane tetracarboxylic acid (BTCA) and 3,3'4,4'-benzophenone tetracarboxylic acid (BPTCA), were found capable of having effective crosslinking reactions with and improving wrinkle recovery angles but also providing different ratings of durable press performance and tensile strength retention values to the treated fabrics. The reaction mechanisms of these two groups of acids are different in crosslinking cellulose. Aliphatic ones can undergo a mechanism of two steps: formation of anhydride of the acids and esterification of the anhydride with cellulose. But, aromatics can proceed through a one-step direct esterification process at relatively lower temperature range and fast speed when reacting with cellulose. In both reactions, several alkaline salts, including sodium hypophosphite (SHP), were found effective and efficient in catalyzing the reactions, and potential non-phosphorus salt alternatives in good catalytic efficiency were discovered, though also possessing some environmental concerns. Overall, a measured inconsistence in durable press performance with wrinkle recovery angels of the crosslinked cotton fabrics treated by different polycarboxylic acids and even catalysts were linked to the molecular sizes of the chemicals. The same relationship explains well for the differences in tensile strength retention values of the fabrics treated by both acids, revealing the impacts of molecular sizes of the acids and catalysts on the performances of the treated fabrics. This presentation will provide a detailed discussion and analysis, which will be extremely helpful for development of novel durable press finishing technologies.

Gel Spinning of Lignin-reinforced Fibers

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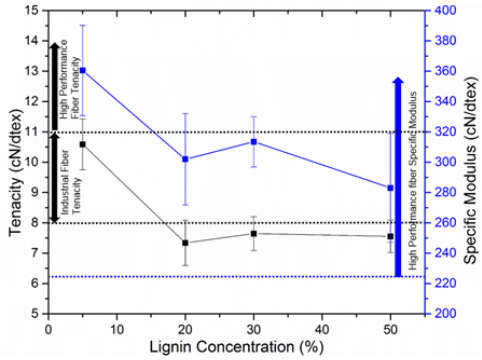
The sustainability of raw materials for the next generation of advanced fibers poses a challenge. However, the use of biopolymers poses a solution. Biopolymers are naturally abundant, biorenewable resources. Their molecular structure often varies with crop source. In contrast, synthetic, petroleum-based polymers have a well-defined, reproducible structure from which high strength and high modulus fibers are made. If successful, we can combine synthetic and biopolymer to form advanced materials, having high performance at high weight ratios of biopolymer. Achieving this goal would offer more sustainable fibers while broadening the use of biopolymers in advanced applications. In this talk, the structure, properties, and processing of biobased fibers are discussed. Composites fibers were prepared from lignin- an aromatic biopolymer at increasing weight percentages (even more than 50% w/w)- and synthetic polymers- polyvinyl alcohol (PVA) and polyacrylonitrile-. Both polymers are well-known for their commercial and exploratory uses in structural composites and as carbon fiber precursors. Gel spinning was employed as the fabrication technique to ultimately achieve highly drawable fibers from homogeneous blends of lignin-polymer in solution. The structural and mechanical reinforcement of as-spun gel fiber and fully drawn fibers containing lignin will be discussed. Interestingly, mechanical stiffness in the high performance fiber range was achieved at high lignin content (Figure 1), along with superior chemical and thermal resistance. Our results also show lignin and matrix polymer oriented along the fiber axes of highly drawn fibers, whose draw ratios increased with lignin content.

Fiber Type	Total Fiber Draw Ratio
5% Lignin	15
20% Lignin	16
30% Lignin	18
50% Lignin	21



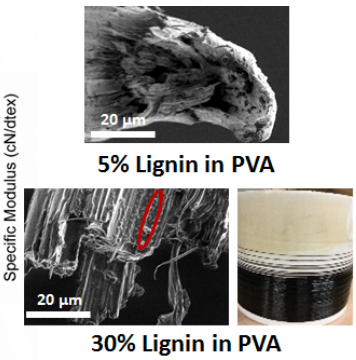


Figure 1. Lignin-PVA fibers were gel-spun with increasing concentrations of lignin (5-50%). Fracture tips revealed fibrillar morphologies of semi-crystalline fibers.

Study of the Wetting Behavior of Micrometer-sized Natural and 3D Printed Natural-like Fibers

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Natural fibers are being increasingly used as reinforcement in polymer composites. However, there is a lack of understanding of the processes that control their wetting behavior, which is essential for obtaining good bonding between the reinforcing fiber and the polymer matrix.

The most common methods for measuring the wettability of single fibers include both tensiometry (Wilhelmy technique) and goniometry. The former consists of a measurement of the capillary force exerted by a liquid on a fiber, while the latter addresses the modelling (e.g. Laplace equation) of the liquid/vapor interface when the fiber is partially immersed in a liquid bath. In the case of natural fibers, both methods are only applicable with restrictions, due to the heterogeneity of their surface chemistry and topography inducing complex phenomena such as liquid sorption/diffusion into the surface layers, diffusion of low-molecular-weight compounds into the liquid, different wetting behavior of the different chemical constituents (cellulose, hemicellulose, lignin and pectin).

Moreover, the difficulties in the characterization of the wetting properties of natural fibers are increased due to their hierarchical structure at different length scales. For instance, a technical hemp fiber is a bundle composed of more than ten elementary fibers (plant cells) (Fig.1-Left) which can be considered as hollow cylinders (Fig.1-Right), with walls consisting of several layers made of crystalline cellulose nano-fibrils aligned with different angles with respect to the longitudinal fiber axis.

By mimicking this complex microstructure through micro 3D printing, and by synchronizing both the force and optical methods, the contributions of chemical surface composition and microstructure effects on the wettability of natural fibers can be decoupled. Technical coir and hemp fibers were used as reference natural fibers. They both show a very complex wetting behavior; while coir exhibits an insignificant swelling (<2%), hemp fibers swell up to 16% in water. However, coir shows porosity up to 45%, which also affects the force reading. By contrasting 3D printed fibers mimicking natural fiber irregularities with real natural fibers, a better understanding of the wettability of hemp and coir fibers was obtained.

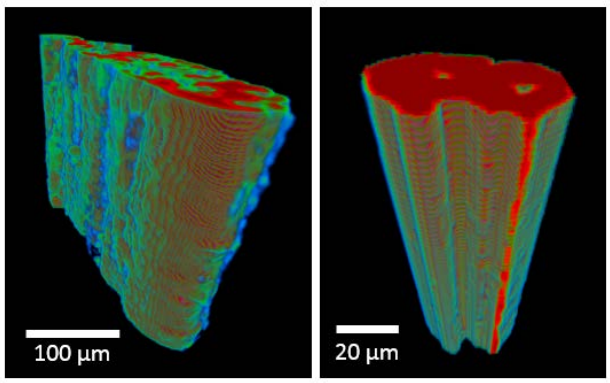

Figure 1: Technical hemp fiber (left), and 2 elementary hemp fibers (right). 3D pictures obtained by µCT.

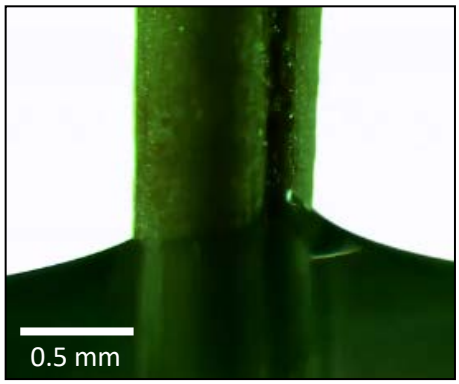

Figure 2: Technical coir fiber during a typical wetting measurement.

Creep of Barkcloth-reinforced Laminar Epoxy Biocomposites

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There is a global surge in the application of natural fiber reinforced polymer composites in various industries. Polymer reinforced composites are faced with dimensional instability over their service life because the real environment of application varies with frequency and temperature. In this investigation, for the first time, alkali-treated barkcloth reinforced epoxy laminar biocomposites were investigated using dynamic mechanical analysis for the creep behavior between 30°C –100°C. The results show that creep is affected by the layering pattern of the laminar composites whereas alkali treatment leads to a higher creep resistance of the composites.

In the recent years, polymer composites from renewable resources have found applications in industry, however, because polymers and polymer composites are viscoelastic in nature among the tests performed to ascertain the dimensional stability of the developed materials is creep [1]. The viscoelastic behavior is best demonstrated using creep and stress relaxation tests; one such tool that can be used in the evaluation of the creep behavior of polymer composites is the Dynamic Mechanical Analysis [2].

MATERIALS AND METHODS

Nonwoven barkcloth fabrics were obtained from Uganda. Green epoxy CHS-Epoxy G520 was utilized. The viscoelastic behavior was analyzed using a Texas Instruments Q800 Dynamic Mechanical Analysis (DMA).

RESULTS

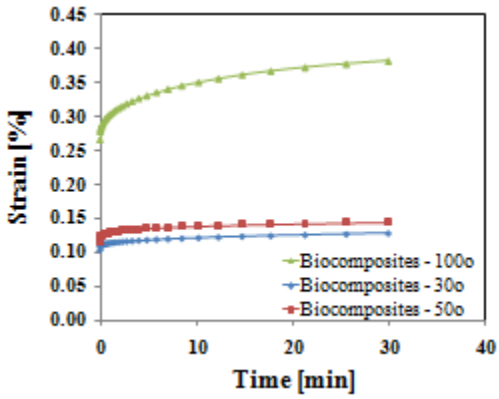

Figure 1. Creep behavior of the biocomposites.

CONCLUSION

Barkcloth biocomposites treated with alkali not only improves the mechanical properties but it also renders the alkali treated composites resistant to creep within the 30-50°C temperature range.

KEYWORDS: Barkcloth; Creep; Mechanical Properties

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Functionalization of Cotton Fiber by Partial Etherification and Self-assembly of Polyoxometalate Encapsulated in $Cu_3(BTC)_2$ Metal-Organic Framework

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This work will cover (1) the room temperature synthesis of a polyoxometalate encapsulated in a $Cu_3(BTC)_2$ metal-organic framework on a cotton substrate, (2) physical and morphological characterization of the developed material, and (3) the characterization of the self-decontaminating properties of this material.

A combination of a Keggin-type polyoxometalate (POM), $[CuPW_{11}O_{39}]^{5-}$, with a $Cu_3(BTC)_2$ metal–organic framework (MOF-199/HKUST-1; where BTC is benzene-1,3,5-tricarboxylate), was successfully self-assembled on a cellulose substrate (cotton) with a room-temperature process (Figure 1). This was achieved by utilizing the inherent functionality of the cotton fibers by partial etherification. $Cu_3(BTC)_2$ metal–organic framework and polyoxometalate encapsulated in $Cu_3(BTC)_2$ metal–organic framework were self-assembled on the carboxymethylate ion sites initiated with copper nitrate using ethanol and water as solvents.

Octahedral crystals were observed on both MOF-cotton and POM-MOF-cotton; both contained copper while the POM-MOF-cotton also contained tungsten. Occupancy of POM in MOF cages was calculated to be about 13%. Moisture content remained at 3 to 4 wt % similar to that of untreated cotton. Hydrophilicity of the cotton was maintained with moisture content of 3 to 4 wt %. Reactivity to both hydrogen sulfide and methyl parathion was higher for POM-MOF-cotton than MOF-cotton.

Reactivity to both hydrogen sulfide and methyl parathion was higher for POM-MOF-cotton due to the Keggin polyoxometalate and the extra-framework cations Cu^{2+} ions compensating the charges of the encapsulated Keggins. The POM-MOF material was found to effectively remove 0.089 mg of methyl parathion per mg of MOF from a hexane solution while MOF-cotton removed only 0.054 mg of methyl parathion per mg of MOF. Given that no degradation products were observed in the hexane solution by HPLC, it was concluded that either degradation products were adsorbed into the surrounding MOF pores or methyl parathion was completely mineralized. This measured self-decontaminating property in conjunction with adsorption properties could make these POM-MOF functionalized materials appropriate for applications needing removal of organic contaminates.

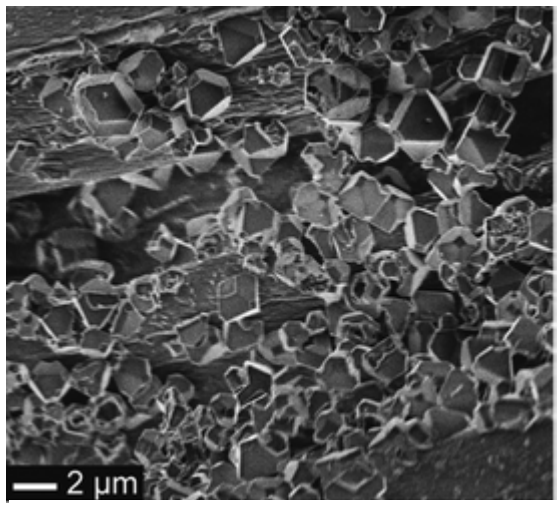

Figure 1. FE-SEM of POM-MOF-cotton

ACKNOWLEDGMENT

Professor Craig Hill and Dr. Zhen Luo are acknowledged for providing the polyoxometalate, $K_5[CuPW_{11}O_{39}]$. This work made use of the Cornell Center for Materials Research Shared Facilities, which are supported through the NSF MRSEC program (DMR-1120296).

“No Waste”: The Development of Sustainable Knitted Clothes Made from PLA Fibers

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This research project, performed with a Masterclass on the subject “Experimental Knitting”, points out the possibilities to create sustainable knitwear by using biodegradable high-tenacity polyester on PLA basis (Diolen 150 BT), made from renewable resources, exclusively used in the automotive interior for safety belts and airbags

The tasks of the project were to show that typical technical materials can also be used for clothing, to create multi-sustainable products and creative dealings with origination processes and development of something completely new by working with the properties of the material, like stiffness and shiny surface, and to implement it in a clothing concept.

To get access to the material the project started with knitting tests by hand on hand-driven and computerized (Stoll CMS 302 TC) flat-knitting machines. Because of the harsh hand feel of this polyester type, it took some time until the results were satisfying. The students “played” with tension, knitting constructions, tested different finishings, treatments and combinations with wool and other materials. As expected: some very different surprising results and some very exciting outfits were generated. The most convincing – because most sustainable results – are those in 100 % pure PLA yarns.

The project shows that, to overcome the limits of standard thinking in creative knitwear design, a confrontation with the material is essential. Samples of research results see below (fig. 1-2: dress with moving surface by MA student Sophia Krinner, fig.3 dress with structures by ultrasonic welding by MA student Theresa Brinkmann).

ACKNOWLEDGMENT
The used PLA yarns are provided by PHP Fibers, Wuppertal, Germany. Special thanks to Sonja Vater of Thamm GmbH, Bonn, for supporting the digital prints.

Modeling Smart Textiles and Processes

Foldable Textile-based Devices Using Conductive Fibers

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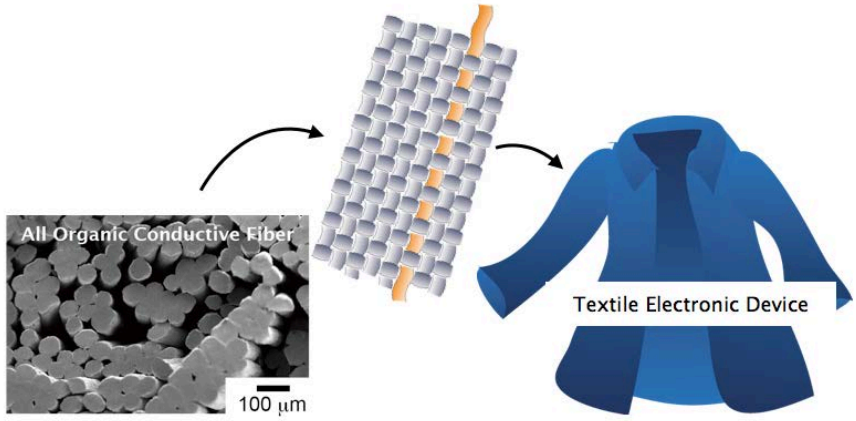
A textile, which is a flexible two- or three-dimensional material consisting of a network of one-dimensional fibers, is a suitable platform of wearable electronics. When miniaturized electronic devices are embedded on one-dimensional conducting fibers, the fibers will have the ability to sense, react, interact, and move. Furthermore, multi-functional wearable systems can be fabricated by assembling each functional fiber component in the textile platform through conventional textile processing techniques including weaving, knitting, crocheting, and knotting. These textile devices can monitor your health, guard you in case of danger, and generate ambient energy by conversion from light, vibration, and temperature difference. Much efforts have been devoted to develop conducting fibers including metal plating, deposition of metal layers, and coating of conductive materials as metal nanoparticles and carbon nanotubes. The deposition of conductive thin layers onto fiber surface has the disadvantage of being expensive, and the fibers are heavy, and brittle. Since the discovery of electronic conductivity for organic polymers, organic conductive polymers have been paid special attention as active components for organic solar cells, printed electronic circuits, organic light-emitting diodes, actuators, electrochromism, supercapacitors, and biosensors. Conducting fibers made from organic conductive polymers such as polyaniline and poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) have been fabricated to realize textile devices without the use of inorganic materials.



In this presentation, I describe the fabrication of textile-based devices using conductive multifilament of poly(3,4-ethylenedioxythiophene) doped with poly(4-styrene sulfonate) (PEDOT:PSS) and poly(vinyl alcohol) (PVA). The multifilament was composed of uniform circular fibers with an average diameter of 60 ± 5 μm and showed good enough mechanical properties for textile processes while maintaining electronic conductivity. The PEDOT:PSS/PVA blended fibers displayed an actuation response when a voltage was applied in air and the foldable textiles based on the PEDOT:PSS/PVA blended fibers worked as flexible electrodes to detect human heartbeats. The organic conductive fibers can be a platform for lightweight wearable electronics.

Dielectric Soft Textile Polymers with Smart Functions: Electro-mechanical, Mechano-electric, Electro-optical

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Polymers conventionally used in textile industry can be electrically functional soft materials. PET, Nylon, PVC, PVA et al. can be the good candidates. We found the electrical phenomena nearly thirty years ago, although the mechanism has remained some ambiguity. The author will discuss the mechanisms of the phenomena in this presentation. Basically, the polymers listed above are usually inactive to the dc electric field application under the conventional conditions, but they turn into active under the softened conditions. For softening, several methods can be applied, such as gelation, plasticizing and etc. Particularly, in PVA and PVC, the remarkable effects has been found. In both polymer cases, colossal specific dielectric constant (nearly 10^4 in mHz-kHz range) was observed and suggested to be the origin of the functions. But the origins of the colossal values are characteristic from each other. In the case of PVA, the origin of the colossal value is solvent based, and in the case of PVC, the origin is very efficient cooperative phenomenon. Cooperativity itself is observed in both cases, but the characteristics are very different each other. In PVC, both components PVC and plasticizer have low value of dielectric constant through the whole range of frequency, but the specific dielectric constant jump up to nearly 10^4 in softened PVC. Initially, we suggested the solvent-drag induced the asymmetric space charge distribution which caused the phenomena, although we realized this is an insufficient explanation. The colossal dielectric constant in low frequency range is a fairly generally observed phenomena, but the relationship between the electrical functions, such as mechanical, optical, etc. was not discussed in details. The author will provide some insight on these topics. The materials are homogeneous and does not have any electrical asymmetry intrinsically in conventional sense. Under the turned-off condition of the dc electric field, we could not detect explicit poling effect. The concept proposed in this presentation can be applied for other polymer systems, and will expand the utility of the widely used “electrically inactive textile polymers” into “electrically active fiber & textile materials”.

In the presentation, the efficacies of the electrical functions are demonstrated on actuators, light deflection, and piezo-electric functions, and will discuss in some details.

ACKNOWLEDGMENT: Contents of this presentations are the works of many students in the author’s laboratory. Many Japanese governmental research funds were also inevitable. Collaborations with some companies were also important contributions for the progress. The author expresses deep appreciation for these supports.

Adaptive Washing Strategy for Overflow Rinsing

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A typical dye house may consume up to 150 Liters of water per kg of fabric. To put this in context an ordinary textile dye house might use as much water as a town with a population of 20.000 people. As demand for clean water resources is becoming more challenging in today's world, it is even more critical to introduce innovative technologies that reduces water consumption. Among dyeing operations, it is recorded that on average, 80 percent of water is used during the rinsing step only. Meantime, current dyeing/rinsing procedures are often decided by experienced dyers. For instance, deciding how many times to wash, how long each washing has to take, how fast must the fabric move through the bath or how much water has to be circulated are all left to the dyer in the absence of rinsing data.

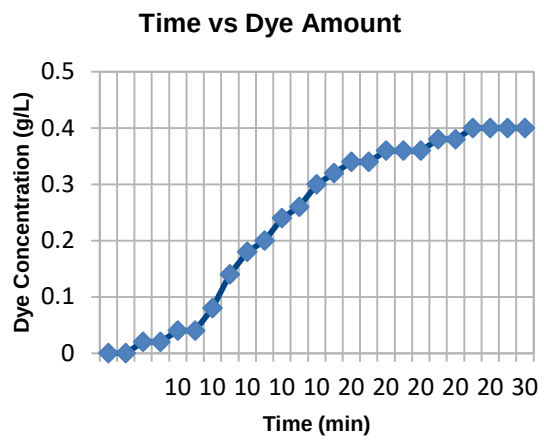

Figure 2: Rinse concentration changes.

In this study, we present our approach for optimizing the rinsing procedure for optimum washing for both jet and overflow washing. To achieve this goal we use monitoring data such as shown in Figure 1 where the change in dye concentration is plotted with respect to time during the rinsing process. Note that at the beginning (time 0), there is no dye in the rinse bath. However, during the rinsing, the amount of dye in the bath increases as unfixed dyes bleed from substrate to the bath. When there is no more or slow bleeding of dyes from the substrate, we could assume that the rinsing step may be completed. Knowing when equilibrium is reached would allow us to optimize rinsing by eliminating extra time or preventing premature termination of the rinsing cycle. It is important to note that early terminations are often the main cause of extra rinsing cycles.

Currently, this seemingly basic strategy could not be adapted in the absence of dye concentration measurement. Using this dye concentration information, we are investigating how to optimize rinsing for more complicated overflow rinsing using AI

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Influence of the Wear of Carbon Nanotubes Grafted on Carbon Fibers

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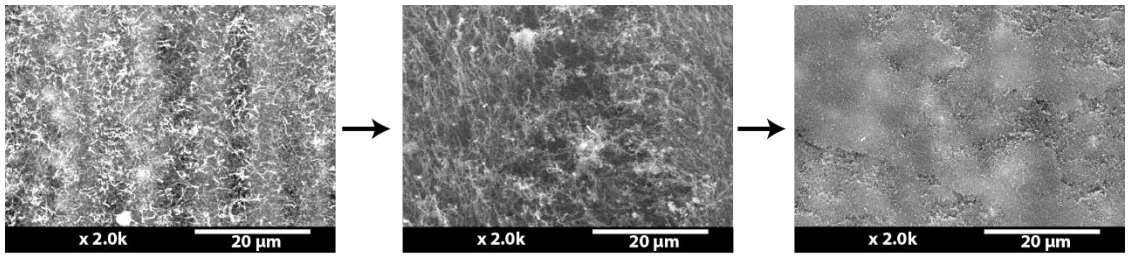
Carbon nanotubes (CNTs) are grafted on the surface of carbon surface to reinforce mechanical properties of composite. During industrial process, the CNTs grafted fabric will be guided with cylindrical systems. This will cause friction stresses and wear on the fabric. The aim of this study is to highlight the wear mechanism of the CNTs due to friction stresses, to analyze this behavior in order to determine their influence on the composite processing.

Multi-walled carbon nanotubes are directly produced on the carbon textile by the flame method using a metallic catalyst [1-2]. The catalyst used influences the CNTs length and diameter, therefore the quality of the CNTs (number of defect).

In order to wear the CNTs, friction tests are processed on a linear reciprocating tribometer, with a cylindrical slider to approach a rolling on a metallic piece [3]. The normal load is of 1N, at a sliding velocity of 20 mm/s and a sliding distance of 20 mm. The wear mechanism of CNTs was highlighted by SEM observation. At first, CNTs are entangled on the surface (a). As soon as the friction starts, CNTs are aligned in the friction direction (b) and then are crushed and formed a transfer film (c), around 10 cycles of friction.



(a) - Initial (b) - 1 Cycle (c) - 10 Cycles

Figure 1: Wear of the CNTs during friction.

In industrial stresses of friction (around 10 cycles), the wear of the surface, whatever the catalyst used, will let the CNTs under a transfer film state [4]. EDX analysis shows that the chemical composition of the worn CNTs is not different from the initial CNTs, so no chemical modification appears during friction. Moreover Raman spectra of worn CNTs are similar to the spectra of initial CNTs, so the transfer film is composed of CNTs, and friction does not create defects on the CNTs.

The results of wettability show the impregnation of the resin with the unworn and worn surfaces and that the catalyst influences the rapidity of the impregnation. In the end, we can predict the same spreading of the resin and no decrease in the mechanical properties of the composites fabricated with worn CNTs grafted carbon fibers.

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Capillary Race in Fibrous Constructs

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To accelerate capillary flow or wicking is desirable for various applications of fibrous constructs. For example, it is preferable to develop fibrous fabrics that can quickly facilitate the flow of liquid sweat from skin side. In addition, wound dressings should allow the rapid transfer of body fluids. Heat transfer devices also favor fast wicking from cold to hot areas through the fibrous wicks for efficient cooling. Water formed in the fibrous gas diffusion layer of fuel cell should transport fast for removal so as to avoid "flooding" that limits the system performance. Paper-based microfluidics always require swift detection and reaction with less flow time.

To this end, we systematically designed innovative fibrous structures for minimum flow time, based on comprehensive understanding of capillary-driven fluid transport phenomena in complex fibrous systems. The dynamic interplay of viscous drag, capillary force and gravity on the capillary was properly optimized for the capillary race [1-6]. The affecting factors including porosity, thickness, fiber diameter, gravity, and flow types were investigated. For instance, we modeled wicking though a two-layer fibrous medium (Fig. 1a) and found the optimal porosity distribution (Fig. 1b) and thickness distribution (Fig. 1c) accounting for the fastest flow.

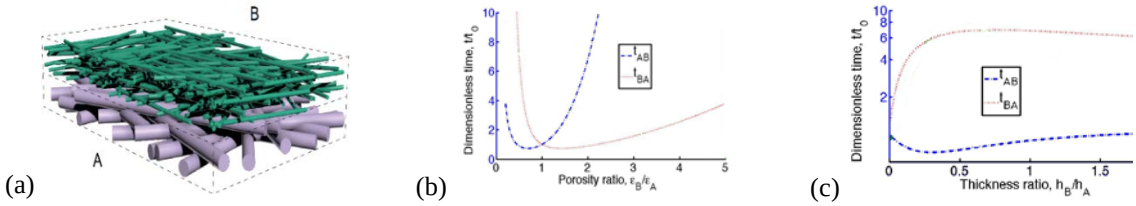

Fig. 1. (a) A two-layer fibrous medium with different porosity and thickness, (b) variations of t/t_0 against porosity ratio $\varepsilon_B/\varepsilon_A$ at $h_B = h_A$, and (c) variations of t/t_0 against thickness ratio h_B/h_A at $\varepsilon_B = 0.5\varepsilon_A$, where t_0 is the constant flow time for the single-layer control sample

Furthermore, we developed a hierarchical structure simply composed of fibrous strips for faster capillary rise, inspired by the directional water transport on the peristome surface of Nepenthes alata (Fig. 2a) [7]. It is demonstrated theoretically and experimentally that the capillary rise in the bio-inspired porous system is much faster than in the controlled strip composed of nanofibers (Fig. 2b).

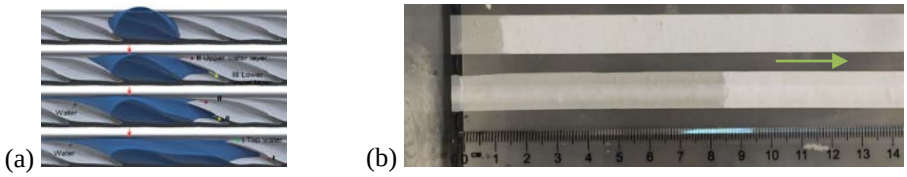

Fig. 2. (a) Illustration of water transport process on the peristome surface of Nepenthes alata (Reprint permission obtained from Nature Publishing) and (b) comparison of capillary rise between the bio-inspired porous system (lower) and the controlled strip (upper) at 4 min (arrow indicates the anti-gravity direction)

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Mathematical Modeling and Experimental Analysis of Dynamic Yarn Path in the Superconducting Magnetic Bearing-based Ring Spinning Machine

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The productivity of most widely used ring spinning process is still much lower in comparison to the rotor or, air-jet spinning method. The main limitation of ring spinning is the friction in ring/traveler twisting system at higher spindle speed, which generates heat and damages the traveler and yarn. The superconducting magnetic bearing (SMB) system can be a right alternative replacing the ring/traveler system. This SMB system consists of a circular superconductor and a permanent magnet (PM) ring (Figure 1). After cooling the superconductor below its transition temperature, the PM ring levitates and it rotates freely above the superconducting ring according to principles of superconducting levitation and pinning. The contact-free bearing system ensures a wear free operation and stable running even at higher speed without any control or, sensor system. This allows to increase the productivity of ring spinning drastically. In a research project of German Research Foundation (DFG-174/33-1), the SMB-system has been developed and integrated in a ring spinning tester (Figure 1).

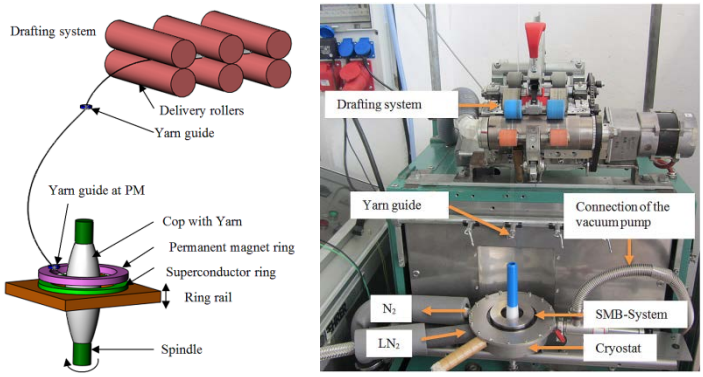

Figure 1: Ring spinning process with superconducting magnetic bearing (SMB) system

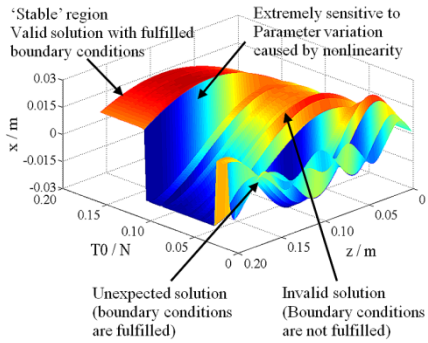

Figure 2: Mathematical modeling of dynamical yarn path in SMB-Spinning

In this project work, the acting forces of the dynamic yarn path considering the SMB twisting element are described with a mathematical model. The numerical solution of the model is conducted with the well-known RUNGE-KUTTA integrator and the shooting method optimizes the solution further to minimize the error of the numerical results. The numerical solution results in a new tension distribution and balloon form considering the SMB system. In order to characterize yarn path, the existing measuring technologies have been either modified or newly developed. Thus, the measured results determine the dependence and effect of different process parameters on yarn path. Moreover, the simulated and measured values are compared to validate the developed model. All the results are planned for the oral presentation in the conference.

The SMB-ring spinning process element has already been patented (WO2012100964 A2) and introduced in the International Textile Machinery Association (ITMA) trade show 2015. Currently, the yarn can be spun up to 20,000 rpm. We are planning to spin yarn up to 50,000 rpm with the developed SMB system through the integration of driving and controlling system of ring spinning machine.

ACKNOWLEDGMENT: This research is funded by German Research Foundation, DFG (Project. No. CH 174/33-1& SCHU 1118/12-1). The authors would like to thank DFG for the financial support**.**

Effect of Rotor Spinning Parameters on Trash Removal Proficiency

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Effective trash removal during yarn spinning is very important due to its influence on the spun yarn quality. In this study, the effect of the rotor outlet pressure, the opening roller (OR) speed and the trash box outlet pressure on the effective trash removal is studied using numerical simulation. The rotor spinning unit geometry dimensions and boundary conditions are presented in Figure 1a and b). A mix of structured hexahedral and unstructured tetrahedral grids was generated using GAMBIT and simulation was conducted based on FLUENT. Since the trash mass is usually larger than the fiber mass, the centrifugal force F_c on the trash imposed by the rotating OR is larger than that on the fibers. The centrifugal force effect facilitates trash removal by discarding trash once it enters the trash removal zone and the fibers are directed towards the transfer channel. One of the likely trajectories of the trash is the red tangent line shown in Figure 1c). If the air velocity along the tangent line is very high, the trash will easily flow back into the roller cavity which affects the yarn quality.

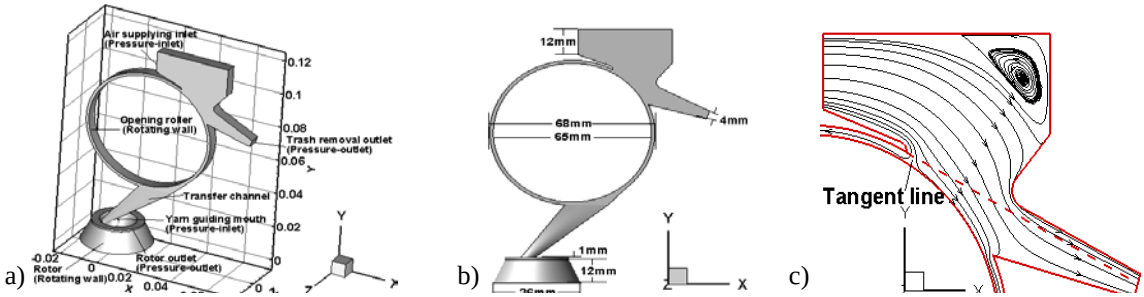

Figure 1: a) 3-D model, b) dimensions of the rotor spinning unit, c) streamlines in the plane z=0 mm.

The drag force (see equation 2) which depends on relative velocity V, has an impact on trash removal efficiency. Results reveal that the rotor outlet pressure has no effect on the air velocity but the trash box pressure increases with increase in air velocity (see Figure 2a and b). The OR speed has an insignificant impact on the airflow (see Figure 2d) but a higher OR speed generates a larger F_c which is useful for trash removal.

$F_C = mr\omega^2$ (1) $F_D = 0.5\rho_{air} A C_D V^2$ (2)

Where m is the fiber mass, r is the (OR) radius ω is the (OR) speed, A is the projected cross-section area of the particle, C_D is the drag coefficient and V is the relative velocity between air and trash.

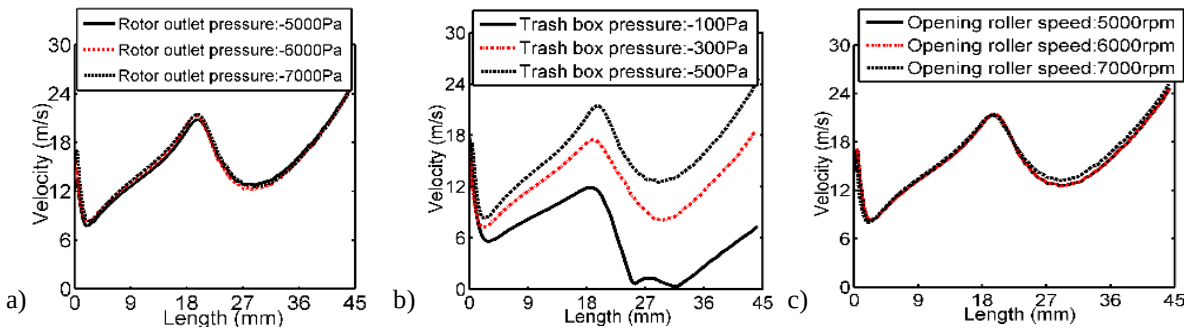

Figure 2: a), b) and c) velocity distributions along the tangent line for different spinning parameters.

Modeling the Dynamic Behavior of Drafting Process

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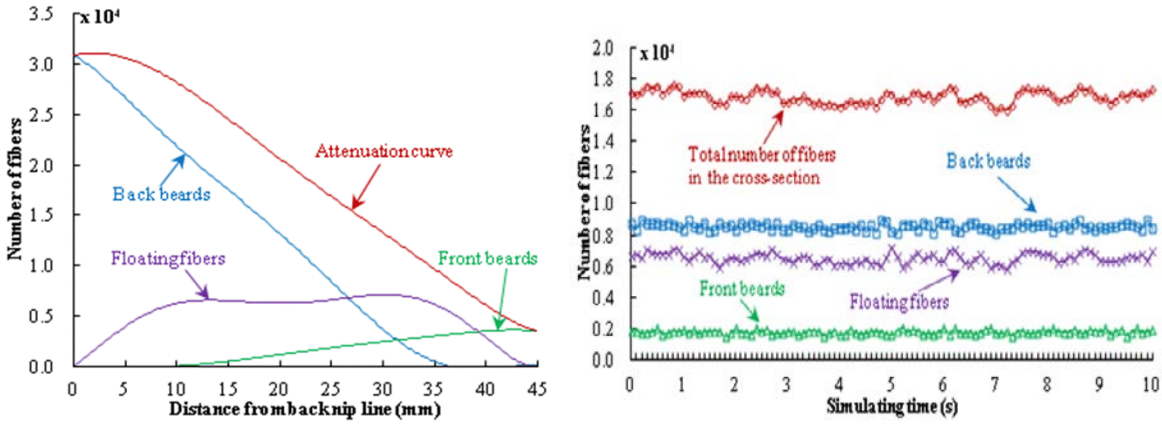
MODELING

The drafting process is a typical stochastic process within all kinds of random factors and conforms to characteristics of the discrete system. In a drafting zone, all fibers would move at the back roller velocity until each fiber is accelerated to the front roller velocity in a certain position near the nip of the front rollers, leading to an increased distance between the fibers. Consequently, the drafting process can be regarded as a process of the rearrangement of the distances among fibers along the axis of the strand.

A drafting zone is a system with each fiber as an entity, whoc attributed are characterized by the parameterization of the fiber properties. The process of an entity from generating to terminating in discrete system is analogous to the process that a fiber passes through the drafting zone. The number of entities during simulation equals to the number of fibers in the drafting zone.

SIMULATION

The drafting conditions are listed as follows: the fiber length is 29 mm, the sliver linear density is 5.5 g/m, the roller gauge is 44 mm, velocities of back and front rollers are 3.31 m/min and 23.5 m/min. Figure 1(a) shows the attenuation curve and different fiber distributions in the drafting zone. Changes in the number of fibers in a certain cross section are shown in Figure 1(b).



CONCLUSION

In this paper, a drafting model was elaborated to simulate the dynamic performance of drafting process. It is a basic model to provide an approach of statistics about the variation of the fiber quantity in a drafting zone. The simulation results illustrate that this model is capable to simulate a dynamic drafting process that the fiber quantity in the cross-section of the strand is decreased and the strand is stretched in the drafting zone. In addition, this model has good extensibility and can be used to simulate each drafting process with appropriate draft settings

Heat Transfer Simulation of Fabrics with Heterogeneous Model

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Thermal comfort is an important factor for designing fabric, which is highly related to the heat transfer in the fabric. From the viewpoint of heat transfer phenomenon, the fabric cannot be assumed to homogeneous body, because constituent yarns are interlaced at a certain weave angle and contact area between yarns varies and the fabric has a lot of air. Therefore, heat transfer phenomenon in the fabric becomes complicated, and it has become difficult to its prediction. Furthermore, there are other difficulties to predict the heat transfer process of the fabric. Due to heterogeneous structure of the fabric, there is a lot of contact area between weft yarn and warp yarn in the fabric. This contact area act as contact heat transfer part in heat transfer phenomena. Unfortunately we do not have the appropriate equipment and theories to measure the contact heat transfer coefficients of yarns in the textile. So in this study, the heterogeneous fabric model (as shown in Fig.1) which the heat transmits separately in the longitudinal and transverse directions along the yarn is developed and the estimation process of the contact heat transfer coefficients of yarns by using simulation and experiment is also proposed. The geometrical fabric structure was constructed based on the cross section of the fabrics observed by the three-dimensional microscope. The parameters used were the mass density, specific heat and thermal conductivity of fiber and air. In this model the heat flow could be calculated and it was compared with the heat flow measured by experiment. Fairly good correlation was observed and the correctness of this heterogeneous model was verified. The simulation of heat transfer in this model indicates that the heat transmits significantly faster along the longitudinal direction than the transverse direction of the yarn, and the equilibrium temperature distribution is greatly related to the longitudinal direction of yarn. These results also suggest that the proposed model can estimate the contact heat transfer coefficients of yarns by using simulation and experiment.

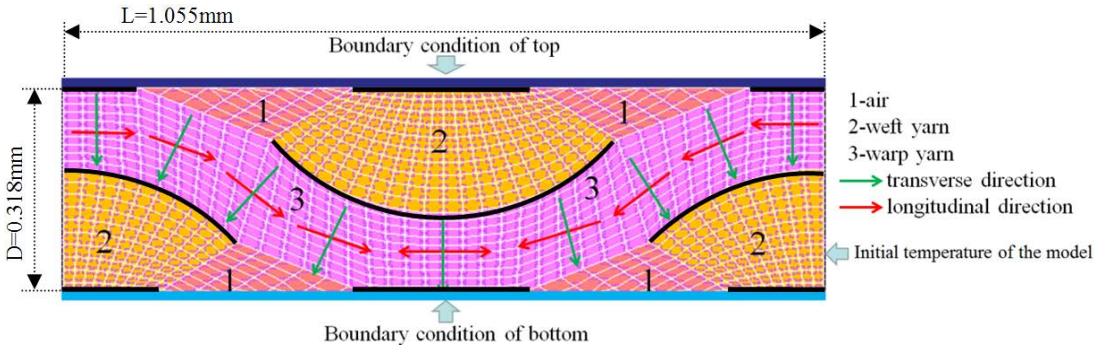

Fig.1. The geometrical fabric structure constructed for this study.

Non-local Self-similarity Fabric Defect Detection

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In apparel manufacturing process, fabric inspection is a vital step to ensure the quality of fabric and locate defects before spreading, cutting and sewing of making up an apparel product. In the market, although a few number of automatic fabric inspection machines exist, they can only be used in textile manufacturing process with the limitation of inspecting single type of fabric, e.g. greige fabric, and the price is extremely expensive. In academic research, fabric defect detection is usually considered as a texture analysis problem since fabric surface can be recognized as two-dimensional (2-D) patterned texture. Over the past three decades, various vision-based approaches, mainly including statistical, structural, model-based and spectral approaches, have been proposed to address this problem. Most of the reported experiments were about fabrics with very limited fabric structure and solid colors under controlled environment and different approaches have their own constraints such that the approaches reported in the literature have not been realized for practical use in real-life environment. Thus, almost all apparel manufacturing plants are still relying on workers' visual inspection on the moving fabric rolls loaded on the fabric inspection machine. However workers are subject to fatigue or boredom and thus unreliable and inconsistent inspection results are often generated. As a result, fabric inspection is highly prone to errors and it allows defects to go undetected.

This paper will introduce a novel automatic fabric defect detection architecture embedded with non-local self-similarity (NSS) based image feature extraction technique for detecting defects on different types of woven fabric structure and color. Figures 1 and 2 show the architecture of the system and the flow of the proposed NSS technique. Results of experiments indicates that the system can effectively detect the defects with 90% accuracy in real-life manufacturing environment on real-time basis. Furthermore, the system can be integrated with the currently used fabric inspection machines and can automatically measure the defect sizes as well as calculate the graded points according to current four-point and ten-point fabric inspection standards.

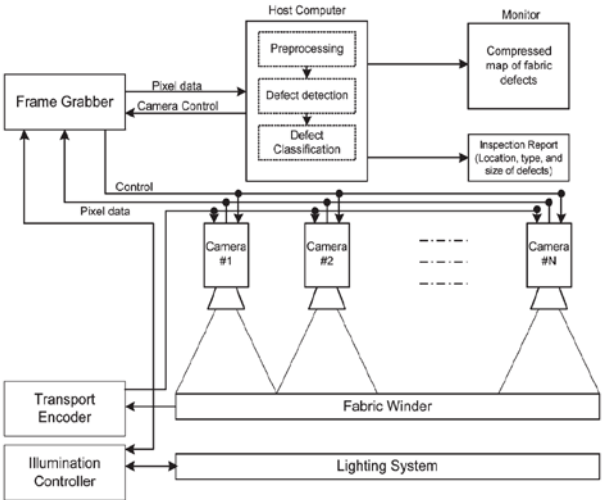

Fig. 1: System Architecture

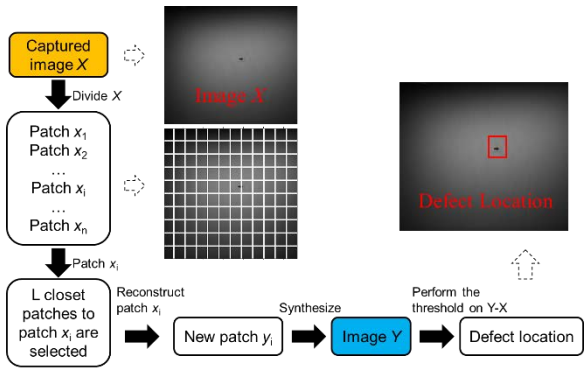

Fig. 2: Flow of NSS-based Technique

Analysis of Electrospinning Bending Region to Determine Fiber Diameter for Non-aqueous Solutions: Evaporation and Water Absorption

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This paper explores the role of the bending region and relative humidity (RH) in determining the resulting electrospun fiber diameter for non-aqueous PVP/alcohol solutions through a combined experimental and modeling analysis. Experimental results show that the bending region is important in determining final fiber diameter for aqueous PEO/water and non-aqueous PVP/alcohol solutions. In the bending region, PVP/alcohol solutions have a complex mass transport including both solvent evaporation and water absorption. The developed model captures the coupled mass and force balances in the bending region and predicts the final fiber diameter of PVP/alcohol solutions, which is verified by experimental measurements over a broad range of operating conditions (fig.1).

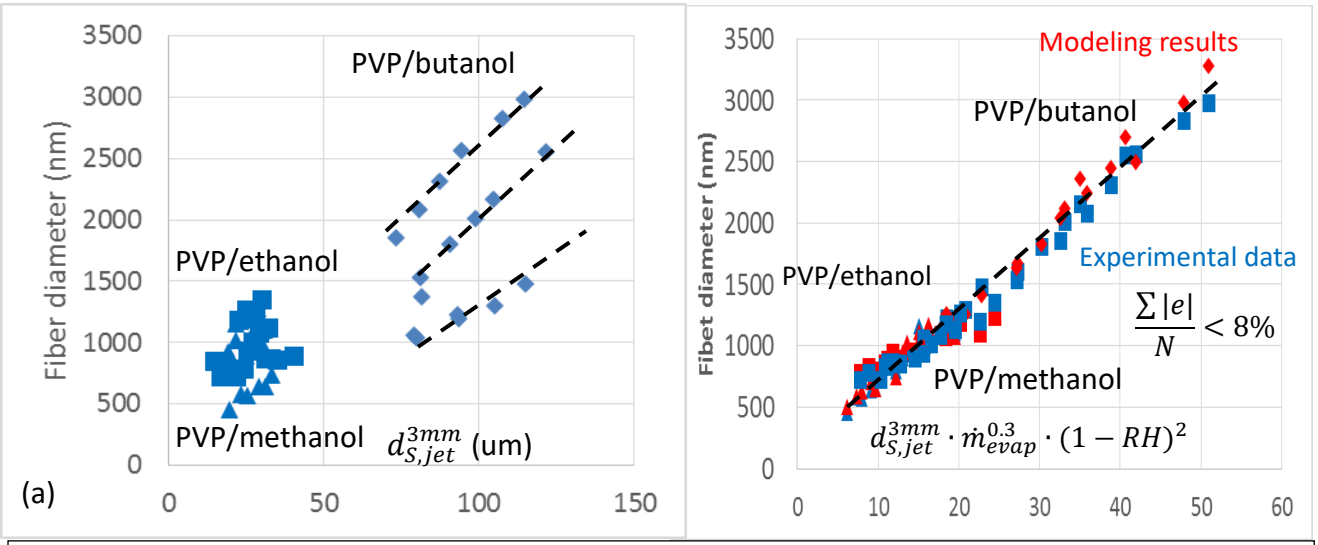

Fig.1 (a) Fiber diameters correlate to measured straight jet diameter under a wide range of operating conditions (RH: 25% - 50%; Flow rate: 0.03 – 0.07 ml/min). (b) Comparison experimental measurements and modeling predictions of fiber diameters for PVP/alcohol solutions.

The predicted fiber diameters are within 8% of experimental observation. The model also provides insight into the dominant physics that determines final fiber diameter. Although the alcohol solvent evaporation is not directly affected by RH, RH affects the water absorption into solvent, which in turn affects balance between viscous and electrical forces. For PVP/ethanol solutions, our modeling results show that as RH increases 25%, the net mass transfer rates (sum of solvent evaporation rate and water absorption rate) decreases ~ 14%, which results in ~ 17% increase in jet length and ~ 50% decrease in viscous retarding force, which lead to a decrease in the final fiber diameter. This paper explains the contributions of mass transfer and force balance which determines the final fiber diameter and how the RH affects the mass transfer and stretching.

ACKNOWLEDGMENT: We appreciate the funding support from the Army (W911QY-11-1-0014).

Finite Element Analysis of Effects of the Mesoscale Material Properties on the Mechanical Response of Woven Fabrics

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In recent years, there have been extensive research efforts focused on the advanced woven fabrics because of their superior characteristics over conventional materials in various applications such as ballistics, composites and medical devices. The development of these kind of technologies depends on understanding the mechanical behavior of the woven fabrics at various length scales. Specifically, woven fabric involve three distinct length scales: (1) Macroscale (Fabric), (2) Mesoscale (Yarns), and (3) Microscale (Filaments). In this multi-scale structure, yarns are often constructed by bundling multiple filaments while the textiles are obtained by weaving the yarns in different architectures. The mechanical behavior observed in each length scale transfers to the next length scale, making the design process challenging and making trial & error approaches cost prohibitive. Thus, numerical models are important tools for studying the mechanical response of woven fabrics before manufacturing and experimental testing phases.

This work aims to investigate the effects of certain material properties of the yarns; such as longitudinal modulus, shear modulus, and friction coefficient on the mechanical behavior of the woven fabrics under uniaxial, biaxial and shear loading. To study the effects of yarn properties on the macroscale mechanical response of a plain weave fabric, a repeating unit cell is created in LS-DYNA with periodic boundary conditions to ensure the periodicity of the model. A design-of-experiment approach, Taguchi method, is adopted to study and determine the significant material parameters affecting the deformation mechanisms and macroscale mechanical response under uniaxial, biaxial and pure shear loads. The proposed finite element method provides a detailed insight into the effects of the material properties on the overall mechanical response of the woven textiles (including other weave architectures) while providing strategies on how to design woven fabrics to obtain a desired mechanical response based on the requirements of a specific application.

Determination of Relative Importance for Raw Material of Yarn Using Hybrid GA-TOPSIS Model

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This paper presents an idea to combine Genetic Algorithm (GA) optimization heuristic with TOPSIS multi-criteria decision making method to render it an optimization capability in a multi criteria setting. The relative importance or weights of different criteria for the selection of raw materials of yarn are determined using the hybrid GA-TOPSIS method. Six quality parameters of cotton viz., strength, elongation, mean length, length uniformity, fineness and short fibre content are regarded as the criteria for raw material selection in an attempt to achieve maximum tensile property of yarn.

The hybrid model is used to randomly initialize the weights of all criteria. A decision matrix is formed using the individual set of weights. The 28 cottons are then ranked according to the relative closeness values (C_i^*) of TOPSIS for whole population of decision matrixes. A separate ranking of these cottons are also made according to the corresponding yarn strength. The agreement between these two ranking methods is evaluated in terms of rank correlation coefficient. The rank correlation equation is used as the fitness function to be maximized and evaluated for whole population. The population of weights is then modified using different operators of GA, namely reproduction, cross-over and mutation. MATLAB 7.11 coding is used to execute the problem on a 2.6 GHz. PC.

Table I: Optimized Weights of the different fibre criteria.

FS (g/tex)	FE (%)	ML (inch)	UI (%)	FF (μg /inch)	SFC (%)
0.33	0.05	0.14	0.27	0.08	0.13

Table I depicts the optimum values of weights obtained using the proposed hybrid GA-TOPSIS technique. The rank correlation coefficient is obtained as 0.914, which shows a reasonably good agreement between the two methods of cotton ranking, shown in Figure I.

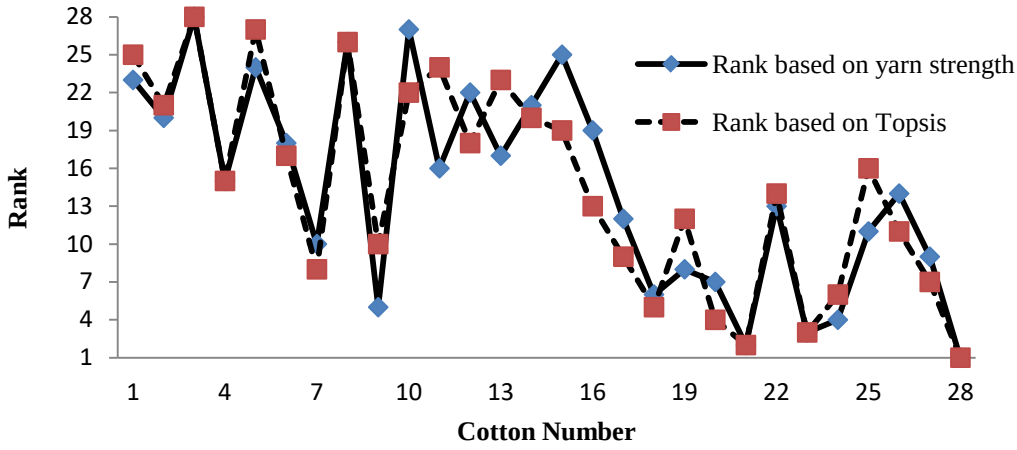

Figure I. Rank of cottons based on TOPSIS and strength data of yarns for 30's Ne count.

The proposed hybrid method uses GA to search the best set of criteria weights by maximizing the rank correlation coefficient deriving from the ranking of cottons based on the relative closeness value of TOPSIS and strength of yarns.

Architecture

The Weaver and the Navvy*:
A Concrete/Textile Collaboration

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This paper will chart a 10 year collaboration between a textile designer (Belford) and an architect (Morrow) that brings together concrete and textiles technologies and techniques, resulting in a range of unique tactile concrete surfaces, commercialized through Tactility Factory. The paper sits next to a sister paper which addresses in more detail the role of the textile designer, the textile components and their characteristics, including technical and design lineages.

This paper will set out the context of the collaboration: historically, culturally, regionally and with a brief critical reflection on the role of textiles within architecture. It will recall the conceptual beginnings of the collaboration and outline the challenges faced during the process of bringing our playful interactions to technical, patented and commercial resolution. The paper will also cover the concrete and fixing technologies and consider elements of scale in counterpoint to those addressed within its sister paper. As practicing researchers/ academics this paper will also map out some of the broader body of theoretical work that has evolved across the lifetime of this collaboration and how it has been informed and formed the 'hand-work'. Finally the paper will conclude with a discussion of where the collaboration has brought us to and where the collaboration goes next. It will reflect both personally and strategically on what the architect has learned from the textile designer and how this might relate to future architectural practices.

Figure 1: From left to right: Linen and Concrete, Velvet and Concrete, Crystal Bead and Concrete (Images are Tactility Factory Ltd. Copyright).

*navvy: a term used to describe manual labourer on building sites—in this context the image of the 'irish navvy' is evoked

Couture Construction

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This paper will chart a 10 year collaboration between a textile designer (Belford) and an architect (Morrow) that brings together concrete and textiles technologies and techniques, resulting in a range of unique tactile concrete surfaces, commercialized through Tactility Factory. The paper sits next to a sister paper which addresses in more detail the role of the architect, the historical, cultural and regional issues raised and the benefits textiles can bring to hard concrete surfaces.

This paper will set out the influences textile design and technologies have on the larger scale conceptual thinking brought to the collaboration by the architect. The textile designer commonly thinks about the immediate nature of textiles, both in the context of a fashion item or furnishing fabric. The parameters of this thinking are defined by the known characteristics of softness and drape of the textile. The collaboration with an architect has forced a re thinking of how textiles are manipulated to produce a beautiful surface, but re negotiating the textile properties of softness into a hard concrete surface. The 10 year collaboration has utilized the original techniques known to the textiles designer and subverted them into new ways of working. Textiles and tactility sit comfortably within their 'normal' environment where they encourage being stroked and caressed. This paper will examine how this perception is altered when embedded and presented as a hard surface within a brutish environment. Textiles and concrete are not only a clash of two different physical properties, but also completely different cultures and ways of thinking. The traditional techniques of velvet devoré (burn out), linen and crystal printing have been adjusted through many years of research to blend and work within the alkaline environment of concrete. Analyses of the beneficial properties of textile techniques have been altered to achieve innovative concrete surfaces. This paper will chart these observations and small but significant changes developed to manipulate the concrete surfaces. It will also reflect on the benefits of being challenged by an architect's way of thinking beyond the normal way of producing textiles.

Figure 1: From left to right: Devore Printing Velvet, Finished Velvet Concrete Surface, Hand Dyeing (Images are Tactility Factory Ltd. Copyright).

Thermally Resistant Membrane Enclosures

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Techstyle Haus was conceived, designed, and built by an international team of faculty and students from Brown University, the University of Applied Sciences, Erfurt, and the Rhode Island School of Design. We combined forces in order to compete in the Solar Decathlon Versailles 2014 – a leading forum to foster new sustainable design strategies. During the two-week exhibition, Techstyle Haus was visited by 80,000 people and seen by many more through publications such as the New York Times, Huffington Post, and Le Monde.

Drawing on expertise of faculty members in engineering and architecture, and working closely with our industry partner Saint-Gobain, we developed a collaborative design process that led to a tensile building enclosure made of high-performance membranes. Using two parallel tensioned nets formed in double-curvature and anchored with hooks and ratchets, we suspended interior and exterior membranes with insulation in-between (Figure 1). We demonstrated a system that is strong, quick to install, lightweight, and can be adjusted to most any form and/or thickness.

Advances in material science have made membranes an appealing alternative to traditional masonry and wood construction. Membranes can be a technically superior alternative to solid sheathing because of how they interact with the environment. Their permeability can vary with changes in humidity and temperature to help keep out unwanted vapor, while also allowing the skin to breathe. Membranes are thus able to passively control humidity and latent heat. However, these membranes are typically attached to traditional framing elements such as wood studs with plywood sheathing or directly to concrete. By questioning "how" and "why" these membranes are applied, we will continue to tap the potential of the material.

After the competition, we installed the 1,000 gross square foot house at the Domaine de Boisbuchet, an academy in France for interdisciplinary art and design workshops. There, the house was adopted as housing for visiting artists, designers, and students from around the world. The enclosure and mechanical systems are currently being monitored for performance.

Figure 1: Four Stages of Construction: Ratchet Straps, Vapor Barrier, Light-Block Textile, and Interior Finish Textile

Project Dimensions
Gross Area: 90.82 m2 (978 sq. ft.)
Net Floor Area: 76.68 m2 (825 sq. ft.)

Wall Assembly Technology

Fiberglass Membrane Coated in Teflon	(Sheerfill II Architectural Membrane)
Weather Barrier	(CertainTeed CertaWrap)
Mineral Wool Insulation, 30 cm (11.8 in.) Thick	(Isover Integra ZKF-032)
Vapor Membrane	(Isover Vario KM Duplex)
Light-Block Textile	(ShowTex Molton Colour)
Interior Finish Textile	(ShowTex PolyStretch P8 CS)

Predictability and Pattern Logic in Textile Architecture

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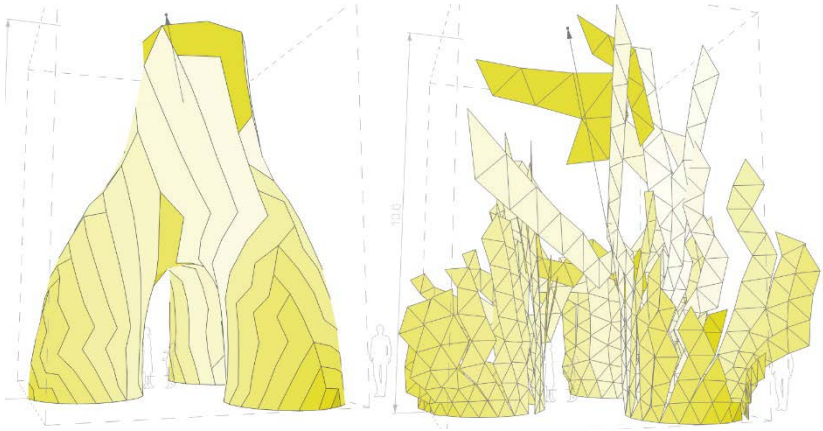

This paper will present research into textile architecture. Textiles are interesting materials for architecture in that they are lightweight, highly formable at macro scale and highly adaptable at micro scale. This enables designers to work with integrated design systems in which materials are created directly for particular performances. The paper will discuss methods for scaling textile systems from the tradition of garments and technical textiles to architectural scale. It will reflect on experiences with two central interfaces that allow transfer from one field to the other: pattern creation and predictability. Using examples from CITA's extensive work with knit, we will discuss our creation of new methods for dynamic relaxation and simulation of knitted textiles.

Fully Fashioned Textiles for Architecture

In CITA we have explored the tradition of pattern cutting as an architectural method of specification. Pattern cutting is different in logic to architecture representation. Where the architectural section or the plan cuts through the represented artefact to reveal the layers of material make up, textile patterns describes its surface. In CITA our work explores planar as well as highly double curved membranes. To create patterns for double curved textile membranes we have created systems for a artefacts into composites of single curved surfaces as well as methods for dynamic relaxation of 3D surfaces into 2D patterns. The paper will discuss the precision of these methods and the way that they are used to interface both cut-and-sew as well as knit-to-shape techniques.

Predictability and Simulation of Knitted Textiles

A second key issue in scaling textiles for architectural application is the ability to accurately understand and predict material behaviour and performance. As textiles scale so does the need for precision. Where there are strong traditions for textile simulation these are very different in scope to the needs for material simulation in architecture (Ramsgaard Thomsen 2016). In highly dynamic textiles such as knit and especially in knit where material specification is graded or detailed with local reinforcements as well as knitted to shape in complex 3D shapes, this become very complex. The paper will present research into material testing of knitted textiles and the integration of test data into bespoke light-weight simulation tools.

Metrology

Evaluating Sources of Variability in Forensic Fiber Trace Evidence Examination

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In 2009, the National Academies of Science (NAS) released a report criticizing the state of forensic science in the United States. The NAS made several recommendations, including the need for more peer-reviewed research on the scientific basis, validity, and reliability of forensic analysis, and the need for tools and protocols for forensic examinations, methods, and practices. One specific recommendation of the report pertaining to fiber trace evidence examination was to find ways to use analytical methods instead of microscopy to analyze fibers. The overall goal of this work is to develop a database of analytical data based on a physical reference collection available to forensic laboratories. Fourier Transform Infrared (FTIR) Spectroscopy is commonly used by trace evidence examiners to analyze fibers. Typically, examiners rely heavily on diamond compression cells to flatten fiber samples for analysis in transmission using a FTIR microscope. In an effort to better standardize this compression step, an adapter has been designed to use a reproducible amount of torque to flatten the sample prior to analysis. Significant work has also been performed to characterize variability within the diamond compression cell and to develop better protocols for use by forensic practitioners in analyzing samples. The results of work to standardize the compression step will be discussed, in addition to considerations for the development of a robust forensic fiber reference database.

Forensic Files: So How Much Blood Was That?

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Textiles are present at most crime scenes, and if the crime was violent, they often have become bloodied. Since textiles are absorbent, they can collect and store information about the crime scene. DNA profiles can be obtained from blood, semen or other bodily fluid stains; this tells *who* the fluid was from, but not what happened. The size and shape of a bloodstain can be used to learn something about *what* happened, but current analyses of the stain shape on textiles has proven difficult to interpret. However, we have found that the size of the stain can be used to determine the volume of blood deposited onto single jersey knit fabrics.

The volume of blood that created the stain is an important indicator of the mechanism that created the blood source, i.e., drip, impact, or high velocity. We have found that the blood wicks into the yarns and the stain expands until the volume of air within the yarns has been replaced by an equal volume of blood. However, classical wicking studies provide little information about the volume of blood that led to the final stain. Our analysis depends on the basis weight of the fabric and the yarn packing factor. From non-contact measurement of the stain along with the hematocrit of the blood and the measured basis weight and packing factor, a good estimate of the original blood volume can be obtained. Even better analysis of the volume can be obtained by measuring the stain size of a surrogate liquid drop of known volume. The diameter of the blood drop before impingement onto the fabric was found to be accurate to within 9%.

ACKNOWLEDGMENT: This work was supported in part by the National Institutes of Justice award numbers 2012-DN-BX-K052 and 2014-IJ-CX-K002.

Characterization of Micron-sized, Bicomponent Islands-in-Sea Fibers Using Various AFM Techniques

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We report on the use of various operation modes in Atomic Force Microscopy (AFM) as tools to acquire qualitative information about distribution and mechanical properties in cross-sections of islands-in-sea microfibers made of nylon (islands) dispersed in a polyester (sea) matrix. The operation modes used here include semi-contact (tapping) mode (SC), force modulation (FM) contact mode, acoustic (AFAM) contact mode, and IR-AFM contact mode. Although the images acquired in SC mode have the lowest resolution, the technique was the least invasive. Both FM and AFAM show comparable results; the image resolution is higher than those acquire with SC mode, however the sample surface is damaged during the imaging. IR-AFM was used to obtain a chemical map of the cross-section of the fiber, which helps with the chemical identification of the materials in the sample. This study shows that the use of different AFM modes is exceptionally suited for the characterization of mechanical and chemical distribution in multicomponent fibers.

Characterization of Mechanical Properties of Micro- and Nanofibers Using Magnetic Probes

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I will review the current status of newly developed technique for characterization of mechanical properties of micro and nano fibers. A fiber is vertically suspended and fixed to the substrate by its upper end. A magnetic probe is attached to the free end of the fiber and when a magnet is turned on, the fiber is forced to bow. By applying different magnetic fields, one can generate a series of different fiber profiles and filmed the process of fiber bending It appears that one can flex the micro-fibers by very small micro or even nano-Newton forces. The fiber profile is successfully explained by the Euler–Benoulli or Timoshenko model of an elastic beam. Using this setup, we characterized mechanical properties of polymeric and ceramic microfibers

Raman Spectroscopy and Chemometrics Applied to Recycled Polyethylene Terephthalate

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For decades, polyester polymer has maintained its position as the polymer of choice for multiple applications. In recent years, recycling of polyester has become very popular in United States. The discussion will involve current market figures to illustrate the relevance of the research. The recycling process studied here was thermo-mechanical recycling, given the challenge of process control, this presentation will discuss the current challenges in recycling and suggest Raman spectroscopy as a viable soft, non-destructive analysis tool for discrimination and potential characterization of the melt stream. The system used complied of using a probe (dynisco size) directly in melt, facing the molten polymer for spectra collection.

Figure 1. Dynisco-like probe (left) and Axiom probe (right)

Some relevant points of the data acquisition and methodology for data treatment will be presented and discussed. Results were found that Raman can be applied to recycled Polyethylene Terephthalate (PET) to ameliorate the production off-quality materials by predicting melt viscosity, fingerprint the extrusion process and potentially detect polymer contaminants. It was found that melt temperature and melt pressure could be predicted using Chemometrics tools, such as OPLS, when spectra were collected from a Raman probe facing the melt in a polyester extruder. This work opens the door to the usage of spectrometer in the extrusion field more often than it is today; most of the Raman work published in polyester is regarding crystallinity and most of the time offline. The presentation will not review the literature to list some of those, but none of the existing literature spends time showing how to predict melt viscosity, for example. The presentation will discuss show how to calculate it from the melt pressure as a validation tool. In the future a lot more important information can be extracted from the same system described here due to the system proposed: spectrometer, probe, statistical method for pre and post processing the data and predictive model. Some important future work will also be discussed.

ACKNOWLEDGMENT: I would like to thank Unifi Inc. for the financial support and Dr. Stephen Michielsen, NCSU COT, for the guidance.

Fibrous Materials for Biomedical Applications

Microfabrication with Cotton Candy: Fibers as Sacrificial Templates for Fluidic Systems

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Due to their tubular shape and ability to be arranged in various patterns (woven, aligned, random non-woven, etc.), there is significant opportunity to employ fibers to aid in fabrication of micro/nano-fluidic systems. With biomedical microfluidic applications in mind, I will provide an overview of efforts from our group and others that leverage fiber-based technologies to form fluidic systems. In particular, I will discuss our efforts to use sacrificial fibrous meshes to form 3D capillary-like microfluidic networks that can be used to sustain cells embedded within thick artificial tissue. Such artificial vasculature is critical to maintaining cell viability and function in scaffolds thicker than a few hundred microns; this limit is imposed by diffusion of soluble compounds that must be exchanged with surrounding media (gasses, nutrients, waste products). While more traditional techniques such as photolithographic patterning and 3D printing are now able to produce microchannels in cell-laden hydrogels, they are unable to form channels of appropriate size and 3D complexity to mimic capillaries. This hurdle is significant because capillaries are the variety of blood vessel that allow critical exchange of nutrients and wastes, and they must address the entire volume of metabolically active tissue. A simple rotary spinning process allows us to produce interconnected fibrous meshes that exhibit architectures similar to the patterns seen in capillary beds, and, with an appropriate choice of materials, we are able to use these to produce intricate microfluidic systems within cell-laden gels. We show that such fluidic networks are capable of providing necessary media to cells throughout the scaffold, and without perfusion through these channels the cells quickly perish. This rapid, scalable fiber-based approach promises to enable the production of thick artificial tissue for both research and clinical applications.

Electrostatically Flocked Chitosan Fiber Scaffolds

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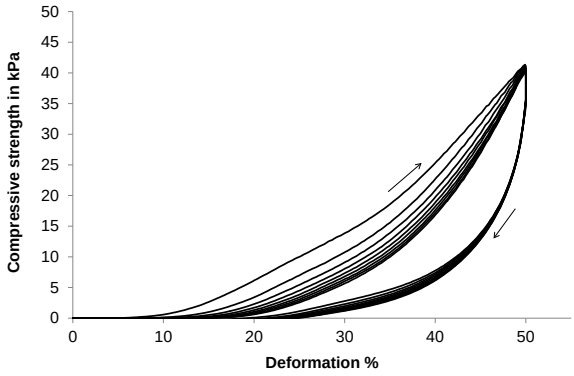
Current cartilage defect treatments in clinical practice are not resulting in regenerated tissues with biomechanical properties close to the original properties. Tissue engineering (TE) has developed rapidly, to overcome this drawback. Within TE chitosan has aroused much interest as a promising material for scaffold fabrication.

In here, the textile fabrication from chitosan powder to chitosan scaffolds is presented. Wet-spun chitosan filament yarns were characterized regarding their dry and wet tensile properties. Yarns were further processed into short flock fibers and were electrostatically flocked onto a chitosan adhesive, resulting in a pure, highly open porous and biodegradable chitosan scaffold. Various chitosan scaffolds were prepared. A thorough analysis in wet state exhibited their geometrical and their mechanical parameters. A pore size of up to 280 µm and a compressive strength of up to 55 kPa at a deformation of 50 % were determined.

Obtained data demonstrated that this straightforward textile production method is suitable for the fabrication of chitosan scaffolds for TE applications.

(A)



(B)

Figure 1. (A) Electrsotaically flocked chitosan scaffold, (B) Loading and unloading curve of a scaffold.

ACKNOWLEDGMENT
We would like to thank the DFG (German Research Foundation) for financial support (grant numbers HU 2107/2-1, HO 1579/1-1 and GE 1133/16-1).

Hybrid Electrospun Chitosan-Phospholipids Nanofibers as a Platform for Biomedical Applications

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Chitosan(s) (Ch), a chitin-derived polysaccharides made of glucosamine and N-actetyl glucosamine, have been explored as biomaterials in biomedical field, due to its known biocompatibility, biodegradability, anti-oxidant, mucoadhesive, hemostatic and antimicrobial properties. The production of functional individual electrospun chitosan fibers demands neutralization and crosslinking methods, which follow two-step protocol or use components with latent cytotoxicity and subsequently limits its use in specific biomedical applications, such as transdermal drug delivery. Herein, it is reported the development of stable, non-toxic chitosan electrospun chitosan nanofibers through the inclusion of phospholipids (P), in one single step aiming to serve as scaffolds for tissue engineering and be used in transdermal drug delivery.

Stable and uniform hybrid Ch/P nanofibers were produced by electrospinning processing, whose nanometers were dependent on the phospholipid content. FTIR and DLS data suggested the occurrence of electrostatic interactions between amine groups of chitosan with the phospholipid counterparts. The nanofibers were shown to be stable up to 7 days in PBS. Cytotoxicity studies showed that neither the cell metabolism nor the plasma membrane integrity was affected upon co-culture of nanofibers with L929 cells, indicating a suitable biocompatibility of the nanomaterial. Additionally, physical interactions between these cells and the nanofibers were observed by fluorescence microscopy, showing the potential of these nanofibers to be used as scaffolds for cell culture. The encapsulation and release of drugs (Curcumin and Diclofenac) and vitamins (Vitamin B12), as model drugs, from Ch/P hybrid systems was investigated, demonstrating their potential utilization as a transdermal drug delivery system.

Chitosan/Phospholipid hybrid electrospun nanofibers with tuned properties that can serve as scaffolds for cell culture and for the release of bioactives, are expected to benefit applications within biomedical field, including tissue engineering and transdermal drug delivery.

ACKNOWLEDGMENT
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Growth of Spinal Cord Explants on Electrospun Polyethylenimine-blended Nanofibers

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OBJECTIVE: Neural tissue cultures display low cell adherence on pure gelatin electrospun nanofibers, and as such *in vitro* cultures require a cationic coating, such as poly-D-lysine (PDL), to promote cell adhesion and growth. Polyethylenimine (PEI) is a cationic polymer with a similar cationic amine structure, which has previously been examined for *in vivo* gene delivery applications, that has never been examined as a copolymer with gelatin for neural scaffolds. In this study, we examined the effect of linear PEI (lPEI) (2,500 MW and 25,000 MW) and branched PEI (bPEI) (600 MW and 10,000 MW) blends of 0.5, 1, and 5 wt% of PEI in formic acid (FA) with 12% gelatin. Growth of dendrites from spinal cord explants on dehydrothermally- and glutaraldehyde-crosslinked samples were was assessed *via* immunostaining and imaging.

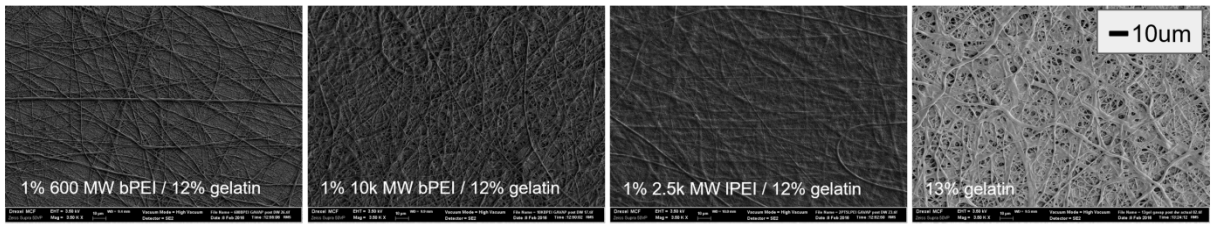

Figure 1: Fiber mat morphologies of 13 wt% gelatin (no PEI) and 1 wt% PEI/12 wt% utilizing 600 MW bPEI, 10k MW bPEI or 2.5k MW Lpei.

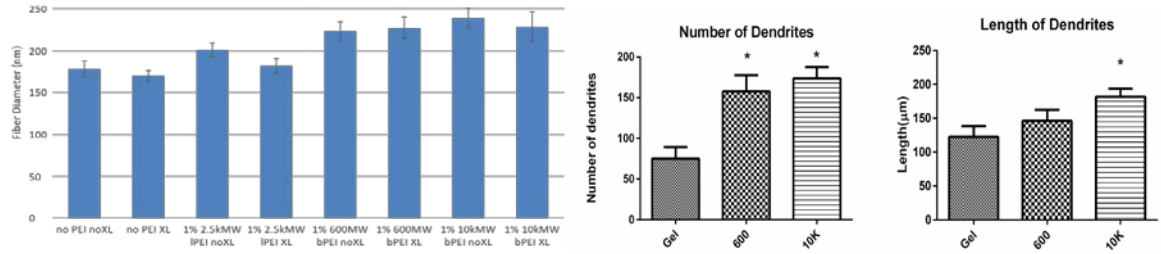

Figure 2: LEFT: Fiber diameters of 13 wt% gelatin (no PEI) and 1 wt% PEI/12 wt% PEI pre- and post-DHT crosslinking. RIGHT: Number and length of dendrites from spinal cord explants on nanofiber mats.

RESULTS: All PEI/gelatin blends could be electrospun; however, the 13 wt% gelatin and the 12 wt% gelatin/1 wt% PEI blends of 2.5k MW lPEI, 600 MW bPEI and 10k MW bPEI maintained a two-dimensional fiber mat morphology (Figure 1) and had statistically similar diameters pre- and post-DHT crosslinking (Figure 2 LEFT); thus, they were used for cell culture studies. SEM imaging pre-and post-stability test demonstrated that DHT-crosslinked fibers had poor stability and GA-vapor-crosslinked fibers had good stability. Both crosslinking types produced similar results in cell culture, with 1% 2.5k MW lPEI killing all of the cells, while 600 MW and 10k MW bPEI promoted increased number and length of dendrites (Figure 2 RIGHT).

CONCLUSION: Bulk addition of MW 600 and 10k branched PEI increases dendrite number and length compared to traditional PDL coating for gelatin nanofiber constructs. Additionally, this is the first demonstrated used of branched PEI in electrospun fiber applications for neural cell culture.

Put Electrospun Nanofibers to Work for Biomedical Research

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Because of its high porosity and large surface area, a non-woven mat of electrospun nanofibers can serve as an ideal scaffold to mimic the extracellular matrix for cell attachment and nutrient transportation. The individual nanofiber can be functionalized through encapsulation or attachment of bioactive species. Besides, the nanofibers can be further processed into various arrays or architectures. In this work, we engineered electrospun nanofibers for use in drug delivery, wound dressing, and tissue engineering.

We aimed to develop biocompatible and biodegradable nanofiber wound dressings using electrospinning in which vitamin D_3 is encapsulated. These nanofiber dressings would provide locally sustained delivery of the compounds and induce expression and secretion of the antimicrobial peptide LL-37 from keratinocytes, monocytes/macrophages, and neutrophils at or near the surgical site or wound and provide a scaffold for healing. We successfully encapsulated 1,25-dihydroxyvitamin D_3 in PCL nanofibers and observed a sustained release over four weeks. Our data also suggest that nanofiber-encapsulated 1,25-dihydroxyvitamin D_3 is more effective for durable induction of hCAP18/LL-37 expression than a non-encapsulated form.

We also aimed to develop nanofiber scaffolds with square-arrayed microwells and combine with microskins for skin regeneration/wound healing. We demonstrated that 3T3 fibroblasts can cover the whole area more quickly and distribute more evenly on our uniquely designed nanofiber scaffolds with square arrayed microwells and structural cues compared to the random and uniaxially-aligned fiber samples. We further demonstrated that covering by radially aligned nanofiber scaffolds can promote the migration of 3T3 fibroblasts seeded to microwells. We also demonstrated that human dermal fibroblasts exhibited the similar behavior as 3T3 fibroblasts when cultured on the nanofiber scaffolds with arrayed microwells and nanostructural cues. We further demonstrated the human skin tissue culture on fibronectin-coated nanofiber scaffolds with square arrayed microwells and nanotopographic cues.

ACKNOWLEDGMENT
This work was supported partially from startup funds from University of Nebraska Medical Center (UNMC), National Institute of General Medical Science (NIGMS) grant 2P20 GM103480-06.

Hybrid Textile for Heart Valve Prosthesis: *In Vitro* Assessment of Various Construction Designs

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INTRODUCTION

Textile polyester could be an advantageous material to replace faulty valve leaflets under mini-invasive surgery. Moreover, combining woven with non-woven fibers in the leaflet material could provide both mechanical resistance and favorable tissue-fabric interaction.

In this study, fine non-woven PET fibers obtained with force spinning were assembled with a woven substrate to form hybrid textiles and valve prototypes. The aim was: (1) to produce non-woven fibers, (2) to perform statistical analysis of the fibers diameter, (3) to investigate different assembling modes between the woven and the non-woven layers, (4) to assess the characteristics and the performances of the obtained materials and valve prototypes.

MATERIALS AND METHODS

SEM images and statistical analysis were used to investigate the effect of the force spinning production parameters (nozzle diameter, spin speed, viscosity…) on the obtained fibers size. Various assembling methods were then tested:

- Sewing (sample 1)
- Ultrasonic welding (sample 2)
- Chemical adhesion (sample 3)
- Thermal adhesion (sample 4)

Following characteristics of the obtained hybrid material were then assessed: roughness, bending stiffness, permeability and valve durability (fatigue tests).

RESULTS

Regarding force spinning, increased speed and reduced nozzle size lead to smaller fibers. Moreover, with reduced viscosity the jet undergoes a higher stretching and consequently finer fibers are formed (down to 3µm). After assembling, the characteristics of the hybrid leaflets are modified as presented in the table.

	Permeability(ml/cm²/min)	**Bending stiffness (mN.cm)**	**Roughness (µm)**
Reference woven textile	5293	$3.3 * 10^{-5}$	0.17
Sample 1	5034	$5.9 * 10^{-5}$	0.44
Sample 2	4852	$4.5* 10^{-5}$	0.57
Sample 3	5027	$3.9* 10^{-5}$	0.54
Sample 4	4202	$8.6* 10^{-5}$	0.53

Chemical adhesion seems to present an advantage providing the lowest bending stiffness. With respect to the fatigue tests, 10 Mio cycles have been already reached with all valve samples and no material delamination could be observed.

CONCLUSION

The force spinning process enables obtaining a non-woven mat with controlled fibers size, which can be assembled with a woven substrate in a durable way. The characteristics of the hybrid textile are slightly different from the reference woven material, but keep in the range of what is needed for the valve application.

Multicomponent Fibers Tailored for Medical Textiles

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Aiming at innovative medical textile applications, product enhancements on the fiber level are very effective, and multicomponent synthetic fibers are among the most promising developments. To combine functionalities in a single fiber, we develop bi- and tri-component fibers with various cross-sections and material combinations. As example, we developed a novel category of bi-component polymeric fibers with a liquid core. Spinning trials resulted in the continuous production of liquid filled fibers with 50 µm diameters, which are expected to open a new field of multilumen micro-catheter applications.

Using bicomponent melt-spinning technology we developed highly flexible prototype polymer optical fibers (POFs) that fulfill the requirements of textile processes and that provide comfort during wear. One sensor principle uses embroidered fabrics of these novel POFs to build a wearable pulse oximeter, where two different wavelengths are used to determine the ratio of oxygenated and deoxygenated hemoglobin. Another sensor principle is based on urethane/siloxane block copolymer POFs integrated into a textile structure. Due to the elasticity of these POFs, the fiber cross-section changes under pressure, out-coupling light, and resulting in a location-dependent, pressure-sensitive fabric.

Our low-pressure plasma sputtering process yields metal coated fibers for the development of smart medical textiles that behave and perform like conventional textiles in terms of robustness, flexibility and haptics. Thin insulating polyurethane coatings have successfully been applied to qualify the fibers to be used as an interconnection platform for technology-driven medical clothing. Additional conductive PEDOT:PSS polymer coatings proved to be sensitive to external conditions, making the respective fibers ideal candidates for combined pressure and humidity sensors.

Adhering Zwitterions to Electrospun Nanofiber Mats Using Bioglue

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Electrospun fiber mats hold great potential for tissue engineering, wearable electronics, and water purification technologies. Unfortunately, these materials are susceptible to biofouling, which can cause detrimental complications, including infections from contaminated medical devices and reduced membrane selectivity. In this project, we exploit the excellent fouling resistance of polymer zwitterions and present electrospun nanofiber mats surface-functionalized with poly(2-methacryloyloxyethyl phosphorylcholine) (polyMPC). This zwitterionic polymer coating maximizes the accessibility of the zwitterion to effectively limit biofouling on free-standing nanofiber mats. Two facile, scalable methods yielded a coating on a cellulose nanofiber mat platform: (i) a two-step sequential deposition featuring dopamine polymerization followed by the physioadsorption of polyMPC; and (ii) a one-step codeposition of polydopamine (PDA) with polyMPC. While the sequential and codeposited nanofiber mat assemblies have an equivalent average fiber diameter, surface chemistry, hydrophilic contact angle, and stability, the codeposited nanofiber mats were smoother. Protein and microbial antifouling performance of the zwitterion modified nanofiber mats along with two controls, unmodified cellulose and PDA coated nanofiber mats were evaluated by dynamic protein fouling and prolonged bacteria exposure experiments. When challenged with the model microbes *Escherichia coli* and *Staphylococcus aureus* for 24 hr, both zwitterion modifications demonstrated superior fouling resistance by statistically reducing microbial attachment over the controls. This study demonstrates that by decorating the surfaces of chemically and mechanically robust cellulose nanofiber mats with polyMPC, we can generate high performance, free-standing nanofiber mats that hold potential in applications where antifouling materials are imperative, such as tissue engineering scaffolds and water purification technologies.

Nanofibers

New Method for Characterization of Oriented Nanofibres

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Electrospinning (ES) is certainly the one of the most versatile methods for producing ultra-fine nanofibrous 2D membranes. Nanofibers, produced by ES technique, have been explored for their unique properties (high surface to weight ratio, highly porous mesh) in various fields such as biomedical, filtration, etc. One major interest of ES process is for developing customized fibrous structure for targeting applications. Usually, the generated nanofiber accumulated on conventional flat collectors are randomly arranged. Aligned fibers can be achieved by using different collectors including static and rotating ones. However, rotating collectors are more complex to design, the surface area of the obtained nanoweb can be relatively small and moreover, only radially oriented nanofibers will be obtained.

The main objective of this work is to produce structured nanofibers from Polyamide-6 (PA-6) focusing on static collectors. Our developed technology (under patent process) allows us to obtain oriented and random nanofibers on the fabricated collectors by adjusting the electric field to change the electric charge in the machine. The nanowebs have been produced by ES on the fabricated collector by varying three main parameters of ES (concentration, needle-collector distance and voltage) through a design of experiment. According to the obtained results, optimum set of parameters to achieve highly oriented nanofibers have been defined. As the micrographs present (Fig. 1), patterned collector allow the production of mat templates made of nanofibers with alternative pattern of oriented and non-oriented areas.

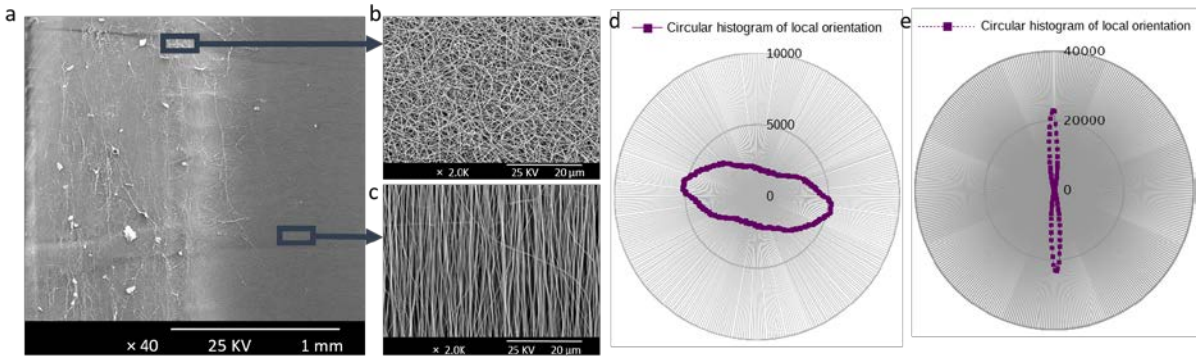

Figure 1: Oriented and non-oriented parts in one sample 40X (a), random nanofibers (b), and highly oriented nanofibers (c) with magnification 2K, circular histogram of local orientation - random (d) and oriented parts (e)

Specific software based on image analysis of SEM micrographs has been used to estimate the orientation of nanofibers. It evaluates the local orientation and isotropic properties such as coherency and energy of every pixel of the image. Therefore, circular histograms of local orientation (Fig.1 d, e) are obtained and contain angular values computed from local orientation of the pixels, weighted by the pixel information coherence. According to the results, this technique allows us to complete analysis of the orientations of nanofibers in producing electrospun mat. In the next step, as mechanical properties of nanofibers materials are highly dependent on the orientation distribution of the nanofibers, the effects of nanofiber alignment on mechanical properties will be examined.

Study of Mechanical Properties of Electrospun PA-6 Nanowebs and Electrospun PA-6/ B Composite as Substitution Membrane for Congenital Diaphragmatic Hernia Treatment

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The diaphragm is the main breathing muscle in the body which is divided into two parts made of both muscles (peripheral part) and tendons (central part). Congenital diaphragmatic hernia (CDH) is a rare defect that occurs while the diaphragm malformation happens between the fourth week and the third month of pregnancy. This process prevents the lungs from growing normally and it affects about 1 over 2,500 babies.

As a current treatment at Strasbourg Civil hospital in France in the case of big hole size, abdominal organs are moved back to the abdominal cavity and the hole will be closed by Gore-Tex prosthetic membrane. The problem is that by growing up the patient, who is mostly a baby, the existing hole in the diaphragm will grow as well. Gore-Tex implant membrane is not elastic enough so the time passing by there is a need to re operate the patients. The prosthesis in 43% of the cases will be removed because of hernia recurrence. To solve this problem, producing a new prosthesis by using electrospinning method could be a solution to reduce the number of planned re operation.

Mechanical test on pork's diaphragm has been done in order to obtain a mechanical idea of feasible and the nearest case to human diaphragm. A comparison between the tensile mechanical properties of tendon part of diaphragm and electrospun PA-6 nanofibers due to its good mechanical and physical properties by using single needle electrospinning machine with 3 different times of electrospinning (3,6 and 9 hours of electrospinning) was done, the results showed that 3h electrospun PA-6 nanofibers are close to tendon in the level of interval force but the elasticity should be increased.

In order to increase the elasticity of electrospun PA-6 nanofibers, a B material is used during the electrospinning process. Electrospun PA-6/ B composite with different time of electrospinning is produced. The average diameter of produced nanofibers is close to the one expected in the specification.

Separation and Modeling of Oil-in-Water Emulsions Stabilized by Different Types of Surfactants Using Electrospun Fiber Membranes

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In this work, we examined the influence of surfactants on the microfiltration of oil-in-water emulsions using electrospun fibrous membranes of poly(trimethyl hexamethylene terephthalamide) (PA6(3)T) with fiber diameters of [121 ± 22 nm]. Four types of surfactants (anionic, cationic, non-ionic and zwitterionic) were used to create monodisperse emulsions of dodecane in water, with average droplet sizes of [475 ± 14 nm]. Both dead-end and cross-flow filtration configurations were employed to study the interaction (i.e. fouling and cleaning) between the emulsion and membrane.

In both dead-end and cross-flow configurations, the emulsions prepared with anionic and non-ionic surfactants exhibited the highest fluxes, around five-fold higher than that for the emulsion stabilized by cationic surfactant. The emulsion with zwitterionic surfactant led to intermediate flux. The oil rejections were generally as high as 90%, with the exception of the emulsion stabilized by non-ionic surfactant, whose rejection was closer to 60%. The observed fluxes using the cross-flow system were about one order of magnitude higher than those observed with the dead-end system, due to a mechanism for foulant removal (cleaning) attributed to hydrodynamic forces. The differences in the fluxes and rejections for emulstions stabilized by different surfactants are traced to electrostatic interactions between the emulsified droplets and the membrane, based on zeta potential measurements.

To study the fouling and cleaning mechanism, several models were also applied in this work. Blocking filtration models suggest that the membranes fouled initially in the regime of complete blocking, but then transitioned to cake filtration as the flux continued to decline. The transition time for emulsion stabilized with non-ionic surfactant was twice larger than that with other surfactants. From the modified blocking filtration models derived by Field, the fitted critical flux of cross-flow filtration was consistent with the recovered flux of dead-end filtration after backflushing. Foulant resistivity modeling supported a series resistance model, consistent with cake filtration. The emulsion stabilized by anionic surfactant showed the lowest resistance, while that stabilized by cationic surfactant showed the highest resistance.

Investigating the Long-term Behavior of PAN Nanofiber Yarns

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Electrospinning technique is very popular nowadays as nanofibers with adjustable morphology can be produced and the setup itself is relatively simple. The potential application of electrospun mats include biomedical, pharmaceutical, solar energy, filtration, sensor and composite applications, etc. There are numerous studies characterizing nanofibers of different polymers and a few of these also include the mechanical properties in general. On the other hand far less attention is given to the long-term behavior of these nanofibers. In order to be able to design a nanofiber filter part or a biomedical scaffold it is crucial to know how the material behaves and how it can resist the loads after the required number of operating hours. Creeping is a typical phenomenon that happens in the above-mentioned cases. The expected lifetime and deformation has to be well-predicted.

In this study the aim was to get useful information on the long-term creep behavior of nanofibers and also to compare them to classical fibers. For the experiments nanofiber yarns were generated. For this polyacrylonitrile (PAN) was dissolved in dimethylformamide (DMF). A single-needle setup was used in a vertical arrangement and nanofibers were collected on an open water surface. The nanofibers were focused to a small spot by the applied special electrode configuration then pulled out from the bath with a winding drum. Continuous yarns were formed this way by the liquid surface tension and mechanical forces.

The mechanical performance of nanofibers was tested by dynamic mechanical thermal analysis (DMA). From these tests the isothermal long-term creep behavior could be determined. Besides these the optimum temperature for hot-drawing of the yarns could also be concluded. Besides the DMA master curve construction the morphology was also investigated and it was found that high orientation of the nanofibers can be achieved by the suggested treatments.

ACKNOWLEDGMENT
The research was supported by the National Research, Development and Innovation Office (OTKA PD116122 and OTKA K116070). The author would also like to thank the Hungarian-American Enterprise Scholarship Found (HAESF) and CIEE for their generous support.

From the Synthesis of Polymers to the Fabrication of Smart Nanofibers

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Smart or stimuli-responsive polymeric nanofibers have gained extraordinary relevance in the last years due to their promising applications in sensors and bioengineering. Temperature-responsive polymers, as one kind of smart materials, respond to changes in temperature and undergo a phase transition at the lower critical solution temperature (LCST). At temperatures below the LCST, these macromolecules are hydrophilic, while at temperatures above LCST they become hydrophobic and collapse. Poly(vinyl caprolactam) (PVCL) is a highly interesting thermoresponsive polymer, since it is biocompatible and its LCST is around 32 ºC (close to body's physiological temperature). Even if in the last decades several works has been published in the synthesis of PVCL polymers and hydrogels, little is still known about its spinnability and fiber formation.

In this work, poly(vinyl caprolactram-co-hidroxymethyl acrylamide) (P(VCL-co-NMA)) copolymers were synthesized, characterized and electrospun, for the first time, to create temperature-responsive nanofibers. NMA is a special type of monomer that self-crosslinks in the presence of heat. Different copolymers were synthesized varying amount of NMA and the effect of the copolymer composition on the LCST and the morphology of the final fibers was studied. Fibers were crosslinked using different temperatures and the crosslinking process was analyzed by FTIR, TGA and DSC. Finally, the temperature-responsive behavior of the nanofibers was successfully demonstrated. When fibers were immersed in water at 23 ºC (below LCST), polymer chains were hydrophilic and therefore, the nanofibers swell (chemical crosslinking prevents the dissolution of the fibers in water). On the contrary, when the temperature of the water was 50 ºC (above LCST), PVCL moieties of the fibers became hydrophobic making the nanofiber shrink.

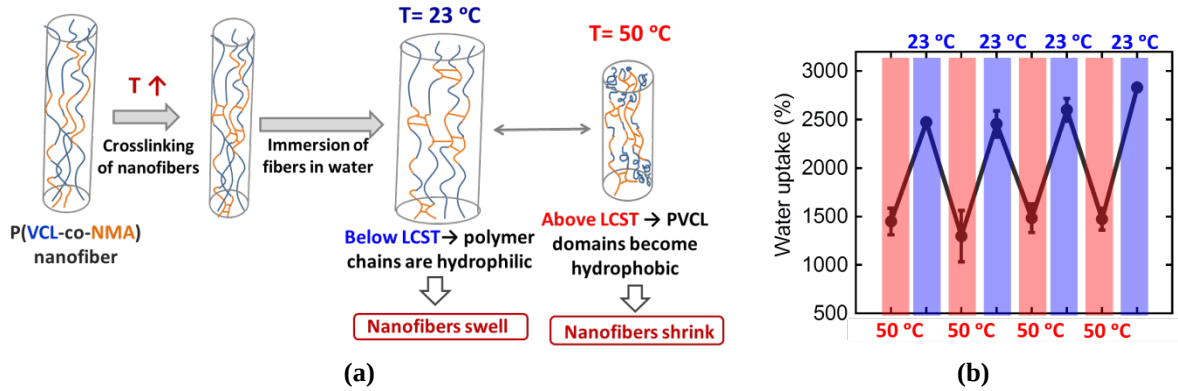

Figure 1. (a) Diagram explaining the P(VCL-co-NMA) fiber formation, crosslinking and thermo-responsive behavior, (b) Swelling-shrinking experiments of a fiber mat at 23 and 50 ºC.

Fiber Formation, Structure, and Properties

Bi-component Fibers for Temperature Adaptive Thermal Insulation

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We have used bi-component fiber spinning to create fibers based on differential coefficient of thermal expansion (CTE) that bend in response to temperature changes. These fibers can be used to create battings or other thermal insulation that changes thickness in response to temperature changes. The result is a thermal insulation that provides more insulation at cold temperature and less at warmer temperatures.

By extending the classic bi-metal spring analysis of Timoshenko **(**Timoshenko, S. Analysis of Bi-metal Thermostats. *J. Opt. Soc. Am.* 1925, **11** (3), pp.233-255.), we have previously shown that it is possible to maximize the bending response of a fiber for any two components by adjusting the ratio of the two components based on the ratio of their mechanical moduli. Simple battings based on syndiotactic and isotactic polypropylene have shown thickness changes of more than 1.5% per degree Celsius.

In this work we have made bicomponent fibers of isotactic polypropylene and linear low density polyethylene and used a commercial process to make battings. The battings were tested on a guarded hot plate with chamber air temperatures of 20, 2, and -5 C. These battings show a change in intrinsic clo of 1.6% per degree Celsius over a 10.3 degree change in average sample temperature. The sample temperature change in these tests is limited by the fact that the samples are placed directly on a constant temperature hot plate surface. Sleeping bags made of these battings show a similar change in total insulation value (10.6% between 20 C and -5 C) indicating the responsive behavior is still seen in the more constrained environment of an end item. Measurements of fiber CTEs as a function of draw ratio suggest our fibers were not optimized.

Braided Structure with Negative Poisson's Ratio

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Auxetic textiles are those having negative Poisson's ratio (NPR) and have attracted great attention in recent years. However, none of them has used braiding technology to achieve the NPR effect. Here we would like to report a novel braided structure with NPR. This particular braided structure is based on tubular braiding and was formed by helically winding a stiffer yarn around a base tubular structure braided with elastic yarns (Fig. 1). The resultant braid is of a regular shape when there is no force applied on it. However, it will be converted into a wave line when stretched (Fig.2). Due to this shape change, NPR effect is achieved. Also, it is possible to add a core yarn in the central of the auxetic braided structure to support the braiding yarns to get better NPR behavior. And by changing the structural parameters such as winding angle, diameter ratio between the winding yarn and braiding yarn and component modulus, auxetic braided structures with various NPR values can be obtained.

Tested under the axial extension, the braided structure shows a significant NPR behavior. To get a better understanding of it, a Poisson's ratio-strain curve has been drawn as shown in Fig.3. It can be seen that the NPR value first goes downward and then climbs with the increase of the longitudinal strain. A maximum value of -4.05 is obtained when the longitudinal strain is 0.07.

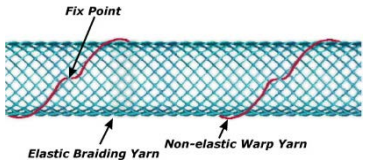

Fig. 1: Schematic of auxetic braided structure

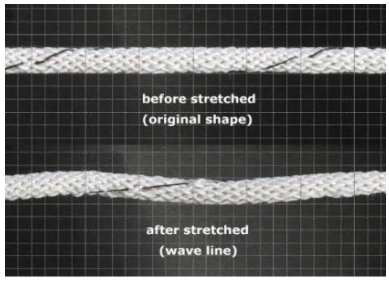

Fig. 2: The shape change of auxetic braided structure

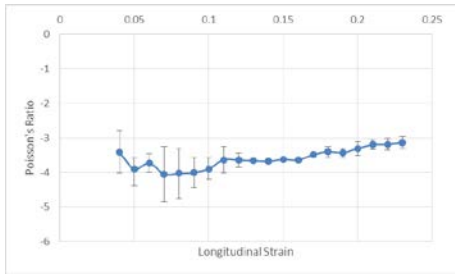

Fig. 3: Poisson's ratio vs longitudinal strain

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Investigation of Nanoyarn Preparation by Modified Electrospinning Setup

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Applications of electrospun nanofibers are currently limited by their poor mechanical properties, low production, and random alignment. Twisted assemblies of nanofibers, including nanofiber-based ropes, cables, and yarns, are expected to have superior strength and a higher degree of order than nonwoven mats due to increased cohesive forces between fibers. In this study, twisted assemblies of polyacrylonitrile (PAN), polyvinylidene fluoride trifluoroethylene (PVDF-TrFE), and polycaprolactone (PCL) nanofibers were fabricated *via* a modified electrospinning setup. The electrospinning setup consisted of a rotating cone-shaped copper collector, two syringe pumps, and two high voltage power supplies. Nanofibers collected across the face of the cone and were drawn into a nanoyarn using an insulating rod. Nanoyarns were produced at rotary speeds of 500, 700, 900, and 1100 rpm. Scanning Electron Microscopy (SEM) was used to analyze the morphology of the nanoyarns, including twist angle, fiber diameter, and yarn diameter. The twist angle of the yarns increased and the fiber diameter decreased as a function of the rotary speed of the collector. The average fiber diameter of PVDF-TrFe nanoyarns was 0.97 μm at 500 rpm, compared to 0.79 μm at 1100 rpm. For PAN nanoyarns, the average fiber diameter decreased from 1.65 μm to 1.2 μm. Moreover, the yarn twist increased from 11.9° at 500 rpm to 35.1° at 1100 rpm for PVDF-TrFe nanoyarns and from 22.6° to 38.1° for PAN nanoyarns. Mechanical testing of the yarns revealed that PVDF-TrFe yarns have a higher strain-to-failure than PAN yarns. Maximum tensile strength was seen in yarns produced at a rotary speed of 900 rpm for PVDF-TrFe yarns and 700 rpm for PAN yarns. Beyond these speeds, yarns were brittle and the strain-to-failure decreased. It is expected that optimization of the uptake speed will result in more uniform nanofiber yarns and improved mechanical properties.

New Styrenic Block Copolymers for Elastic Nonwoven and Fiber Applications

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Several new SEBS polymers and compounds have been introduced by Kraton Performance Polymers for elastic nonwoven and fiber applications. MD1648 is one of the newest polymers developed for elastic melt blown fabrics and elastic laminates which has a nominal MFR of 220 at 230°C and 2.16kg. In addition to being high flow and single phase at polypropylene process temperatures, MD1648 processes and spins well on conventional melt blown equipment. Typical melt blown fabric properties are equivalent to commercially available elastic films and fibers used in diaper tabs, waistbands and pant side-panels. MD1648 is available in commercial quantities as a dense pellet and is currently being evaluated in elastic melt blown fabrics, compounding and adhesive applications. In addition, we will introduce a new semi-crystalline styrenic block copolymer that offers good oil and chemical resistance and can be spun into elastic and strong yarns.

Overview of HIB Process for Making High-performance Fibers

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Several techniques and treatments have been developed for production of high-performance fibers. The inherent problems of low productivity, high production cost, and high energy consumption, complexity of chemical reaction, mass transfer, and waste recovery systems make most of them inappropriate for industrial applications. Horizontal isothermal bath (HIB) is an alternative eco-friendly simple treatment that can be used during melt spinning process for production of technical textile fibers. The method contributes to high tensile properties through developing unique fiber morphology, transformable into highly oriented, order crystalline structures under mild drawing and heating. The HIB process has been applied to several semi-crystalline polymers such as polyester, polypropylene, and nylon-6 and filaments with tensile performance comparable to and even better than melt-spun fibers were produced. This overview considers research work published on structural and mechanical properties of HIB fibers.

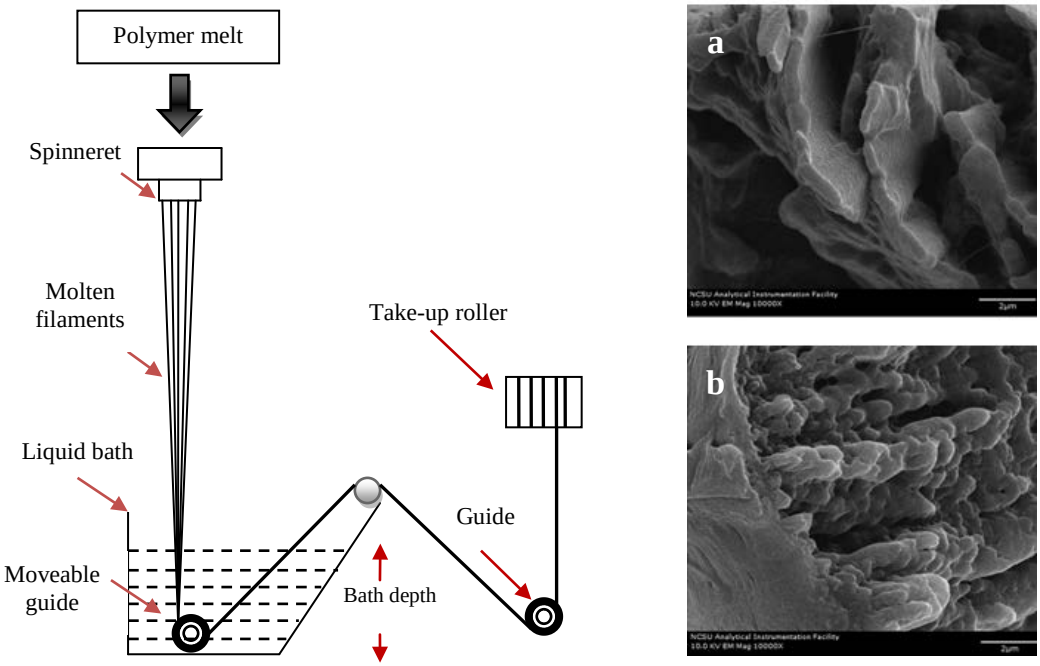

Figure 1. Left: Scheme of horizontal isothermal bath (HIB) method. Right: Morphology of drawn no HIB (a) and drawn HIB (b) nylon-6 fibers (DR=1.38) [1].

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Electrospinning Polyelectrolyte Complex Coacervates into Fiber Mats

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Green processing of intractable polyelectrolyte complexes (PECs) into electrospun nanofiber mats has the potential to enable new materials for use as drug carriers and wound dressings. PECs are responsive soft materials made via the complexation of oppositely-charged polymers in aqueous solution. PECs have long been considered intractable to either thermal or solvent processing methods. However, recent work has demonstrated the role of inorganic salt as a plasticizer in PECs to facilitate the solid-to-liquid phase transition, thus, PECs are "saloplastic." Coacervates, or liquid phase PECs, form a polymer-rich dense phase in equilibrium with a supernatant that is polymer-poor over a narrow range of salt concentrations. In this work, we demonstrate the first example of direct electrospinning of PECs in the form of coacervates to form fibers from aqueous solutions. We use poly(styrene sulfonate sodium salt) (PSS) and poly(diallyldimethyl ammonium chloride) (PDADMAC), a pair of strong polyelectrolytes, as a saloplastic system in potassium bromide (KBr) salt solution. We analyzed the effect of the polymer solution properties on forming PEC fibers, such as, the salt concentration in PEC coacervates. Also, we studied the effect that apparatus properties have on the electrospun fiber diameter, such as, the strength of electric field. More consistent and smaller diameter fibers were obtained by electrospinning coacervates at a higher total salt concentration and a higher applied voltage. The resulting electrospun PEC fibers are robust when exposed to acidic, neutral, and basic conditions, as well as in the presence of various organic solvents. Moving forward, we will focus on using PEC-based electrospun fibers for the controlled delivery of small molecules for biomedical applications.

Slip-effect Functional Air Filter for Efficient Purification of PM2.5

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Fabricating air filtration membranes (AFM) with high filtration efficiency and low air resistance that are both adamant intercept of particulate matter and easy transmission of air molecular is extremely urgent and significant due to abominable particulate matter pollution; however, construction of such materials is still confronted with enormous challenging. Herein, slip effect structured ultrathin fibrous membranes (40-180nm) with decreased air resistance are successfully fabricated through regulating lithium chloride concentrations in precursor solution. The average fiber diameter of 71 nm is demonstrated as the most effective size interval for slip effect, which is in close proximity to air molecular mean free path (65.3 nm) making air molecules bypass the nanofibers with maximum probability, thereby decreasing the air resistance. Benefiting from slip effect, the resultant PAN fibrous membranes are endowed with low air resistance of 29.5 Pa, high PM2.5 purification efficiency of 99.087%, good transmittance of 77% and long service life. The successful fabrication of such intriguing materials may provide new insight into the design and development of high-performance AFMs for various applications, such as anti-smog window screening.

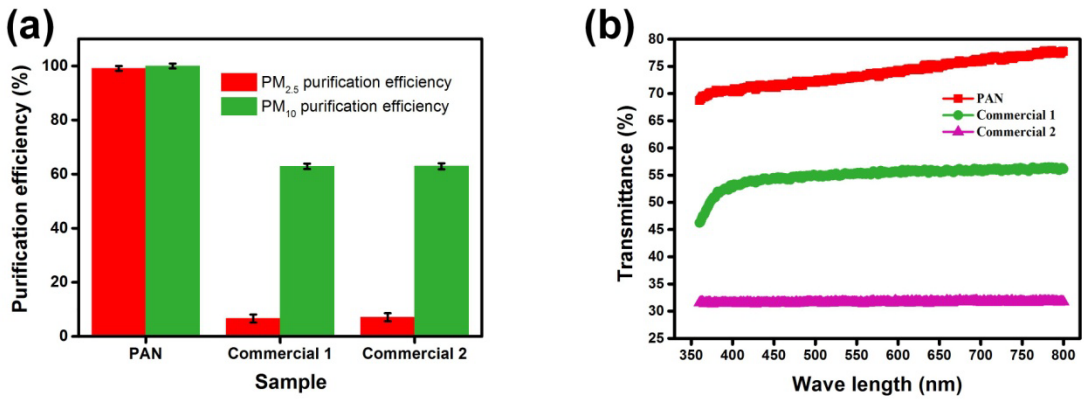

Fig. 1: (a) Purification efficiency of $PM_{2.5}$ and PM_{10} (b) Transmittance in the range of visible light wavelength of PAN, Commercial 1 and Commercial 2.

High-performance Electrospun Polyethylene Fibers by Gel-Electrospinning

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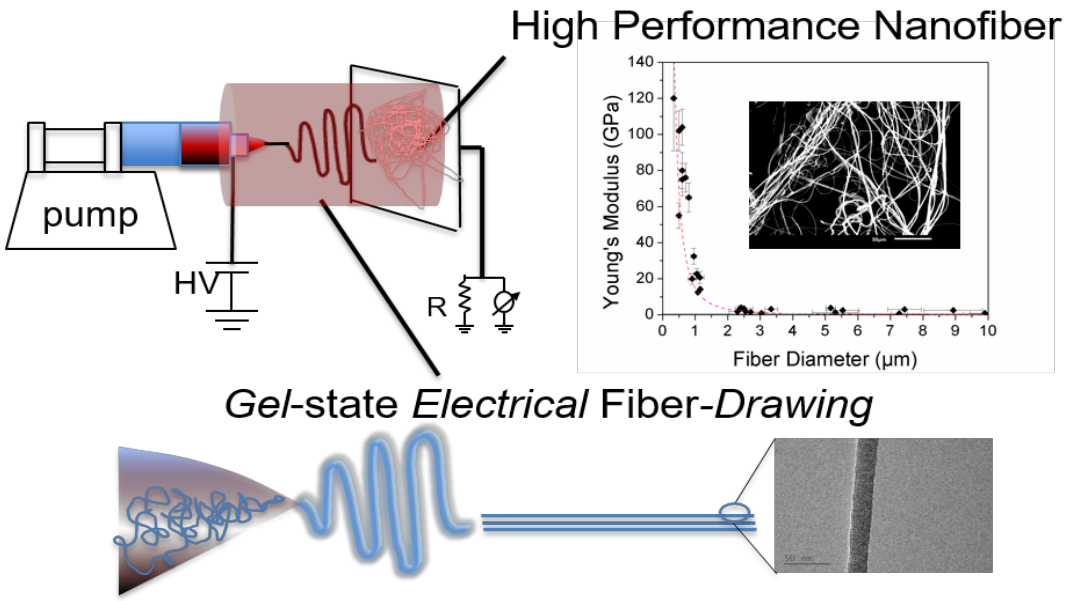

Figure 1. An overview of the gel-electrospinning process and the resulting higher performance material produced. The entangled polymer gel solution is electrically drawn into crystalline fiber with high molecular orientation. These continuously produced materials exhibit mechanical properties of a high performance material, with Young's moduli of 100 GPa.

Electrospinning has been widely used over the last decade to fabricate polymeric fibers with submicron to micron diameters for various applications, such as filters, battery materials, and biomaterials. Despite their many unique properties, electrospun nanofibers tend to be weaker than conventional polymer fibers, especially when compared to engineered high performance materials such as Spectra®. Inspired by a commercial gel-spinning process, we developed a novel procedure that we have dubbed "gel-electrospinning," wherein a polymer gel is drawn by electrical forces to obtain high performance fibers with submicron diameters. Using this process, we fabricated ultrahigh molecular weight polyethylene (UHMWPE) fibers with diameter less than 0.5 μm and moduli greater than 100 GPa from solutions of *p*-xylene and *tetra*-butyl ammonium bromide at elevated temperature. Here, we report the tensile modulus, ultimate tensile strength, and toughness of these fibers, along with their crystallinity to demonstrate the structure-property relationship among these parameters. The key to the production of these fibers is careful control of the temperature and rheology in several process zones.

ACKNOWLEDGMENT
Funding for this work was provided by the U.S. Army through the Natick Soldier Research, Development and Engineering Center (NSRDEC). The authors are grateful to the U.S. Army-funded Institute for Soldier Nanotechnologies (ISN) and the National Science Foundation-funded Center for Materials Science and Engineering (CMSE) for use of facilities and equipment.

Thermoplastic Coating of Glass Fibres in the Nozzle Drawing Process

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The film stacking method is the industrial standard for the manufacturing of fibre reinforced thermoplastic composites (FRTCs) [1]. An alternative to this is commingling thermoplastic fibres with reinforcment fibres, e. g. glass fibres, into hybrid yarns [2]. However, the composites produced by the use of film-stacking or hybrid yarns cannot achieve an optimal impregnation of reinforcement fibres with the matrix polymer. This stens from the high melt viscosity of thermoplastics, which prevents a uniform wetting of the reinforcement fibres. Leaving some fibers is unconnected to the matrix. This leads to composite lower strength than theoretically possible. The aim of the research is the coating of a single glass filament in the glass fibre nozzle drawing process to achive a homogenous distribution of glass fibres and matrix in the final composite. The approach uses particles with a diameter from 2 to 15 µm of Polyamid 12 (PA 12) which are electrostatically charged and blown at an E glass filament in the nozzle drawing process as seen in figure 1. The particles adhering to the filament are melted by infrared heating and winded afterwards. This development will allow the homogenous distribution of fibres and the matrix in a thermoplastic composite allowing a higher fibre volume content leading to improved mechanical properties. Even though the glass filaments could be coated with PA 12, a homogenous sheath could not be achieved in this investigation. Therefore further research will focus on an improved homogeneity by reducing the agglomeration of PA 12, using dried PA 12 and enhancing the overall nozzle setup.

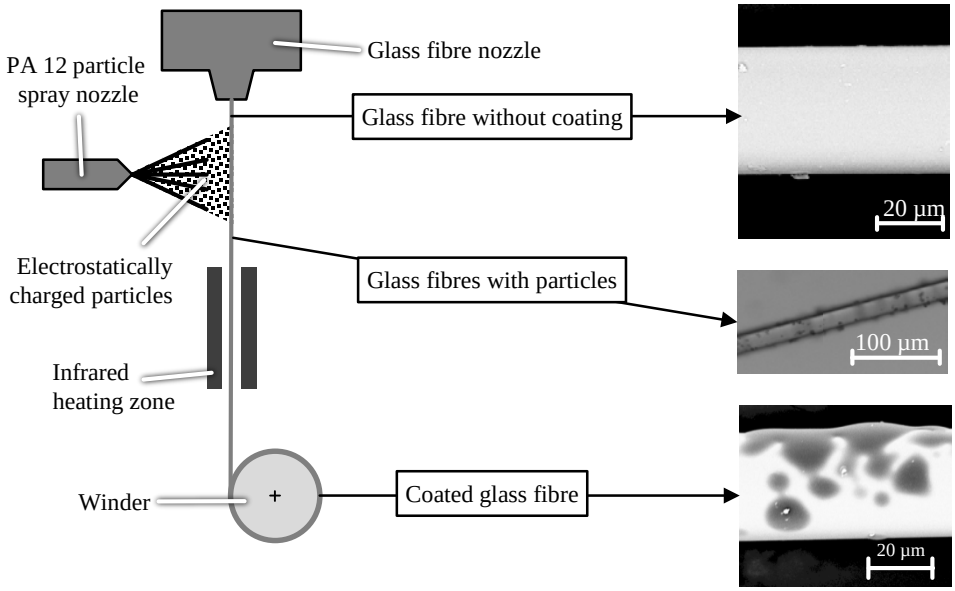

Figure 1: Nozzle drawing process for glass fibres with a coating of PA 12 particles and infrared heating zone

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Invention (Recognition) of High-modulus, Low-shrinkage Tire Cord: A Model for the Development of Fiber Structure and Properties

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High Modulus, Low Shrinkage Tire Cord (HMLS) was invented and patented by the Celanese Research Company in the early 1970's (Jaffe et al. U.S. Patents # 4,101,525, 4, 195,052). The recognition that that high stress spinning creates a fiber morphology in semi-crystalline polymeric fibers that allows the favorable decoupling of orientation dependent mechanical properties, i.e. tensile modulus, and orientation dependent dimensional stability. This data was developed from careful process-structure-property relationship studies on polypropylene PE, PET and other fibers. Correlation of DSC events with TMA and DMA data, supported by a variety of mechanical testing, optical and X-Ray diffraction techniques allowed the generation of a model of polymer morphology as a function of stress applied prior to crystallization; a model that has remained useful over the decades and that contributed to the commercialization of a number of products and processes including Celgard® microporous membranes, HMLS tire yarn and high performance LCP fibers.

Influence of Molecular Orientation on Crystallization Behavior of Poly(ethylene terephthalate) Measured by Fast Scanning DSC

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It is well known that the crystallization rate of polymeric materials increases significantly with the development of molecular orientation. With the aim of conducting the quantitative analysis of the crystallization rate of uniaxially oriented poly(ethylene terephthalate) (PET) fibers and biaxially oriented PET films, differential scanning calorimetry (DSC) measurements were carried out at various heating rates using a conventional DSC along with a fast scanning DSC, with which measurements at heating rates higher than 1000 K/s was possible.

Cold crystallization temperature (Tc) is known to decrease with the increase of molecular orientation and decrease of heating rate. When the conventional DSC was applied for the samples with high molecular orientation, cold crystallization proceeded immediately above the glass transition temperature (Tg). Accordingly, quantitative analysis of crystallization rate was not possible.

When the fast scanning DSC was applied for those samples, there was a significant fluctuation in the thermograms near Tg because of the shrinkage of samples. In the measurements of single PET filaments, it was found that the fluctuation decreases with the reduction of filament length. When the length was less than 45 μm, the thermograms were stabilized, however, sensitivity of the chip sensor was not good enough for the detection of cold crystallization.

To overcome this problem, pre-thermal treatment was applied to the samples on the chip sensor at heating and cooling rates of plus and minus 2000 K/s up to the temperature of 120 ^{o}C. After this treatment, shrinkage of the samples proceeded whereas there was no significant occurrence of crystallization. In the subsequent measurements at various heating rates, the base-line shift of glass transition and the exothermic heat of cold crystallization were clearly observed. Time versus temperature program with pre-thermal treatment for analysis of cold crystallization is shown in Fig.1, and typical example of the thermograms obtained at various heating rates are shown in Fig.2.

Application of this pre-thermal treatment technique to the samples of various degrees of molecular orientation enabled us to evaluate quantitatively the effect of molecular orientation on crystallization rate. It was found that, even after shrinkage and loss of birefringence by the pre-thermal treatment, the uniaxially oriented sample with the orientation factor of 0.34 and biaxially oriented sample with the orientation factor of 0.53 showed the crystallization rate about 1000 times faster than that for the unoriented sample.

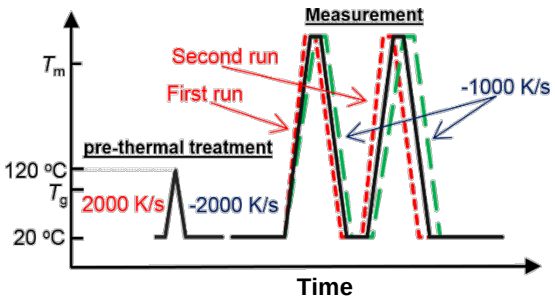

Fig. 1: Time-temperature profiles for analysis of cold-crystallization behavior of oriented PET fibers and films.

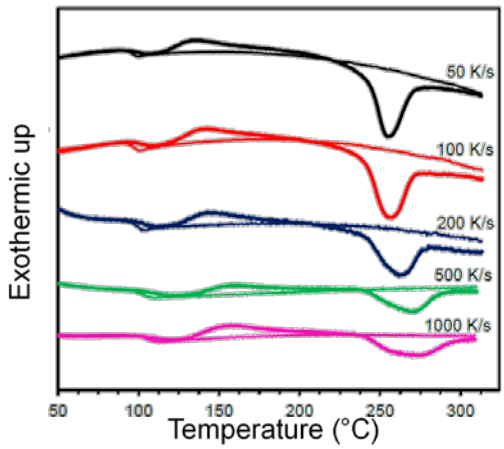

Fig. 2: Fast scanning DSC thermograms for PET films stretched to the draw ratio of 2.5×2.5. Measurement was conducted after pre-thermal treatment shown in Fig.1. Thick and thin lines at each heating rate represent thermograms of the first and second runs, respectively.

Touch-spinning and Magnetospinning of Nano- and Microfibers

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We introduce simple and controllable approaches for drawing single filament nanofibers from polymer solutions or melts. *Touch-spinning*[1] is an inexpensive and scalable method that eliminates the effects of dielectric properties of polymer solutions associated with electrospinning. A rotating rod or a set of rods can be applied to draw the fiber from a droplet of polymer solution. The resulting fiber diameter is controlled precisely in the range of 0.04-5 μm by adjusting the rotational speed and polymer concentration. The spinning setup can be used to wind a single filament into unidirectional, orthogonal or randomly oriented 2D and 3D meshes with controlled density. Touch-spinning offer opportunities beyond 3D printing due to the controllable fiber diameter and a several orders of magnitude greater speed of scaffold fabrication. This method can be implemented in the laboratory and industrial manufacturing

In *magnetospinning*[2], a setup almost similar to touch-spinning is used for the preparation of the nano- and microfibers, however, a colloidal dispersion of the stabilized magnetic nanoparticles is involved in the process. This technique uses an external magnetic field to provide a continuous drawing of the fibers with highly controlled diameter in the range of 0.05–20 μm. Magnetospinning can be used to fabricate the non-magnetic and highly loaded magnetic micro and nanofibers, including biopolymer, Teflon©, porous, or composite nanofibers from various polymers and polymer composites. Also, the fibrous mats can be used to create scaffolds for tissue engineering.

The *two-droplet reactive magnetospinning*[3] is one of the magnetospinning applications to fabricate the nano- and microfibers that involve very fast diffusion-limited chemical reactions and ion exchange. This approach can be applied for two miscible or two immiscible liquids, each with their own merits. The technique is based on the magnetic field-directed collision of the ferrofluid droplets with the liquid droplets that contain complementary reactants. The collision, beginning of the chemical reaction, and fiber drawing are self-synchronized. This technique is used to synthesize, cross-link, and chemically modify the fiber-forming polymers in the stage of fiber formation. It also provides new opportunities for the fabrication of magnetic and non-magnetic polymer fibers as scaffolds for other biomedical applications.

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Effect of Crystal Orientation on Cellulose Nanocrystals/Polyvinyl Alcohol-Nanocomposite Fibers Produced by Dry Spinning

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Polyvinyl Alcohol (PVA) is water soluble, semi-crystalline, biodegradable and biocompatible synthetic polymer having wide range of potential applications.[1] PVA based fibers are commonly used in tissue scaffolding, membranes, drug delivery, optics, textile, adhesive, packaging industry, and others. However, PVA fibers have low mechanical strength and are subject to plasticization in humid environments. To overcome such shortcomings, reinforcing fillers like Cellulose Nanocrystals (CNCs) are incorporated. CNCs are renewable and biodegradable rod-like nanoparticles (5-10 nm wide, 50-500 nm in length). They have been widely used as reinforcing fillers due to their unique properties such as high aspect ratio, low density, high mechanical properties, and biocompatibility. In this study, CNC reinforced PVA fibers were dry spun to study the effect of crystal orientation of CNCs within fiber. CNCs display anisotropic mechanical properties (higher elastic modulus in longitudinal axis than transverse axis). Hence, by controlling the orientation of CNCs during dry spinning, higher mechanical properties can be obtained in aligned direction. The degree of orientation along the dry spun fiber axis was analyzed quantitatively by 2D X-ray diffraction using Herman's order parameter. Surface morphology of these fibers was analyzed by scanning electron microscopy (SEM) and optical microscopy. Furthermore, the thermo-mechanical properties were tested by thermal gravimetric analysis (TGA), differential scanning calorimetry (DSC) and dynamic mechanical analysis (DMA).

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Studies in Strain-induced Polymer Crystallization: Joys of Uncovering Simple Relationships in Complex Systems

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Polymers have a strong predilection for disorder - for forming entangled spaghetti-like chaos – and may exist in various states of partial disorder that are difficult to predict or characterize. Yet order, in the form of molecular orientation and crystallization, can be induced in these systems to great effect, by suitable combinations of strain (stress), strain-rate, and temperature. Sorting out the separate and combined effects of the wide range of thermomechanical processes available to entice the emergence of ordered structures from high entropy states can seem daunting. However by focusing on one deformation mechanism - in this case, drawing (stretching) -, and one class of polymers - in this case, amorphous-crystallizable polymers such as poly(ethylene terephthalate) and poly(ethylene naphthalate), - it has been possible through painstaking data collection to reveal simple power law relationships and superposition effects that have remarkable predictive power, and can provide important mechanistic insights at the molecular level.

For example, when the degree of crystallinity is plotted against draw time for any draw temperature in the approximate range Tg to Tg + 30^{o}C, it is found that the effect of changing strain rate is simply to shift the curves along the log-time axis. The shift factor required to superpose the curves is related to stain rate by a power law and the value of the exponent **n** reflects the rate of molecular relaxation at the draw temperature. Moreover, curves of **n** vs. draw temperature at different molecular weights can be superposed. As a result of uncovering these relationships, empirical equations permit prediction of the degree of crystallinity and the crystallization rate for any combination of draw ratio, strain rate, draw temperature and molecular weight. From this type of analysis, additional insights on strain-induced crystallization in amorphous crystallizable polymers will be discussed, including applicability to industrial fiber and film drawing processes.

Synergistic Reinforcement of Regenerated Silk Fibroin Fiber with Graphene Oxide/Titanium Dioxide Hybrid Filler

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Graphene oxide (GO) and titanium dioxide (TiO_2) are good fillers to reinforce polymer materials, respectively. In this work, a hybrid filler of GO and TiO_2 with different weight ratios of GO:TiO_2 and a fixed total weight (0.15%) was used to improve the mechanical properties of regenerated silk fibroin (RSF) fibers. The synergistic effect of the hybrid filler on the secondary structure, crystalline structure and mechanical properties of the RSF fibers were studied. Rheology results of RSF/GO/TiO_2 spinning dope showed that with the increase of weight ratio of GO:TiO_2 in the hybrid fillers, the viscosity of the spinning dope gradually increased. Fourier transform infrared spectroscopy (FTIR) and synchrotron radiation wide-angle X-ray diffraction (WAXD) characterization showed that the β-sheet content, crystallinity and mesophase content of the composite fibers decreased as the weight ratio of GO:TiO_2 increased. This indicates that the two dimensional GO sheets affect the crystallization of RSF more obviously than the one dimensional TiO_2 particles. On the contrary, the TiO_2 provides more contribution to the formation of mesophase than the GO. The orientation of crystalline region and mesophase of the RSF fibers were also improved when the weight ratio of GO:TiO_2 was 2:1. The RSF/GO/TiO_2 fibers exhibited evident improved tensile properties compared with neat RSF fibers. In the case of the 2:1 weight ratio of GO:TiO_2, the breaking strength and initial modulus of the RSF/GO/TiO_2 fibers were significantly improved by 51.6% and 74.4%, respectively, in comparison with neat RSF fibers. The enhanced properties of RSF/GO/TiO_2 was mainly attributed to the synergistic interaction among RSF, GO and TiO_2. The incorporation of hybrid fillers into RSF matrix provides a method to fabricate high performance composite materials with novel functions, such as UV resistance and antibacterial properties.

ACKNOWLEDGMENT

This work is sponsored by the National Natural Science Foundation of China (21274018), “Shuguang Program” supported by Shanghai Education Development Foundation and Shanghai Municipal Education Commission (15SG30), DHU Distinguished Young Professor Program (A201302), and the Fundamental Research Funds for the Central Universities.

Clothing and Textile Comfort

A Novel Female Sweating Thermal Manikin for Thermal Comfort Evaluation

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Thermal manikins simulating human body's thermal regulatory system are essential tools for understanding the heat exchange between human body and the environment and also for evaluating the thermal comfort of clothing and near environment. However, most existing thermal manikins adopt a male's body shape and no sweating female thermal manikin has been reported so far. Furthermore, it is unclear how body shape (viz. male vs female) affects the heat loss and perspiration from the body. We report on a novel female sweating thermal manikin "Wenda". Thermal properties of the nude body and clothing ensembles measured on "Wenda" are compared with those measured on the male manikin "Walter". It was found that, while the larger surface area to volume ratio of the female body reduces the thermal insulation of the nude manikin, it increases the apparent evaporative resistance at the same time. This may be due to the fact that, the curvaceous female body increases the surface still air layer to add resistance to heat loss by conduction and perspiration by diffusion, while the larger surface area significantly increases radiative heat loss when the manikin is naked. It was further shown that, clothing thermal insulation and apparent evaporative resistance measured on Wenda are typically 0~11% higher than those measured on the male sweating fabric manikin-Walter, probably due to the greater clothing microclimate volume on the female manikin resulting from the looser fitting of the garments on the smaller female body and the more curvaceous surface of the female body.

Engineering Design of Knitted Fabrics for Optimal Thermo-physiological Comfort as Well as UV Protection

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Cotton knitted fabrics with typical porous structure are found to be more comfortable as summer wear due to high breathability and permeability. However, in hot climatic condition the porous structure of knitted fabrics leads to less heat transmission through conduction and more exposure of body skin to the dangerous UV rays. Hence, the fabric properties like air permeability, thermal conductivity and UV protection are becoming conflicting in nature. For instance, higher air permeability encompasses low thermal conductivity as well as low UV protection and vice-versa. Therefore, a multi-objective optimization comprising of the simultaneous maximization of air permeability, thermal conductivity and UV protection of a knitted fabric would lead to a set of Pareto optimal solutions which are non-dominating in nature. In this work, an elitist multi-objective evolutionary algorithm based on Non-dominated Sorting Genetic Algorithm (NSGA II) has been used for the purpose of optimization.

An optimization problem requires mathematical relationship between decisive controllable factors and the objective functions. Yarns spun with 100% cotton fibres were used to prepare single-jersey knitted fabric samples by choosing four controllable factors, namely loop-length, carriage-speed, yarn-input-tension and yarn-count, each at three different levels. Total 36 single-jersey fabric samples were prepared in a 12 gauge computerized flat knitting machine as per 4-factor-3-level orthogonal block Box and Behnken experimental design.

All samples were properly conditioned and subsequently evaluated for air-permeability, thermal-conductivity and UV protection. Using the experimental results, the quadratic regression equation for each response variable as a function of the controllable factors were constructed by least-square method. In the fitted regression equations only the regression coefficients which are statistically significant at 95% confidence limit were considered.

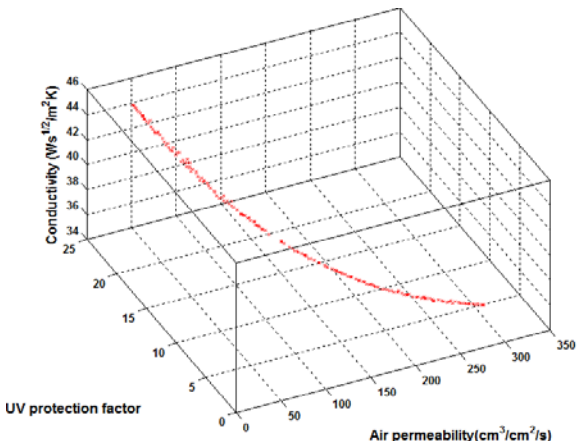

Figure 1: Pareto optimal front for air permeability, thermal conductivity, and UV protection factor.

Figure 1 shows the Pareto optimal front which helps in obtaining the effective controllable factors for engineering design of knitted fabrics with optimal thermo-physiological comfort as well as UV protection. As all solutions in the Pareto front are the optimal solutions, therefore the choice of a particular optimal solution over the others exclusively depends upon the requirement of the end user.

Chemical Protective Clothing Comfort Performance Study: Comfort and Textile Material Fundamental Properties

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Clothing is one of the important means to protect human-beings from hazardous environments. Chemical protective clothing (CPC) is designed to prevent damage to the body and fatalities from the effects of chemical and biological substances. The key issues on CPC performance focus on clothing performance, and heat strain associated with wearing protective materials. The aim of this study is to characterize the CPC comfort performance and textile material fundamental properties. These textile material properties that relate to physical and thermal comfort will provide fundamental data for an evaluation of the thermo-physiological strain and physical burden of CPC made of these materials. Eight types of commercially available CPC were evaluated in this study: Nomex® woven fabric (acting as control for common work wear) (1), Dupont® CPC with Environmental Protection Agency (EPA) designated protection level A (1), level B (2), level C (1), level D (1), and military CPC (2). Among these eight types of CPC textile materials, Nomex® and military CPC are woven fabrics, while CPC from Dupont® are laminated nonwoven fabrics with different layers. The air gap size and distribution developed between clothing and a human body play a critical role in clothing performance, specifically for thermal protective clothing. The thermal insulation of the CPC textile materials were evaluated with no spacer, 3mm air gap spacer, and 6mm air gap spacer. The results (Figure 1) showed that the thermal insulation (R_{cf}) increased as the increase of the air gap size, which indicated that the thermal protective performance of CPC was affected by the air gap. An overall relationship was developed between the CPC comfort and textile material properties. The research findings could provide the technical basis for further development of high performance protective clothing.

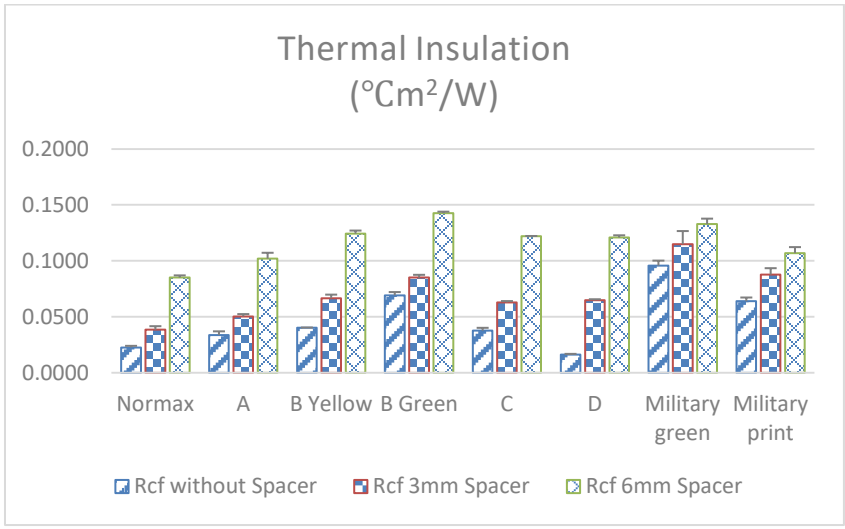

Figure 1. Comparison of thermal insulation (R_{cf}) of CPC textile materials with different air gap sizes.

ACKNOWLEDGMENT
We would like to acknowledge the College of Human Science (CHS) at Iowa State University for the CHS Research Enhancement funding of this project.

Investigation of Value-added Component for Denim Fabrics Based on the Tactile Sensation

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The consumer is looking for some additional values for clothing such as “comfort”, “new” or something unique character for himself or herself. However, the preference of consumer for clothing is very broad and difficult to make target for producers. In this study, the sensory evaluation is conducted in order to investigate new value-added quality aiming at creation of new fabrics.

Sample chosen is denim, which is one of the most popular fabrics in the world. Two categories of fabrics were prepared; (1) Denim and denim-like fabrics made from cotton, high quality wool, cotton/wool blend, cotton/polyester blend and high quality linen, (2) Popular denim fabrics in the recent Japanese market. Physical and mechanical properties were measured using the KES-F system.

In the first sensory evaluation, fifty-five university students including twenty-one oversea students in Japan assessed sample group (1). The Semantic Differential method was used in a manner that each sample was compared to the standard cotton denim (14oz/yd^2). The most preferred sample as “High quality” and “New” was found which made from high quality wool. This sample was also evaluated as “Soft”, “Thin”, “ Flexible” and “Smooth” and bending rigidity is smaller than those of linen and cotton samples.

In the second sensory evaluation using sample group (2) were carried out in Ecole Nationale Supérieures d’Ingénieurs Sud-Alsace (ENSISA) in France and Kyoto Institute of Technology in Japan by 36 students from each institute. Seven samples including standard cotton denim and high quality wool used in the first experiment are included. Table 1 shows the adjectives pairs used. As a result, the “New” was strongly correlated to “Comfortable” for Japanese students, but low correlation for French students. The high extensibility along the fabric weft direction can influence on the comfort evaluation. For French students, “New” was highly correlated with “High quality”. Two samples, which are wool 2/1 twill, and Cotton/Polyester/ PU blend of satin, are regarded as higher ranked in “New” and “High quality”. Both samples were evaluated as soft touch.

Table I: Evaluation adjective pairs

Sensory words for the physical property		
Hard	-	Soft
Thick	-	Thin
Smooth	-	Coarse
Stretch	-	Unstretch
Sensory words for the value		
Beautiful	-	Does not feel beautiful
Comfortable	-	Uncomfortable
Functional	-	Does not feel functional
Attractive	-	Does not feel attractive
High Quality	-	Low Quality
Expensive	-	Cheap
New	-	Old
Stylish	-	Does not feel stylish
Like	-	Dislike

ACKNOWLEGEMENT: We would like to thank all participants to evaluate fabrics. We also thank Prof. Dominique C. ADOLPHE in Ecole Nationale Supérieures d’Ingénieurs Sud-Alsace for his kind assistance. JSPS KAKENHI Grant Numbers 24220012 and 15H01764 supported this work.

Preliminary Results of an Anthropometric Study with Brazilian Women in Portugal Using the Kinect Body Image System

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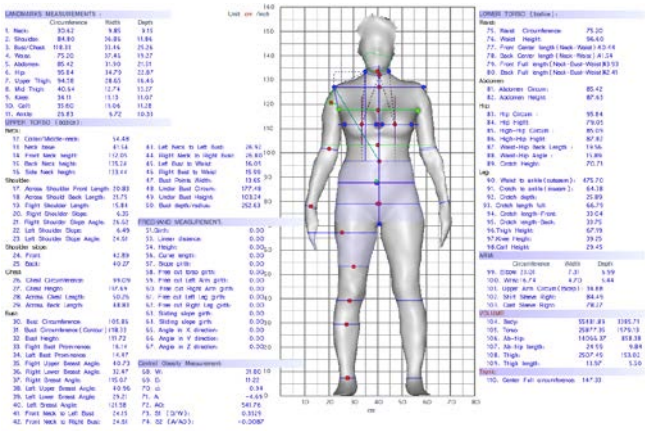
There is a lack of standardization when analyzing the measurements used in pattern design by the Brazilian fashion industry. This project aims to achieve an accurate anthropometric study of the Brazilian women living in Portugal, using a 3D body scanner. The currently available data is insufficient, with relevant differences for the same body measurements.

Kinect Body Image (*KBI*) was the technological device used in the experiment. It scans the human body using four *Microsoft Kinects*, producing a 3D surface, in less than one second.



When the 3D body shape is captured, landmarks and body dimensions are automatically determined. A software translates them in handle information for further treatment and analysis. The scanning result is a virtual manikin image, with the landmarks and a list of the measurements collected for the different parts of the body.

This preliminary study involved the scanning of a sample of 60 Brazilian women, residents in the North of Portugal, aged between 20 and 62 years. It was accomplished at University of Minho, in the cities of Braga and Guimaraes, between 15th and 30th of June 2016.

34 measurements were selected for this study, considering their relevance in the industrial pattern design process. Each volunteer was scanned four times and an average value calculated for each variable. Data was collected in the KBI software and exported to a *Microsoft Excel* spreadsheet for analysis and manipulation.

The analysis of the measured variables was stratified in three age groups. The first composed by volunteers aged between 20 and 30 years (23 participants), the second between 31 and 45 years (20 participants) and the third between 46 and 62 years (17 participants). This stratification was important due to the biotype differences of the sample.

Overall, results achieved with *KBI system* are satisfactory for collection of measurements needed for pattern design process of clothing for the average body types of Brazilian women. However, this preliminary study enhanced the importance of using a larger sample in each age group, considering also different physical body types. Thusincreasing the accuracy of the study in providing relevant data for the industry aiming this market.

ACKNOWLEDGMENT: This work is financed by FEDER funds through the Competitive Factors Operational Program (COMPETE) POCI-01-0145-FEDER-007136 and by national funds through FCT-Portuguese Foundation for Science and Technology, under the project UID/CTM/000264.

A Comparative Analysis for Water Absorption and Transport Test Measurement for Fabrics

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Water absorption and transport properties are critical not only to the success of wet processes, but also to the wear comfort, especially for sportswear, hygiene products and protective clothing. In the textile industry, there are a variety of measurement methods varying in amount and way of water supplied, measurement technique and mechanisms. Image-analysis, optical, gravimetrical or electrical technique were commonly used while spectroscopic technique, like X-ray microtomography and nuclear magnetic resonance, was employed in rare cases due to its high cost. Here, water absorption and transport properties of fabrics with different geometry and hydrophilicity were characterized by a number of conventional tests and two recently developed water transport testers: Spontaneous Uptake Water Transport Tester (SUWTT) and Forced Flow Water Transport Tester (FFWTT). Testing principle of these test methods is briefly outlined while their accuracy, efficiency, versatility, reproducibility, sensitivity and validity are systematically compared. The results suggest that SUWTT and FFWTT have superior performance in terms of information provided, testing time, reproducibility, sensitivity and validity to subjective wetness sensation. All in all, the current study can help fabric engineers or hygiene product developers to choose the most suitable water absorption and transport test method based on their product requirements and resource availability.

Study of the Thermal Comfort of Mattress Using Supine Thermal Manikin

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This paper studied the thermal comfort of mattress using supine thermal manikin. In general, a person normally spends 1/3 of life time on sleeping. Therefore, sleeping comfort would significant affect the quality of life. For evaluating the comfort of sleeping, thermal comfort is one of the key factors. In order to obtain objective evaluation, using supine thermal manikin is a viable option. However, a majority of thermal manikin is made of plastic or metal in hollow structure, it may not totally reflect compression effect of weight on mattress. As a result, in this research, a manikin with weight of 75kg was used for studying the thermal comfort of mattress, which can simulate a more realistic compression due to body weight on mattress. Both thermal insulation and evaporative resistance were measured in this study for evaluating the thermal comfort of mattress. By combining the thermal insulation and evaporative resistance, permeability index of mattress is calculated and reported in this study at the same time, which is a useful index for indicating the thermal comfort of mattress with the consideration of both heat loss and mass loss. Five mattresses were tested in this research. Each sample was tested for three times and the duration of each test was 8 hours. The result indicated that a mattress with the design of parallel concave or trough-like feature on the surface of mattress could help to reduce the evaporative resistance, and thus could enhance the thermal comfort of mattress.

Children's Apparel for Medical Accommodations: Designed for Use with Pump, Catheter, or Port

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Children who are required to use a pump, catheter, or port or similar medical devices due to a specific health condition such as diabetes, treatment for cancer, and/or heart conditions can feel stigmatized due to the obvious presence of such a device. The assumption is that normal-appearing clothing will help make these conditions more bearable and positively impact the children's self-esteem. A survey of the market reveals that there is limited market availability of apparel that combines functional and aesthetic aspects of clothing and, at the same time, would accommodate the need for concealing medical devices and therefore allowing for a normal appearance for these children.

The purpose of this study is to evaluate the market need for such clothing and explore the perception among parents and other caretakers, not just of the market need, but details such as price point, types of modifications, and the desirability of branding of modified apparel.

This project has been designed in three phases: 1) extensive interviews with a small number of parents whose children are required to use such a medical device, 2) the development of attractive prototype garments of 100% cotton with slits or pouches to accommodate the medical devices without being noticeable and to eliminate the possibility of static charge that could interfere with the equipment, and 3) the development of a questionnaire in both English and Spanish to be given to parents and caregivers of these children to identify and define the need. Phases 1 and 2 have been completed and current work is being conducted on Phase 3.

Prototype garments will be presented as examples of the types of apparel that could be developed to meet this need. The questionnaire will be administered to contacts made through hospitals and clinics in Harris and Montgomery Counties in Texas. The questionnaire, in addition to exploring the need for such apparel, will also identify whether there is a desire for branded apparel among this population and will identify the price point that would be acceptable to the consumer.

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Anthropometric Data Collection of Portuguese Children with Overweight and Obesity

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This paper presents the applied methodology to collect anthropometric data of children with overweight and obesity from 4 to 11 years old, of both sex, residents in northern Portugal. The methodology is part of a research being developed in a PhD program in Textile Engineering at University of Minho. The research is motivated by the considerable increase of childhood obesity since the beginning of the XXI century. In parallel with this, it starts from the recognition that clothing industries are not prepared to offer products with fashion features and appropriate ergonomic modeling measures for these children, and that the majority of published studies in ergonomics and anthropometry fields are not focused on this population. Therefore, the research aims to develop appropriate clothing to meet ergonomic needs of that child population through an anthropometric study, using the 3D body scanning technology. The research nature is defined as an applied research with a descriptive and exploratory study. The research departs from a literature review on size charts and anthropometric studies. Data collection is performed through anthropometric measurement of children and application of semi-structured questionnaires, and data analysis include the comparison of data collected and the development of specific size charts for children with overweight and obesity. A fashion collection is planned to be deployed in order to validate research findings.

The developed methodology comprises the following main steps: development of strategies to gain access with elementary schools; establishment of formal contacts and meetings with principals to present the research goals; obtaining of parental consent; assembling and calibration of 3D body scanning equipment; development of the protocol to collect children anthropometric data; data treatment for further analysis. Regarding ethics issues and to avoid a possible source of psychological abuse by peers, all child of same classrooms are measured, without distinction of overweight or obese ones. In conclusion, a discussion of main challenges encountered during anthropometric data collection is presented.

KEYWORDS: anthropometry, overweight and obesity, 3D body scanning.

Recovering Hydrophilicity of Wrinkle-free Cotton Fabric via Nanoparticle Treatment

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Nowadays, there's a high demand of wrinkle-free garments for natural looking and comfort. The conventional wrinkle-free finishing is based on the cross-linking reaction between cotton fabric and the formaldehyde based reagents such as dimethyloldihydroxyethyleneurea (DMDHEU). The DMDHEU reacts with hydroxyl (–OH) group on cotton which increases wrinkle-resistance and shape retention. However, the finishing contrarily reduces the hydrophilicity of the fabric due to the reducing of number of –OH groups; consequently, it weakens the moisture sorption capacity and wicking properties, as well as the comfort of the clothing. Therefore, recovering the hydrophilicity of wrinkle-free finished cotton is one of the urgent needs in the fabric market.

In this work, we demonstrate progress towards that goal—surface modifying the wrinkle-free cotton fabrics by hydrophilic silica nanoparticles. The nanoparticles were anchored on the fabric via electrostatic interaction with the hydrophilic sites on the surface created by plasma pre-treatment. By tuning the treatment conditions, we turned the hydrophobic wrinkle-free fabric to be superhydrophilic. The superhydrophilicity was durable after several months and 20 cycles of washing. Besides, the wrinkle-free and handling performance still retained after treatment. Therefore, we believe this is a reliable method to recover the hydrophilicity and comfort of the wrinkle-free cotton fabric.

Nanofibers and Energy

Ultralight Nanofiber-assembled Cellular Aerogels with Superelasticity and Multifunctionality

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Three-dimensional nanofibrous aerogels (NFAs) that are both highly compressible and resilient would have broad technological implications for areas ranging from electrical devices and bioengineering to damping materials, but creating such NFAs has proven extremely challenging. Here, we report a novel strategy to create fibrous, isotropically-bonded elastic reconstructed (FIBER) NFAs with a hierarchical cellular structure and superelasticity by combining electrospun nanofibers and the freeze-shaping technique.[1] Our approach, for the first time, causes the intrinsically lamellar deposited electrospun nanofibers to assemble into bulk aerogels with tunable densities and desirable shapes on a large scale. The resulting FIBER NFAs exhibit densities of > 0.12 mg cm^{-3} (the lightest materials ever reported), rapid recovery from 80% compression strain, energy absorption similar to elastomers, efficient sound absorption and elasticity-responsive conductivity (Figure 1).[2,3] The successful synthesis of such fascinating materials may provide new insight into the design and development of multifunctional NFAs for various applications.

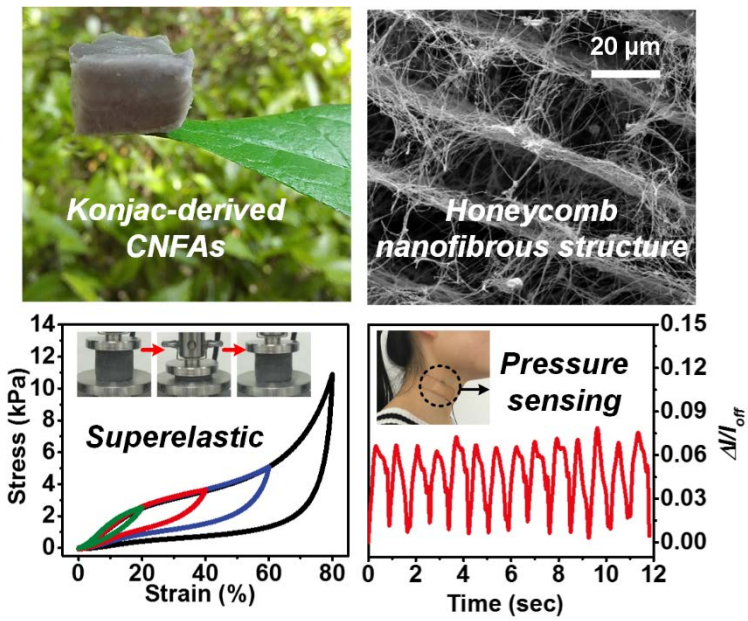

Figure 1. Ultralight and superelastic nanofibrous aerogels can detect dynamic pressure with a wide pressure range and high sensitivity, which enable to monitor in real time and in situ real pressure signals such as human blood pulses.

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Facile Synthesis of Highly Carboxylated Electrospun Nanofibrous Membranes for Efficient Protein Adsorption

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Fabricating protein adsorbents with high adsorption capacity and appreciable throughput is extremely important and highly desired for the separation and purification of protein products in the biomedical and pharmaceutical industries, yet still remains a great challenge. Herein, we demonstrate the synthesis of a novel protein adsorbent by in situ modifying the eletrospun ethylene-vinyl alcohol (EVOH) nanofibrous membranes (NFM) with critic acid (CCA). Taking advantage of the properties of large specific surface area, highly tortuous open-porous structure, abundant active carboxyl groups, superior chemical stability, and robust mechanical strength, the obtained CCA-grafted EVOH NFM (EVOH-CCA NFM) present an excellent integrated protein adsorption performance with a high capacity of 284 mg g^{-1} towards the positively charged template protein of lysozyme, fast equilibrium time of 6 h, ease of elution, and good reusability. Meanwhile, the adsorption performance of the EVOH-CCA NFM can be optimized by regulating buffer pH, ionic strength and radius, and initial concentration of protein solutions. More importantly, the obtained protein adsorbents showed an excellent dynamic binding efficiency of 250 mg g^{-1} solely driven by the gravity of protein solution, which matches well with the demands of the high yield and energy conservation in the actual protein purification process. Furthermore, the resultant EVOH-CCA NFM also possess unique selectivity for positively charged proteins. Significantly, the successful synthesis of such intriguing and economic EVOH-CCA NFM may provide a promising candidate for the next generation of protein adsorbents for rapid, massive, and cost-effective separation and purification of proteins.

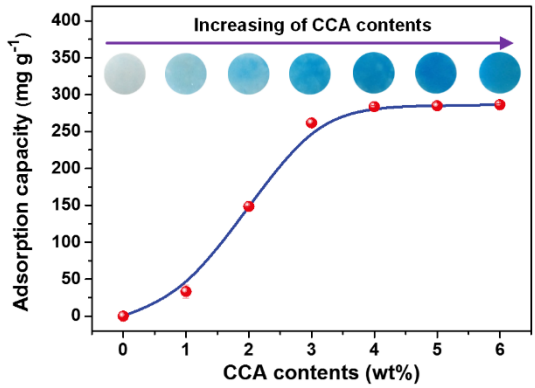

Figure 1. Adsorption capacities of EVOH-CCA NFM modified with various contents of CCA within adsorption time of 12 h. The insets are the corresponding photographs of membranes colored by coomassie brilliant blue after saturation adsorption of lysozyme.

Superwetting Hierarchical Porous Silica Nanofibrous Membranes for Oil/Water Microemulsion Separation

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Creating a practical and energy-efficient method with high efficiency to separate oil-in-water emulsion, especially those stabilized by surfactants, has proven to be extremely challenging. To overcome this challenge, a novel and scalable strategy was developed for the synthesis of superhydrophilic and prewetted oleophobic nanofibrous membranes by a facile in situ synthesis method. The as-prepared membranes have shown superhydrophilicity with ultralow time of wetting and promising oleophobicity to achieve effective separation for oil-in-water emulsions. These new membranes having a good mechanical strength have shown an extremely high flux of 2237 L m^{-2} h^{-1} with extremely high separation efficiency. More importantly, the membranes exhibit excellent antifouling properties for long term use and good thermal stability, thus making them important candidates for treating wastewater produced in industry and daily life. Such membranes are also ideal for high viscosity oil purification such as purification of crude oil.

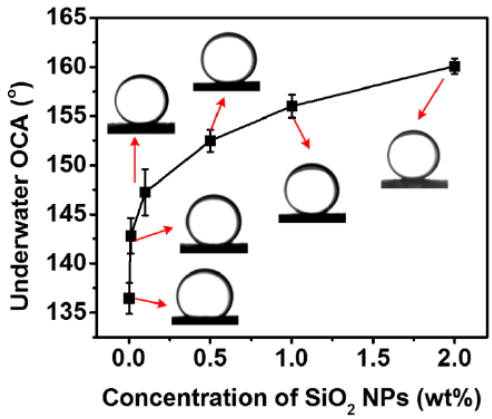

Figure 1. Variation of the underwater OCA of the membranes with increasing of SiO_2 NP concentrations.

Electrospun Carbon Nanofibers for Electrochemical Biosensing and Energy Storage

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Fibrous carbon materials have attracted widespread attention, both fundamentally and for practical applications. Recently, electrospinning of certain polymers (e.g., polyacrylonitrile (PAN)) followed by thermal treatment emerges as a simple, efficient and scalable method to generate electrospun carbon nanofibers (ECNFs). Electrospinning has the advantages of simplicity, low cost, and high reproducibility. Elucidation of structure-property relationships governs and expands the utility of the ECNF material system. The structural modulation strategies of ECNFs have been reviewed comprehensively by Inagakiet al. The common strategy to control the structures and properties of ECNFs is to incorporate functional ingredients such as nanoparticles and carbon nanotubes (CNTs).

In contrast, in this work, we focus on manipulation of the intrinsic electrochemical activities of PAN-derived turbostratic ECNFs through control of synthesis conditions and post-treatment, without using additional noncarbon components. First, we examine the effects of the carbonization temperature on the densities of electronic states (DOS) and electrochemical sensitivities of ECNFs, and demonstrate ultrawide-range sensing using continuous high-DOS ECNFs. Second, we investigate the effects of microwave-assisted oxidation on the surface chemistry and electronic structure of turbostratic ECNFs with abundant edge sites, and study the relationship between the oxidation degree of the ECNFs and their electrocapacitive energy storage capabilities. This work aims to provide valuable insights into controlled modulation of the microstructural, electronic, and electrochemical properties of PAN-derived ECNFs. Notably, carbon-based devices (e.g., sensors, electrocatalysts, supercapacitors, and batteries) share electrochemical similarities to a high degree, and several carbon structural modulation strategies apply generally to each application area. Therefore, the methods reported here and the knowledge on the structure regulation process are potentially applicable to a wide range of carbonaceous materials for a variety of important electrochemical applications.

Synthesis of Lithium Ion-Sieve Nanoparticles and Evaluation of Li^+ Adsorption

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INTRODUCTION

The increase in lithium demand is driven in many industries, most prominently is its use in electric cars for batteries. Lithium can be extracted from salt brine then processed to obtain lithium carbonates to produce various lithium compounds. Recent studies suggest an effective method utilizes ion-sieve adsorbents that selectively extract lithium from water containing Li^+. The work described here focuses on the synthesis of lithium ion-sieve absorbents that has demonstrated excellent adsorption rate (67.5% by weight) in synthetic brine water.

MATERIALS AND METHODS

Synthesis of Lithium Ion-Sieve Nanoparticles: Lithium ion-sieve was prepared using the method described in Figure 1. The microstructures of the ion-sieve were evaluated using a scanning electron microscopy (SEM).

Lithium Ion Adsorption Measurement: 90 mg ion-sieve nanoparticles were stirred into a 1mM/L lithium hydroxide aqueous solution. 11 clear solution samples (6 ml/each) were taken at t = 0 to t = 10 hours. Adsorption of the lithium ion-sieve was evaluated by the concentrations of these samples which were measured using an inductively couple plasma-mass spectrometer (ICP-MS).

RESULTS AND DISCUSSION

SEM images of the ion-sieve nanoparticles are shown in Figure 2 depict spherical bundles of rod like structures. The adsorption measurements are shown in Figure 3. The adsorption was significant at t = 5 minutes (67.5%). The change of the adsorption after 5 minutes was small. Although there were fluctuating values of absorbance was 14.91 mg L^{-1}(69.5%) after 10 hours. The results show that the ion-sieve has a high adsorption for Li^+, which demonstrated the potential of lithium extraction application.

CONCLUSION AND FUTURE WORK

Ion-sieve created by importing the template ion lithium, having similar characteristics to lithium. Making it easier for the template ion to get in enables the compound to be highly selective to remove Li^+ from other ions in aqueous solution. The final absorbance of 69.5% shows that the ion-sieve can be used effectively adsorbing Li^+ from aqueous solutions. For future work, incorporating the lithium ion-sieve nanoparticle into polyacrylonitrile / dimethyl fluoride fabric to capture Li^+ in brine water for an effective lithium recovery. Two different methods, one of incorporating ion-sieve into electro-spinning. Second synthesizing the ion-sieve onto the fiber by incorporating the nano-fiber into the hydrothermal method.

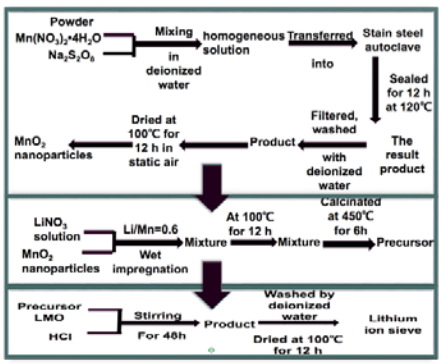

Figure 1. Synthesis of Lithium Ion-Sieve Nanoparticles.

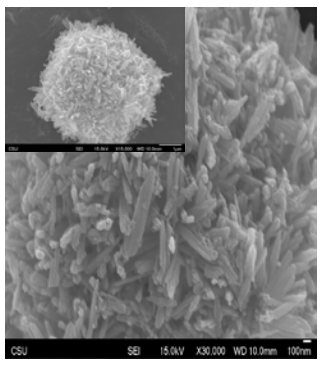

Figure 2. The SEM images size of the particles are uniform (4-5 μm).

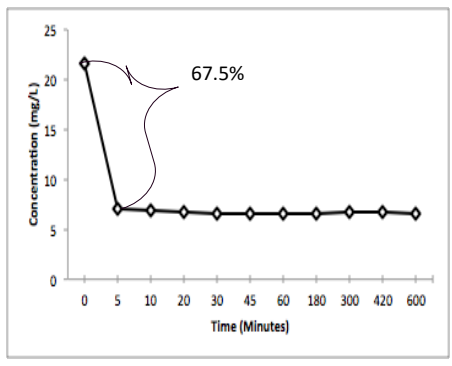

Figure 3. The initial concentration of Li^+ was 21.59 mg/L. 67.5% adsorption after 5 minutes. When t= 10 hours adsorption was 69.5%.

Polyacrylonitrile/Polymer-derived Ceramic Co-continuous Nanofiber Membranes via Room-curable Organopolysilazane for Improved Lithium Ion Battery Performance

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This work will demonstrate how the presence of ceramics can alter the electrochemical performance of non-woven membranes used in lithium ion batteries. Polyacrylonitrile (PAN) and ambient temperature curable organopolysiloxazane (OPSZ) were combined to successfully fabricate PAN/polymer derived ceramic (PDC) hybrid nanofiber separator using a single-step electrospinning process. The amount of added precursor was varied from 10 to 30 percent to characterize the effects of various loadings on the mechanical, thermal properties and electrochemical performance on the hybrid membranes. TEM images reveal all composite fibers have a thin (~ 5nm) ceramic-rich sheath layer surrounding each fiber. In addition, there is also ceramic present inside the fiber with the ceramic forming continuous network within the nanofiber at high concentrations. The interconnected ceramic network within the fiber disrupts the polymers ability to properly crystallize, leading to an increase in amorphous regions with an increase in ceramic inclusion. The presence of the ceramic on the surface of the membrane in addition to the increased amorphous regions leads to excellent ionic conductivity and cycling performance. The 30 wt% PDC sample has an ionic conductivity of 1.05 mS/cm compared to 0.29 mS/cm of pristine PAN separator. All separators with additional PDC content showed increased initial capacity and capacity retention at 0.2C charging and discharging rate; with the 90:10 wt%, 80:20 wt%, and 70:30 wt% of PAN:PDC showing 89%, 90% and 93% capacity retention of graphite/$LiCoO_2$ full cells over 100 cycles, respectively. In rate capability testing, PAN/PDC fibers demonstrated increased capacity retention even at increased charge rates. The results suggest that the increased ionic conductivity and wetting behavior by both the ceramic within the membrane and on the surface of the membrane are more correlated to an increase in capacity retention and rate capability than the porosity.

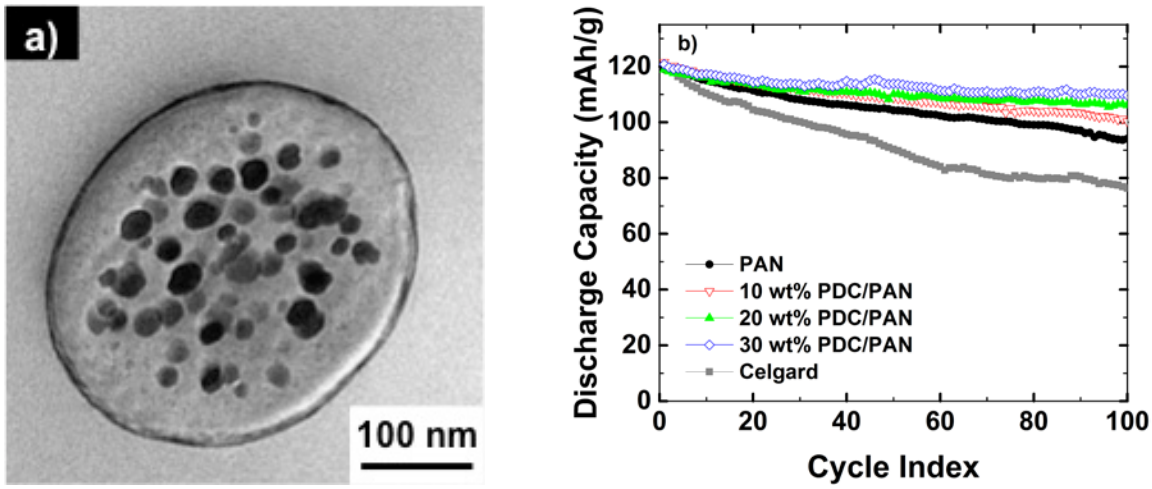

Figure 1: a) TEM images of 30wt% PAN/PDC composite fiber, b) Cycle performance of LiCoO2/graphite full cells with various separator membranes at 0.5C.

ACKNOWLEDGMENT: This work was supported by Axium Nanofiber, LLC and EMD Performance Materials. This work made use of the Cornell Center for Materials Research Shared Facilities which are supported through the NSF MRSEC program (DMR-1120296).

Freestanding Nanofiber Electrodes for Supercapacitors and Batteries

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Fabrication of novel three-dimensional material architectures is essential for development of energy storage devices that allow high rate operation with sufficient energy capacity. After a short description of our group's overall research, I will present our specific work on development of binder-free freestanding nanofiber-based electrodes using a simple electrospinning methodology for application in supercapacitors (EDLC/Pseudocapacitors) and lithium-sulfur batteries. I will also talk about our work on molecular dynamics (MD) simulations to understand the effect of elongational flow, a key characteristic of electrospinning, on assembly within phase separating polymer blends – a material system relevant to the fabrication of nanofiber electrodes.

We have developed porous carbon nanofibers (PCNF) that exhibit specific surface area of >1500 m2/g and multi-levels of pore sizes in the range of micro (< 2 nm), meso (< 50 nm) and macropores (> 50 nm). We studied these materials both as electrodes in electric double layer capacitors (EDLC) (with aqueous and ionic liquid electrolytes) as a platform for polyanilene (PANi) deposition to develop hybrid supercapacitors. The unique combination of pores at different length scales allows us to achieve a battery-like energy density of up to 80 Wh/kg, while retaining high power and cycle life in EDLCs. In-operando infrared spectroelectrochemistry was conducted to understand the transport of ions through the carbon electrode pores and its effect on performance in ionic liquid-based EDLCs. In the hybrid supercapacitor devices, we demonstrated that the PCNF mats retain their EDLC behavior post PANi coating providing excellent electrochemical performance that integrates electric double layer and pseudocapacitive energy storage. We have also investigated the use of nanofiber materials for battery devices – Li-S, Li-O2 and redox flow batteries. In particular, for Li-S battery devices, we have demonstrated a facile methodology to localize soluble polysulfides that results in a high initial discharge capacity and capacity retention during cycling.

Electrospun Polyacrylonitrile/Polystyrene Nanofibrous Membranes Applied in Protein Adsorption Through Hydrophobic Force

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Hyrophobic interaction chromatography (HIC) known as a gentle method for protein purification, provides an alternative chromatographic technique to the most widely used mode. Generally, the HIC column were packed with porous resin beads, which has relatively high adsorption capacity, but with low flow rate and high pressure drops. In order to enhance the adsorption performance, the adsorptive media should have large surface area, and higher porosity, which matches well with nanofibrous materials. Therefore, in this study, polyacrylonitrile/polystyrene (PAN/PS) composite nanofibrous membranes applied in protein adsorption and purification were fabricated by blend electrospinning. Taking advantage of the hydrophobicity of phenyl group on PS and hydrophilicity of nitrile group on PAN, these amphiphilic composite membranes were both available for protein binding and water wetting, and their wettability can be regulated by adjusting the ratio of PAN to PS. Effects of PS/PAN nanofibers' chemical compositions and morphologies on protein adsorption were evaluated. The results showed that the water contact angle reached to the plateau when PS/PAN was 5/95, as well as the protein binding capacity. The morphologies of nanofibers were controled by regulating fibers diameter and surface roughness, and the results showed that the protein binding capacity increased as fibers diameter decreasing, which fitted well with inverse relationship. While, the effect of surface roughness was more complex, which was dependent on microstructures' size and proteins' size. Furthermore, effects of adsorption conditions were also studied, such as sodium sulfate concentration, initial protein concentration, adsorption time and pH value, and by optimizing these conditions, the maximum static binding capacity of bovine serum albumin can reach to 68 mg/g. Moreover, proteins adsorbed on these mats can be released by alcohol aqueous elution buffer. Thus these PAN/PS nanofibrous membranes could be a promising HIC media for effective adsorption of proteins.

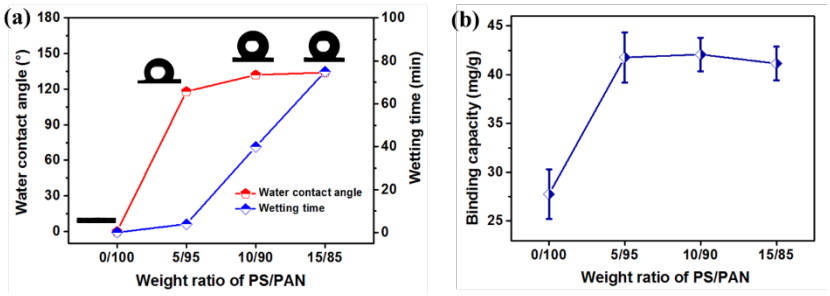

Figure 1. (a) Water contact angle, wettability and (b) protein binding capacity of PS/PAN membranes with different weight ratios and similar fiber diameter.

In Situ Synthesis of Flexible Hierarchical TiO_2 Nanofibrous Membranes with Enhanced Photocatalytic Activity

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Construction of nanoparticle modified titanium dioxide nanofibrous membranes (TiNFs) with a mesoporous and stable nanoparticle-nanofiber composite structure would have significant implication for environmental remediation; however, currently nanoparticle-TiNFs are generally brittle with poor structural integrity upon large deformation; thus, creating flexible, robust, and stable nanoparticle-TiNF composites has proven to be extremely challenging. Herein, we report flexible and hierarchical mesoporous TiO_2 nanoparticle (TiO_2 NP) modified TiNF (TiNFNPs) composites fabricated by the combination of sol–gel electrospinning and in situ polymerization. The electrospun TiNFs served as templates and a synthesized bifunctional benzoxazine (BA-a) was used as a novel carrier and fixative for non-agglomerated growth of TiO_2 NPs. Benefiting from the large surface area, high porosity, homogeneity, stable nanofiber–nanoparticle composite structure, and robust mechanical properties, the as-prepared anatase TiNFNPs exhibited excellent photocatalytic activity towards methylene blue including fast degradation within 30 min, good reversibility in 4 cycles, and easiness of recycling. Moreover, the degradation products have been analysed and TiNFNPs exhibited better photodegradation performance towards methylene blue compared with a commercial catalyst (P25). Significantly, the successful synthesis of such fascinating materials may provide a versatile platform for further development of nanofibrous membrane-based photoreactors towards water and air pollutant treatment.

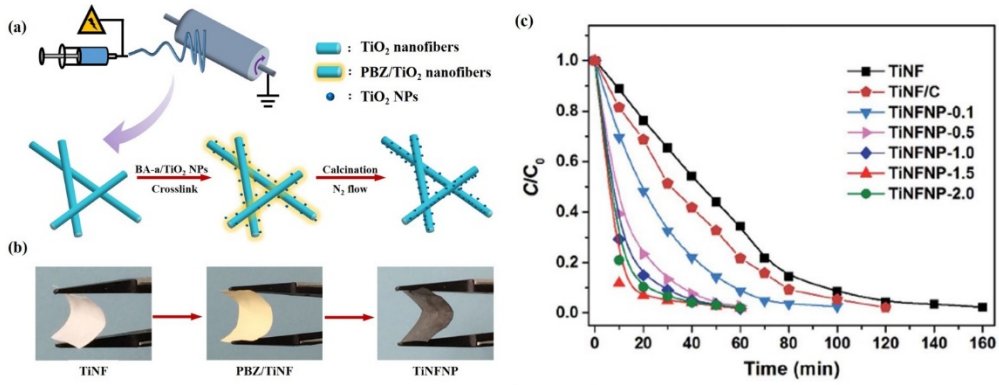

Fig. 1: (a) Schematic illustrating the synthetic pathways of the. TiNFNPs, (b) Optical photographs of TiNFs, PBZ/TiNFs, and TiNFNPs, and (c) Photocatalytic degradation profiles of MB.

Costume, Fashion, and History

Kalamkari Revamping: Traditional vs Conventional Pretreatment Processes

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In bulk scale production, pre-treatment is the very first step in the wet processing of textiles. It includes various methods such as singeing, desizing, scouring, bleaching and mercerization. The objective of pretreatment is to remove natural impurities and increase absorbency of the textile fabric, which helps improving dyeability of the fabric.

The word 'Kalamkari' is derived from two Hindi words 'Kalam' and 'Kari' (or Karigari), 'Kalam' meaning pen and 'Kari' meaning hard work. Kalamkari printing as such painting, therefore, means printing carried out by hand by means of a pen. There are two main styles of Kalamkari, the block printed that is practiced in the town of Machilipatnam and the hand painted style that is largely practiced in the town of Srikalahasti. The block printed kalamkari is commonly seen and used in a variety of lifestyle and home products.

Traditionally in Kalamkari, desizing and bleaching are the only pretreatment processes which are done since ancient times using water and cow dung respectively. In the present study the hand painted style was chosen to study the effect of conventional pretreatment processes on Kalamkari due to its ease of application in comparison to traditional processes. The findings of this study will help to understand the relevance of pretreatments in Kalamkari using traditional natural dyes. The fabric which was pretreated with desizing, scouring and bleaching sequentially using industrially accepted processes displayed unappreciable results as compared to the greige fabric, only desized fabric and only bleached fabric on further painting. It is clear from the study that one can choose either desizing or bleaching or no pretreatment for kalamkari based on final finish requirement. The option of bulk scale established conventional pre-treatment process will offer economical option to the traditional artisans.

KEYWORDS: Kalamkari, traditional prints, pretreatment, bulk scale production

Assessing Fastness Properties of Kalamkari Painted Fabric

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Fashion is a derivative of tradition. Traditions are collages of culture at different times in history. India has a variety of such collages and each piece of the collage contains various art forms that have lived on for generations. One such prolific art form is Kalamkari. Though the traces of this art form date back 5000 years, it was only after the Persian influence in Southern India few hundred years ago was the term Kalamkari coined. Kalam stands for writing aid and Kari stands for art. This art form uses two types of kalams – a flat one for filling in colors and a pointed sharp tipped one for outlines. Kalamkari is generally done on a finely woven cotton fabric as this makes more meticulous craftsmanship possible since delicacy in design depends on the quality of cloth used. This is a tedious method because it involves 17 steps namely dunging, treatment in myrobalan solution, creating design using black ink, painting and washing of each color (red, yellow and blue) and final washing . Also the fastness wasn't a problem earlier as the fabrics were used as art piece rather than a fashion accessory which did not require all the fastnesses to be of high order.

The proliferation of fashion based programmers on the satellite television channels has increased the consciousness of the average Indian masses about the changing trends in the global fashion. Indian ethnic designs are considered as a significant facet for the fashion houses and garment manufacturers all over the world. India also plays a vital role as one of the biggest players in the international fashion arena for fabrics, while sourcing for fashion wear. India's strengths are due to its tradition, hence, in this study an attempt is made to understand the fastness properties of traditionally painted Kalamkari fabric which are hitherto not reported. Fastness properties such as light fastness, washing fastness and rubbing fastness were assessed. Traditionally painted kalamkari fabrics subjected to fastness properties assessment showed excellent results for light fastness whereas unacceptable results for rubbing and washing fastness with reference to fashion industry.

KEYWORDS: Kalamkari, fastness properties, fashion industry, traditional art, cotton

Interdisciplinary Product Development: Leveraging Fiber and Material Development in Technical Apparel

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New fiber and material application play a vital role in developing technical apparel that is innovative and transformative, especially in the sports, protective, and medical markets. The quest for more innovative products is beginning to bring technical apparel designers and material developers closer together throughout the product development process. A clear understanding of how the product development process changes as multiple companies work together, common issues that arise as diverse teams form, and how interdisciplinary alliances improve product innovation at various stages of the product development process are crucial as technical apparel companies seek to advance their product offerings. The purpose of this research was to explore the interdisciplinary product development process for technical apparel.

A case study was conducted for the development of a flexible cool vest in which fiber and material development occurred as a central aspect of the product development process. Five companies worked together in various capacities to create the cool vest. Data was collected from interviews, observations, a site visit, and design development documentation.

Analysis of data and evaluation of the interaction between the five companies demonstrated that elements of interdisciplinary collaboration occur at every stage of the design process and forms of communication had to be altered in order to work across disciplines. This research demonstrated that when technical apparel is developed in interdisciplinary teams, the process is dependent on the industries, companies, people, and product components involved. Figure 1 is a model of the *inputs*, *process*, and *outputs* of the interdisciplinary product development used in the case study. The case study revealed that an interdisciplinary approach to the development of materials and technical apparel products is a way for companies to access new types of knowledge and create strategic alliances to solve more complex design problems.

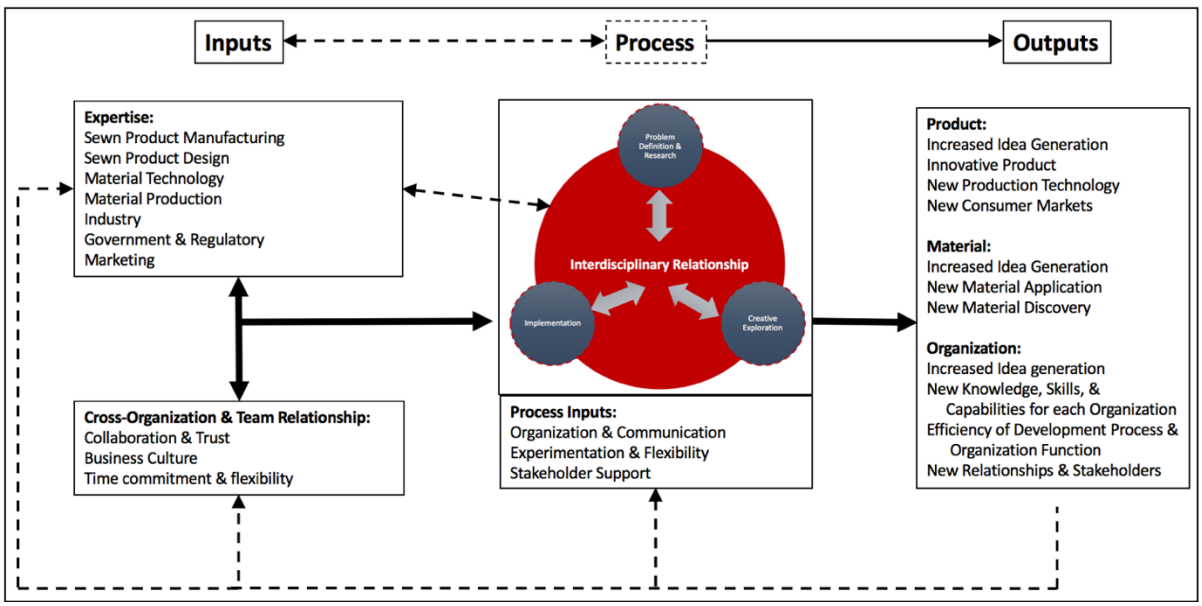

Figure 1. Interdisciplinary Product Development: *Inputs*, *Process*, and *Outputs* Model.

Production of Material Culture in Guatemala

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The back strap loom is a tool that uniquely requires a weaver's body in a way no other loom might. A loom is defined as a tool which creates and maintains tension on threads so that they can be woven. An unseeming bundle of thread and sticks are stretched between body and post; until the body activates the threads they remain inanimate, lifeless. A few iterations of this loom exist in various regions, however my research focuses on the practices conducted by Maya women living in the south highlands of Guatemala. Specifically, the Kaqchikel town of San Antonio Aguas Calientes. For the greater Maya community, the cloth produced with this tool embodies great spiritual and cultural significance. Material symbols of region, class, age, and values are brocaded in the woven fabric of women's blouses. The *huipil*, the blouse worn by Maya women throughout Central America, has been made on the back strap loom displaying regionally specific motifs for centuries. However, the mid 20th Century saw the value of *huipiles* shift from cultural to monetary. Over the summer months of 2016 I conducted ethnographic field research in which I practiced participant observation, conducted interviews, captured documentary footage, and, above all, practiced the craft of back strap loom weaving. Not only observing the physical intimacy between the weaver and their cloth but beginning to understand a process which has been maternally passed down for generations. To weave weft through warp, the weaver tightens and loosens the tension of threads by pushing and pulling her body weight. Her body rocks forward and back as weft threads move from side to side, her cloth manifests itself as a literal extension of her own labor power. Material culture produced while bound to vertical posts act as a language within the Maya community. They tell you both a woman's past and her present. *Huipiles* tell the story of women's work and class struggle in the precarious economy of 21st Century Guatemala.

Technical Apparel

Female Breast Shape Classification Based on Analysis of CAESAR 3D Body Scan Data

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This study explored the variation in female breast shape across the younger (age: 18-45), non-obese (BMI < 30) North American Caucasian population, and proposed a classification method for breast shape. 41 relative measurements, i.e. ratios and angles, were constructed from 66 raw measurements (circumferences, distances, depths, widths, etc.), extracted from 478 CAESAR (Civilian American and European Surface Anthropometry Resource) scans through self-developed Matlab programs. Data were examined through Shiny app for outliers and skewed distribution. 70 subjects were regarded as outliers and were removed. The remaining data were transformed and standardized before further analysis. Multiple data mining techniques, multivariate statistical methods, including Principal component analysis, Cluster analysis, Random forest, Discriminant analysis, MANOVA (Multivariate analysis of variance), were applied to the data. Moreover, an algorithm was proposed to visualize clustering outcomes in the form of side profiles of breasts. With the help of the algorithm, this study was able to compare the grouping results of three most commonly used clustering methods, namely Hierarchical clustering, K-means clustering, and K-medoids clustering. It was found that K-means clustering is the best in giving the most distinctive breast shapes and presenting good stability and repeatability as visualized in side profiles. In the end, breast shapes were categorized into three and five groups by two different cluster number selection criteria proposed by the study: 1) based on misclassification rate; 2) based on Goodness-of-Fit of model. The clustering results also show that six or more clusters can end up with many of the clusters having only minimal differences; and less than three clusters can end up with clusters that have unsatisfactory distinctions, due to the counterbalance of data variation caused by the insufficiency in cluster choices. Furthermore, several of the relative body measurements (two ratios for the three-cluster case, and four ratios for the five-cluster case) were identified to be critical in defining breast shape. The findings and the proposed methods of this study can contribute to the development of improved shape and sizing systems of bra products that work for both manufacturers and consumers. The new methodology developed in this study can also be applied to other types of intimate apparel products where an understanding of body shape plays a key role in body support, comfort and fit.

Adaptive Clothing and Its Application for Female Breast Cancer Patients with Lymphedema

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Adaptive clothing specially designed for those with disabilities is transforming fashion for the differently-abled user. Examples range from modified jeans for wheelchair users to tailored jackets for people with sclerosis. This clothing offers the wearer several functions such as, comfort, a sense of empowerment and independence as well as conformity with society. With an estimated $250 billion industry in the United States for adaptive wear, potential research for people with disabilities is combining the fields of apparel design and fiber science with physical therapy [1]. Some benefits of adaptive clothing for people with disabilities include closure modifications and patterning alterations are used to make it easier to change or remove clothing [2]. These changes are of particular benefit to those with limited range of motion or dexterity in the arms and chest area, as seen with women who have lymphedema resulting from breast cancer surgery.

Our investigation focuses on the use of mechanical compression, advanced textiles and apparel design solutions that aim to provide relief to the wearer as well as aid in the drainage process. Due to the removal or damage of lymph nodes resulting from treatment, it is recommended to "[apply] pressure to the arm, hand, or trunk, the lymph moves in the correct direction [3]." By selectively varying textile properties throughout the design with different structures, fiber content and bonding processes, a functional, variable compression system can deliver targeted pressure precisely where the user needs it. This can prevent range of motion restrictions that are often seen in high compression garments. Another consideration is the need for cooling during the recovery process, which causes many women to place ice packs in the underarm or near the incision area. Fabrics with cooling and moisture wicking qualities also have the potential to provide relief while maximizing comfort, due to less bulk and lower weight. Function, fit and comfort are key factors along with the ease of donning and doffing. With a client-centered design approach, a functional and adaptive garment is created for our user in this case study.

KEYWORDS: Technical Apparel, Fibrous Materials for Biomedical Applications, Clothing and Textile Comfort, Smart Textiles, Adaptive Fashion, Functional Garments, Breast Cancer, Cooling Fabrics, Compression Materials, Disability

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Degradation Mechanisms in Unidirectional UHMWPE Soft Ballistic Inserts

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The long-term stability of materials used in body armor is of the utmost importance to the law enforcement and military communities. While previous studies have examined the effect of ageing on virgin ultra-high molecular weight polyethylene (UHMWPE) fibers on metrics such as oxygen uptake and tensile strength, no one has focused on the unidirectional soft ballistic inserts in which these materials are typically used. In this work, physical and chemical changes in UHMWPE fibers extracted from laboratory aged armor are investigated. Our results suggest that UHMWPE fibers extracted from artificially aged unidirectional soft ballistic inserts have a lower crystallinity and a different morphological distribution compared to fibers extracted from unconditioned ballistic inserts. Examination of the extracted fibers thorough electron microscopy also revealed the formation of kink bands, which are a morphological deformation of several successive bands at an angle of 50° to 60° to the fiber axis. This is a result of plastic deformation mainly attributed to mechanical stress and increased compression of the fibers. Our data also suggests that the oxygen concentration is higher at these kink bands as compared to non-defective areas of the same fiber. To better understand the role of oxygen in the degradation process of these fibers, we have also assessed the oxidation index of fibers extracted from various panels and panel areas of aged and non-aged body armors. This presentation will examine the changes on the physical and chemical structure, as well as the mechanisms of degradation involved in unidirectional soft ballistic inserts containing UHMWPE fibers, as a result of mechanical stress, temperature, and humidity.

Comparison of Stretch and Recovery Properties of Polyester and Polyamide Knitted Fabrics for Compression Sportswear

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Stretchable fabrics have diverse applications ranging from casual apparel to performance sportswear and compression therapy. Application of compression garments in sportswear is one of the emerging field in technical textiles as they dramatically enhance wearer's performance just by wearing it. The objective of the present study is to compare the performance and compression properties of stretchable weft knitted plaited fabrics produced with elastane incorporated polyester and polyamide yarns. Twelve samples each from both these yarns were manufactured in which elastane linear density and ground yarn loop lengths were taken as predictor variables and stretch, recovery, thickness, bursting strength and compression properties were taken as response variables. It was found that elastane incorporated polyamide fabrics showed better elongation and stretch% than elastane incorporated polyester fabrics, however the latter showed better recovery after stretch. Elastane incorporated polyamide fabrics showed better compression properties than elastane incorporated polyester fabrics. Moreover, fabrics produced from higher elastane linear densities showed better stretch and recovery properties than fabrics produced from lower elastane linear densities in both types of yarns. Comparing all results, it can be concluded that the combination of polyamide/polyester as ground yarn along with higher elastane linear density can be used to produce efficient compression sportswear with above 80% stretch and recovery properties. However, polyamide is found to be more suitable for sportswear with somewhat better stretch and recovery properties and ultimately produced better compression on the cylindrical body. The findings of the study may be helpful in deciding appropriate manufacturing specifications of athletics sportswear to attain specific stretch, recovery, and compression properties.

KEYWORDS
Compression garments, Sportswear, Knitted structures, Elastane incorporated yarns

The Fiber Society—A History

The Fiber Society—A History

RECAP

This session will tell the story of the 75-year history of The Fiber Society. The Society had its beginnings in the early 1940s; the Textile Research Institute at Princeton was formed at nearly the same time. The interaction of these two organizations and the meetings on fiber science convened by the Gordon Conferences had a significant impact on fiber science research and development.

The speakers in this session are Michael Ellison, the *de facto* historian for the 75th anniversary, Subhash Batra and Bhuvenesh Goswami, two of the crucial figures in the relatively recent history of the Fiber Society, being very active members of the Society and serving as secretary and treasurer, respectively, for many years, and David Salem, who was at TRI and has knowledge of the mutual support of the two organizations. We are very fortunate to have these gentlemen share their perspectives with us. We will encourage active participation from attendees in this session, so come prepared to comment!

M. Ellison (ellisom@clemson.edu)

The early history of the Fiber Society: Recap of first talk at Mulhouse (Spring 2016) and continuation to 1960 or so.

S. Batra (subhash_batra@ncsu.edu)

Some personal memories, thoughts, and highlights from 2001-2007.

B.C. Goswami (gbhuven@clemson.edu)

The people of TRI, the Fiber Society, and the Gordon Research Conference on Fiber Science: Jack Dillon and Jim Lyons; Julian Jacobs (secretary of TRI who also became secretary/treasurer of the Fiber Society); and, Luddy Rubenfeld (secretary/treasurer for 25 years).

D. Salem (david.salem@sdsmt.edu)

The Textile Research Institute and the Fiber Society: Foundations of Fiber Science Research in the United States.

Posters

Analysis of Water Contact Area on a Superhydrophobic Web

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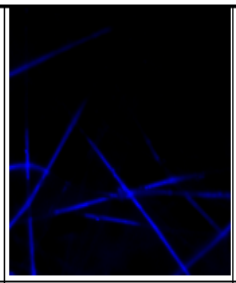
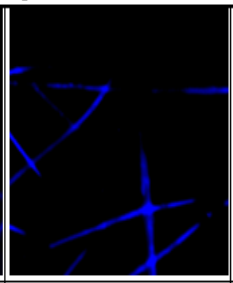
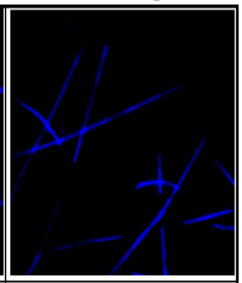
INTRODUCTION: Polystyrene (PS) electrospun web can be used as an excellent substrate for superhydrophobic surface due to its low surface energy (~33 mN/m) and process-ability to form various roughness. As the Cassie-Baxter model explains, the presence of roughness amplifies the intrinsic hydrophobicity/hydrophilicity of materials. Previous studies attempted to predict the solid fraction of the Cassie-Baxter model, which is the fraction of surface area that liquid is in actual contact with, by measuring geometric dimensions of roughening features; however, direct observation of actual contact area between liquid and irregular fibrous surface is limited. In this study, we aim to fabricate superhydrophobic PS nonwoven mats by electrospinning process and vapor deposition of 1H,1H,2H,2H-perfluorodecyltrichlorosilane (PFDTS)and to characterize the solid fraction of the produced web.

APPROACH: PS webs were electrospun under different polymer concentrations and solvent mixtures. PS substrates were treated by air plasma to attach –OH groups before the vapor deposition of PFDTS. Air plasma treatment itself increased the surface energy of PS; however, with PFDTS coating, the surface energy was decreased. The wettability was characterized by contact angle (CA) and sliding angle measurement. The actual wet solid fraction was observed by staining the rough electrospun web with a hydrophobic fluorescent dye, coumarin. The fluorescent microscope images were analyzed in ImageJ.

RESULTS AND DISCUSSION: A smooth surface of PS film showed CA of 95˚. CAs on the electrospun web were greater than that of film due to the increased roughness of the web. The web with grooved fibers achieved CA>150˚. PFDTS deposition lowered the surface energy to about 15.8 mN/m. PS web with PFDTS deposition presented high water contact angle up to 169˚ and low sliding angle about 3˚. For the PFDTS treated electrospun web, CA for liquid with 42 mN/m surface tension was still higher than 150˚. The solid fraction was observed by staining the surface with coumarin. The measured solid fraction corresponded fairly well with the theoretically estimated solid fraction (according to Cassie-Baxter), demonstrating the treated surface follows the Cassie-Baxter wetting state. Further study is recommended to develop an advanced characterization method that visualizes the solid fraction in 3D.

ACKNOWLEDGMENT: This work is supported by 3M Non-Tenured Faculty Grant; USRG from the Kansas State University; and CHE-SRO Award from the Kansas State University.

Table I. Solid fraction measured for PFDTS treated PS and predicted CA: actual CA for this sample was 169˚.

Fluorescence microscopy			
Solid fraction measured from fluoresced area	0.029	0.032	0.036
Contact angle predicted by the above solid fraction	170°	169°	168°

Simple Method of Feather Keratin Extraction and Development of Nanofibers from Feather Waste

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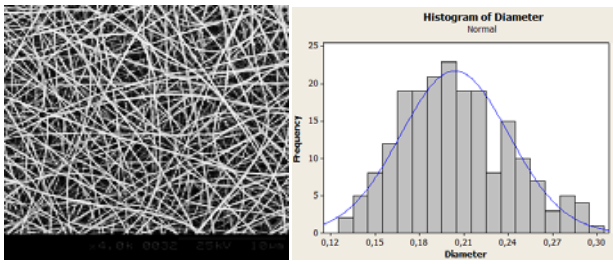
Annually, the poultry industry produces billions of tons of chicken and duck feathers worldwide. Most of these waste products are incinerated in landfills resulting in pollution of atmosphere and land. For these reasons, it was crucial to develop new ideas for commercial applications of feathers and downs as fiber byproducts. Application of biodegradable materials is considered as the most effective solution for a number of the environmental pollution problems caused by synthetic polymers. Feathers are one of the most important potential resources to produce biodegradable materials because they are mainly composed of keratin (91% of β-keratin, 1.3% of fat and 7.7% of water). Recently, keratin has received much attention due to its potential applications in tissue engineering. While silk fibroin, human hair and wool keratin have been adopted for the production of keratin products for most of the time in biomedical materials application, keratin from feathers for biomedical materials has not been described yet and represents an entirely new approach to the generation of feather keratin based on nanomaterials. Electrospinning is one of the techniques to produce nanofibers. This technique is the most widely studied and has also demonstrated the most promising results in terms of tissue engineering applications. Therefore, this paper is focused on the development of a simple, low cost and ecological method of extraction of the keratin from feathers and downs and on the production of nanofibers nonwovens made of this extracted keratin. This investigation has confirmed the characteristics of the infrared absorption spectrum of keratin extracted from chicken and duck feathers. The diameter surface from nanofiber nonwovens was analyzed using a scanning electron microscope and statistical methods were used to validate the analysis. According to the study, we notice that nanofibers have a very good regularity because of their standard deviation of 0.04 and diameter size of 0.20 nm and do not present defects as reported by visual analyses. Nanofibers from feather keratin have a potential to be a recycled product for textile and material industry. Moreover, recycled feathers not only reduce the costs of the final products but also create an environmental movement to develop an eco-friendly circular economy.



(a) (b)

Figure 1. SEM picture of Keratin nanofiber (a) and diameter histogram (b).

ACKNOWLEDGMENT: This work was supported by the *Coordenação de Aperfeiçoamento Pessoal de Nível Superior* under a PhD Grant number 2753138.

Charge-assisted Tailoring and Its Effect on Surface Modification of Chitosan Nanofibers

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Polyelectrolytes are used on a broad scale in various medical applications, because of their unique properties and availability. Nowadays, this group of materials is used for wound dressings, tissue scaffolds or drug delivery systems through various processing methods. The processing of polyelectrolytes using electrospinning technique is fraught with difficulties arising from the excess of charges in the polymer solution, which leads to the instability of the stream due to the large repulsion forces in the polymer jet [1]. An appropriate selection of high voltage polarity on the spinning nozzle can affect the process efficiency and additionally influence the fibers' surface chemistry [2]. Chitosan is an example of a semi-crystalline polysaccharide, which is commonly used in biomedical applications. The protonated amino groups are responsible for the formation of polycations, which subsequently form compounds with natural and synthetic anions [3].

The aim of our research was to investigate the effect of the polarity applied to the spinning nozzle on the spinnability of polycaprolactone/chitosan nanofibers and the concentration of the amino groups on the fibers surface. Moreover, we investigate its effect on further bioinspired surface modification with chondroitin sulfate (CS). Nanofibers with 5-25% w/w of chitosan were studied, applying either negative or positive voltage on the spinning nozzle. This process was followed by a surface modification with chondroitin sulfate using layer-by-layer strategy to create polyelectrolyte complexes. The introduction of synthetic polymer molecules into the solution reduced solution viscosity and improves mechanical properties. Contact angle data indicated the correlation of applied polarity on surface composition in the chitosan blend fibers. For all blends prepared with negative charge on the spinning nozzle, significant increase of wettability is observed comparing to fibers prepared with positive polarity. SEM analysis indicates the effect of polarity on fiber diameter distribution and morphology. Additionally there is no effect of the polarity applied to the needle on PCL crystallinity as shown from DSC analysis. Mechanical tests of fiber mat and AFM analysis also indicate significant effect of polarity on the properties of PCL/chitosan nonwovens.

ACKNOWLEDGMENT: The project was supported by the National Science Centre Grant No. PRELUDIUM 2014/15/N/ST8/03757 and partially by The Kościuszko Foundation.

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Rope Recoil: Analysis and Control Strategy

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Recoil upon failure of a rope or rope-based system is a serious concern spanning many industries and risking both property damage and personal injury. Efforts to control or assess recoil damage often focus on energy absorption within the rope structure. Efforts to address the effect of tensioned rope length on the recoil behavior are less successful. We have assessed this effect from a probabilistic standpoint. This result allows one to determine the minimum length necessary to drive a recoil event and, thereby, assess the effect of design parameters on recoil reduction. This information can be used to better understand the overall safety consideration to be had when using ropes in industry.

We have, furthermore, sought a novel way to control recoil that is not dependent on energy absorption. This alternative recoil reduction method focuses on creating a known failure location in a rope system. With a known failure location and known strength limitation it is then possible to contain the recoil event.

This recoil reduction method has been validated to provide required recoil event warning and recoil event reduction. This method can also be incorporated into existing rope applications with minimal impact. With the threat of recoil danger mitigated, it is possible to ensure a safer and more dependable work environment for both personnel and property.

Towards Accurate Color Prediction of Woven Fabrics: Three-dimensional Structural Modeling

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In the textile industry, accurate predictions of the final colors of woven fabrics from yarn colors at the early design stage can lead to significantly reduced or even eliminated physical sampling, a time consuming and costly process to match the target color, prior to production. Nevertheless, color prediction modeling for woven fabrics so far has been undertaken only to a small extent in academia. In the previous studies, the geometrical and colorimetrical modelings of woven structures were conducted with the use of single-layered fabrics on the assumption that all fabrics have a two-dimensional flat surface. These two-dimensional modelings, however, generally yielded inaccurate color prediction results, especially in lightness and chroma, which are believed to be due to their overlooking the three-dimensional forms of yarns and their intersections of which the higher heights cause shadows on the fabric surface. This paper presents the first part of our comprehensive study on the three-dimensional geometrical and colorimetrical modelings of woven fabrics by using different types of three-dimensional woven structures, single- and double-layered fabrics in various colors.

In total 70 woven samples, single- and double-layered fabrics in 35 colors, were constructed with the use of white yarns for warp and red, yellow, green, and blue yarns for weft. All the yarns were the same polyester yarn with a diameter of 0.175mm. In double-layered samples, the first and second layers were constructed to have the same color, i.e. weft color arrangement, and weave structure, i.e. 1/7 sateen with a thread density of 45x30/cm which was also used for single-layered samples. Thus, theoretically, the second layer does not affect the appearance of the first layer as the second layer is perfectly hidden underneath the first layer with the same color and structural conditions. Based on this assumption, previous two-dimensional color prediction models predict different single- and double-layered samples with the same face layer to have the same physical color attributes (Figure 1). However, the result of spectrophotometric measurements in this study showed that the samples actually have different color attributes with approximately 3 ΔE_{ab}, justifying the need for an accurate three-dimensional modeling of various woven fabrics.

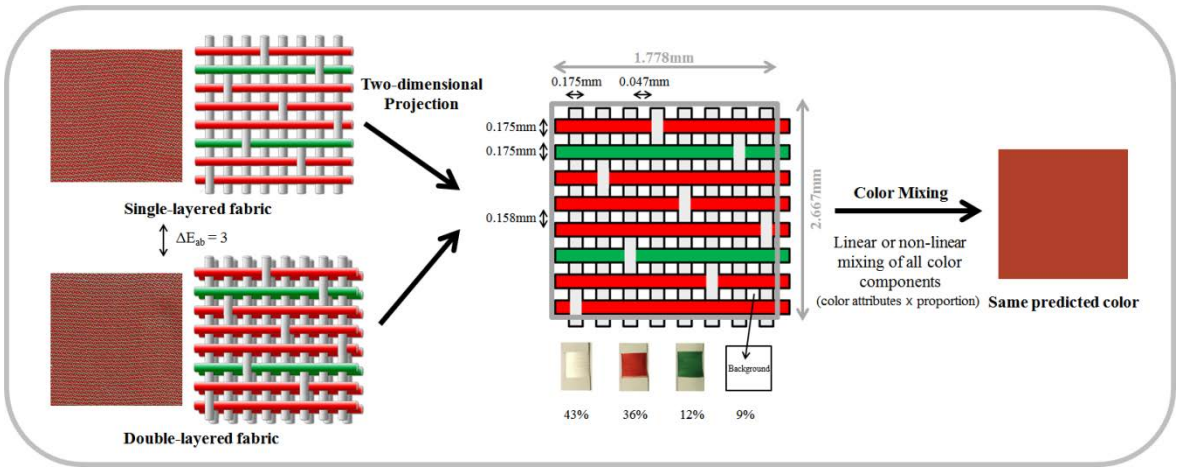

Figure 1. Drawback of using previous two-dimensional color prediction methods for three-dimensional fabrics

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Color and Colorfastness of Nanosilver-treated Cotton by UV Photo Reduction and Chemical Silver Plating Methods

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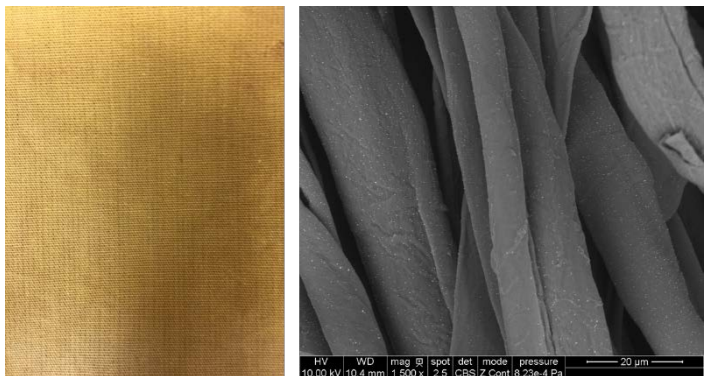
Nanosilver treated fabrics have drawn a lot of attentions because of their unique properties such as antibacterial and UV protective properties. Recently, nanosilver is also claimed to be a future advanced colorant for fabrics such as cotton, silk, and wool because of its unique localized surface plasmon resonance property. The purpose of this study is to examine and compare the color and colorfastness properties of nanosilver treated cotton plain woven fabrics and cotton jersey knit fabrics. UV photo reduction and chemical silver plating treatments were used to apply nanosilver to the cotton fabrics. The color properties such as CIE LAB coordinates (L*, a*, b*, c*, h), color strength (K/S) and light wavelength absorption were examined to identify the color properties of the cotton plain woven fabrics and cotton jersey knit fabrics treated nanosilver by the two methods. The digital camera imaging (Figure 1(a)) and scanning electron microscopy (SEM) imaging (Figure 1 (b)) confirmed the presence of naonsilver on the two types of cotton fabrics. Colorfastness against dry and wet rubbing, washing, perspiration, and light was conducted and evaluated according to AATCC standards. Statistical comparison and analysis was conducted by SPSS 2.



(a) (b)

Figure 1. Cotton plain woven fabrics with nanosilver treatment. (a) Digital camera imaging; (b) SEM imaging.

The Physical Aging of Electrospun PLA/PLA-b-PEG Fibers

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Nanofibers, with high surface area to volume ratio can be ideal substrates for diagnostic devices to detect contaminates in aqueous media. Several characteristics, however, that must be present prior to their function include (i) a hydrophilic nature, (ii) insolubility in aqueous media, (iii) an appropriate functionality to target specific contaminates, and lastly, (iv) a suitable shelf life. Of the characteristics mentioned, shelf life of nanofibers has been the least studied. In this study, nanofibers electrospun from dopes containing high molecular weight poly(lactic acid), (PLA) and PLA-b-poly(ethylene glycol), (PLA-b-PEG) block copolymers electrospun from dimethylformamide are characterized during a forty-eight week aging study. After fibers are electrospun they are placed in a conditioning room at 21˚C at 65% relative humidity to hasten the aging process. As with previous research using these particular spinning dopes, this study finds phase separation of PEG to the fiber's surface is aided by electrospinning. With time very little difference is observed in fiber diameters, however, other characteristics are greatly influenced. The amount of water the fiber is able to wick per gram of sample decreases with time for the copolymers studied until it reaches a fairly constant level that still exceeds the amount of water uptake/gram of PLA fibers. At the beginning of the study, a distinct melting point (T_m) of PEG is present, indicating phase separation of PEG in differential scanning calorimetry measurements. Over time, the melting peak diminishes to the point that the T_m of PEG is no longer differentiable from the PLA glass transition temperature. PLA-b-PEG block copolymers are able to aid in the crystallization of PLA with the shorter block length copolymer aiding in greater crystallization than the longer block length. The PLA crystallinity did not change with aging time. This study concludes that the initial phase separation and crystallization of PEG within the PLA/PLA-b-PEG fibers does not represent the equilibrium morphology of the system. After aging, the fibers equilibrate to a morphology that retains surface hydrophilicity of the fibers suitable for use in diagnostic devices.

Crosslinked Poly(vinyl alcohol) Nanofibers and Textiles

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Crosslinked PVA (poly (vinyl alcohol) has found many uses in applications such as filtration [1][2][3] and drug release substrates [4]. Current literature however has only studied the effect of crosslinking on electrospun PVA fibers. A crosslinked PVA knit textile with a specifically engineered structure could expand the potential usefulness of PVA fibers into applications such as improved fit bandaging or smart textiles. While the level of crosslinking is greatly determined by degree of hydrolysis of the PVA, it was hypothesized that a change in structure of the PVA substrate could be used to affect the level of crosslinking, thus controlling a change in the mechanical properties. A study was conducted to compare the effects of crosslinking on the mechanical properties and material characteristics of PVA substrates produced by machine knitting and electrospinning. Variables include knit structure and tension, level of alignment in electrospun fibers and methods of crosslinking for both. For each PVA sample type, mechanical and material properties were measured for non-crosslinked, glutaraldehyde vapor treated and sebacoyl chloride treated variations.

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Properties of High-tenacity PTT Yarns

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ABSTRACT
Poly trimethylene terephthalate (PTT) is an interesting polyester for textile products, as it has combined physical properties of nylons (PA-6 and Pa-66) and other aromatic polyesters (PET and PBT) [1]. The aim of this study is to examine the effect of horizontal isothermal bath (HIB) method on the structural and mechanical properties of PTT multifilament yarn. To achieve that, characterization methods including differential scanning calorimetry, X-ray diffraction, birefringence, and tensile testing were performed on the treated and untreated yarns. The results showed that the frictional drag of the bath increased the orientation and the crystallinity up to 0.065 and 47.94%, respectively. Drawing the HIB yarn at draw ratio of 1.11 increased the tenacity up to 4.76 g/d and reduced the strain down to 51.76%. The obtained tenacity is greater than the maximum strength (3.3 g/d) reported before.

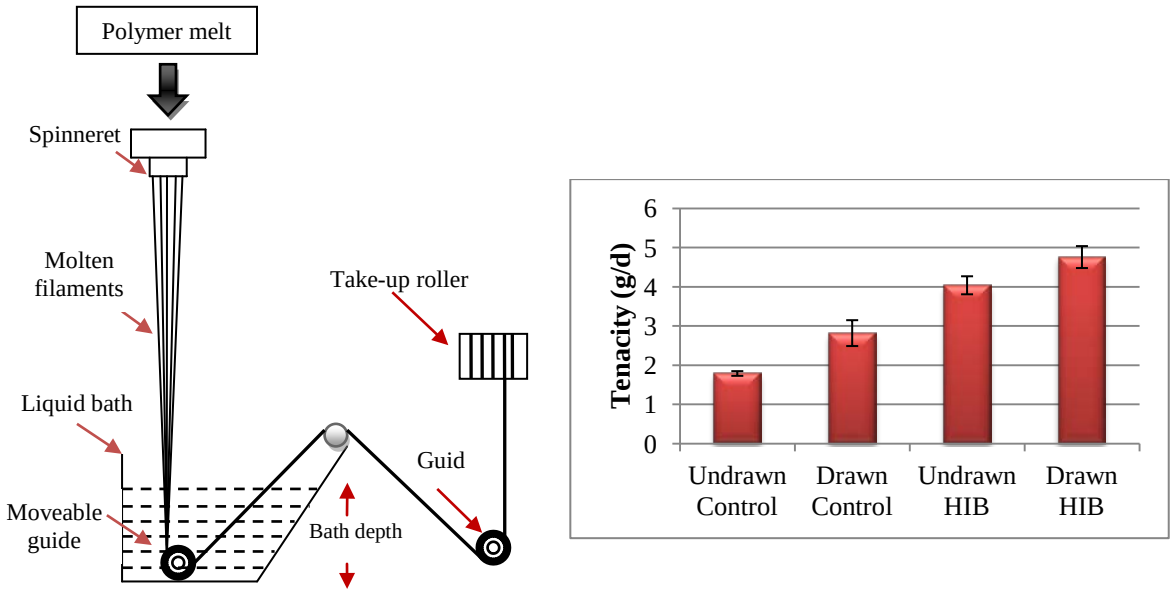

Figure 1. Scheme of horizontal isothermal bath (HIB) method [2] (Left). The tensile strength of undrawn and drawn (DR=1.11) control (no HIB) and HIB fibers (Right).

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Degradation of High-performance Polymeric Fibers: Effects of Sonication, Humidity, and Temperature

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High performance fibers are characterized by properties such as high strength and resistance to chemicals and heat. Due to their outstanding properties, they are used on applications under harsh environments that can degrade and decrease their performance. Fiber degradation due to different chemical and mechanical factors, is a process that begins at a microstructural level. Changes in the polymer's chemical or physical structure can alter their mechanical properties. Knowledge of the structure-properties relationship and the effects of environmental chemical and physical factors over time, is crucial for the improvement and development of high performance fibers.

In this study ballistic fibers of poly(p-phenylene terephthalamide) (PPTA) were studied. Methods of accelerated degradation were used to mimic the wearness of the fibers over long periods of time at a smaller time range. Fibers were subjected to ultrasonication in aqueous solution at pH 7 for up to six hours in order to produce surface damage. Once degraded, properties like the creep behavior of these fibers were studied under a humidity range of 0-80% and temperatures of 30^{o}C and 60^{o}C. Characterization of the chemical and mechanical properties of degraded PPTA fibers were characterized by infrared spectroscopy (FTIR), dynamic mechanical analysis (DMA), and tensile testing to failure.

Fabric-based Soft Actuators for a Soft Robotic Glove

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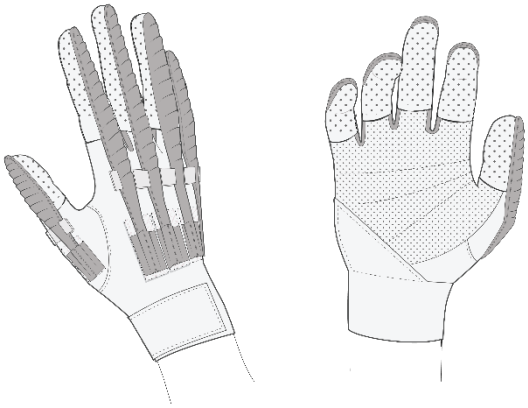

Fig 1. Grip Glove

The Grip Glove is a soft robotic, fabric-based glove that aims to assist users with disabilities such as weak grip strength and limited hand and finger function (Fig 1.). Lightweight, fabric-based pneumatic actuators are designed to interface comfortably and conformal to the hand and provide movement and articulation of the user's fingers to grasp and hold everyday objects.

The Grip Glove is composed of a lightweight, high friction hand wrap and five fabric-based soft actuator modules that deliver force to the fingers and support hand opening and closing. Each actuator is a layered assembly composed of (1) a high stretch knit material with anisotropic stretch properties, (2) a balloon made of thermoplastic elastomer (TPE), and (3) a strain-limiting knit material with stretch properties similar to a finger's natural skin strain. In this configuration, the textile pocket limits the expansion of the inflated balloon. The pneumatic pressure is transmitted to the knit materials, which responds with greater deformation of the upper, high stretch knit with respects to the lower, strain limiting knit. The result is a bending motion designed to kinematically mimic the flexion of human fingers.

In order for fabric-based soft actuators to deliver appropriate force to the fingers to grasp, support and manipulate objects, actuation modules need to grade in a way that correlates with varying finger sizes (e.g. thumb, pinky, index). An anthropometric study was conducted to determine an actuator sizing system that incorporates joint placement (e.g. MCP, PIP, DIP joints) in addition to general finger length and circumference (Fig.2). The study also collected skin strain data to better determine material stretch properties that accommodate the hand and actuators in active positions and degrees of flexion.

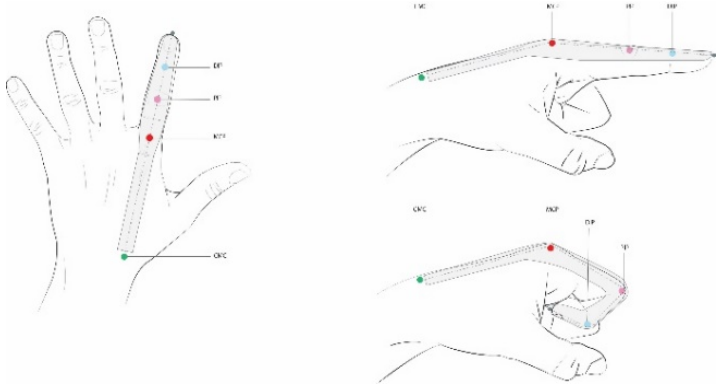

Fig 2. Anthropometric Study on Human Finger Joints and Hand Shape Change in Active Positions

Future work will involve the evaluation of the glove in improving grip strength and a user's ability to manipulate objects with spinal cord injury patients.

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Design and Feasibility of Two-way Actuating SMA Device for Smart Wear

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The final goal of this study is to develop a Smart-Slit, a device for versatile ventilation which controls temperature and humidity within clothing. The device is a low-power driven and operated with a switch; it implements two-way actuating using one-way shape memory alloy (SMA). As the first step, effective shape and controlling force of the device was investigated in this study.

For the clothing applications, SMA has been used based on temperature induced operation in which SMA controls sleeve/garment length or crease by using one-way SMA and insulating power or thermal protection by using two-way SMA. These applications utilized advantages of SMA that detect and actuate without sensors or actuators. However, in many cases transformation temperatures are beyond comfortable ranges, for that reason the applications to clothing were limited to extreme conditions such as sub-zero cold weather or fire fighting environment. SMA actuator in this study is a switch operating system; accordingly wearers can control the time and duration of transformation and operate within comfort ranges of microclimate temperature.

SMA actuator that works both ways for expansion and contraction, opening and closing in this case, could be designed in two ways; by using one-way SMA or two-way SMA. In case of using one-way SMA, it works as an automatic clamping device but reverse action should require external forces such as gravity or recovery force of elastic objects. In use of two-way SMA, it is trained to have bi-directional movement and should be able to maintain its shape for the intended period. This requires the condition of maintaining transformation temperature that causes operation, hence constant energy supply to keep the temperature. Suitable actuators for smart wear, which is a moving environment, can be controlled arbitrarily in the various changeable environment of wearers and satisfy limited power supply situation. Consequently, arbitrary swift of two-way reaction and portability are required.

This study suggested a novel construction of actuator to operate two ways by using 2 channels of one-way SMA. In order to create versatile opening system, a pair of two SMA (transformable body 1 and 2) was connected to each other and applied voltage to transformable body 1 (in charge of opening) or body 2 (in charge of closing) alternatively. By doing so, the resilience of stimulated body can transform the other unstimulated-pliable body. For investigation of operating efficiency, from 0.2ϕ to 0.5ϕ diameter of SMA at an interval of 0.05ϕ were applied to make actuators and their transforming force of stimulated bodies and stress-strain characteristics of unstimulated bodies were measured and compared. From the analysis operating efficiency, the optimal diameter of SMA was figured out. Smart-slit using the SMA actuator is applicable not only to smart wear but also to other functional textile products such as tent, sports and leisure gears.

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Electrospinning of Novel Chitosan-MXene Fiber Composite for Antibacterial Bandage Applications

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Cost-effective, wound dressing materials that are additionally antimicrobial, antibacterial, and anti-inflammatory have been shown to decrease recovery time compared to conventional bandages. The natural biopolymer chitosan, the *N*-deacetylated derivative of chitin, is an excellent candidate for the creation of these new wound dressing composite materials due to its inherent antibacterial properties combined with its nontoxicity and biodegradeability. The two-dimensional transition metal carbonitrides, otherwise known as MXene, have a $M_{n+1}X_nT_x$ composition where M is an early transition metal, n=1,2, or 3, X is carbon or nitrogen, and T is a variable surface termination; have demonstrated excellent chemical compatibility with bulk chitosan. The large surface area and negatively charged interlayer spacing of the MXene Ti_3C_2 provides a potential drug delivery mechanism as well as a method for the adsorption uptake of wound excretion.

In this study, novel electrospun chitosan-MXene composite fibers were investigated due to their antiseptic and antibacterial properties, respectively. Electrospun chitosan-MXene fiber morphology and diameter were measured with SEM-EDS and XRD, which confirmed the presence of titanium within the fibers. Average diameters of the chitosan-MXene fibers are 165 ± 46 nm. Furthermore, glutaraldehyde vapor deposition was utilized to crosslink the chitosan, which would allow the fibers to survive in an aqueous environment. Glutaraldehyde crosslinking was monitored by FTIR and SEM indicated an increase in the fiber diameters by 2.4%. MXene loading was set at 10% during fiber production and was found to be easily tunable. The porosity, water vapor permeability, mechanical properties, and antibacterial properties of this composite fiber mat are under investigation.

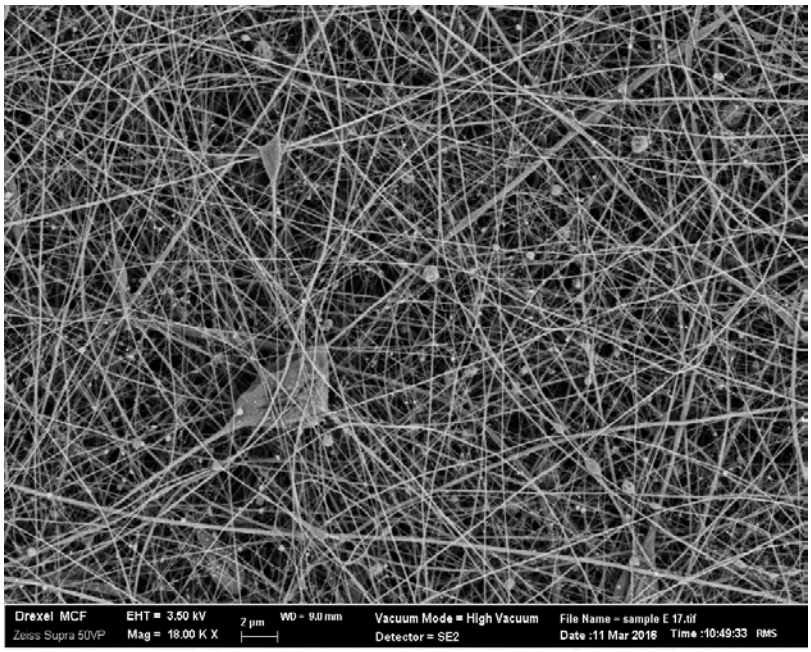

Figure 1. SEM of the chitosan-MXene fiber composite.

Synthesis, Characterization, and Electrospinning of P(VCL-co-MMA) Biocompatible and Thermoresponsive Polymers

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Smart or stimuli-responsive polymeric nanofibers have gain extraordinary relevance in the last years due to their promising applications in sensors and bioengineering. Temperature-responsive polymers, as one kind of smart materials, respond to changes in temperature and undergo a phase transition at the lower critical solution temperature (LCST). At temperatures below the LCST, these macromolecules are hydrophilic, while at temperatures above LCST they become hydrophobic and collapse. Poly(vinyl caprolactam) (PVCL) is a highly interesting thermoresponsive polymer, since it is biocompatible and its LCST is around 32 ^{o}C (close to body's physiological temperature). Even if in the last decades several works has been published in the synthesis of PVCL polymers and hydrogels, little is still known about its spinnability and fiber formation.

If PVCL homopolymer is directly electrospun, the created nanofiber mat will rapidly dissolve when immersed in water at temperatures below the LCST. Therefore, in order to create a non-water soluble thermoresponsive nanofiber, PVCL was copolymerized with methyl methacrylate (MMA) to create poly(vinyl caprolactram-co-methyl methacrylate) (P(VCL-co-MMA)) copolymers. Different copolymers were synthesized, characterized and electrospun varying their composition and the thermoresponsive behavior of the created nanofibers was analyzed. Finally, a poly(vinyl caprolactram-co-methyl methacrylate-co-acrylic acid) (P(VCL-co-MMA-co-AA) copolymer was also synthesized and electrospun to obtain pH and temperature responsive nanofibers.

Electro-optical and Thermal Responsiveness of Liquid Crystal Fiber Arrays

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ABSTRACT

The light modulating properties of electrospun liquid crystal fibers were investigated toward the potential application of optoelectronic fibers. The core-shell electrospun fibers are produced from 4-pentyl-4'-cyanobiphenyl (5CB) and polylactic acid (PLA). The structure of the fibers was optimized to form uniform core-shell fibers that are electro-optically switchable and thermally responsive. In this study, we show the optimization of fiber morphology to control not only the size and morphology of the polymer shell, but also the liquid crystal texture by controlling both electrospinning parameters as well as the collection set-up. The liquid crystal in the fiber core has all of the optical properties of the low molecular weight liquid crystal and responds to changes in temperature and to applied electric fields. We demonstrate that the liquid crystal fibers exhibit tunable thermo-optical properties that enable the use of fiber mats to produce highly flexible and wearable liquid crystal thermal sensors.

Keywords: electrospinning; liquid crystal/polymer composites; optoelectronic fibers; self-assembly; stimuli responsive

A Functional Apparel Approach for Soft Exosuit Design

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Recently, a major focus of wearable robotics has been the development of lower-limb exoskeletons to reduce the metabolic cost of walking [1-6]. Many exoskeletons use a series of rigid linkages/interfaces to span the lower extremities and anchor to the human body [5-6]. However, our lab incorporates lightweight and conformal functional apparel termed "soft exosuits" to apply joint moments via tensile forces in parallel with the muscles, thereby reducing the required muscular activation [4]. The goal with soft exosuit interfaces is to use a structured functional textile to anchor to the human body in order to maximize comfort, minimize component migration on the body, and maximize power delivery. However, such a goal is challenging given the natural compliance of human tissue, sensitivity of human skin, and wide variability in human anatomy. This work aims to define functional design guidelines to maximize exosuit performance, with a particular focus on materials consideration, component patterning, and component fit. Participant testing is employed, where quantitative data of component performance, as well as comfort and usability feedback are collected. Through iterative cycles of testing and design improvements, the exosuit is further optimized.

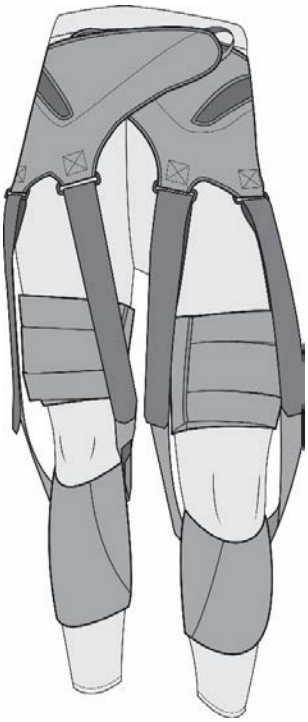

Figure 1. Soft exosuit components including; a waist belt, thigh piece, calf wrap and straps over a base layer.

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Development of New Hockey Gear for Enhanced Neck Laceration Protection

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Hockey is an intense sport that requires appropriate cut protection. While wearing protective equipment like gloves and shin pads are required, wearing a neck guard is only recommended in USA Hockey. Due to lax regulations, according to a study (Stuart MJ, 2009,) only 45% of 26,342 registered USA hockey players wear hockey neck guards, causing 485 players to experience light or severe neck laceration. However, 27% of injured players worn hockey neck guards at the time of accident, engendering doubts about current neck protectors' performance. This study, therefore, investigated current neck protectors' cut resistance and suggested materials and design solutions for enhanced protection.

The research team evaluated 8 combinations of cut resistant materials: Kevlar, Carbon/Spectra blend, and Dyneema textiles, with an understanding of required protection and material properties for hockey neck guards. Cut resistance tests were conducted following ASTM F1790 Standard Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing with Cut Protection Performance Test Equipment. Cut resistance was measured by the weight (in grams) needed to cut through material with 25 mm blade travel. The weight ranges corresponding to performance levels of 3, 4 and 5 were 1,000-1,499 g, 1500-3,499 g, and above 3500 g. The Carbon/Spectra blend rib knit was tested on the straight and cross grain, yielding performance levels of 4 and 3, respectively. Only 3 layered Kevlar received level 5, while the two commercial neck guards only received level 3. Orientation and fiber content were both found to influence cut resistance levels.

Our analysis on commercial neck guards and interview with an expert ice-hockey manufacturer identified need for secure placement, a large coverage of protection, convenience of donning, thermal comfort and aesthetic considerations. Based on these key factors, two new prototypes were developed: extended bib style and all-in-one. Design process, unique design features and findings of this study will be further discussed in the presentation.

Using Commingled Yarns Made from Nanomodified Polypropylene and Glass Fibres for Microwave-based Heat Pressing

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Both the automotive industry as well as the aerospace industry aim to achieve the lowest possible weight at maximized mechanical properties. The use of lightweight structures mainly results in a reduction of operating costs of the finished products [1]. In order to achieve these efficient lightweight structures while staying profitable, fibre reinforced thermoplastic composites (FRTCs) are being developed. For instance, FRTCs can be produced from hybrid yarns consisting of commingled thermoplastic and reinforcement fibres. The hybrid yarns are processed to fabrics through various textile processes subsequent to commingling. In a final step the fabrics are heated and consolidated by the use of heat pressing to form fibre reinforced components. Considering the production process, the heating and cooling times of the organic sheets are the cycle-time determining factors. Shorter cycle times lead to higher outputs, thus reducing the costs per part. To achieve a reduction of heating times, microwave active hybrid yarns containing nanomodified polypropylene filaments are produced and examined at the Institute for Textile Technology Aachen (ITA). The "Micropress" project is based on researches dealing with nanomodification and commingling of hybrid yarns [2, 3]. The microwave technology exhibits further advantages like high energy efficiency and volumetric heating [4]. By implementing microwave technology into an existing heat pressing process, FRTCs are being manufactured from unidirectional polypropylene and glass fibre woven fabrics. The investigation of this modified manufacturing process includes the commingling of glass and nanomodified polypropylene fibres, the characterisation of the yarns' properties and the manufacturing of applicable textile fabrics. Furthermore, the heating behaviour of various specimens by microwave irradiation is observed with laboratory microwave equipment. In the final step, the manufacturing of FRTCs by the newly developed production method is realised and the obtained samples are optically and mechanically characterised.

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Surface Modification of Nanofibrillated Cellulose and Nanocrystalline Cellulose for Textile Coating and Dyeing

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Cellulose is the most abundant, renewable, biodegradable and environmentally friendly organic compound found in nature. Cellulose is found in wood, plant fibers, marine animals, algae, fungi, and bacteria. Nanofibrillated cellulose (NFC) is composed of fibrils with high aspect ratio (length to width ratio). These fibrils have lengths and widths in the micrometer and nanometer scales. Nanocrystalline cellulose (NCC) is in the form of whiskers or nanosized crystals. These whiskers have a high aspect ratio, and they are highly crystalline. NFC and NCC solutions or gels can be employed to bind dye, antimicrobial, flame retardant, stain and soil resistant, hydrophilic, and other molecules to polyester, acrylic, polypropylene, nylon, cotton, and other types of textile fabrics. In this study, we develop a new dyeing process using modified NFC and NCC gels with polyethylenimine (PEI) and poly(oligoethylene glycol methacrylate) (POEGMA) to improve the adhesion between nanocellulose gels and textile fabrics to make stable, smooth, and thin films for coating of textile materials. This technique reduces consumption of water and energy compared to the conventional dyeing method. The conventional dyeing process requires massive amounts of water and produces large volumes of waste water. The dyeing technique using nanocellulose gels eliminates the need for enormous quantities of water and substantially decreases the amount of waste water. In this novel method, amorphous region and surface area of nanocellulose gels are two critical parameters in increasing dye uptake and dye fixation. Cellulase enzyme treatment of nanocellulose gels results in changes in surface area and crystallinity of the cellulose gels. Cellulase by slowly degrading crystalline regions of cellulose gels improves dyeability of gels without excessively damaging cellulose structures and properties. Therefore, in this study, cellulase treatment of nanocellulose gels before dyeing process is suggested to increase the surface area and accessibility of amorphous regions in nanocellulose gels.

Development and Testing of a Stitched Stretch Sensor for Measuring Human Movement

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INTRODUCTION

Measurement of human movement is important for monitoring activity, providing feedback to change activity, and as a means to control devices such as for communication or mobility. Tools available to assess movement are expensive, and range from optical motion capture lab equipment [1] through wearable devices with sensors like inertial measurement units (IMUs) [2]. The purpose of this study was to develop and test a textile-based stretch sensor with the potential to measure human movement via a softer, more aesthetically pleasing, less expensive mechanism.

EXPERIMENTAL DESIGN

Thirteen conductive threads were purchased for stretch sensor testing [3] and the optimal thread was determined by comparing the linear mass density (denier) and linear resistance. Then eighteen samples (two lengths – 2 and 6 inches, three stitch geometries – classes 304, 402, and 406 [4], and three knit textile substrates - 90% polyester/10% spandex, 90% nylon/10% spandex, and 95% cotton/5% spandex) were fabricated using the optimal thread. Each sample was elongated by 30% and retracted five times on a custom made 3D printed testing apparatus.

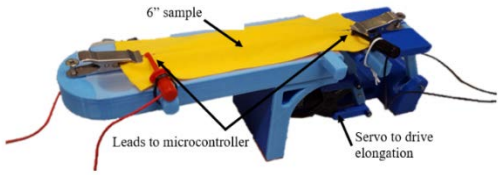

Figure 1: Custom 3D printed testing apparatus

RESULTS

Resistance was sampled at 75Hz during these trials. Elongation and retraction trials were superimposed, and resistance was plotted against length. The line of best fit was calculated and by comparing the r^2 value and slope, the optimal configuration was determined: stitch 304 (zig-zag) on a nylon/spandex substrate in a 6-inch length, $r^2 = 0.83$, slope = 6.29 KΩ/inch.

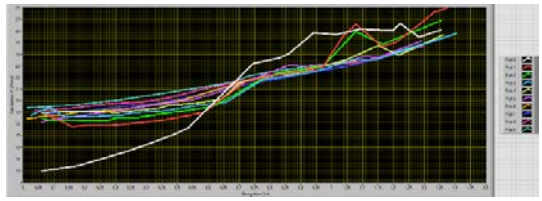

Figure 2: Stitch 304 on a nylon/spandex substrate

CONCLUSION AND FUTURE WORK

An r^2 value of 0.83 shows that with the optimal configuration, of thread type, textile substrate, and stitch geometry, the stretch sensor can deliver accurate, repeatable results. This change in resistance could then be mapped to determine joint angles. Further testing will focus on assessing repeatability over time and human subjects testing with the sensors strategically stitched in a compressive garment [5] to capture joint movement while mainitaining a comfortable, aesthetically pleasing interface.

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Sleepwear with Lateralized Thermal Properties for the Treatment of Sleep Disturbance in Women

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INTRODUCTION

Our innovation is specially constructed sleepwear for the treatment of sleep disturbance caused by thermal dysregulation, a problem that is most often seen in women. We have designed and tested a simple and comfortable garment with lateralized thermal properties that promote either thermal conduction or thermal insulation depending upon body position. This innovation will allow sleepers to auto-regulate skin temperature through subtle movements during brief transient arousals, preserving overall sleep architecture.

BACKGROUND

Thermoregulation plays a key role in promoting and maintaining sleep. Temperature dysregulation and sleep disturbance (difficulty initiating or maintaining sleep) commonly occur in menopausal women with vasomotor symptoms such as hot flashes and night sweats. The use of an ingested telemetry pill has established that asymptomatic postmenopausal women – like premenopausal women – have a thermo-neutral zone of approximately 0.4 °C in which neither warming mechanisms such as shivering nor cooling mechanisms such as sweating are activated, whereas symptomatic women enjoy no such buffer range. Consequently, symptomatic postmenopausal women virtually always feel either too hot or too cold to some degree.

INNOVATION

The sensitivity of women with menopausal symptoms to ambient temperature changes suggests it may prove beneficial for them to maintain as narrow a temperature range as possible during sleep. Wearing a specially constructed garment (Fig. 1) – which we have dubbed "Janus Sleepwear"– that promotes either thermal conduction or insulation depending upon body position (Fig. 2) will allow women to fine-tune skin temperature through movement. We believe a person wearing Janus Sleepwear will be able to effectively "steer" her body (turning to the left or right side) in response to subjective and subconscious perceptions of thermal discomfort to maintain optimal conditions within the thermo-neutral zone while asleep.

PROTOTYPE TESTING

We have constructed several prototypes of sleepwear with lateralized thermal properties and obtained encouraging preliminary data in small-scale piloting of the garment.

RESULTS

Preliminary results indicate that Janus Sleepwear can facilitate more rapid cooling, compared to control sleepwear, when the conductive side faces up toward the ambient environment and can maintain temperature with less loss of heat when the insulating side faces up toward the ambient environment.

FUTURE WORK

We will be piloting our garment in a clinical study of menopausal women with insomnia complaints. The primary aim of this study will be to demonstrate that, in symptomatic menopausal women, wearing sleepwear with lateralized thermal properties will improve objectively measured and subjectively reported sleep quality.

Fig. 1 Janus Sleepwear

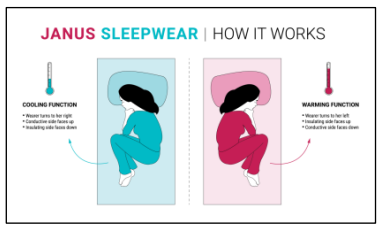

Fig. 2 Method of Operation

NMR Study of Wrinkle-free Cotton Fabrics Treated with Polypropylene Glycol-di-epoxide and 1,2,3,4-butanetetracarboxylic Acid

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Wrinkle-free cotton fabrics have traditionally been characterized by techniques such as FTIR (Fourier Transform infrared spectroscopy), tensile testing and wrinkle recovery angle measurement. In this study, solid ^{13}C NMR (Nuclear Magnetic Resonance) was directly applied to wrinkle-free cotton fabrics to detect the crosslinking reaction between the crosslinker and the hydroxyl groups of cellulose. No grinding the fabrics into powder is required for solid ^{13}C NMR studies. For the well-known non-formaldehyde crosslinker, 1,2,3,4-butanetetracarboxylic acid (BTCA), sodium hypophosphite (SHP) and sodium propionate (NaP) were compared in catalyzing the reaction between BTCA and cotton fabrics. For epoxide-based crosslinker, such as polypropylene glycol-di-epoxide (PPG-di-epoxide), two catalysts, NaOH and $MgBr_2$, were compared in the crosslinking reaction. PPG-di-epoxide underwent nucleophilic substitution to interact with the hydroxyl groups of cellulose. The combination of BTCA and PPG-di-epoxide was also investigated in this study.

Characterization of Micron-sized, Bicomponent Islands-in-Sea Fibers Using IR-AFM

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We report on the use of Infra-Red Atomic Force Microscopy (IR-AFM) as a tool to acquire qualitative information about distribution of nylon (islands) dispersed in a polyester (sea) matrix in bicomponent, island-in-sea fibers. Absorption sweeps were performed in four different locations within one fiber in order to obtain an IR absorption spectrum. A full fiber map was obtained by exciting the fiber with a IR beam at 1724 cm^{-1}, resulting in the excitation of polyester. The same fiber was then scanned at 1640 cm^{-1} in order to obtain the corresponding map for nylon. As the fibers are composed of 85% polyester and 15% nylon, the signal for nylon was significantly weaker than the one for polyester. Sample thicknesses of 300 nm and 500 nm were considered, and while a loss of resolution was expected with thicker samples, the signal measured was stronger thus resulting in sharper images. IR-AFAM allows the creation of chemical maps in multicomponent fiber structures.

Synthesis of α-MnO2 Nanocrystals Using Natural Extracts of Vitis Vinifera Stems and Malus Domestica "Cortland" Apple Peels

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Manganese dioxide nanoparticles were prepared using a green synthesis process with natural extracts from Vitis vinifera grape stems and Malus domestica 'Cortland' apple peels. We used a two-step synthesis method to render highly crystalline α-MnO2 phase nanocrystals: (1) a nucleation step from the reduction of KMnO4 in presence of the natural extracts and (2) a thermal treatment for solid-state growth. TEM and FESEM provided direct evidence on morphology of nanoparticles and helped elucidate the nucleation and growth mechanism. The catalytic activity of the products was tested for degradation of Indigo carmine dye in water. This study shows an effective green synthesis method to grow α-MnO2 nanorods, and suggests that the prepared nanoparticles exhibit structural and magnetic properties similar to nanoparticles synthesized using traditional solvents.

KEYWORDS: Manganese dioxide; Green synthesis; Catalyst; dye degradation

Characteristics of PU Nanoweb Treated with Ag Nanowire Solution and Exploration as a Strain Sensor

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This study suggests a simple methodology of fabricating conductive polyurethane nanoweb for usage in textile strain sensor. The purpose of this paper is to (1) fabricate conductive polyurethane nanoweb coating with silver nanowire (2) investigate change in electrical resistance of polyurethane nanoweb under stretch (3) evaluate surface and mechanical properties of treated nanoweb. The polyurethane nanoweb was purchased from Pardam, s.r.o. (Ltd) and the nanoweb was cut into round shape specimens whose diameter was 8.5cm. Silver nanowire dispersed in ethanol (AgNW) was purchased from KLK Co. and AgNW was diluted by mixture with ethanol. The ratio of AgNW to ethanol varied (20:80, 40:60, 60:40, 80:20 and 100:0). Electrical conductivity was imparted to the polyurethane nanoweb by dip-and-dry coating process utilizing AgNW. Initial electrical resistance of the specimens was measured and its change was recorded with stretch by 20% and release of the nanoweb. Scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS), atomic force microscopy (AFM) and surface profiler were used to analyze surface properties. Tensile properties of the highly conductive specimens were measured (20±1℃, 50±5% RH). Electrical resistance of the specimens was decreased in accordance with the increasing amount of AgNW. The electrical resistance increased under stretch and it decreased back when they were released. The diameter of treated nanoweb decreased by 33.98% on average due to generation of crimp. This structural change can be derived from hydrogen bond between hydroxyl group (-OH) of ethanol and ether group (C-O-C) of polyurethane fiber which made nanoweb more stretchable. The thickness of the nanoweb decreased with the shrinkage. The thickness of the coated layer ranged from 0.9 to 1.2μm. SEM with EDS and AFM analysis projected the polyurethane and silver nanowire attachment to fibers. According to the surface profiler test, surface of the specimens became less rough after the treatment since the silver nanowire network covered the space between fibers. Both tensile strength and elongation at break increased after the treatment to impart electrical conductivity on nanoweb.

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A Comparison of Garment Sleeve Patterns for Korean Women

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To make clothing comfortable for daily work or sports activities, the sleeves of top clothing should fit well at arms and shoulder. Among the various sleeves, a raglan sleeve has been regarded as a comfortable sleeve to move the upper limb. Raglan sleeve is distinguishing sleeve whose shoulder seams extend from underarm to the neck lines.

In this study, the researchers searched the suitable method for Korean young women. They compared several sleeve pattern making methods The compared pattern making methods were ESMOD method of France(A), Muller method of Germany(B), Hyungsook Lee method of Korea(C) and New-Bunka method of Japan(D). Raglan sleeve and set-in sleeve patterns were developed for an average size of Korean women in their twenties. Experimental garments with set-in sleeve and raglan sleeve were made with muslin. The expertise of clothing construction (n=8) evaluated the experimental garments. The evaluations were performed for overall appearance, amount of ease, skewness, and creases lines.

The results show that the set-in sleeve made by C method was highly assessed for Korean young women's figure in overall appearance and the proper amount of ease. It showed outstanding assessment in back appearance of sleeve($p \leq .01$) and shape of bodice with sleeve($p \leq .05$). It showed also good fit at arms($p \leq .05$) and front and back armpit ($p \leq .05$). However, it showed poor fit at the clavicle and scapula($p \leq .05$).

There were no significant differences among four methods in appearance evaluation for raglan sleeve among 25 evaluation elements. Only for the shoulder length and the amount of back ease, raglan sleeve made by C method showed good fit($p \leq .05$). Raglan sleeves showed improper amount of ease at back bodice for all methods. Every raglan sleeve showed poor fit at the back raglan seam line. These results indicate that the further study needed for raglan sleeve drafting method to make a good fit raglan sleeve pattern for Korean.

ACKNOWLEDGMENT: This work was supported by the Brain Korea 21 Plus Project of Dept. of Clothing and Textiles, Yonsei University in 2016.

Attachment of Donor-Acceptor Stenhouse Adducts Photochromic Compounds onto Cotton Fabrics

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We report on the chemical attachment of a new photochromic organic molecule onto cotton fabrics. The photochromic molecule used in this study is a type of Donor-Acceptor Stenhouse Adducts (DASA) that switches color when exposed to visible light/heat. The attachment process included two steps:

1. Modification of cotton with N,N-methyl(2-bromo-ethyl)ammonium bromide in order to generate a secondary amine functionality in the cotton fabrics;
2. Ring opening of the activated furfural in 5-(furan-2-ylmethylene)-2,2-dimethyl-1,3-dioxane-4,6-dione by the modified cotton fabrics.

These two steps allowed the formation of DASA molecule on the surface of the cotton fabrics. The DASA modified cotton fabrics can change color from red to yellow when exposed to liquid water, and they return from yellow to red when heated. The color of the DASA modified cotton fabrics can also fade away when exposed to visible light and recover after heat up. This is the first time that this type of DASA molecules is immobilized onto a solid substrate without losing functionality. The modified fabrics can be used as sensors or made into responsive clothes.

From Bio-waste to Green Composite Using Non-edible Starch and Modified Sisal Fibers

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Eco-friendly and completely biodegradable 'green' composites were fabricated by using modified continuous sisal fibers and non-edible starch based resin in a facile and cost effective manner. Starch was extracted from defatted mango (*Mangifera indica*) seedcake, so far considered as waste residue after oil extraction. Optimum combination of mercerization and heat-treatment was done on the sisal fibers under tension to improve their mechanical properties and interfacial adhesion with starch. Composite laminates were fabricated using a hand lay-up process followed by curing in a hot-press. The mechanical properties of these composite laminates were investigated.

Electrospinning of Polyisobutylene-based Thermoplastic Elastomers and Characterization of the Electrospun Fibers

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Poly(alloocimene-*b*-isobutylene-*b*-alloocimene) triblock copolymer (AIBA) is a novel polyisobutylene-based thermoplastic elastomer that can be synthesized by living carbocationic polymerization. Since former studies revealed that the polymer is biocompatible, the possible applications for this elastomer include pharmaceutical and biomedical ones focusing on breast cancer treatment. AIBA can be an ideal matrix for controlled drug delivery systems while the mechanical properties (stiffness, high elongation) also make it suitable for the purpose. Applying the material in the form on nonwoven fiber mats gives higher flexibility and the material can be tailored to many different shapes. Electrospinning gives the possibility to create such ultra-fine fibers and hence reaching a better bioavailability at the same time.

AIBA was successfully synthetized with a low molar mass distribution (2.3) and a weight average molar mass (M_w) of 440 kDa, measured by size-exclusion chromatography. Theoretically a polymer with such characteristics is ideal for fiber drawing or electrospinning. In this study the polymer was dissolved in chloroform in various concentrations. As AIBA is an excellent insulator, therefore it was mixed with poly(ethylene glycol) (PEG), M_w=2050 Da in a ratio of 80:20 in order to provide electrical conductivity to the polymer solution.

From the solutions electrospinning could be carried out successfully, resulting in ultra-fine fibers. The effects of the most important parameters (voltage, spinneret-collector distance, solution concentrations) have been investigated. It can be concluded that fine fibers with uniform morphology can be obtained from the new AIBA polymer making possible to create drug delivery systems.

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Water-based Electrospinning as a Facile and Scalable Method to Directly Deposit PVA-Silicon-Graphene Nanoribbon Nanofibers for High-performance Li-ion Batteries

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Silicon with a theoretical capacity of 4200 mAh/g is the best candidate for the next generation of Li-ion battery anodes. However, it suffers from colossal volume expansion (300% of its original size) and crack formation upon cycling and thus its capacity quickly fades. Several strategies such as use of nanoparticles and composites have been employed by researchers to overcome aforementioned issues. However, all the modifications to silicon have to be done in an economical manner for the product to become an industrial realization.

In this work we employ water-based electrospinning to disperse silicon nanoparticles (SiNP) and graphene nanoribbons (GNR) along PVA nanofibers to directly make an anode of functional fiber mats on top of the copper current collector. This method is environmentally friendly, compatible with a role-to-role production, and by-passes several long-winded steps in the conventional paste-based electrode making. Physical and chemical properties of the nanoparticles and their dispersion affect the fiber morphology and ultimately electrochemical performance of the composite material. Graphene nanoribbons, made by unzipping carbon nanotubes, offer unique nanostructures and electrochemical properties when inside the composite fibers. To elucidate the effect of nano-inclusion geometry on fiber morphology and electrochemical performance of the fiber mats, GNRs and their precursor CNTs were incorporated into PVA and characterized using microscopy and electrochemical techniques. Figure 1 shows morphology of the obtained fibers with GNR inclusion. It was observed that GNRs outperform their precursor CNTs in terms of overall capacity and retention. PVA-SiNP-GNR fibers exhibit an initial capacity of more than 3000 mAh/g at a rate of 0.2 A/g, and still have 300 mAh/g when tested at 8.4 A/g. This outstanding performance should be attributed to the unique morphology of the fibers and utilization of GNRs, which facilitate ionic and electronic transfer. High deformation rate imposed on the polymer jet during electrospinning results in a uniform dispersion of nanoparticles. Void spaces created in the nonwoven fiber mat provide room for silicon expansion, while shortening the diffusion length of Li-ions. Comparison of the electrochemical performance of two different size GNRs with their precursor CNTs will also be presented.

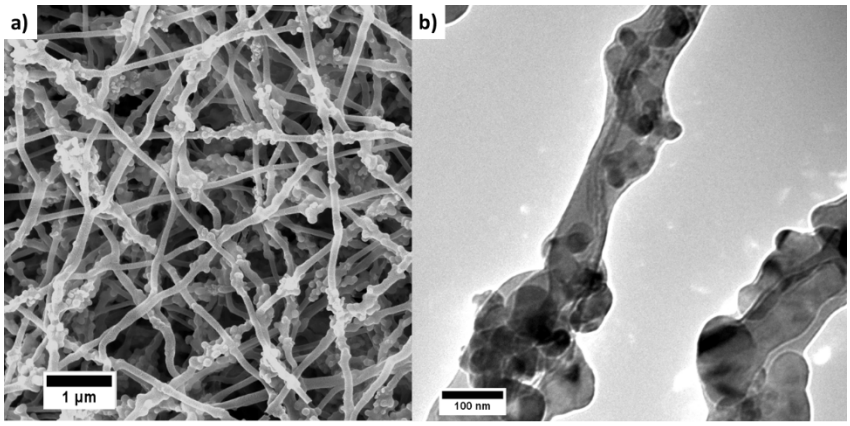

Figure 1. a) SEM and b)TEM images of PVA-SiNP-GNR fiber anode for Li-ion battery

Wear Trials of Knit T-shirts With and Without a Phase Change Material

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Phase change materials (PCMs) are widely applied to textile products. Because of the small quantity of PCMs incorporated in fabrics, whether the effect of PCMs is sensible by humans or not is a controversy. In order to assess the effects of PCMs on the human body, it is important to compare specimens with and without a PCM by wear trials.

Two test garments, namely large-size long sleeved T-shirts, were made of knit fabric (Nylon 77%, PU 23%). The experimental garment (Exp) was treated with a microencapsulated PCM on the skin-side of the knit fabric by a digital printing technique. For the control garment (Ctrl), no further treatment was used. Eight male subjects in their 20s, who volunteered to participate in this study, were divided into two groups which had different environmental conditions. Sensors were attached to five sites (stomach, left shoulder, neck, right shoulder blade, left waist) of the body and to the same sites of the test garments. In accordance with the test protocol, microclimate, body weight loss, clothing weight gain, subjective sensations (thermal, moisture, comfort; ASHRAE 7 scale), and fabric hand were measured respectively.

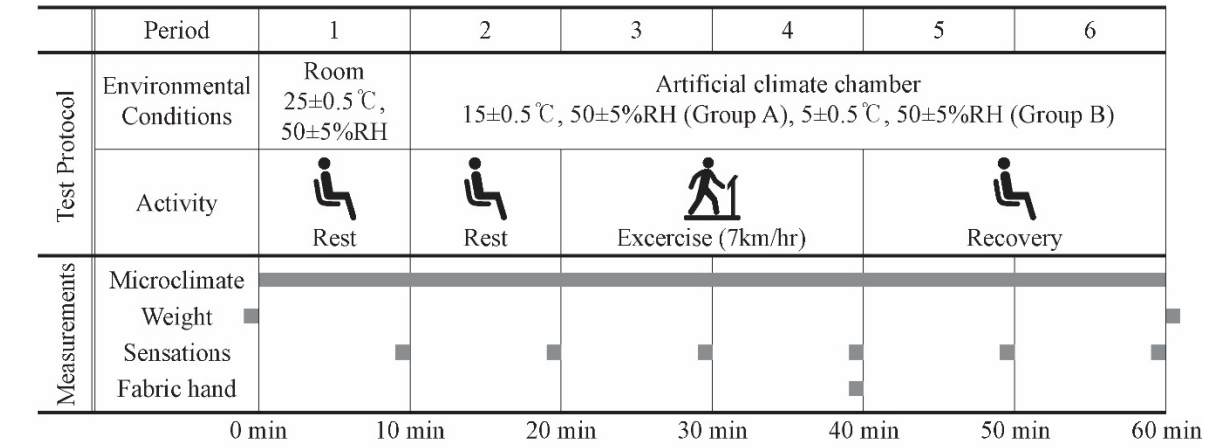

Figure 1. Test protocol and measurement

In group A, after exposure to a 15 °C condition, Exp showed a temperature buffering capacity by generating heat. In Period 3, the temperature difference between Exp and Ctrl started increasing. In Period 4, while the subjects were dripping with sweat, the temperature of Exp rapidly increased. In Period 5, as the subjects stopped exercising, the pumping effect which delivered heat outside of the microclimate decreased, while the temperatures of both Exp and Ctrl rose. In Period 6, as the subjects remained in a cold condition, the microclimate temperature declined in Exp and Ctrl. In group B, on the other hand, Ctrl showed a higher temperature than Exp in most periods, since the PCM could not perform the temperature adaptability under the condition of 5 °C.

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In-situ X-ray Study of the Deformation Mechanisms of Nonwoven Aramids

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Nonwovens have attracted much interest in the industry due to their characteristic high surface area, high porosity and low cost. However due to the complexity of deformation mechanisms in these materials, controlling the mechanical properties has been challenging. Therefore, it is of great importance to establish the fundamental understanding of the relationship between the microstructure and the macroscopic behavior. Motivated by this, mechanical properties and deformation mechanisms of aramid nonwovens as a function of areal weight using several analytical tools were reported. The initial fiber orientation alignment was found significantly different within nonwoven types according to XRD patterns. Fiber orientation evolution in both monotonic tensile and stress relaxation tests was tracked using in-situ X-ray diffraction. Fiber alignment along loading direction was observed in all three types of nonwovens as the strain increased. The results suggested that areal weight is not necessarily a predictor of the mechanical properties of aramid nonwovens and fiber alignment plays a vital role in the performance of these materials.

Hydrophobization of Cotton Fabrics via Silica Nanocoatings

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Wettability of solid surfaces is dictated by both surface energy and its roughness. Hydrophilic materials can exhibit improved hydrophobicity when their surface is roughen or modified with chemicals with lower surface energy. Cotton, one of the most widely used biomaterials in textile industry, absorbs most liquids including water and oil. In efforts of developing self-cleaning textiles, many have tried coating the material with fluorocarbons that are highly effective in achieving superhydrophobicity but notorious for their toxicity and non- biodegradability. We have investigated the hydrophobization of cotton fabrics by coating them with silica nanoparticles and decorating them with non-fluorinated organosilanes. We found that the degree of hydrophobicity of the treated cotton depends largely on the silica particle sizes as well as their surface functionality at the same level of particle dose. In the present study, two different size groups of silica nanoparticles (15–30 nm and 100–125 nm) and four different types of surface functional groups (ethyl-, n-butyl-, hexyl-, and phenyltriethoxysilane) were evaluated. The smaller set of silica nanoparticles were prepared by the C dot synthesis protocol; the bigger set by the Stöber method. The organosilane was added after the termination of bare silica particle synthesis to promote a more effective surface modification. Other parameters such as curing temperature and time, organosilane to bare silica ratio, and the time of organosilane addition have also been optimized. Our results suggest that the effectiveness of hydrophobicity increases with ethyl- < n- butyl- < hexyl- ~ phyenyltriethoxisilane; smaller particles < larger < larger-smaller LbL deposition at a given curing condition. These results present an alternative to create functional fluorine-fee coatings for cotton.