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Evaluation of the Suitability of the Renewable Bio-Plastic Polylactide for Optical Elements in Lighting Systems

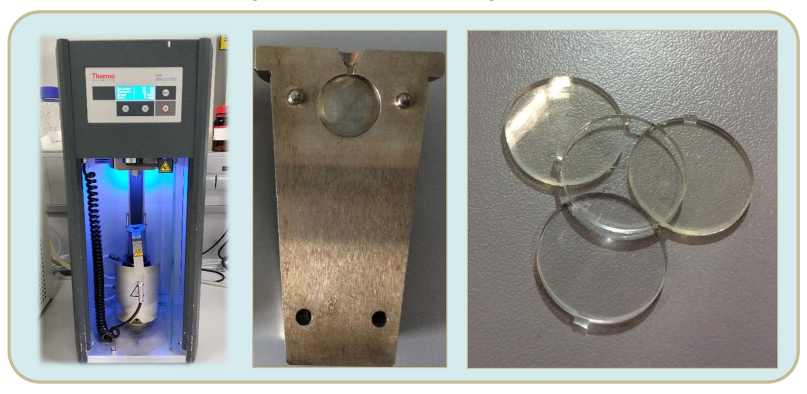
M. Hemmerich,[1*] R. Scholz,[2] S. Saha,[1] F. Walther,[2] J. Meyer[1]
[1] Hamm-Lippstadt University of Applied Sciences, Photonics and Materials Science, Marker Alle 76-78, 59063 Hamm
[2] TU Dortmund University, Department of Materials Test Engineering (WPT), Baroper Str. 303, 44227 Dortmund
* moritz.hemmerich@hshl.de
HAMM-LIPPSTADT UNIVERSITY OF APPLIED SCIENCES

Introduction

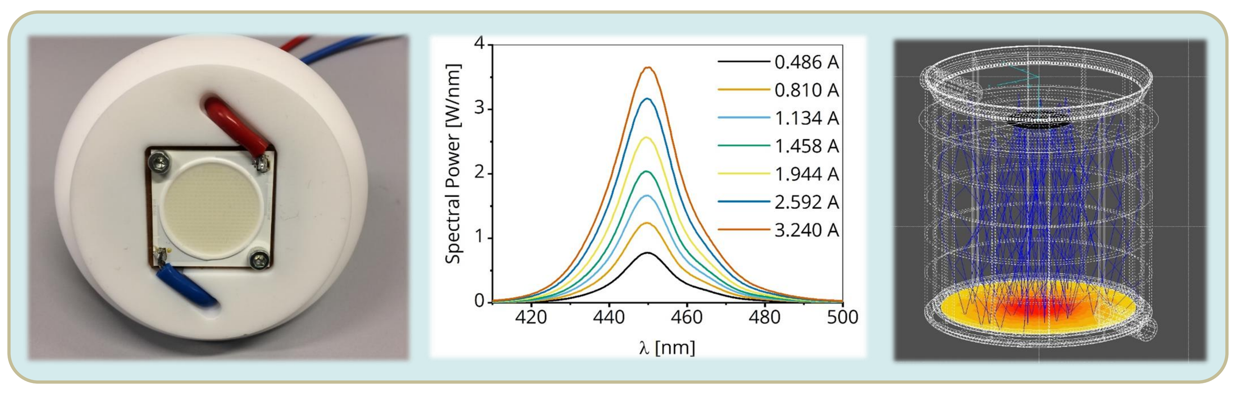
Due to their high durability and energy efficiency, modern semiconductor light sources are an excellent solution for the vast majority of lighting applications [1]. However, for the associated luminaires petroleum-based plastics often are used and do not contribute to the sustainability of these devices. In order to implement a holistic, sustainable development in lighting, it would be important to examine eco-friendly substitutes. A possible alternative may be the bio-plastic polylactide (PLA) which is based on renewables, is biodegradable and has excellent optical properties [2]. Optical components in lighting are exposed to ever increasing levels of irradiance [3], therefore it is important to test the stability of optical materials (PLA and PC as reference) with respect to radiation and temperature. For this purpose, a dedicated test setup has been developed and evaluated.

Approach

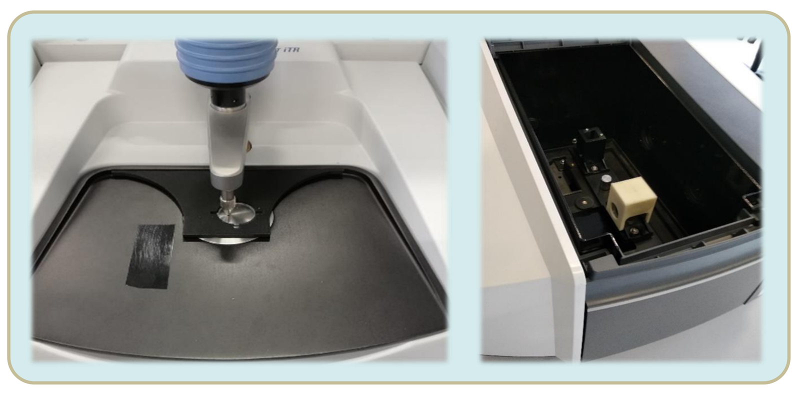
Injection molding of PC (Tarflon LC1500, Idemitsu Kosan, JPN) and PLA (L130, Total Corbion, NL)



Aging with blue light, 450 nm high power MCOB LED, 36 W optical power

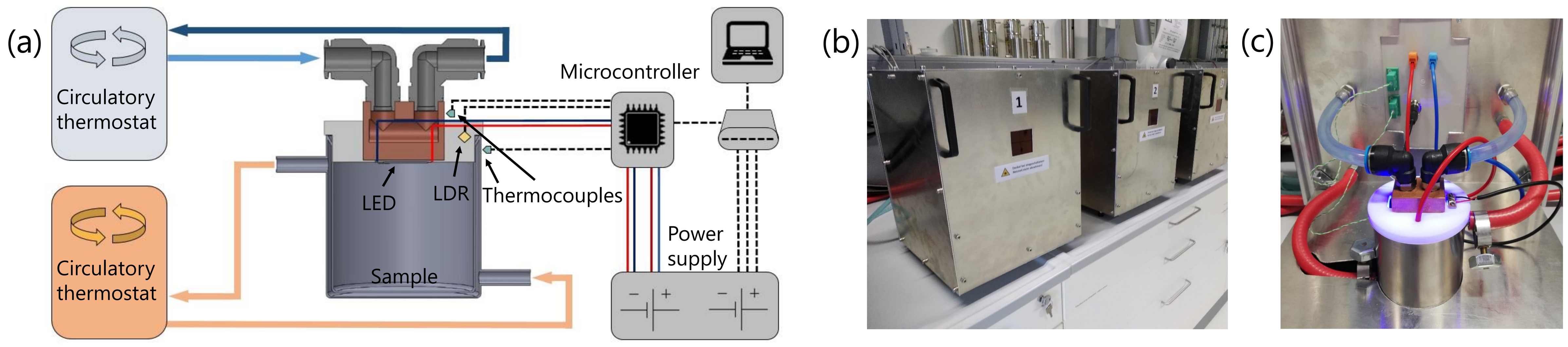


Examination at predefined times by UV/vis- and FTIR-spectroscopy



Aging Setup

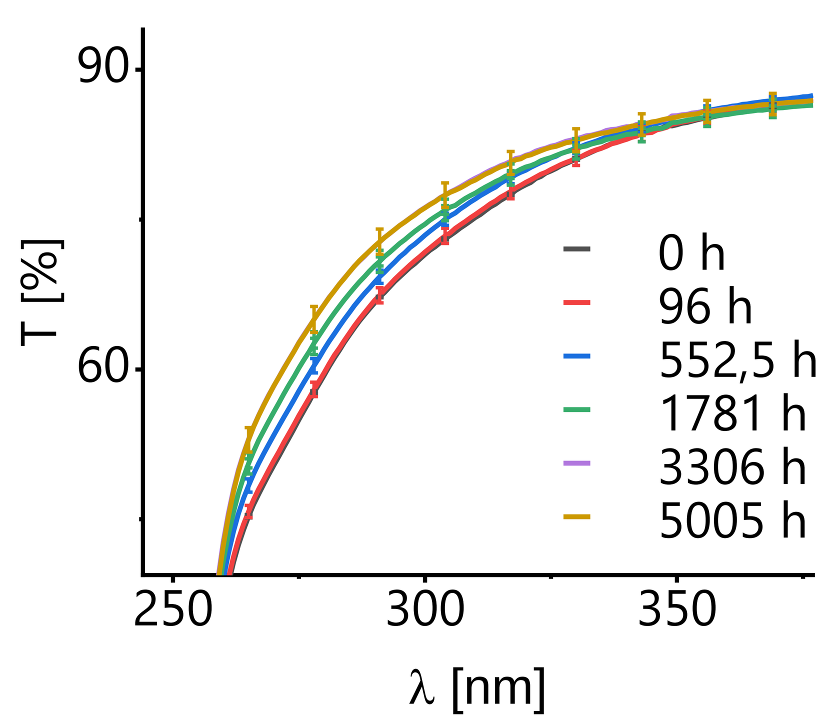
The innovative design of the test setup enables temperature control of the sample, independent of the radiation power of the LED. Stable operation of the irradiation source over time is ensured by water-cooling of the LED used. Traceable aging processes are ensured by monitoring of the operating parameters with several built-in sensor units. In order to achieve a higher throughput, twelve sample chambers can be operated simultaneously. [4]



Monitored Liquid Thermostatted Irradiation Setup (MLTIS): (a) Schematic representation; (b) enclosures for radiation-protection; (c) aging unit with corresponding sensors, electrical and fluidic connections.

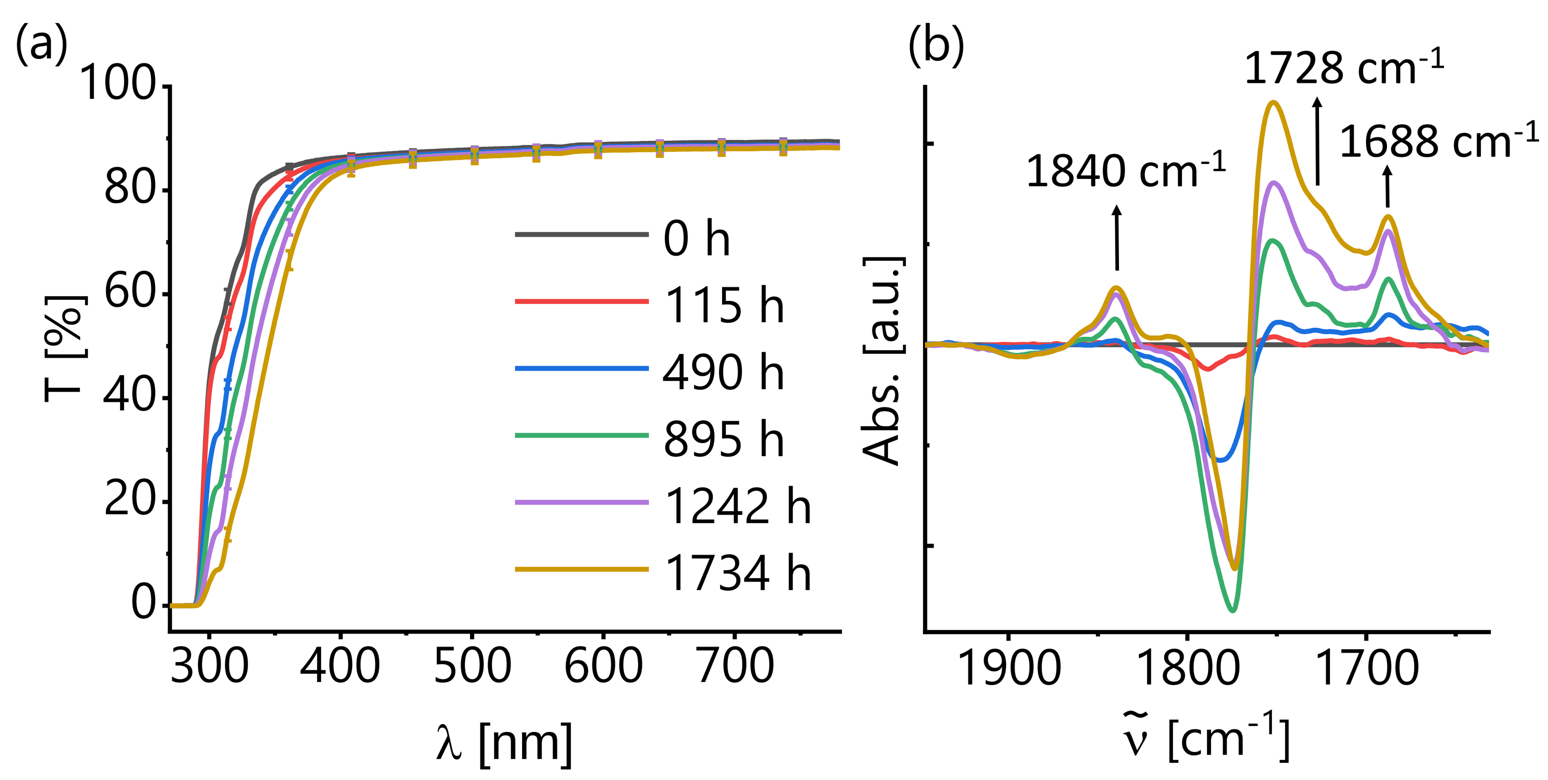
Results

PLA: UV/vis-spectroscopy of aged PLA samples shows an increase in transparency in the short-wavelength range between 260 and 350 nm. This increase could indicate the loss of built-in UV-absorbers. In the FTIR spectra new bands indicating oxidative processes could not be detected.



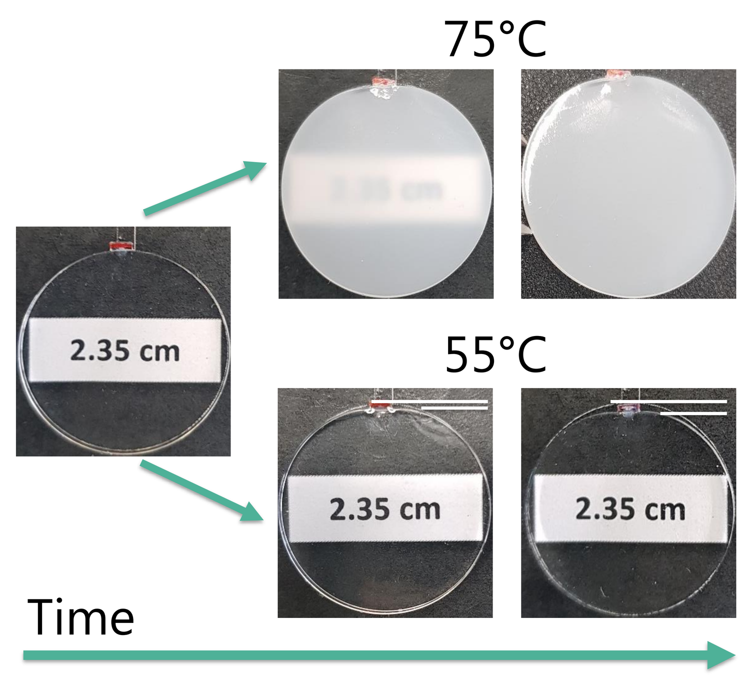
Averaged **PLA** UV/vis spectra at different aging times.

PC: The transmission spectra of PC after 1734 hours show continuously increasing absorption in the short wavelength range with aging time. The obtained FTIR spectra indicate the formation of known photo-oxidation and photo-Fries products in the carbonyl region at 1840, 1728 and 1688 cm^{-1} [5].



(a) Averaged UV/vis spectra; (b) Relative changes in absorbance in the FTIR spectra (carbonyl region) compared to the initial spectrum.

Thermal: At a temperature of 75°C, the PLA samples crystallize after only a few days. At 55°C, the sample shrinks in the vertical direction.



Thermal effects on PLA samples at 55°C and 75°C

Summary

The MLTIS test setup enables accelerated aging of various polymeric materials under controlled and traceable aging conditions. The optical properties of these samples are analyzed by spectroscopic methods and compared to virgin reference samples. PLA is considered to be unaffected by blue LED radiation. The limiting factor for the usage of neat PLA in optical applications is the low upper temperature limit, determined by the onset of crystallization at above 55°C. Regarding PC, a decrease in transmission and indications of oxidation could be detected within time frames simulating high load use conditions. MLTIS testing will be continued for further in-depth studies including different materials and aging conditions.

References

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