Converting light into motion: Autonomous LCE actuators

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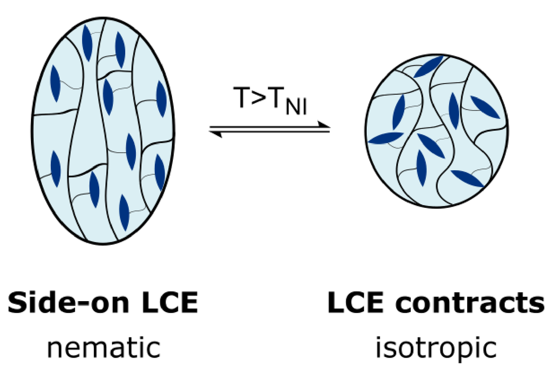
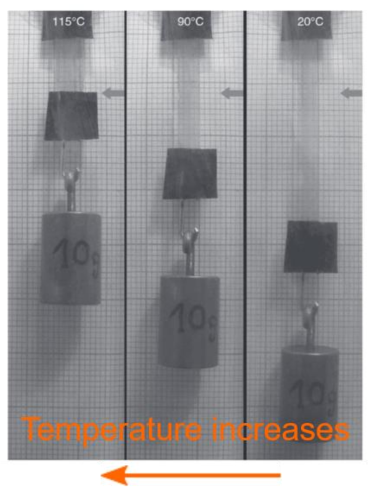
Background: Liquid crystalline elastomers

Liquid crystalline elastomers (LCE) are often described as artificial muscles due to their ability to perform reversible actuation movements. These movements are triggered by inducing a phase transition of the liquid crystalline phase. Possible triggers include temperature, light or external fields (magnetic or electric).

Light is a particularly favorable trigger as it is non-invasive, easy to handle and allows for rapid responses and wavelength-specific changes.



The LC phase transition leads to actuation of the elastomer. The order of the LC phase is destroyed upon heating. This leads to relaxation of the elastomer and the sample contracts. The process is fully reversible (Shape-memory effect).

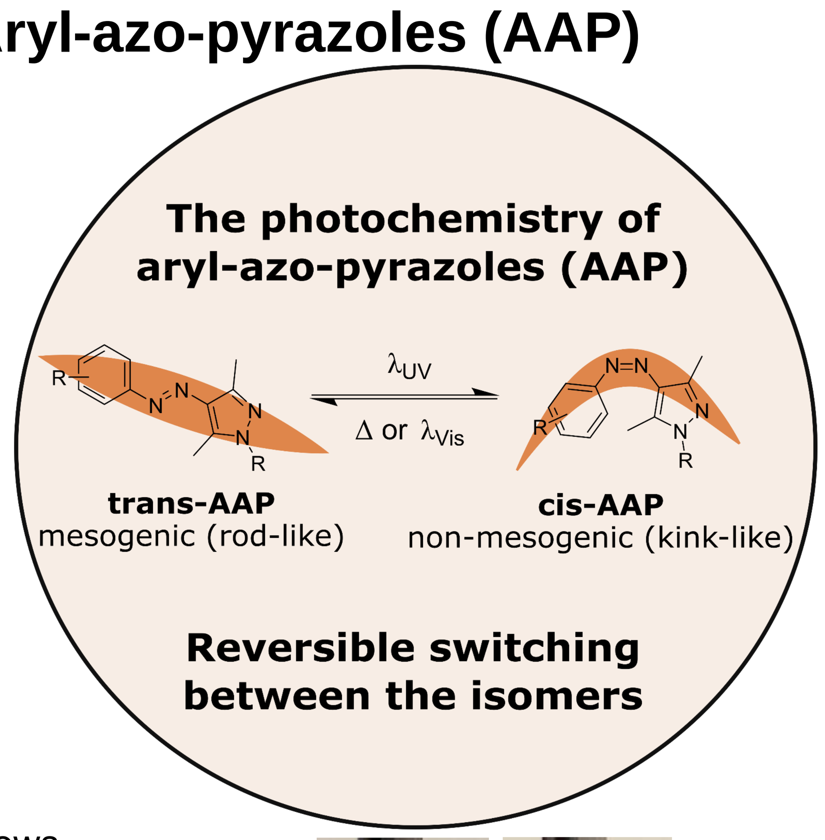


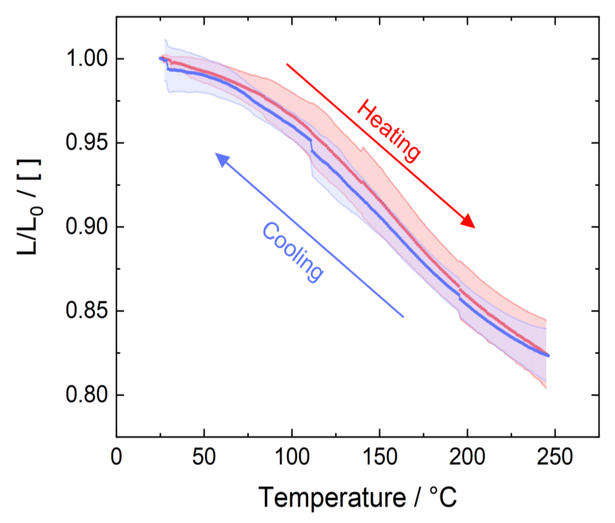
An LCE lifts up a weight (10 g) upon the temperature-induced phase transition. The LCE contracts due to the relaxation of the elastomer. Shown is the first demonstration of strong actuation performed by the group of Finkelmann (1980). Finkelmann's group performed pioneering work in this field at the University of Freiburg. Graphic adapted from [1].

Converting light into motion: Aryl-azo-pyrazoles (AAP) as light-responsive triggers

AAPs are light-responsive motifs with outstanding photochemical properties

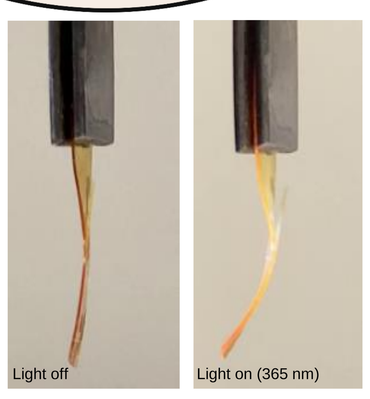
- The **rod-like trans-form** acts as a mesogen and fits into the liquid crystalline phase
- By switching to the **kink-like cis-form**, phase transition is induced and the LCE contracts



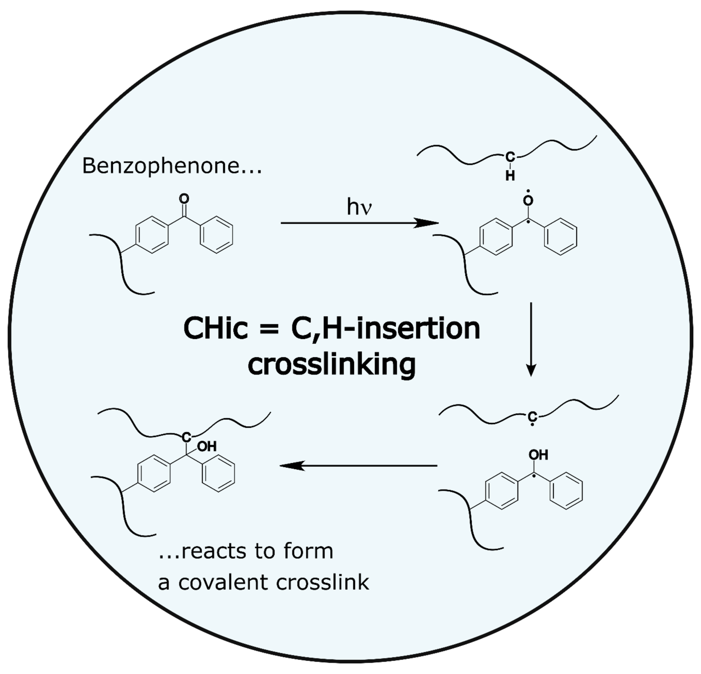


…which allows them to be actuated by heat…

…and by light.



Future directions: Pre-polymers and the CHic-Reaction[4]



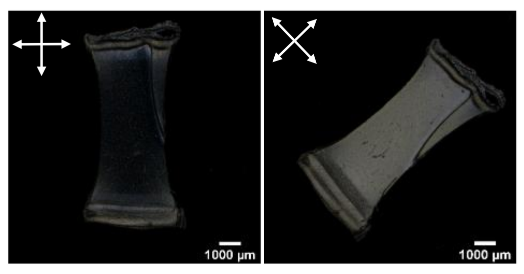
CHic = C,H-insertion crosslinking

- CHic-able motifs (e.g. Benzophenone, see graphic below and **Figure 6a**) can react with **any aliphatic C,H-bond** in the proximity, making the reaction **universally applicable**
- The reaction is activated by light or heat, depending on the chemical nature of the CHic-group
- By changing the CHic-group, the crosslinking process can be tailored to the requirements of the specific polymer chain
- With CHic-able groups, **no other reagents and no subsequent purification steps** are required
- Further advantages include **short reaction times, mild conditions and facile processing**

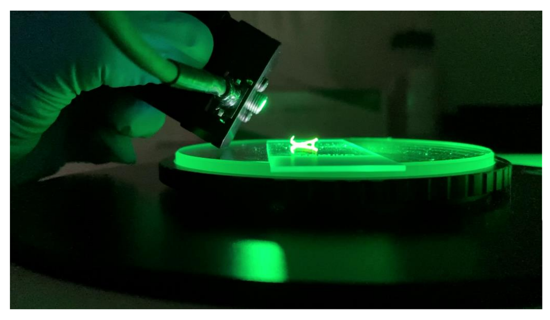
Future work will also include incorporating these materials into demonstrators with defined functionality

Equipment and techniques

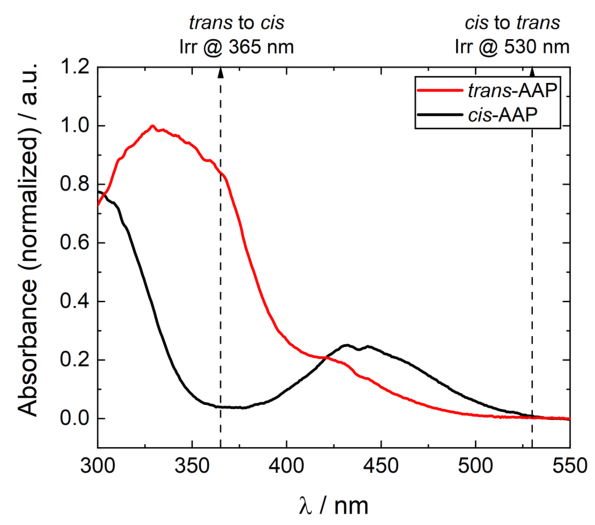
The focus of this work is the synthesis of novel LC monomers and the fabrication of free standing LCE. The LC monomers and elastomers are characterized and tested with the following techniques and equipment



Polarized optical microscopy (POM)

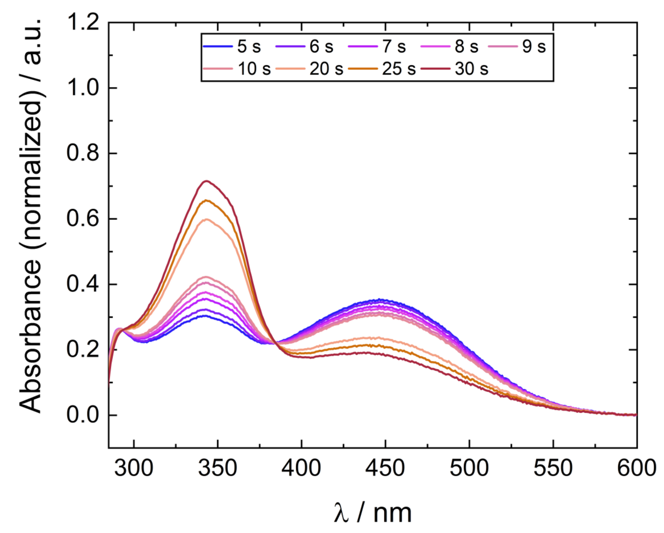


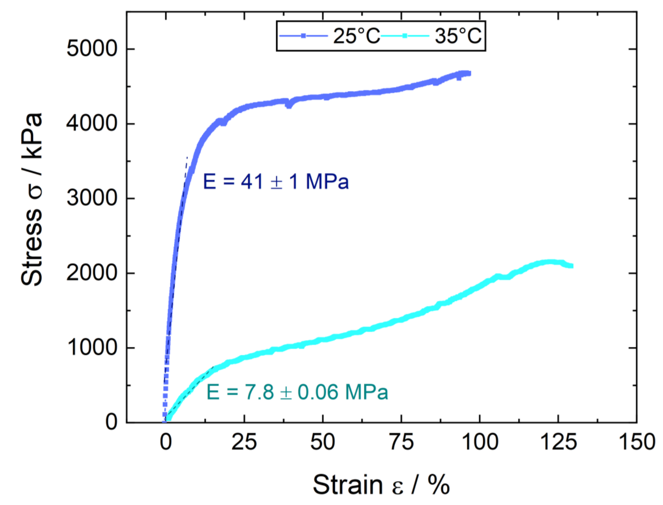
LEDs with different output powers and wavelengths



(Polarized) absorption spectroscopy (UV/Vis and IR)

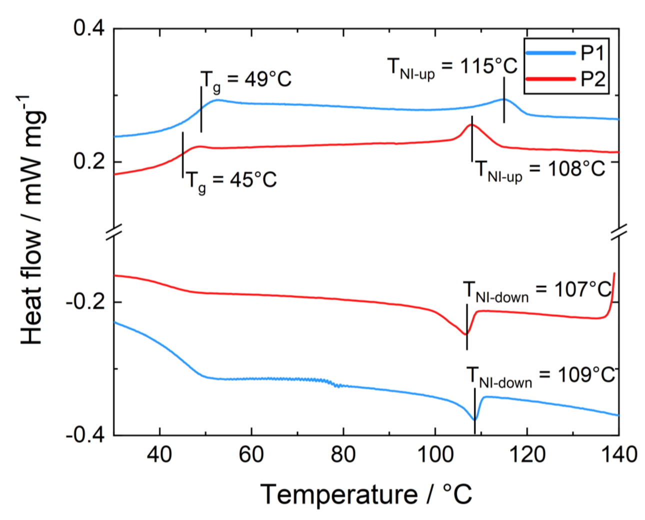
Time- and irradiation dependent UV/Vis and NMR





Dynamic mechanical analysis (DMA) and tensile testing

Differential scanning calorimetry (DSC)



Acknowledgements

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Literature

[1] S. Krause, F. Zander, G. Bergmann, H. Brandt, H. Wertmer, H. Finkelmann, *Comptes Rendus Chimie* **2009**, *12*, 85.

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Further information

This project is part of Research Area B within the *liv*MatS Cluster of Excellence

Research Area B
Adaptivity

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