Success Story
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# Smart polymers for self-healing and recycling strategies

Novel stimuli-active polymer systems have been developed and tested within the framework of Polymer Competence Center Leoben GmbH. The research work aims at approaches towards smart and innovative material features in order to contribute to the key sections of a product value chain including a closed circle economy and recycling of raw materials. Architecture as well as material properties of the polymers are specifically controlled and altered in response to external stimuli. These material concepts afford opportunities towards the preparation of mendable polymers and polymer composites with enhanced recycling properties.

## Moving from products at the end of life cycle towards smart materials

Composite materials have gained increased attention in high-performance products, which are based on two or more constituent materials, e.g. glass, carbon, metals and ceramics. For these composite materials, different polymers are often used as a matrix material. In numerous applications, high-performance polymers cannot be recycled at the end of the life cycle of a product. Thus, valuable materials cannot be recovered ending in a massive consumption of resources and no sustainability with respect to the materials used.

Shock, impact and cyclic stresses can cause a failure of affected parts on microscopic or macroscopic scale. A breakdown of the entire product involves an early end of the predicted life cycle.

Production processes without closed cycle of material management constitute a crucial problem in a world of finite resources. Thus, the key issues for future intelligent materials are supposed to be towards improved recycling strategies or self-healing concepts in order to prevent a premature end of product life.

## Smart polymers – focusing on switchable properties

In the framework of recent research at PCCL stimuli-responsive polymer materials are designed. Characteristic architectures and properties of the materials can be controlled and changed on macromolecular scale in response to an external stimulus (e.g. heat, light). As alterations on a molecular level have distinctive impacts on macroscopic material properties, the introduction of molecular switches in polymer materials and polymer networks have become a popular route for the preparation of innovative materials with enhanced recycling as well as self-healing ability.

In particular, light of suitable wavelengths is applied as an external stimulus for the material concepts that are currently developed at PCCL. One concept exploits light-sensitive chemical

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groups, which are introduced in the polymer network and are specifically cleaved when the material is illuminated with light. Controlled material degradation by light becomes feasible and with the use of these photo-responsive material concepts, composite materials with enhanced recyclability and recovery of the used resources can be produced.

Self-healing of materials is achieved by the introduction of switchable and light active moieties to the polymer network. These moieties specifically and preferentially cleave upon mechanically induced damage (e.g. crack). The cleaved molecular bonds can be regenerated again in response to light. Thus, the material properties of the former polymer network are efficiently regained. Additionally, these moieties are able to fluoresce when cleaved and the inserted crack is detectable and visualized with the use of fluorescent light.

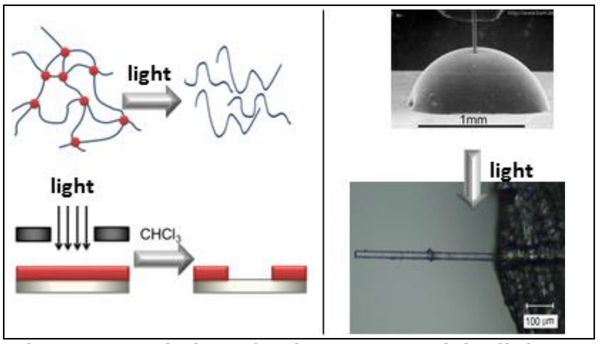

**Fig. 1: Degradation of polymer network by light (schematic representation, left) and the recovery of reinforced glass fibers from a polymer matrix (right)**

Polymers with switchable properties open up a new generation of smart materials with the capability of enhanced recycling and self-healing of mechanically induced cracks.

Besides the recovery of valuable resources, the employment of light allows the design of energy efficient processes since the use of light as external stimulus offers the possibility to control alterations in the molecular structure at defined positions as well as at room temperature.

Moreover, an extension of the product life cycle is particularly achieved due to self-healing ability of the material. Thus, the lifetime of components can be enhanced significantly.

Future research projects further aim at the implementation, realization and application of the developed material concepts for marketable and daily life products.

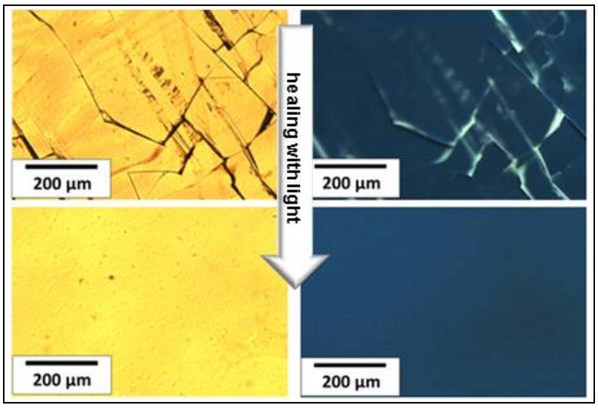

**Fig. 2: Healing of mechanically induced cracks (left) and detection of cracks by the use of fluorescent light (right)**

## Impact and effects

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