Self-healing polymers based on novel biomimetic materials

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Outline

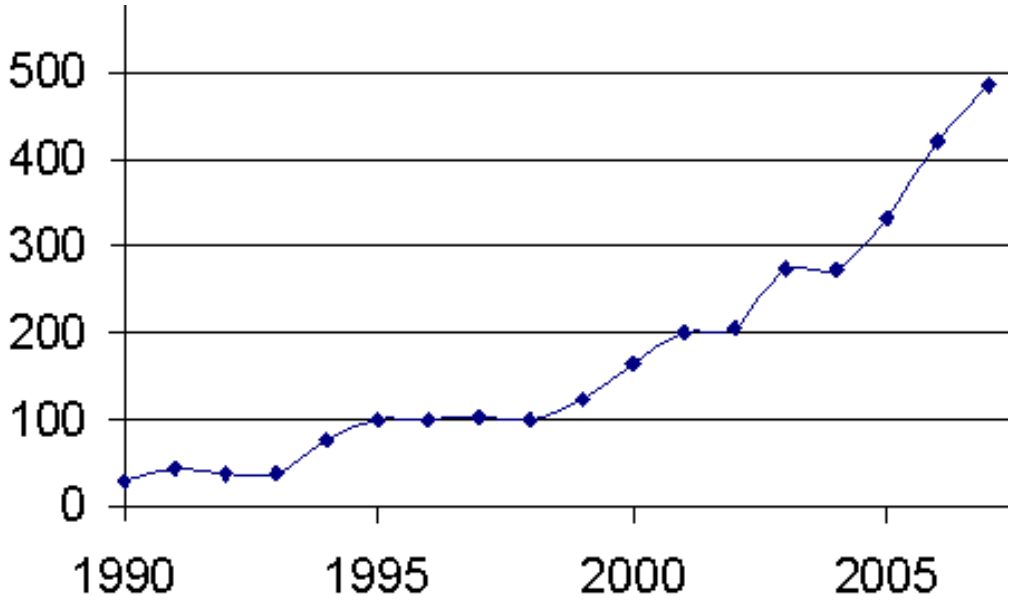
Self-healing polymers based on novel biomimetic materials

- Self-healing materials – State of the art
- Project OSIRIS – aim, idea and approach
- Sustainability aspects concerning the OSIRIS project
- Conclusion & Outlook

Self-healing materials – State of the art

Publications & Patents

SciFinder, Literature research: »self-healing OR self-repairing«



Recent revue:
Wu, D.Y., Meure, S., Salomon, D.
Self-healing polymeric materials – A review of recent developments
Prog. Polym. Sci., 33 (5) 2008, 479-522

Self-healing materials – State of the art

Institution	Research subject
University of Illinois	Microcapsules for polymeric materials
University of Bristol	Hollow fiber composites
MPI Düsseldorf	Anti-corrosion coatings
MPI Potsdam	Self-healing cellulosic fibers, anti-corrosion coatings
TU Delft, DCMat:	Bacterial crack-healing (concrete), self-healing conducting polymers
Fraunhofer UMSICHT	Sealing materials based on hydrogels
University of Freiburg	Biomimetic self-healing pneumatic structures
CNRS-ESPCI, Paris	Self-healing rubber

Project OSIRIS (Start: 01.06.08)

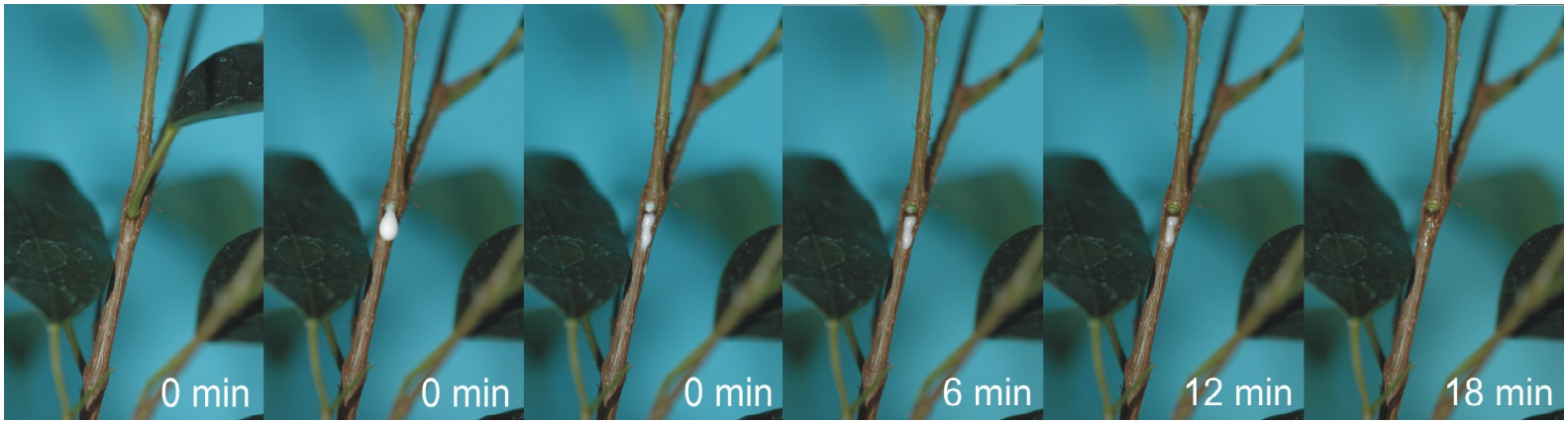
Motivation

- Increasing usage of polymers in applications with high mechanical stress
- Cases of breakdown of devices before reaching their limit loads
- Recent solution: preventive substitution after predetermined service life or number of cycles; acceptance of failures
- Abrupt failures are mainly caused by growing micro-cracks

Project OSIRIS

Idea

- Healing of micro-cracks before reaching critical dimensions
- Autonomous repairing process without external stimulus
- Biomimetic approach: self-healing botanical models



Source:
Prof. T. Speck,
University of Freiburg

Project OSIRIS

Approach

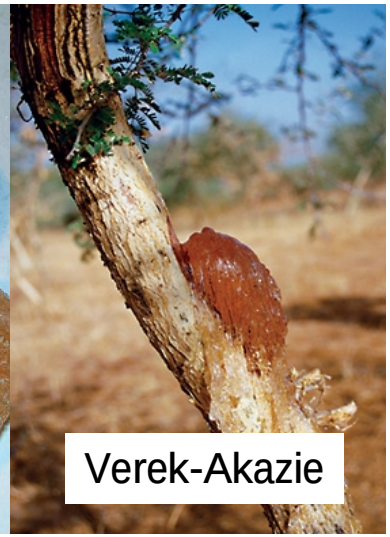
- Botanical secretions/reservoirs (biomimetic model)
- Analysis and evaluation of botanical self-healing mechanisms
- Analogy observation regarding
  - Chemistry, physics of compounds/compound interaction
  - Geometry/ structural design
  - Fluid mechanics
  - Efficiency of the healing process
- Transfer to technical systems
- Simulation of micro-crack generation and propagation in the self-healing composite and in the reference material

Project OSIRIS

Approach – Botanical secretions

- Promising model compounds: resins and latices (e.g. caoutchouc, gutta-percha, …)

Resin: gum arabic



Latex: caoutchouc

Source:
Prof. T. Speck,
University of Freiburg

Approach – Botanical reservoirs

- Model reservoir/transport systems: capsules and micro-tubes

Micro-tubes (scorzonera)

Spherical reservoir (mimosa)

Source: Prof. T. Speck, University of Freiburg

- Chemical, structural design of the reservoirs
- Chemistry, rheology & adhesive properties of the secretions
- Activation and mechanism of fluid transport into (micro-)cracks
- Structure, mechanical properties and durability of the finished crack healing process

Project OSIRIS

Approach – Healing mechanism of natural latex

- Rubber particles and hevein vacuoles are present in natural latex
- Hurting the plant results in bursting of these vacuoles (pressure differences)
- Free hevein molecules interact with glycosilated binding sites of rubber particles, building a three-dimensional network
- This bridging reaction leads to the coagulation of latex

Transfer options

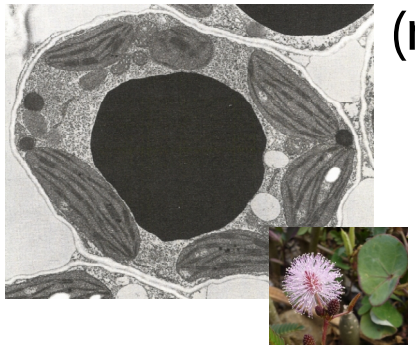
- Using pressure differences as self-healing stimulus (internal stimulus)
- Using capsulated mini-emulsions as self-healing components

Project OSIRIS

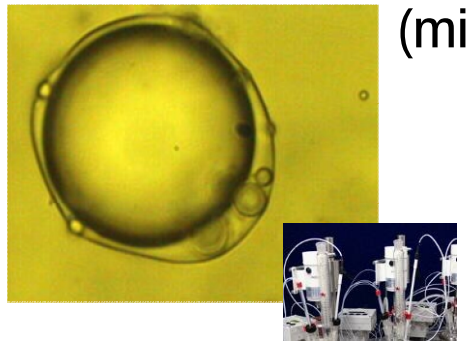
Approach – Transfer options

- Construction of reservoirs/ transport systems on the basis of synthetic micro-capsules (e.g. MF-resin and polyurea), phase separation (solid emulsions) or micro-tubes (glass capillaries)
- Self-healing system based on e.g. polycations + nanoclays, living polymers + monomers or monomers + catalysts

Spherical reservoir (mimosa)



Spherical reservoir (micro-capsule)



Source: Fraunhofer UMSICHT

Project OSIRIS

Approach – Application transfer

- Polymeric matrix: types of rubber (e.g. NBR, EPDM, TPE)
- Implementation of self-healing components into the different matrices
- Comparison reference material vs. self-healing polymer, analysis of function and efficiency of self-healing

Demonstrators based on rubbers: sealing, gaiter, flexible elements,…

Project OSIRIS

Sustainability aspects

- Assessment on the basis of accepted sustainability rules
- Evaluation of the projects impact on different dimensions
- Comparison to alternative approaches and technologies
- Definition of relevant indicators

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SYSTEM OF SUSTAINIBILITY RULES (translated according to Kopfmüller et al., 2001)		
Essential Rules and their Classification		
Securing of human existence	Preservation of the social productivity potential	Preservation of the development potential and of the prospective freedom of action
Securing the human health	Sustainable usage of renewable resources	Equal opportunities regarding education, career, information
Ensuring the satisfaction of basic needs (nutrition, education …)	Sustainable usage of non-renewable resources	Participation in social decision-making processes
Autonomous securing of livelihood	Sustainable usage of the environment as a sink	Preservation of cultural heritage and cultural diversity
Distributive justice regarding options to use the environment	Prevention of unjustifiable technical risks	Preservation of cultural functions of nature
Compensation of extreme differences in income and wealth	Sustainable development of material, human and knowledge resources	Preservation of social resources

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- Reduction of emissions
- Additional usage of hazardous chemicals

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- Increase of service life time of rubber-sealing
- Reduction of losses caused by leakage

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- Reduction of emissions
- Decrease of recycling options

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- Increase of the service life time of devices
- Strengthening biomimetic knowledge

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- Biomimetic approaches as drivers for the preservation of diversity; esteeming nature's teaching character

Conclusion & Outlook

Self-healing materials

- Emerging field of R&D with a variety of approaches and applications
- The OSIRIS project aims at biomimetic self-healing polymers using botanical models
- The impact of the project will be evaluated concerning sustainability aspects

Further challenge

- Creating materials with renewable, continuously working self-healing components

THANKS….

…for funding: BMBF

…for paying attention: You

www.bionische-innovationen.de/projekte.html