Fraunhofer IAP

Fraunhofer Institute for Applied Polymer Research IAP

Smart Materials Summit, 06.11.2025

Programmable Materials - Microcapsules

Dr. Christian Neumann

Programmable transport of heat and active substances

Cluster Programmable Materials (CPM)

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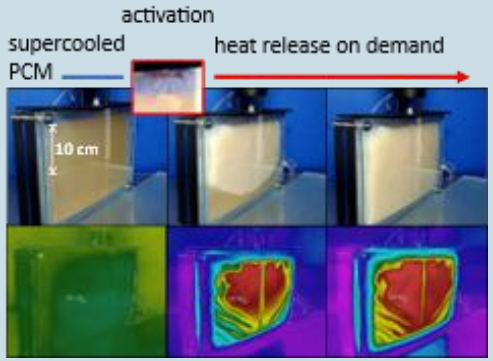
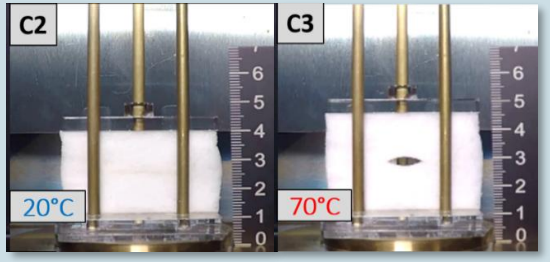
Programmable transport of heat and active substances

Cluster Programmable Materials (CPM)

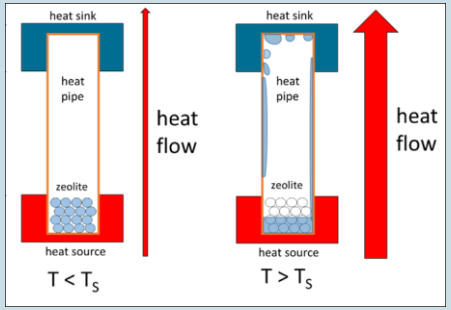
Switchable Phase Change Materials (sPCM)



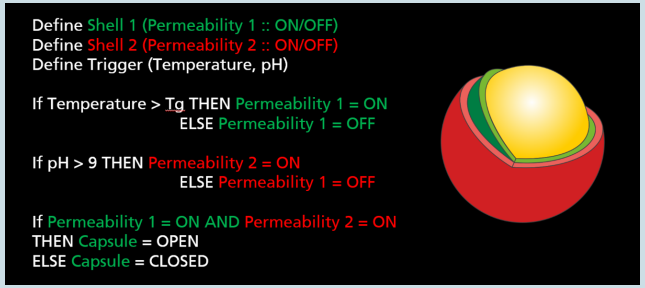
Programmable shape change (shape memory polymers)



Programmable heat pipes



Programmable Microcapsules



https://worldofprogmat.org/

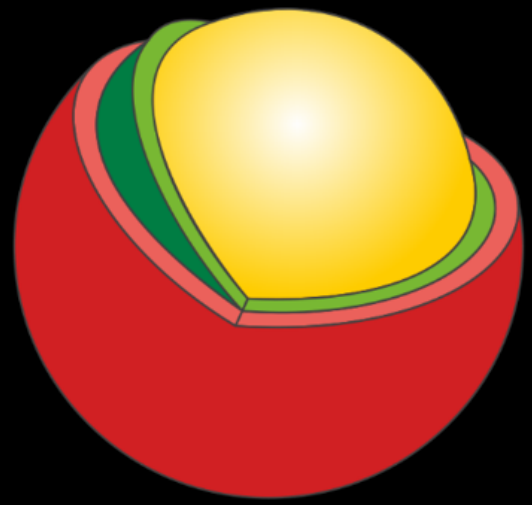
Vision – Programmable Microcapsules

Define Shell 1 (Permeability 1 :: ON/OFF)
Define Shell 2 (Permeability 2 :: ON/OFF)
Define Trigger (Temperature, pH)

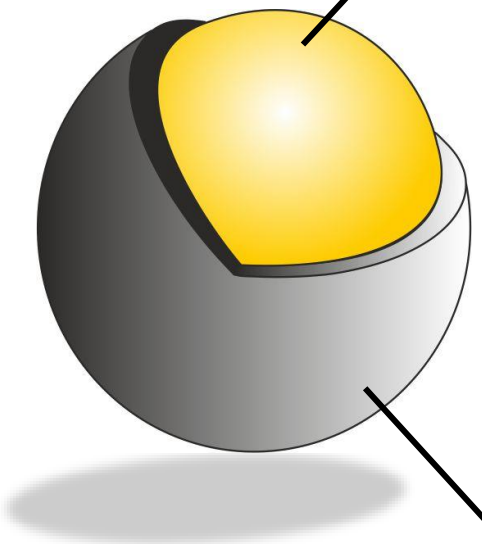
If Temperature > Tg THEN Permeability 1 = ON
ELSE Permeability 1 = OFF

If pH > 9 THEN Permeability 2 = ON
ELSE Permeability 1 = OFF

If Permeability 1 = ON AND Permeability 2 = ON
THEN Capsule = OPEN
ELSE Capsule = CLOSED



Microencapsulation of different substances



0,1 µm to 2000 µm

Core Substances

Smart Materials
- Phase change materials
- Thermochromic pigments
- Reactive components
- Lubricants

Reactive Components
- Catalysts
- Initiators

Agriculture
- Fertilizer
- Presticides
- Insect repellant

Polymer additives
- Fire protection
- Pigments

Cosmetics
- Fragrances

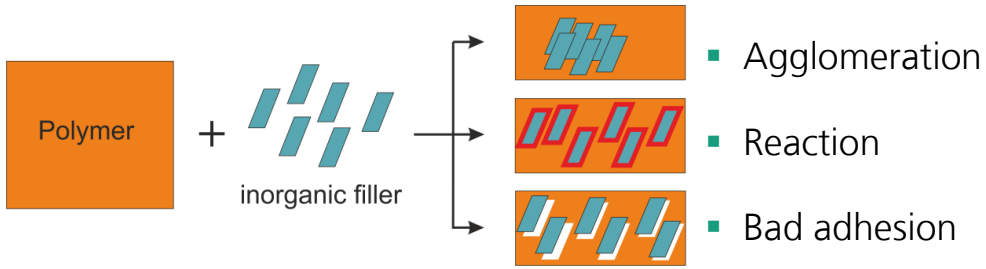
Food-/animal Feeding
- Vitamines
- Dyes
- Biocides
- Organisms
- Micro-nutrition

Trigger

Mechanical
Temperature
Humidity/water
pH
Light
(Bio)degradation

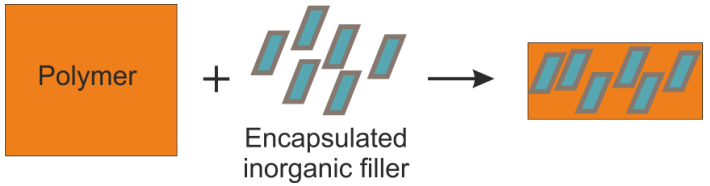
Improved stability and dispersibility for functional polymer films

MF technology for technical applications

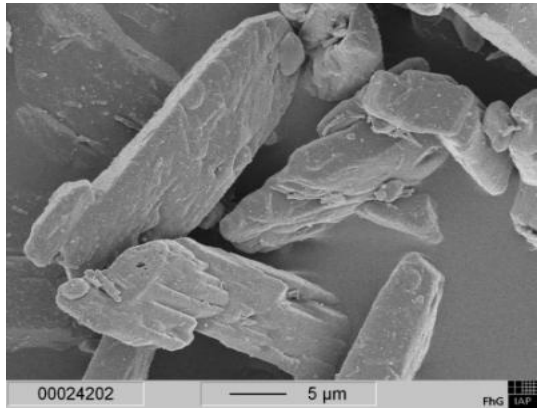


- Agglomeration
- Reaction
- Bad adhesion

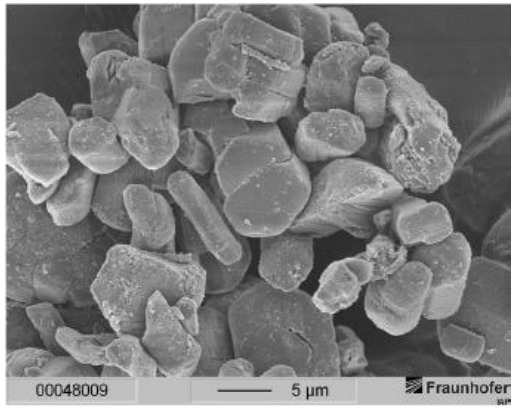
Microencpasulated



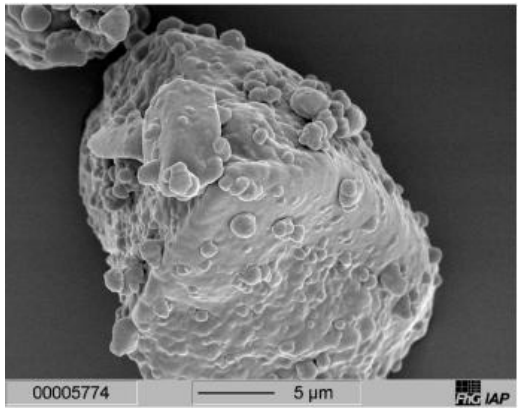
- Good dispersion
- No reactions
- Good adhesion



Copper flakes for greenhouse PE films



Ammonium polyphosphate for PU-based materials



Red phosphorus for special flame-retardant applications

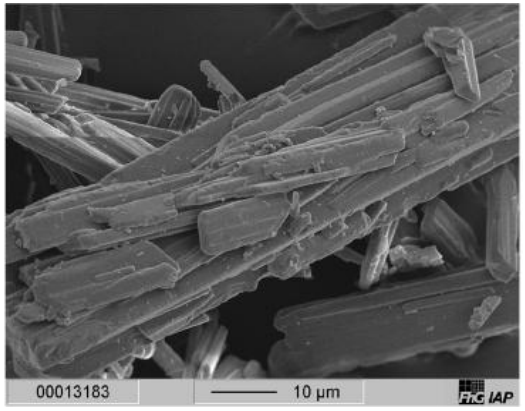
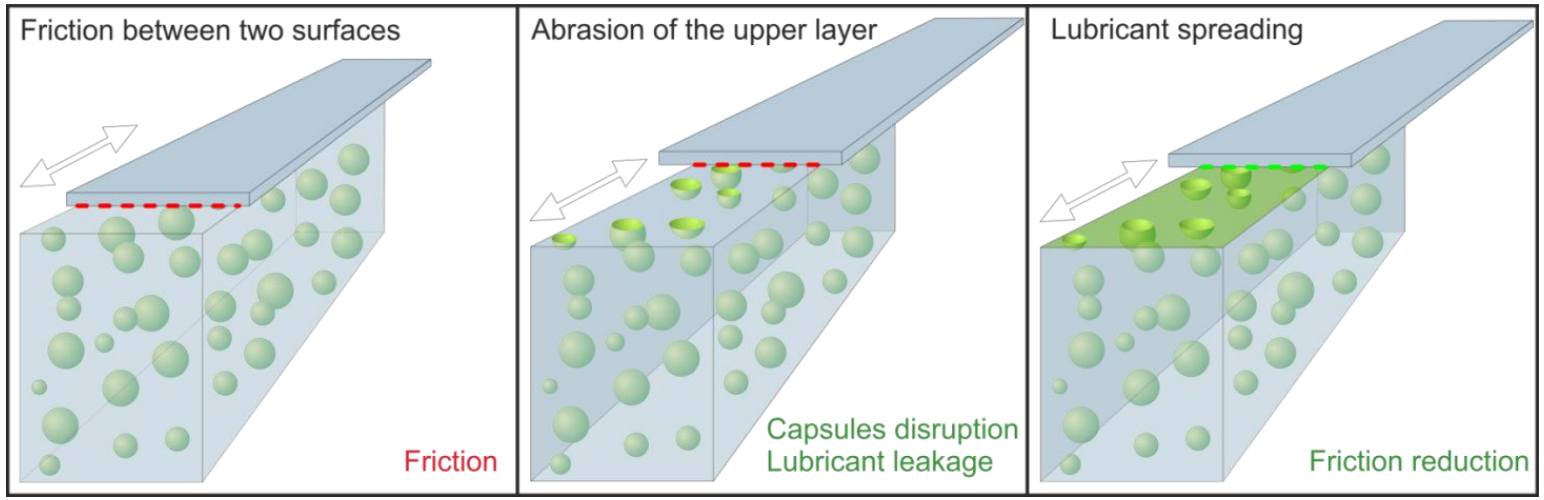
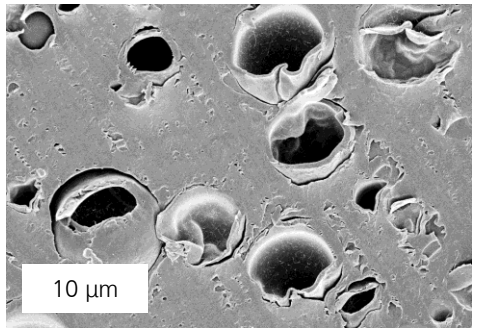
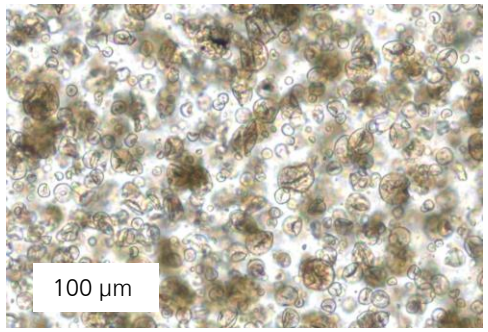


Photo- and thermostabilizers for agricultural films

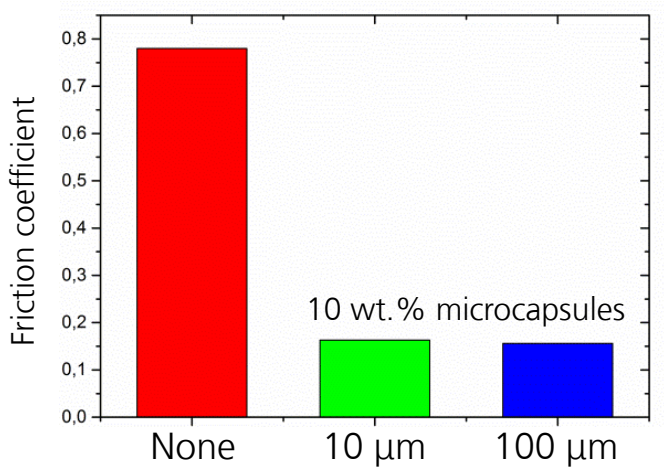
Self-lubricating plastics







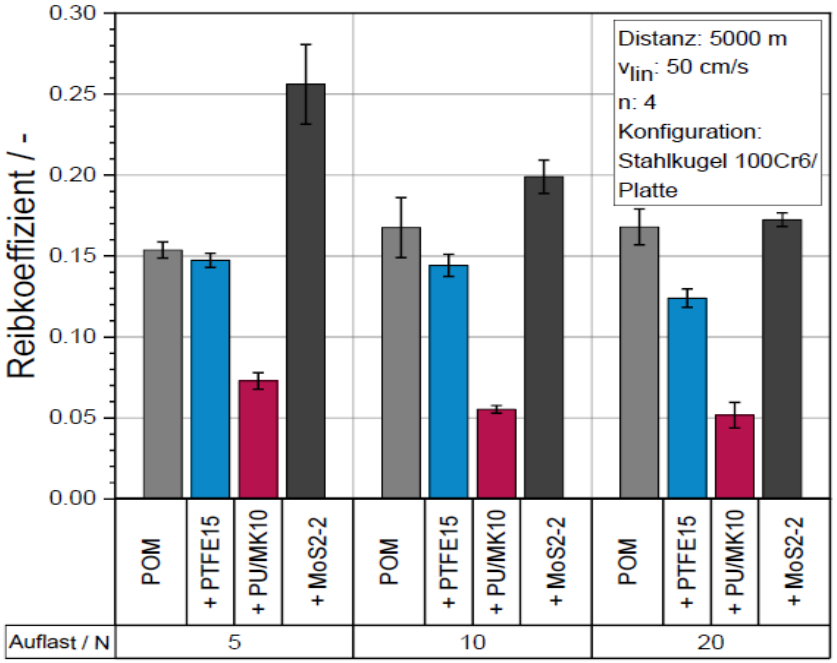
REM and microscopy images of microcapsules integrated in polymer matrix (left = latex coating, right = POM)

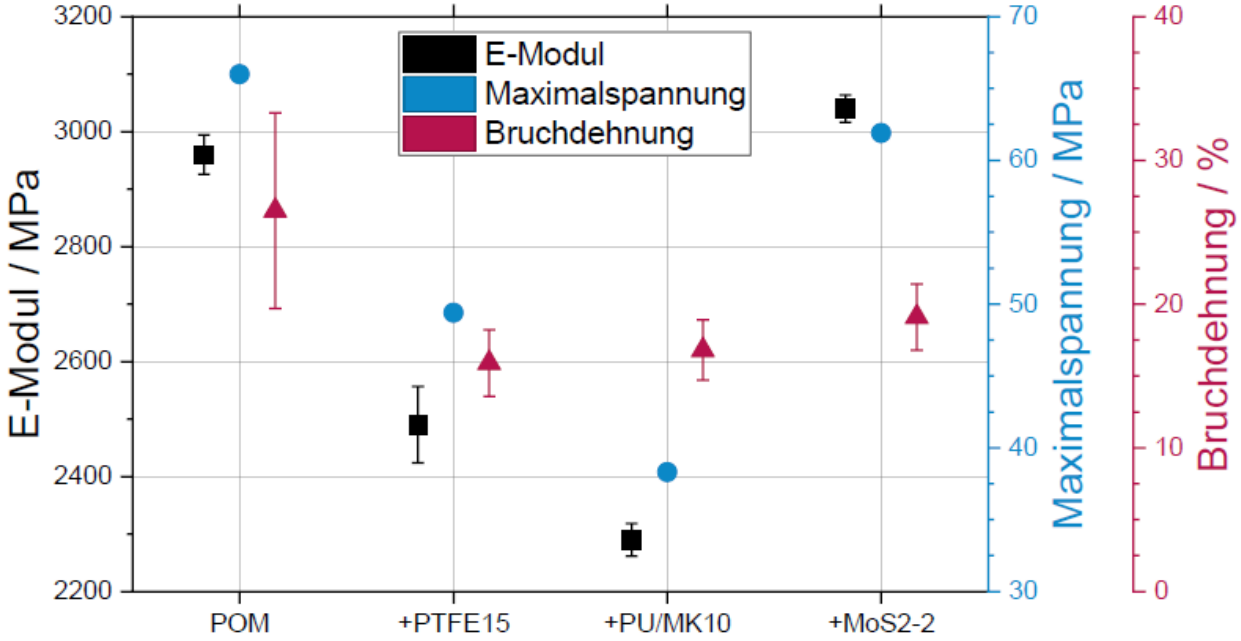


Friction coefficient for polymer without (red) and with 10 wt% lubricant-filled microcapsules (green = 10 µm, blue = 100 µm).

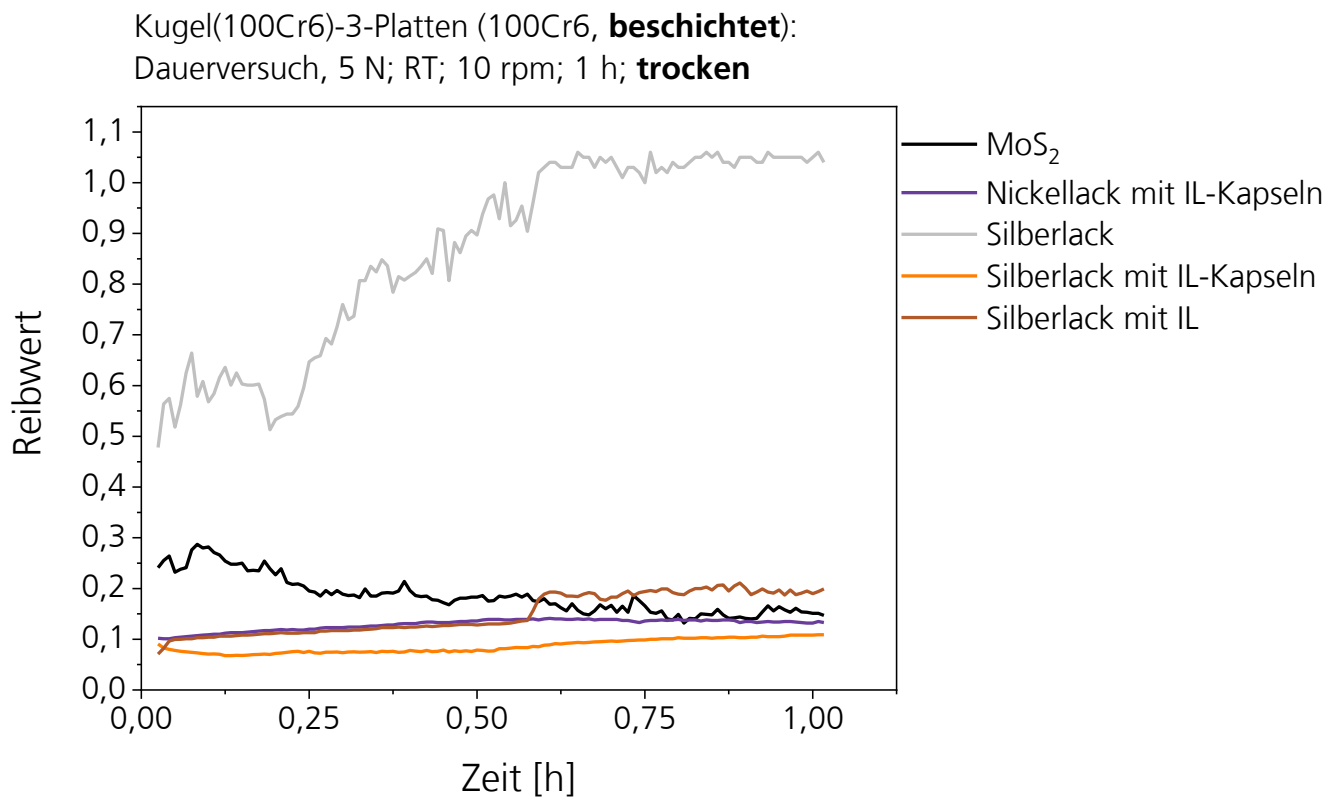
Tribological and mechanical properties of different microcapsule composites

POM

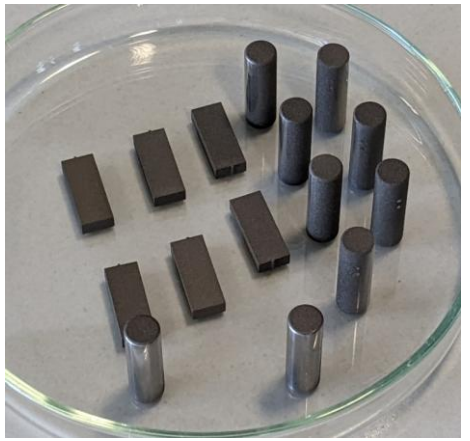


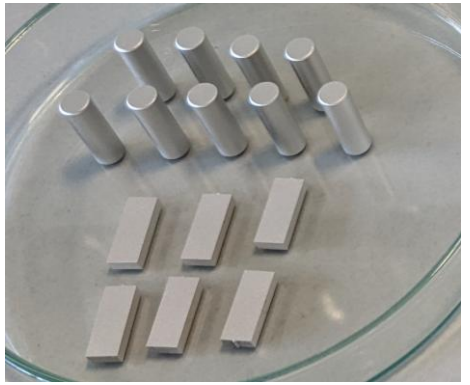


Tribological investigation in microcapsule coatings



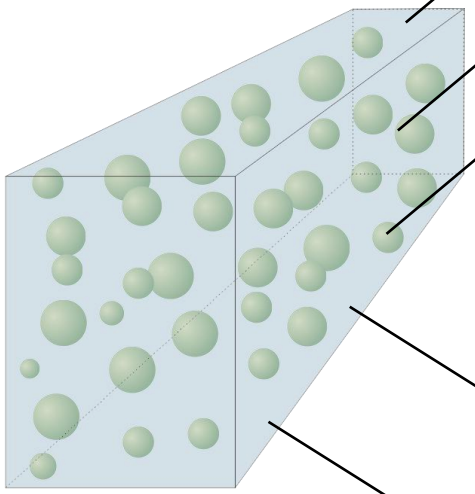
Nickel coating with capsules





Silver coating with capsules

Current research topics of polymer parts with microcapsules



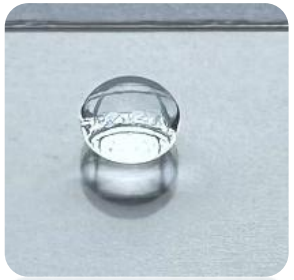
Controlled release of lubricants

Controlled release of superhydrophobic substances

Controlled release of plasticisers

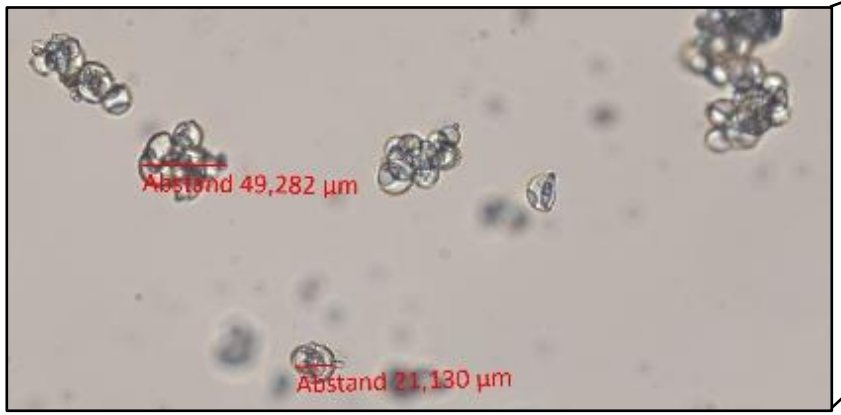
Controlled release of UV-protecting agents

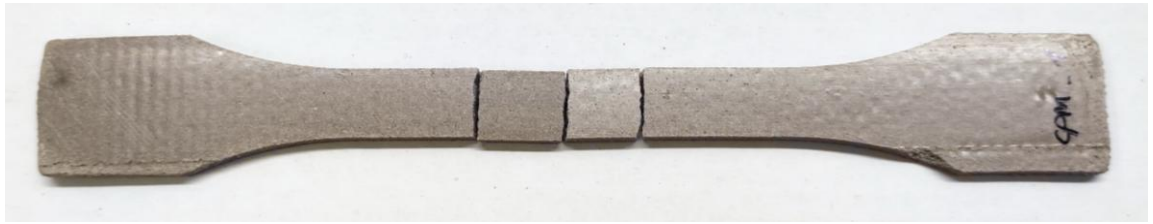
Thermochromism, mechanochromism, photochromism

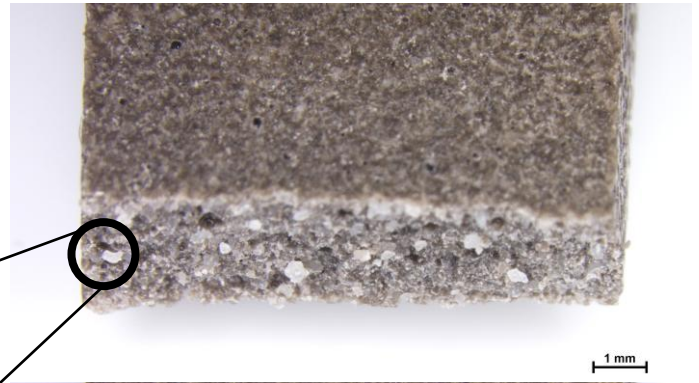


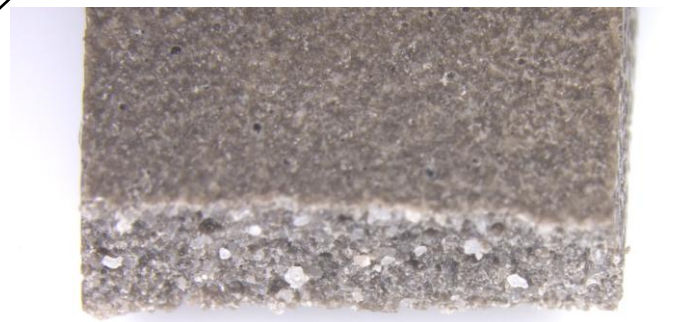
Composites with microcapsules

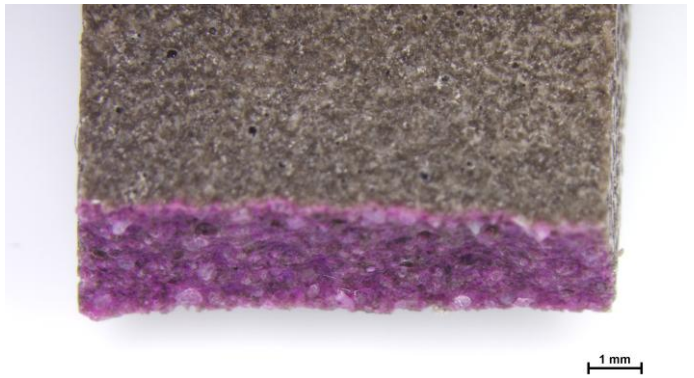
Concrete-based materials with microcapsules for release upon fracture





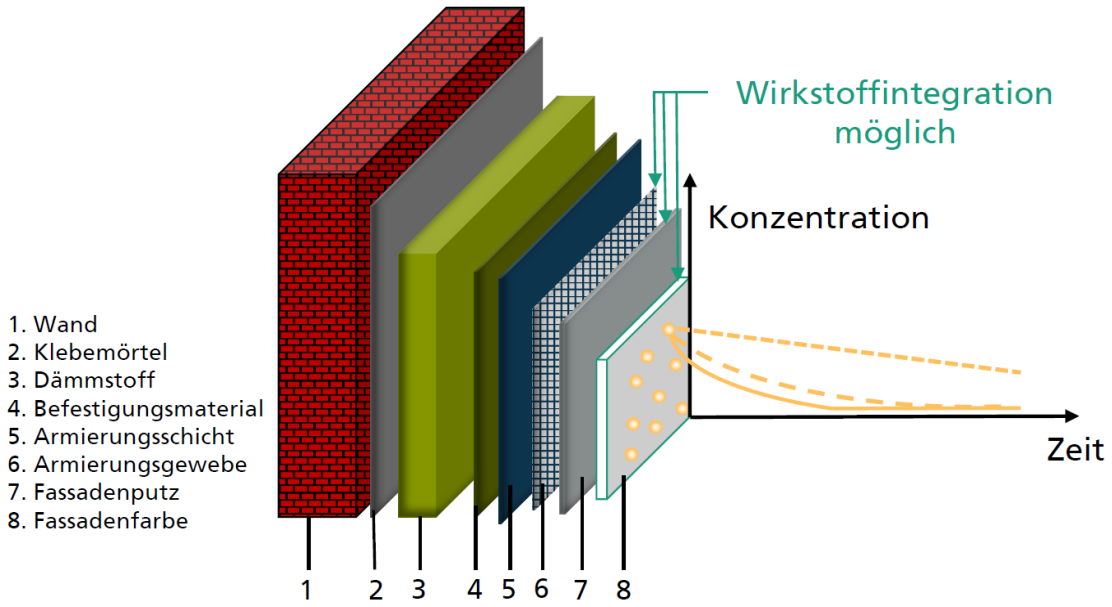


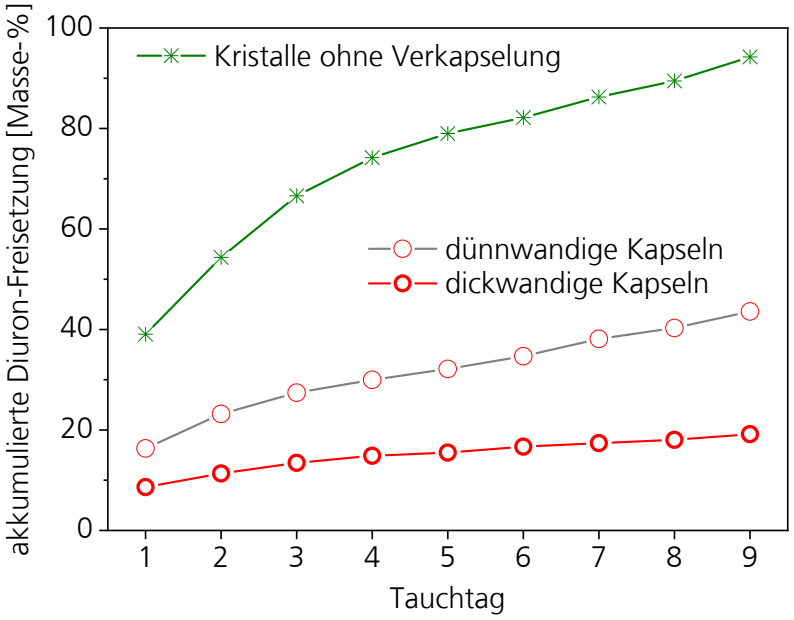




Controlled release of biocies for prevention of algae growth on facades

Water responsive microcapsules for controlled release of biocides





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