Fraunhofer IAP

Fraunhofer-Institut für Angewandte Polymerforschung IAP

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High temperature switching shape memory polymers for industrial applications

Theodor Galambos, Kerim Temme, Thorsten Pretsch

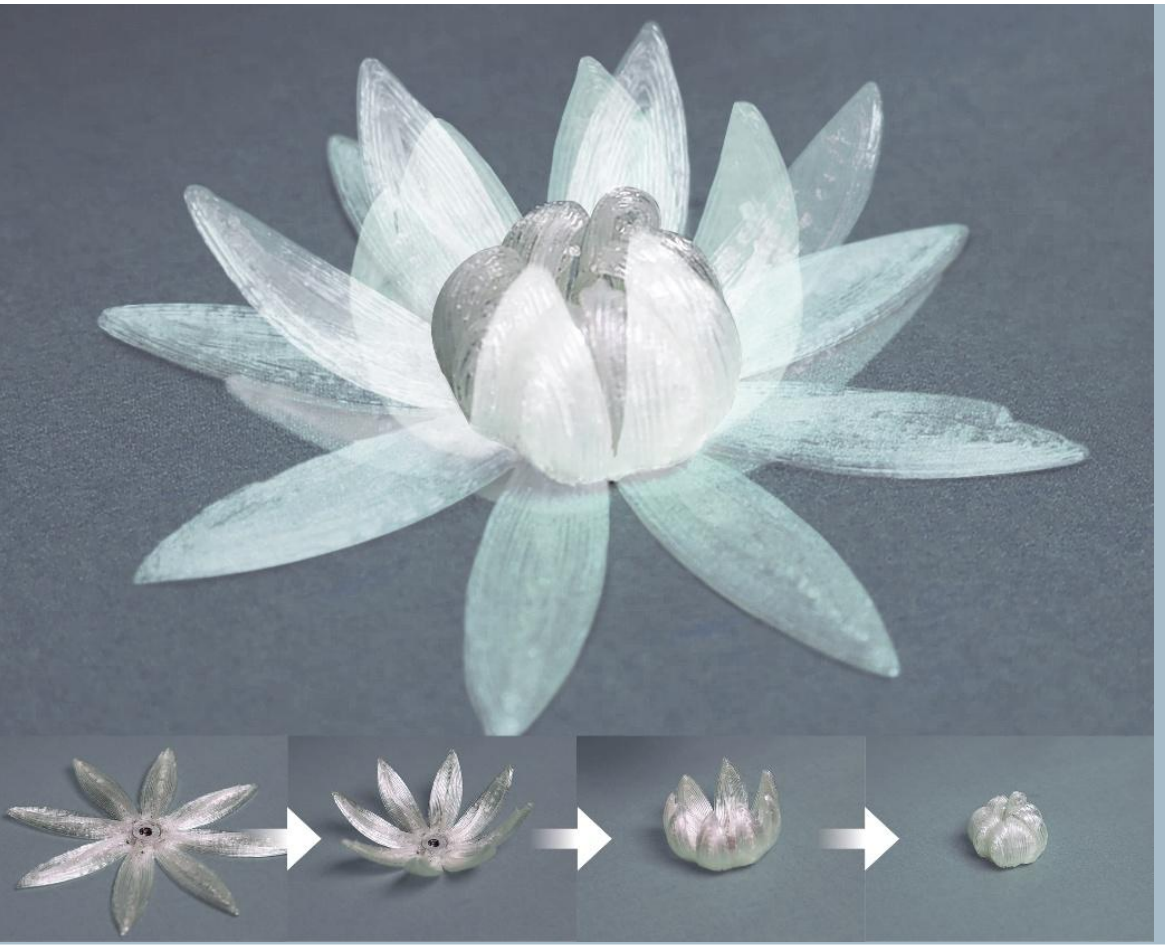
High temperature* switching SMPs

Content

*** T > 90 °C**

Introduction

Polyurethanes with Shape Memory Properties

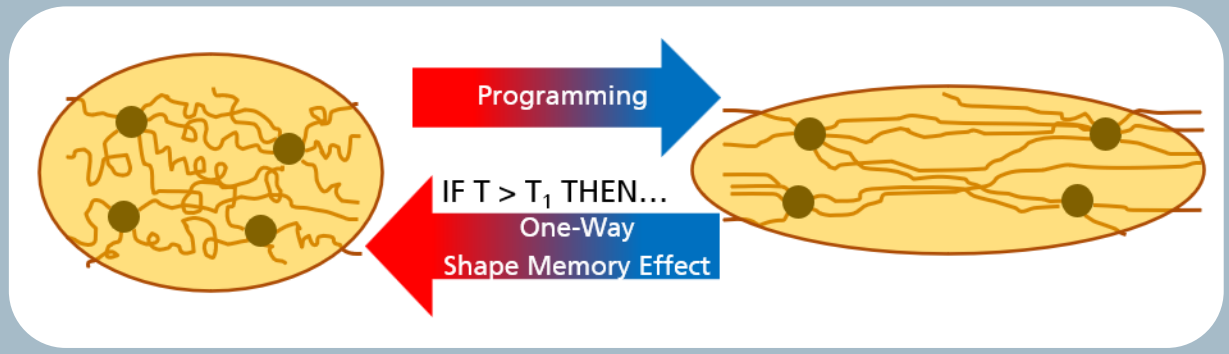


01

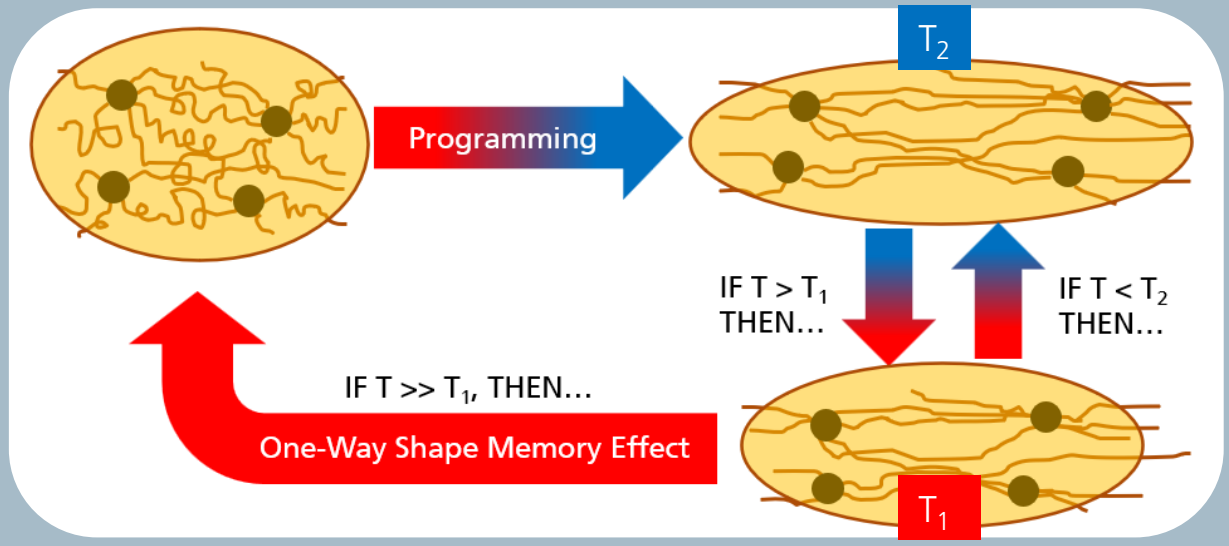
From programming to stimulus-responsiveness

Shape Memory Polymers
Functional Principles

One-Way Shape Memory Effect

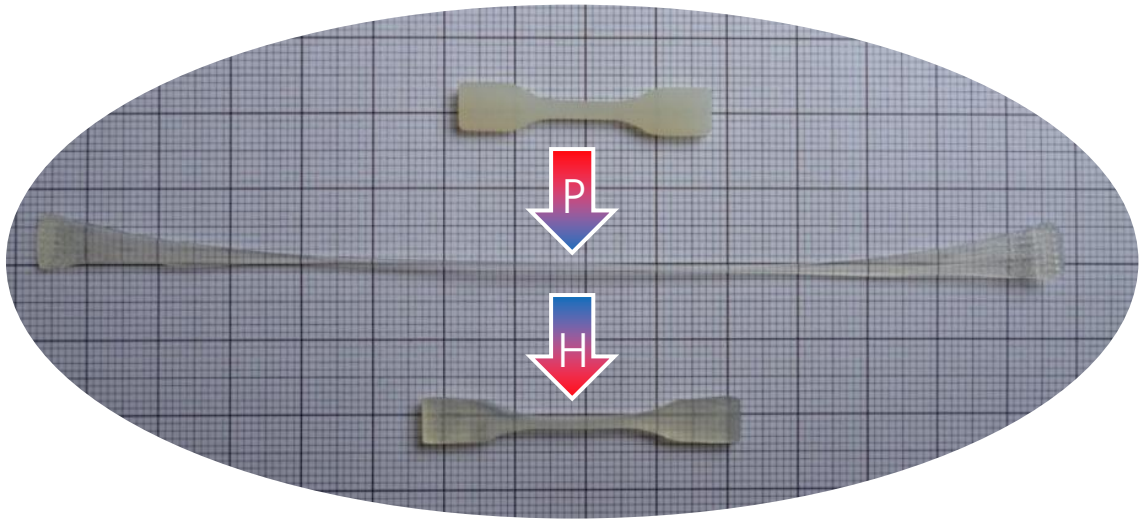


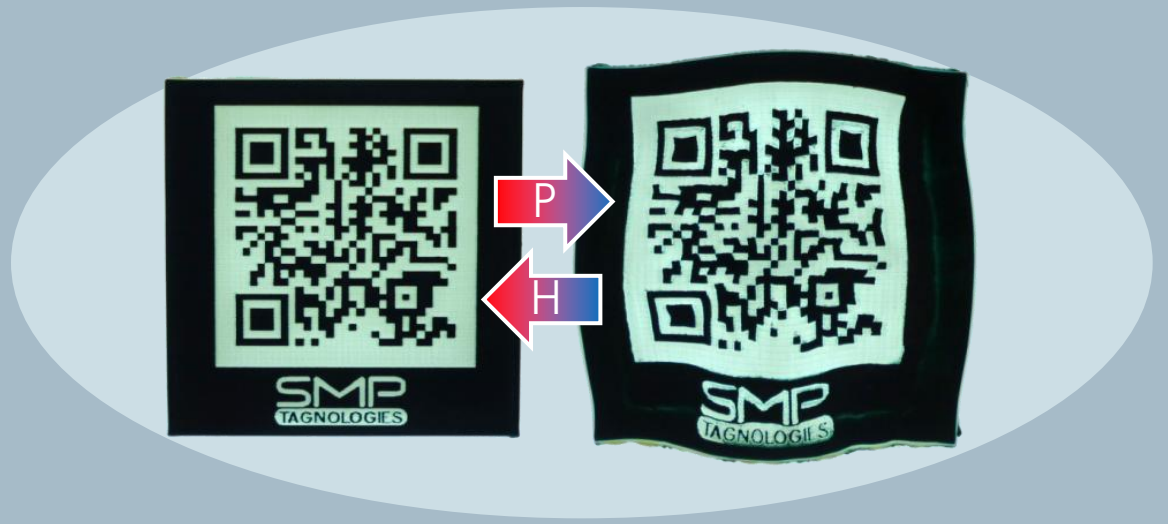
Two-Way Shape Memory Effect



Thermoplastic Polyurethanes

Shape Memory Properties





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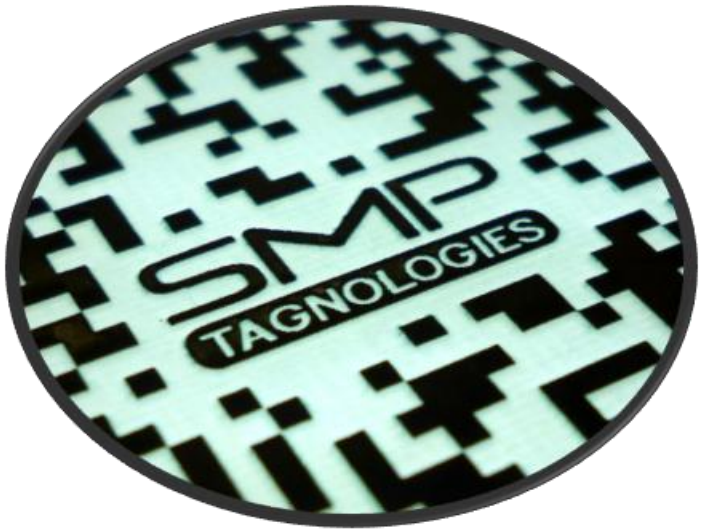
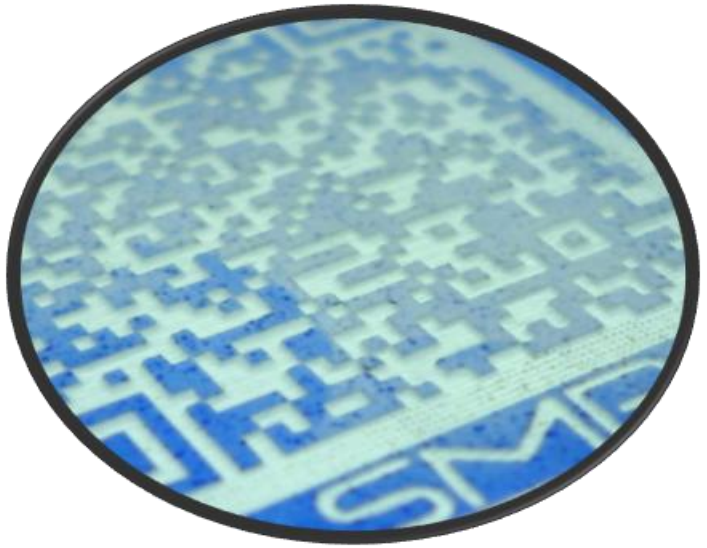
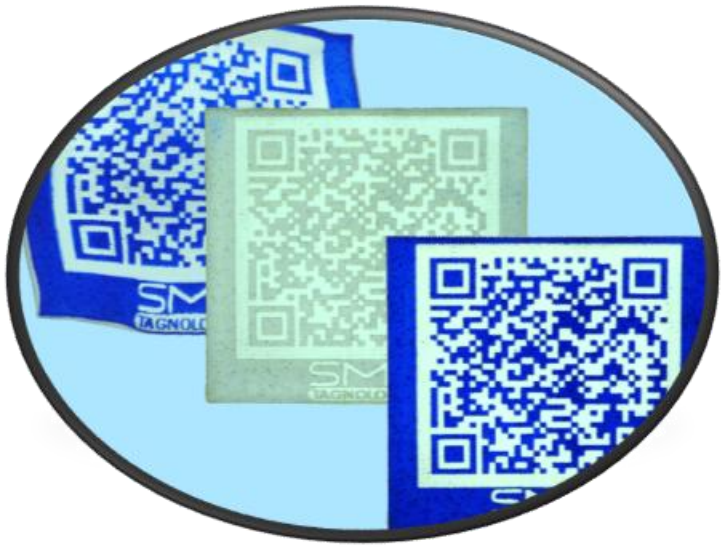
Multifunctional Polymer Materials

Thermochromic and Shape Memory Properties

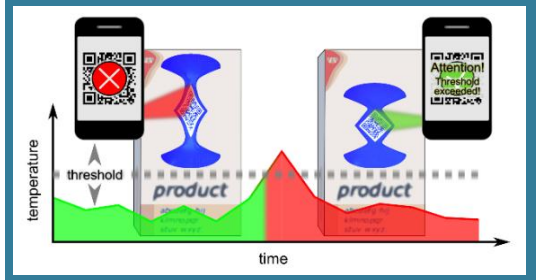






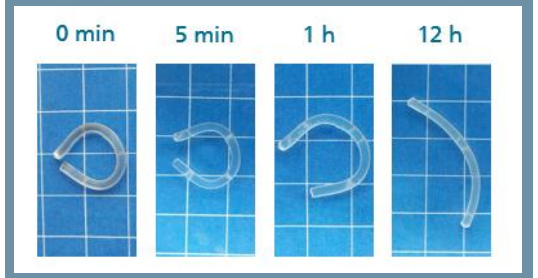
Shape Memory TPUs & Composites

Stimulus-Responsiveness



Temperature

The one-way shape memory effect can be triggered by increasing the temperature.

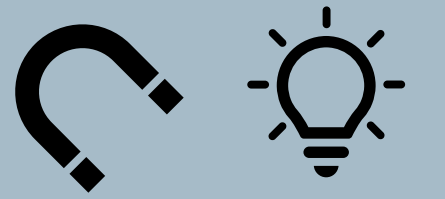


Water

Water can also be used to trigger the one-way shape memory effect.

Electricity

Electroactive SMPs change their shape when an electrical voltage is applied.



Further stimuli possible:
Light and magnetic fields

We offer:

Customized adaptation of TPU materials to your requirements.

High temperatures occur in the automotive sector, in fire protection or in the aerospace industry. This can lead to the unintentional triggering of shape memory effects, motivating a need for SMPs that switch at higher temperatures.«

Thermoplastic Polyurethanes

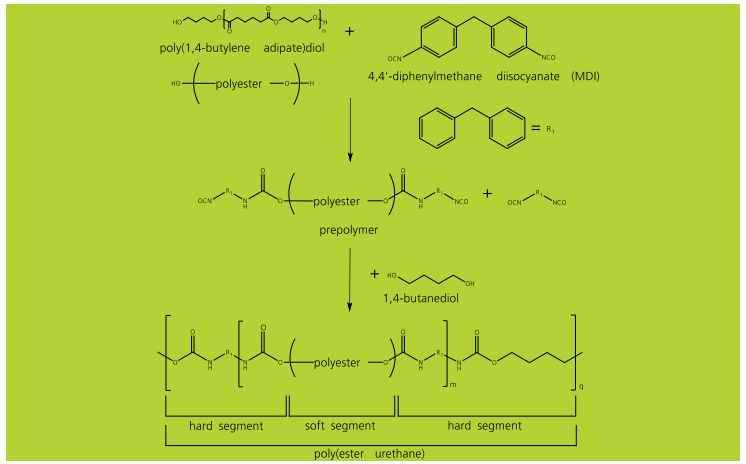
Development

02

From synthesis to programming

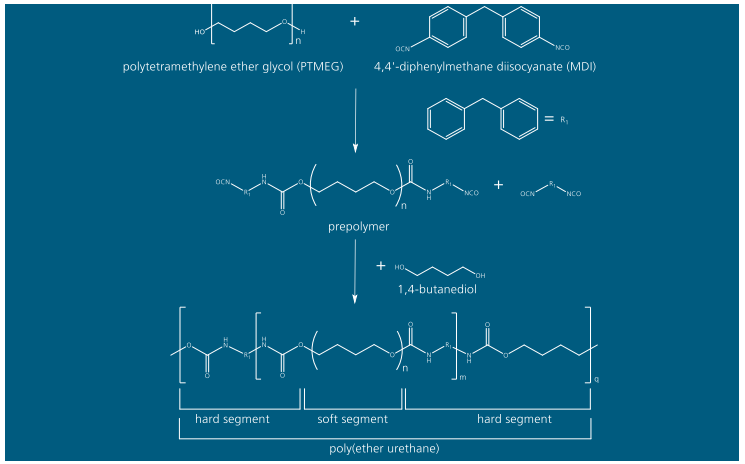
Thermoplastic Polyurethanes

Synthesis



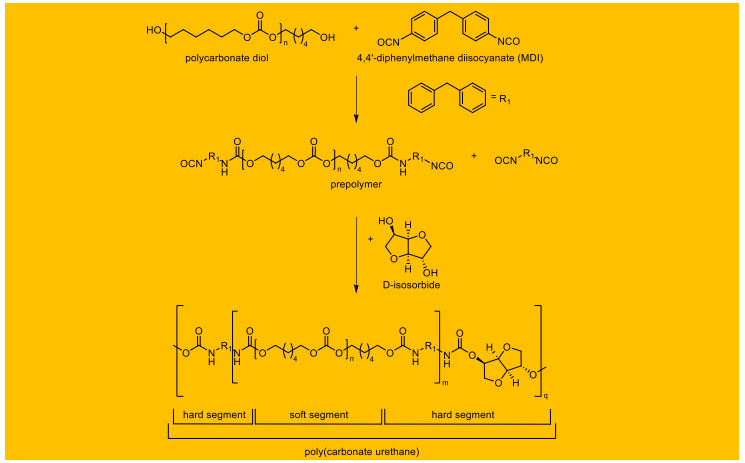
Poly(ester urethanes)

- High tensile, tear and abrasion resistance
  → Use in shoe soles, conveyor belts and protective films (cell phones)
- Excellent oil and grease resistance
- High burst pressure resistance
  → Use in high-pressure applications



Poly(ether urethanes)

- High impact abrasion resistance
  → Use in bumpers
- Excellent hydrolysis resistance
  → Ideal for wet or tropical applications
- Excellent bending strength
  → Suitable for hoses, seals, bent parts

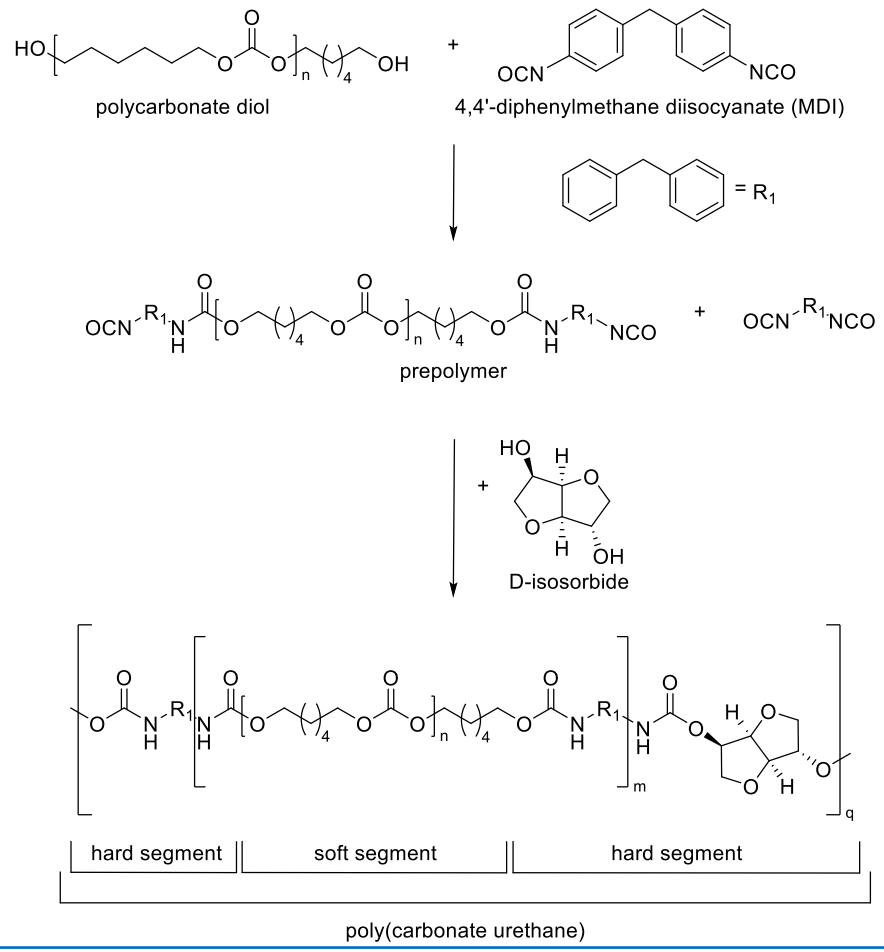


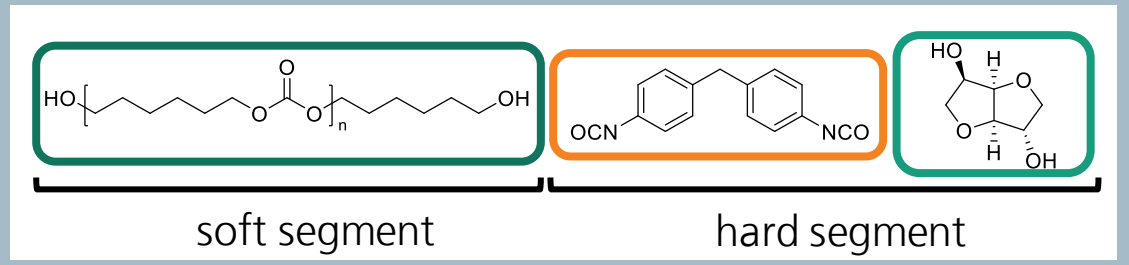
Poly(carbonate urethanes)

- Excellent hydrolysis resistance
- High oxidative stability tolerates sterilization processes without embrittlement.
- Biostable and biocompatible
  → Preferred for medical and implant parts

Poly(carbonate urethanes)

Synthesis

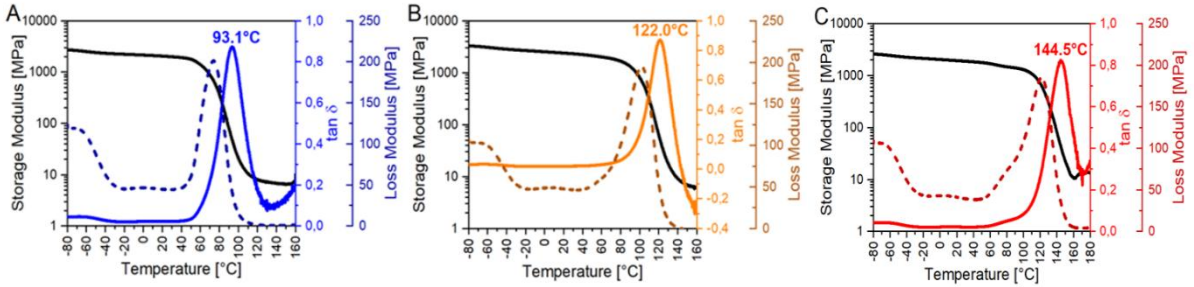




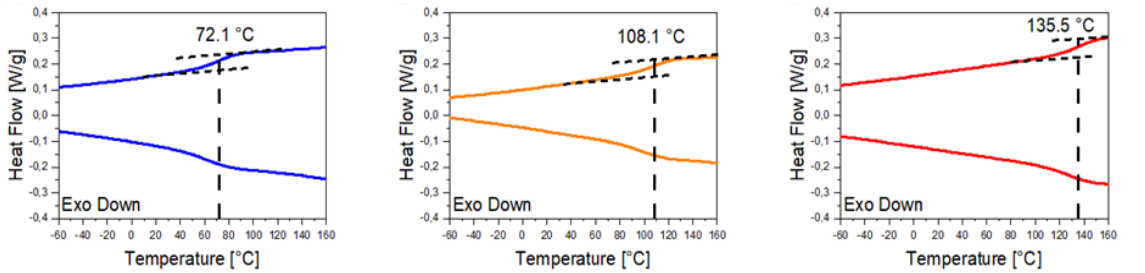
Poly(carbonate urethanes)

Characterization

Dynamic Mechanical Analysis (DMA)

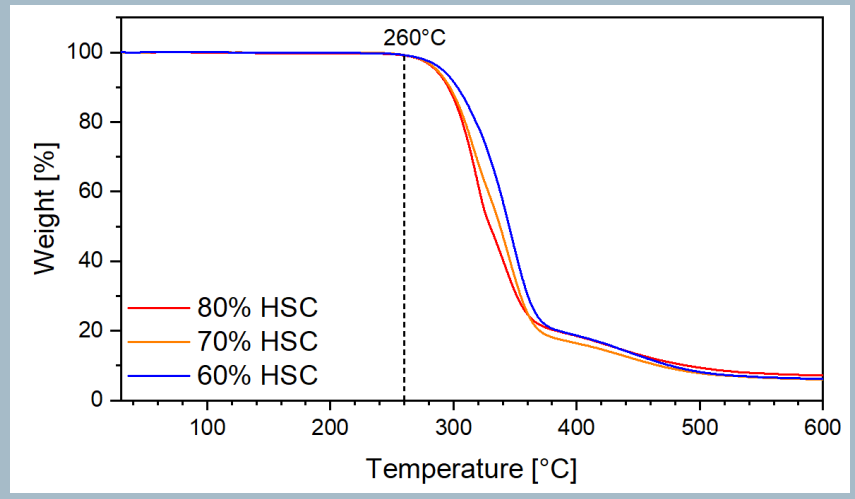


Differential Scanning Calorimetry (DSC)

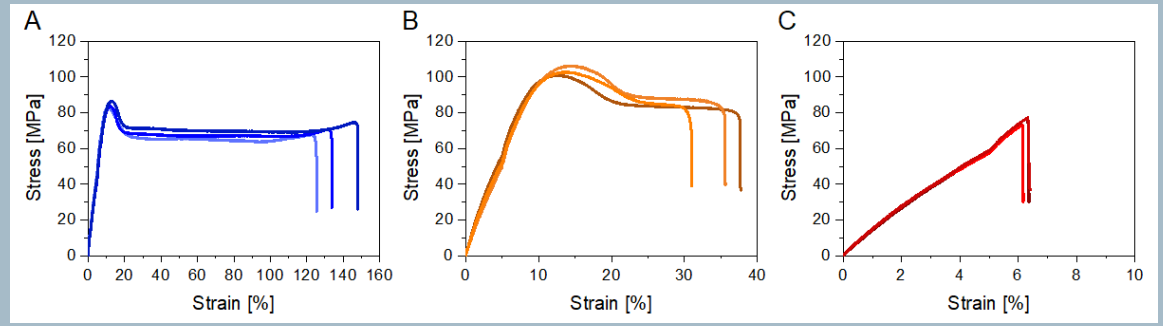


60 wt% HSC **70 wt% HSC** **80 wt% HSC**

Thermogravimetric Analysis (TGA)



Tensile tests



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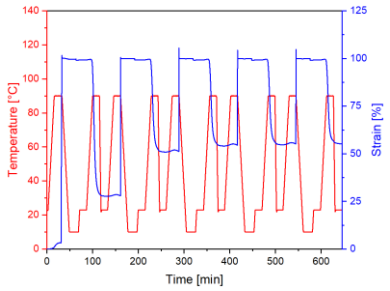
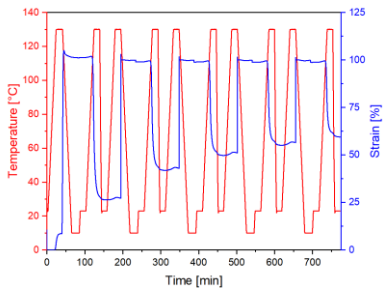
Poly(carbonate urethanes)

Characterization

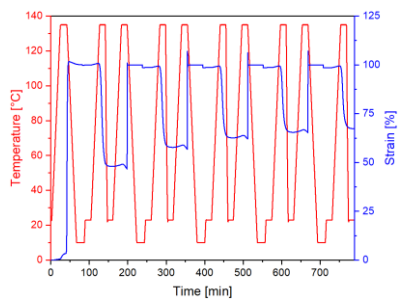
Dynamic Mechanical Analysis (DMA)



60 wt% HSC



70 wt% HSC



80 wt% HSC

Thermoplastic Polyurethanes

Processing

Customized & efficient

Material Development

Synthesis and Processing of thermoplastic Polyurethanes

- Development of ester-, ether- and carbonate-based TPUs
- Tunable physical and functional properties
- Applications: Semi-finished products, products with shape memory properties

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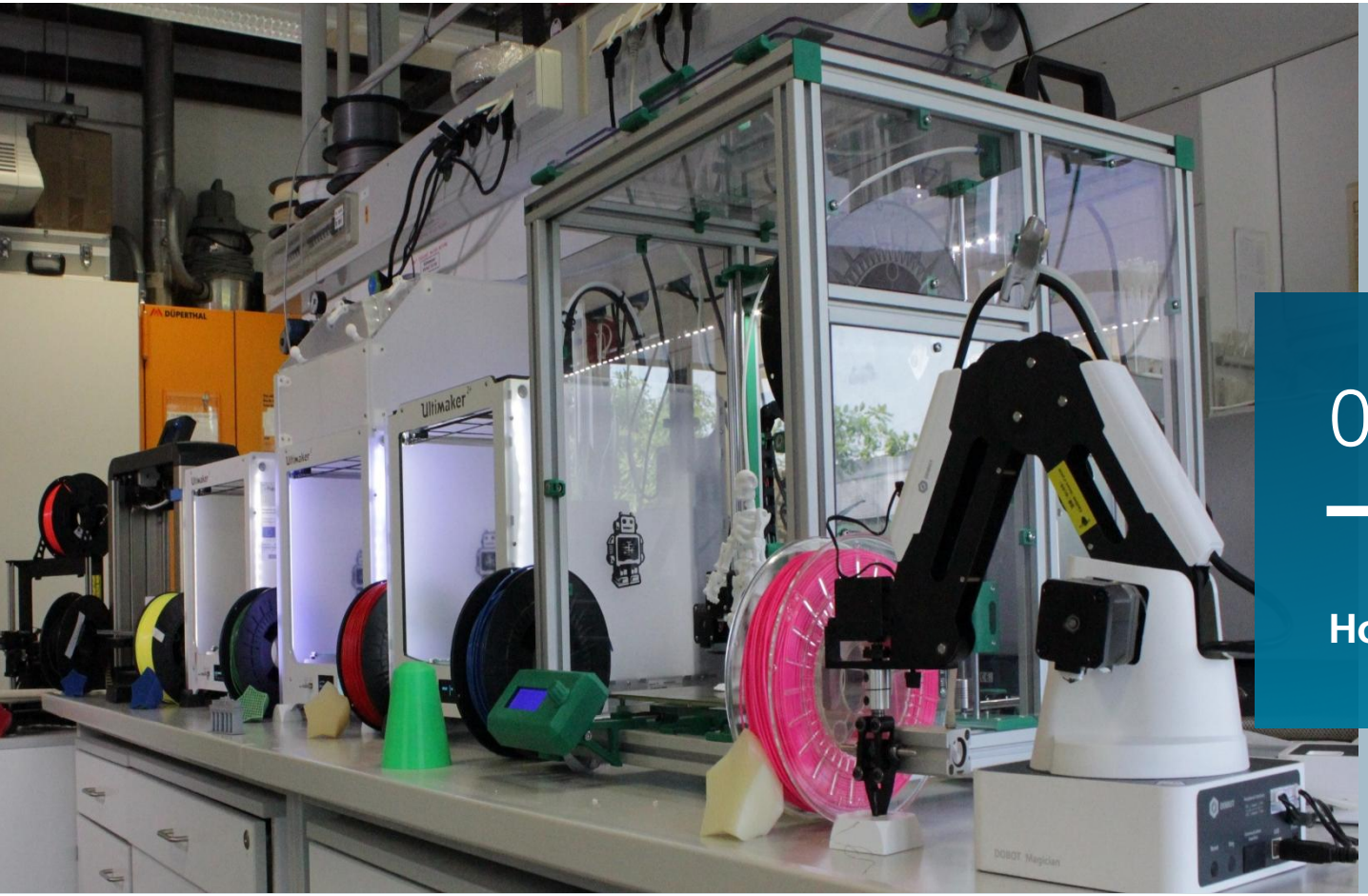
Additive Manufacturing

Polyurethanes with Shape Memory Properties

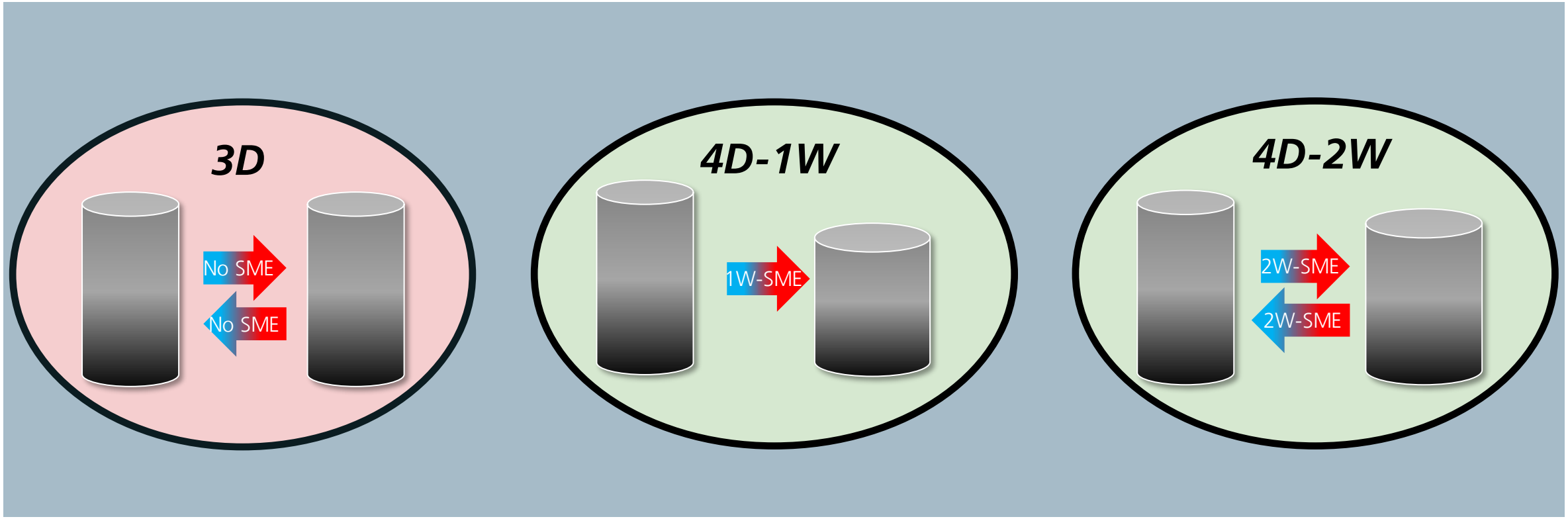


03

How to control stimuli-responsiveness?

Additive Manufacturing

3D/4D-Printing with Shape Memory Polymers

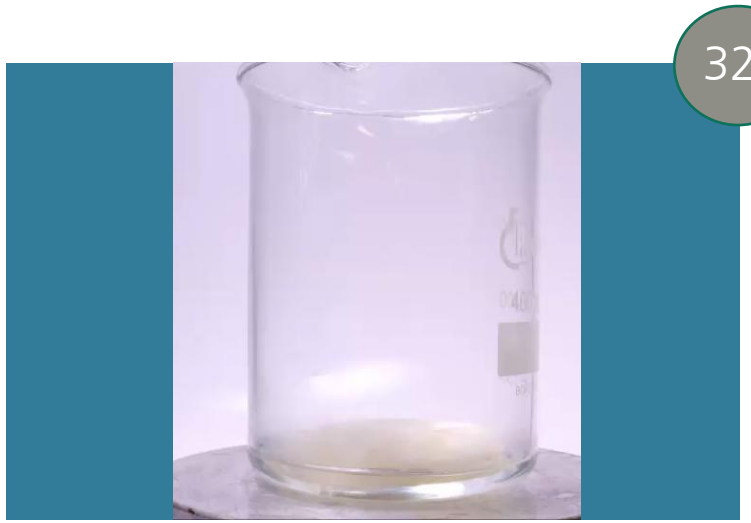


3D Printing & Programming

Fused Filament Fabrication using Shape Memory Polymers

Earring / Jewelry

- Manufactured by synthesis, processing, 3D printing and programming (1W SME)
- Almost unlimited number of shapes can be programmed.



Toy Duck

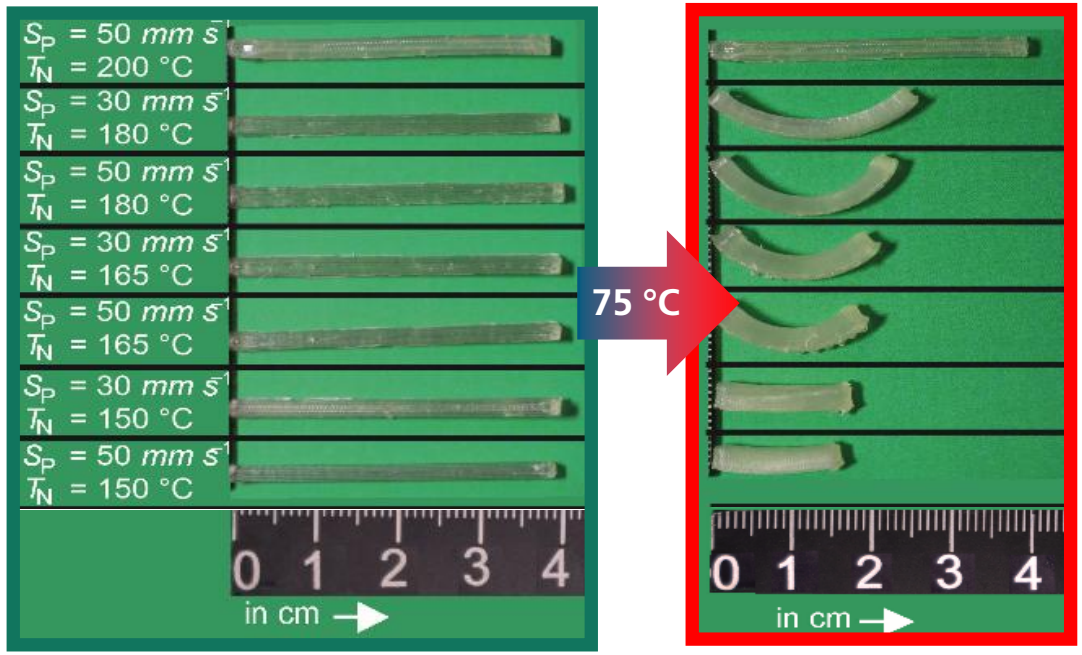
- Manufactured by synthesis, processing, 3D printing and programming (1W SME)

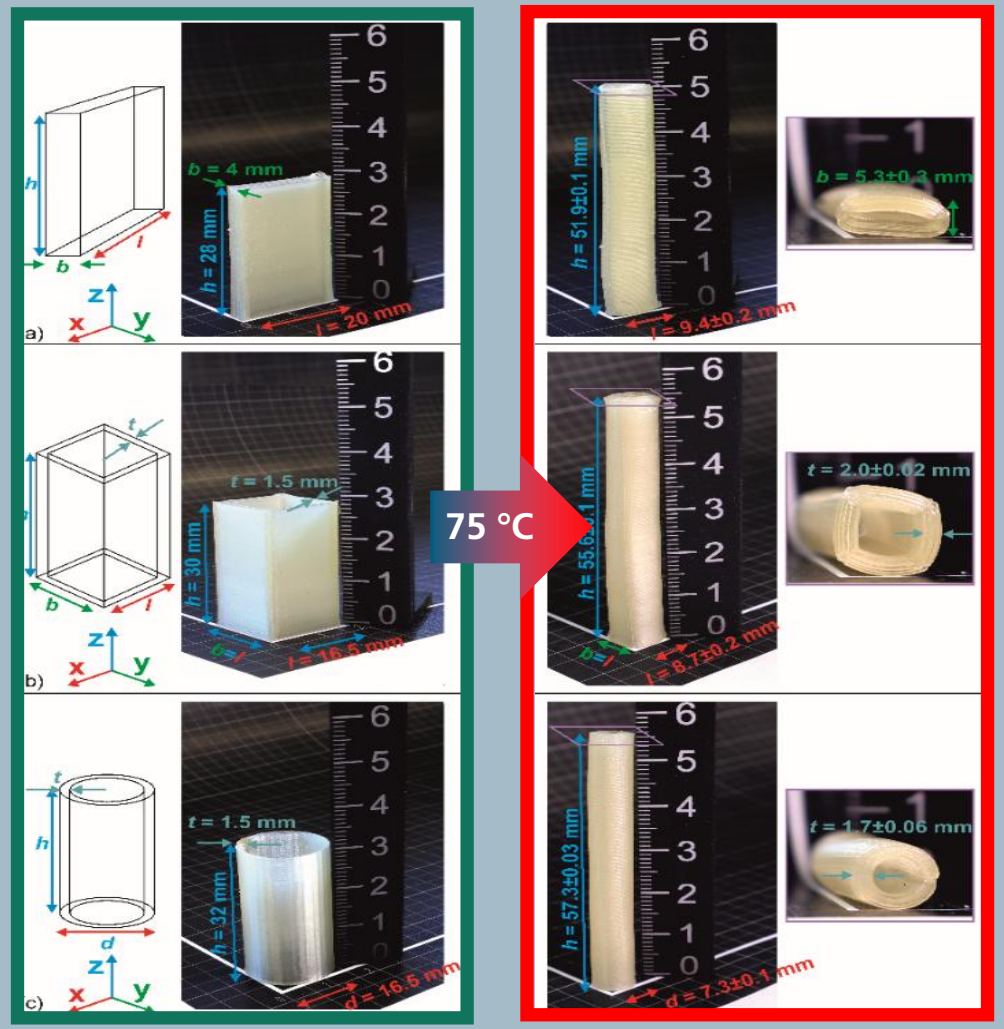
Thermally switchable Gearbox

- Manufactured by synthesis, processing, 3D printing and programming (2W SME)
- Actuation between 23 °C and 58 °C
- Thermal overload protection in gearboxes

Additive Manufacturing

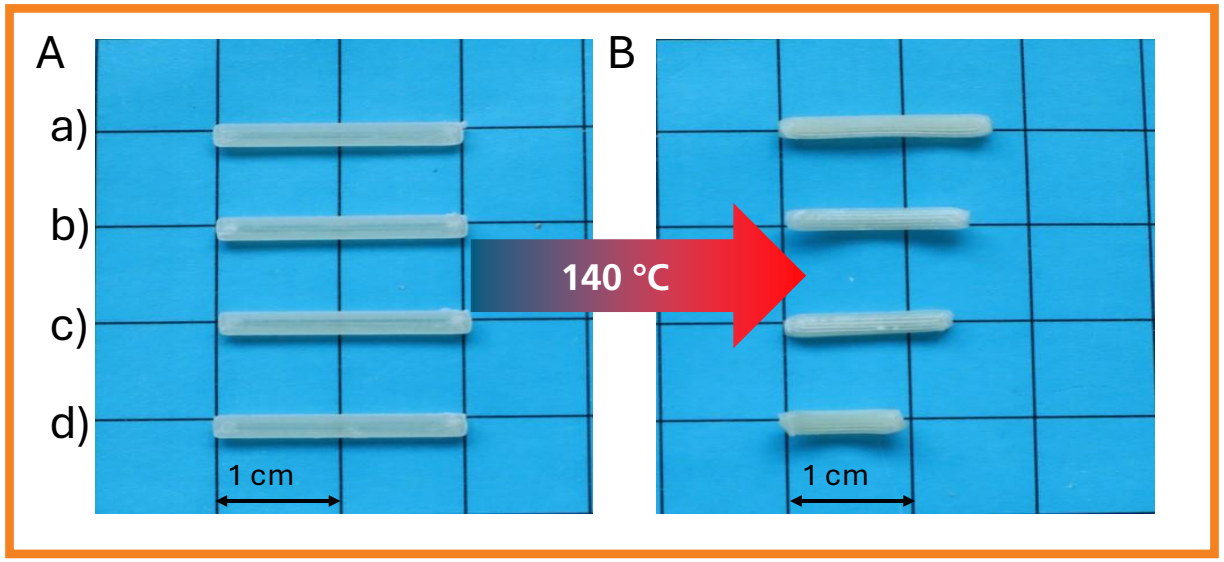
4D Printing with Shape Memory Polymers

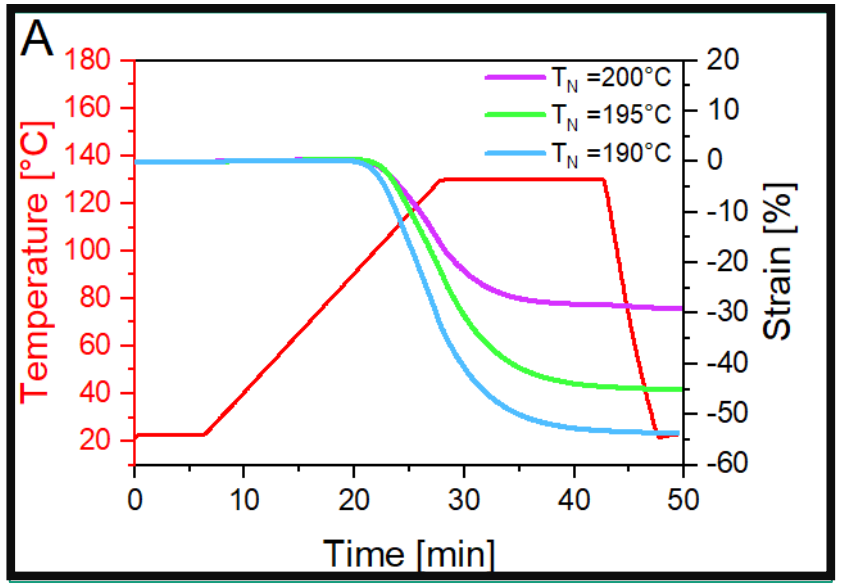




Additive Manufacturing

4D Printing using PCU70





Additive Manufacturing

Sealing Caps

Material and Technology Development

Customized, efficient & sustainable

Sealing Caps

- Development of heat-shrinkable objects
- 4D printing on site
- Applicability for sealing transport lines and closing pipes (infrastructure)

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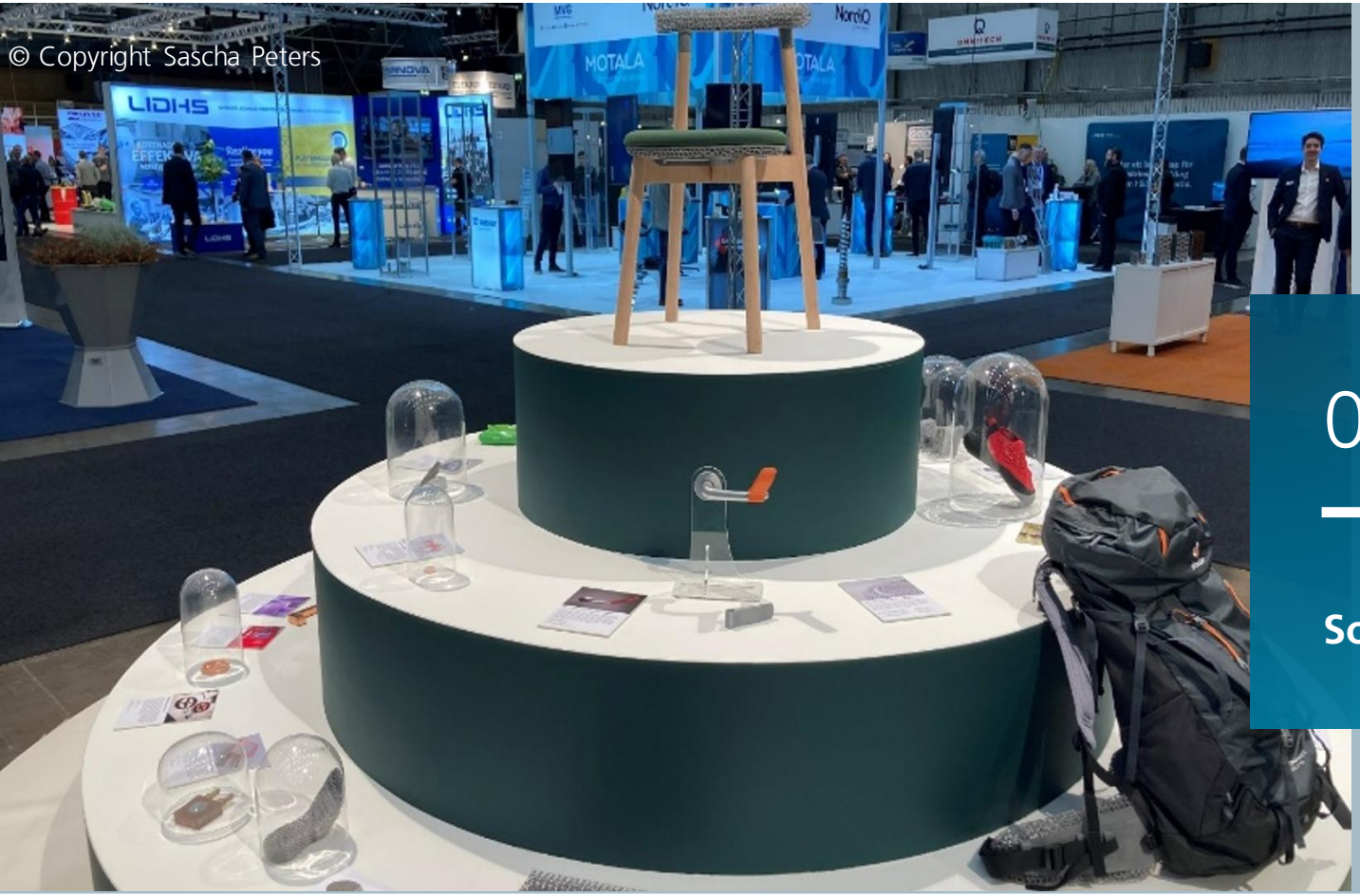
Summary and Outlook

Polyurethanes with Shape Memory Properties



04

Some final thoughts…

Shape Memory Polyurethanes

Summary & Outlook

Polyurethanes
…can be adjusted within a wide range of parameters in terms of their physical and functional properties.
… can be used for shape changes at elevated temperatures.

Sustainability
…starts with the selection of the synthesis building blocks and continues with resource-saving processing.
Thermoplastic polyurethanes can be reprocessed.

Programming
… opens up sustainable concepts.
Programmable material behaviors enable new applications. The functionality is embedded in the material.

4D Printing
…is the integration of physical material functions.
…can play the role of a technology accelerator, helping to address new applications.

4D Printing
Technological Benefits

4D printing has the potential to develop into a cross-sectional technology with which many new applications can be addressed.

Key benefits include:

1. **Material efficiency**: Production of lightweight structures and filigree objects
2. **Energy efficiency:** No thermomechanical (post) treatment is required.
3. **New materials available:** "High temperature applications" can be addressed.
4. **Sustainability:** Mechanical recycling, end-of-life and reuse concepts


Was wäre, wenn
unsere Schuhe ihre Form an unsere Bewegungen anpassen könnten?
Was wäre, wenn
Gebäude
Ihren Wärmehaushalt
autark und dezentral
regulieren könnten ?
WORLD OF PROGMAT

Thank you for
your attention!

Acknowledgement

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European Regional Development Fund

Strengthening technological and application-oriented research at scientific institutions (StaF guideline)

Federal Ministry of Education and Research BMBF

The Group

Contact

Dr. Thorsten Pretsch
Division Synthesis and Polymer Technology
Tel. +49 331 568-1414
thorsten.pretsch@iap.fraunhofer.de

Fraunhofer IAP
Potsdam Science Park
Geiselbergstraße 69
14476 Potsdam

www.iap.fraunhofer.de