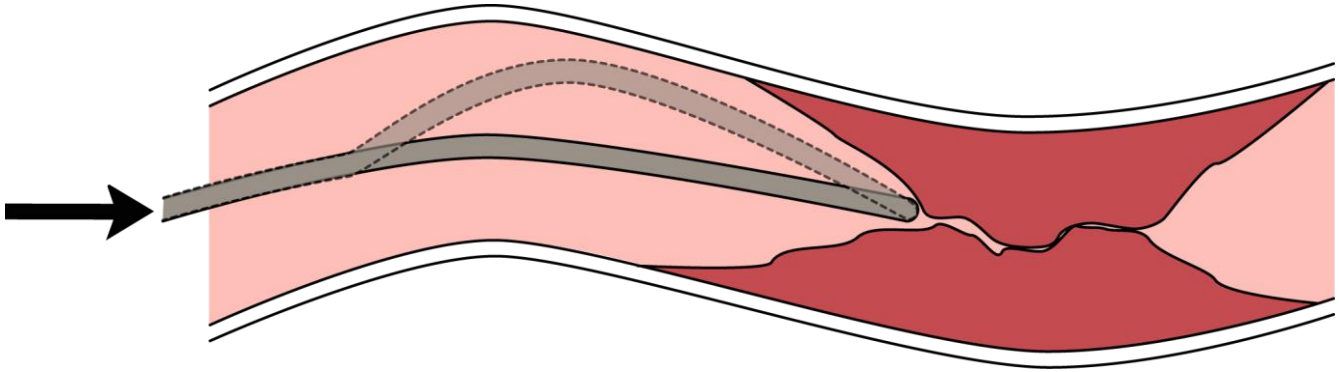
3D printing of Shape Memory Polymer for medical devices with actuation and variable stiffness

Loïc BLANC

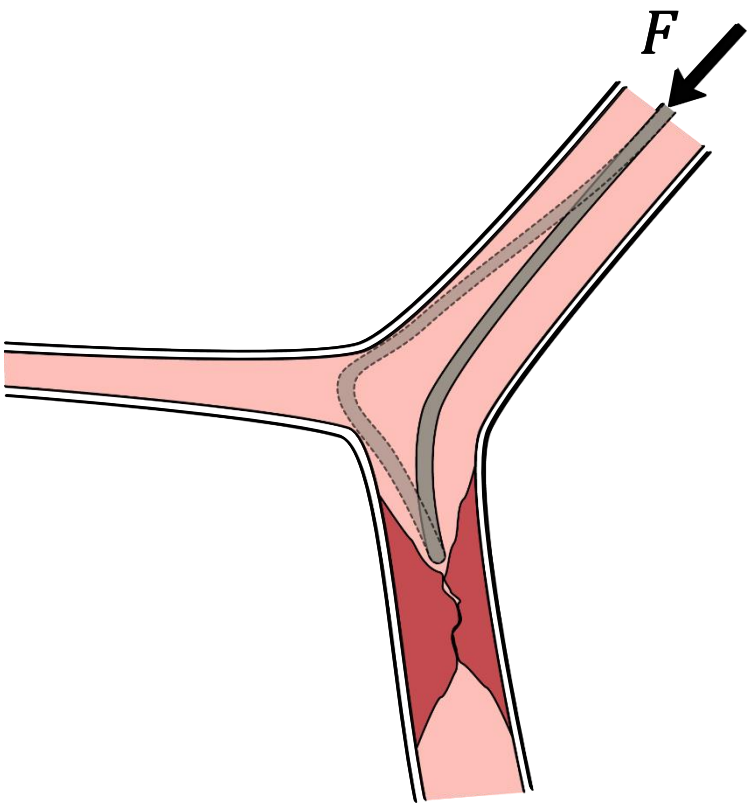
In collaboration with
Prof. P. Lambert, Prof. A. Delchambre, Prof. J.-M. Raquez,
Dr. A. Toncheva

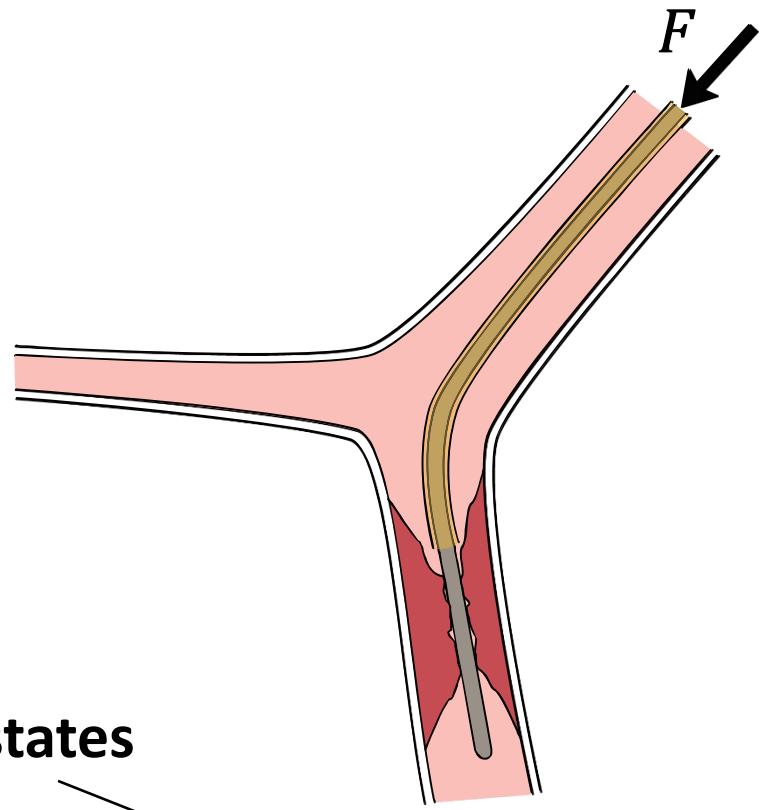
The inability to pass through the occlusion is the main cause of unsuccessful CTO recanalization



CTO: *Chronic Total Occlusion*

We need flexibility and … rigidity





2 states

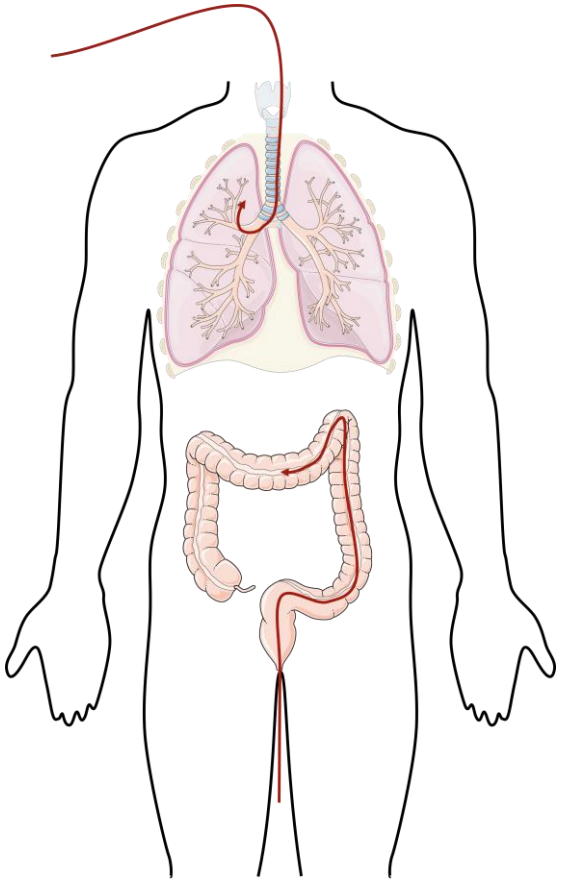
Flexible

insertion, shaping

Rigid

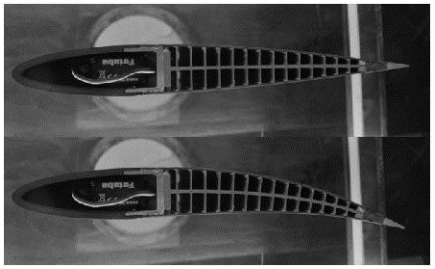
shape fixation, force transmission

There are many applications …

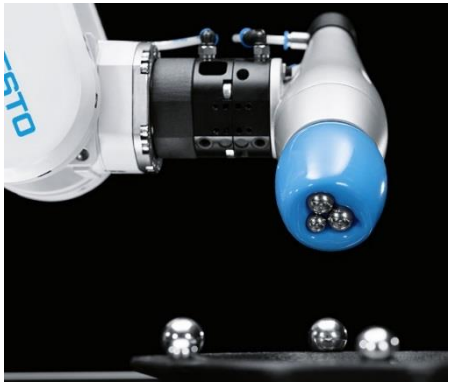


Adapted from Servier Medical Art

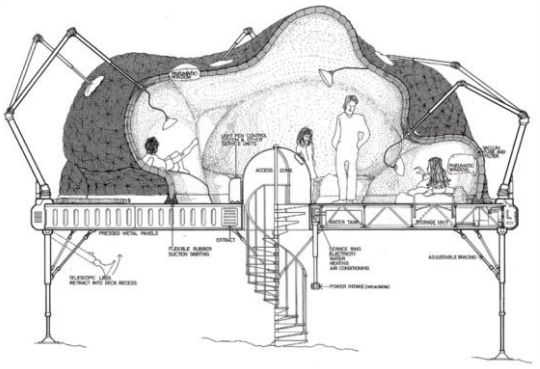
Holland 2014



Beaverstock 2015

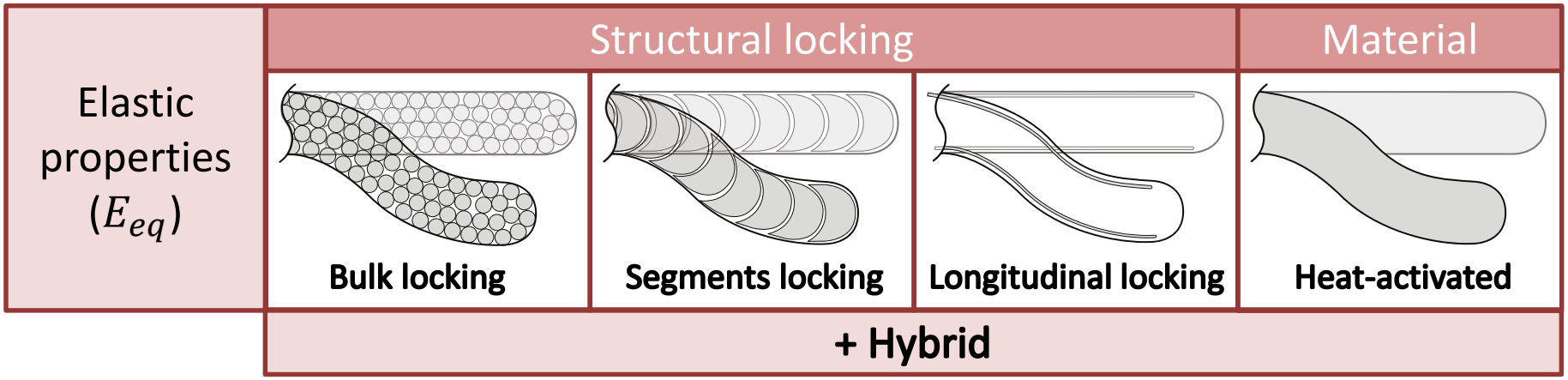


Festo FlexShapeGripper



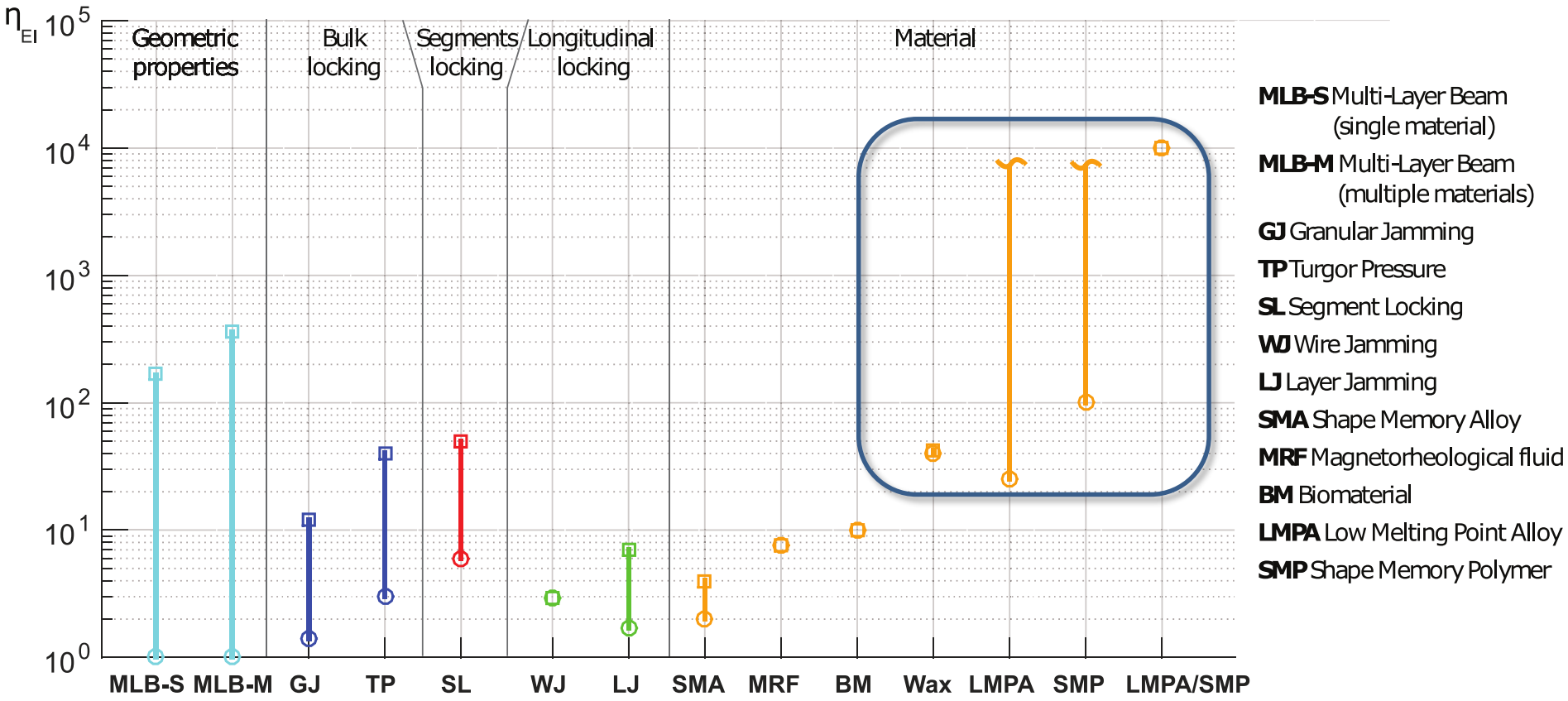
Huijben 2014

… and many solutions

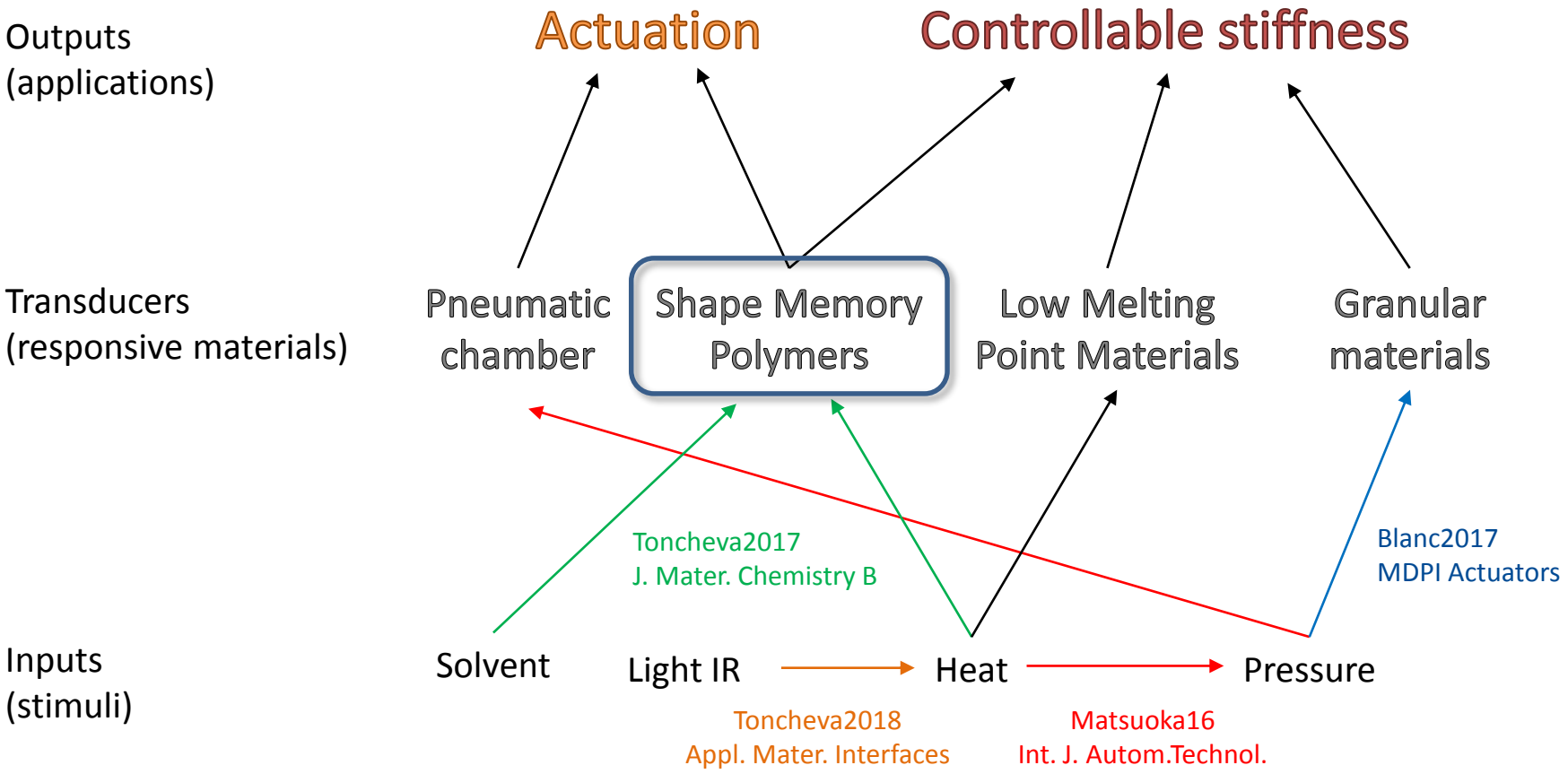


The heat-activation gives the highest stiffness gain

Stiffness gain: $\eta_{EI} = (EI)_{rig}/(EI)_{flex}$



We can actuate and control the stiffness of devices



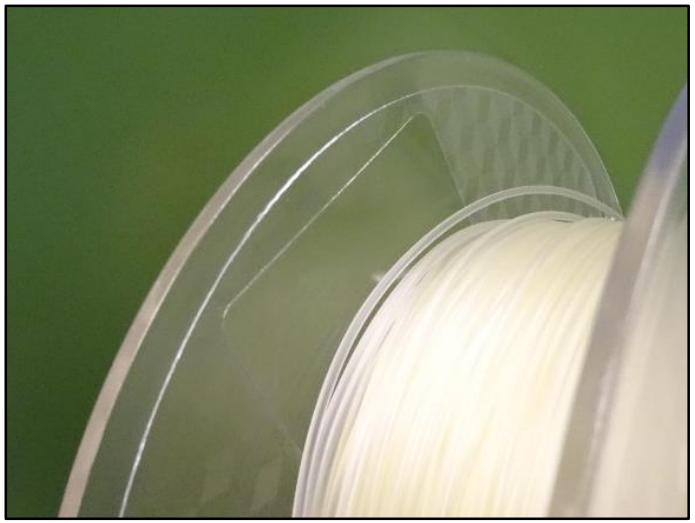
Materials

We work with two commercial polymers

Phase transition

Polycaprolactone (PCL)

Glass transition



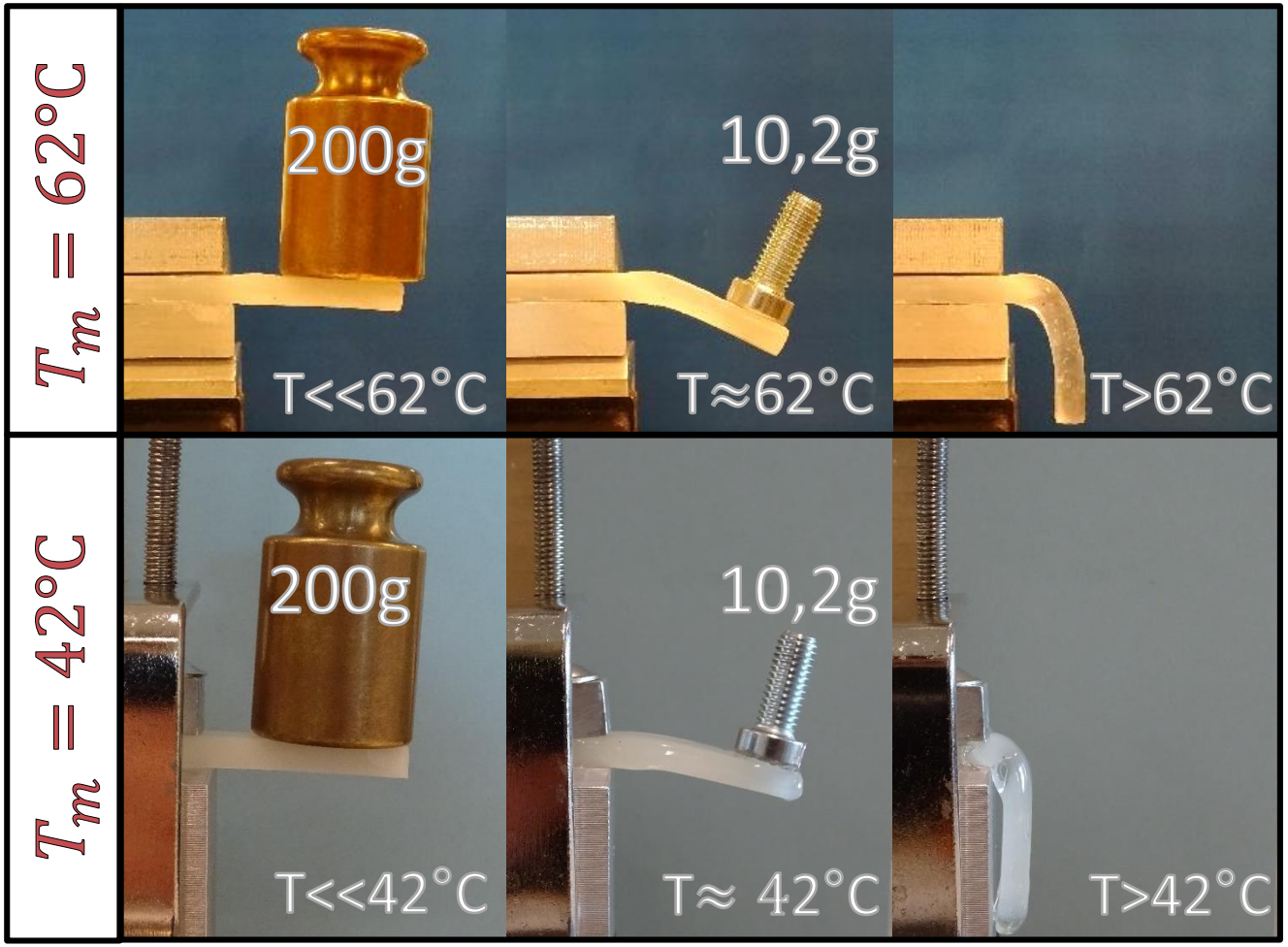
Shape Memory Polymer (SMP)

Controllable stiffness
No actuation

Polycaprolactone (PCL) is soft

Molding

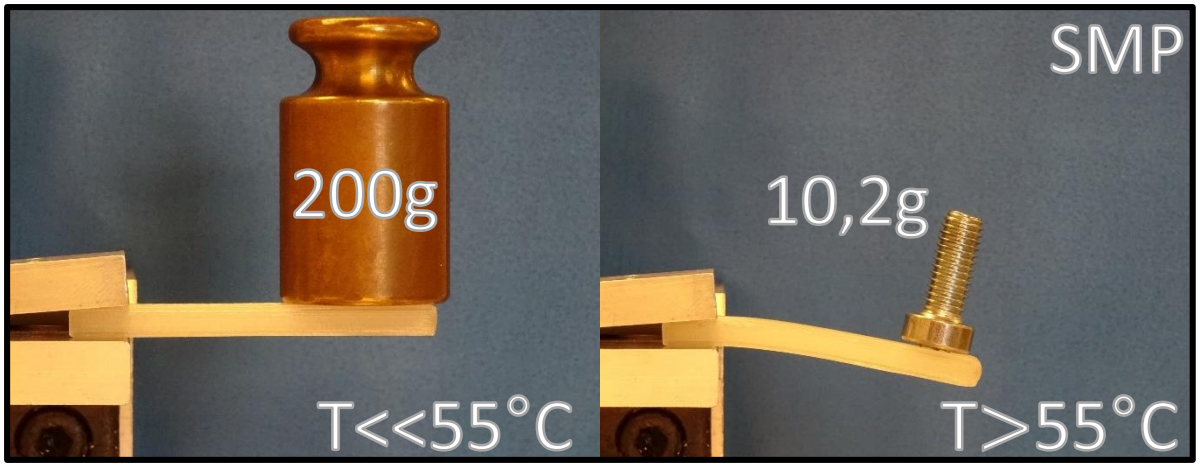
3D print

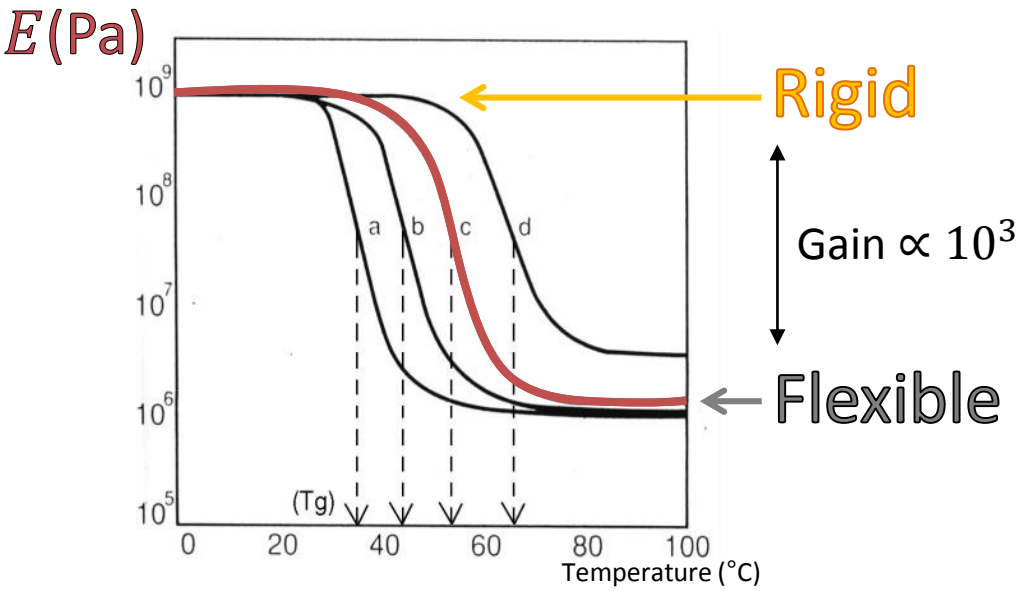


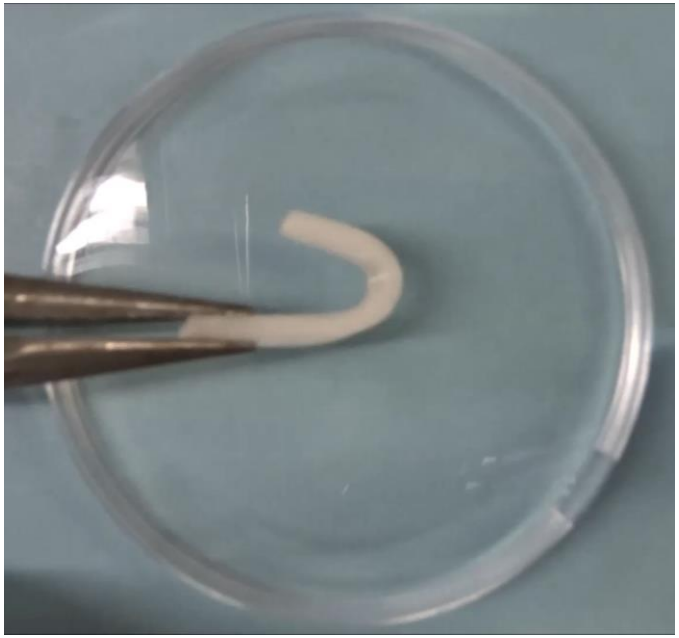
+

Controllable stiffness
Actuation

Shape Memory Polymer (SMP) is smart







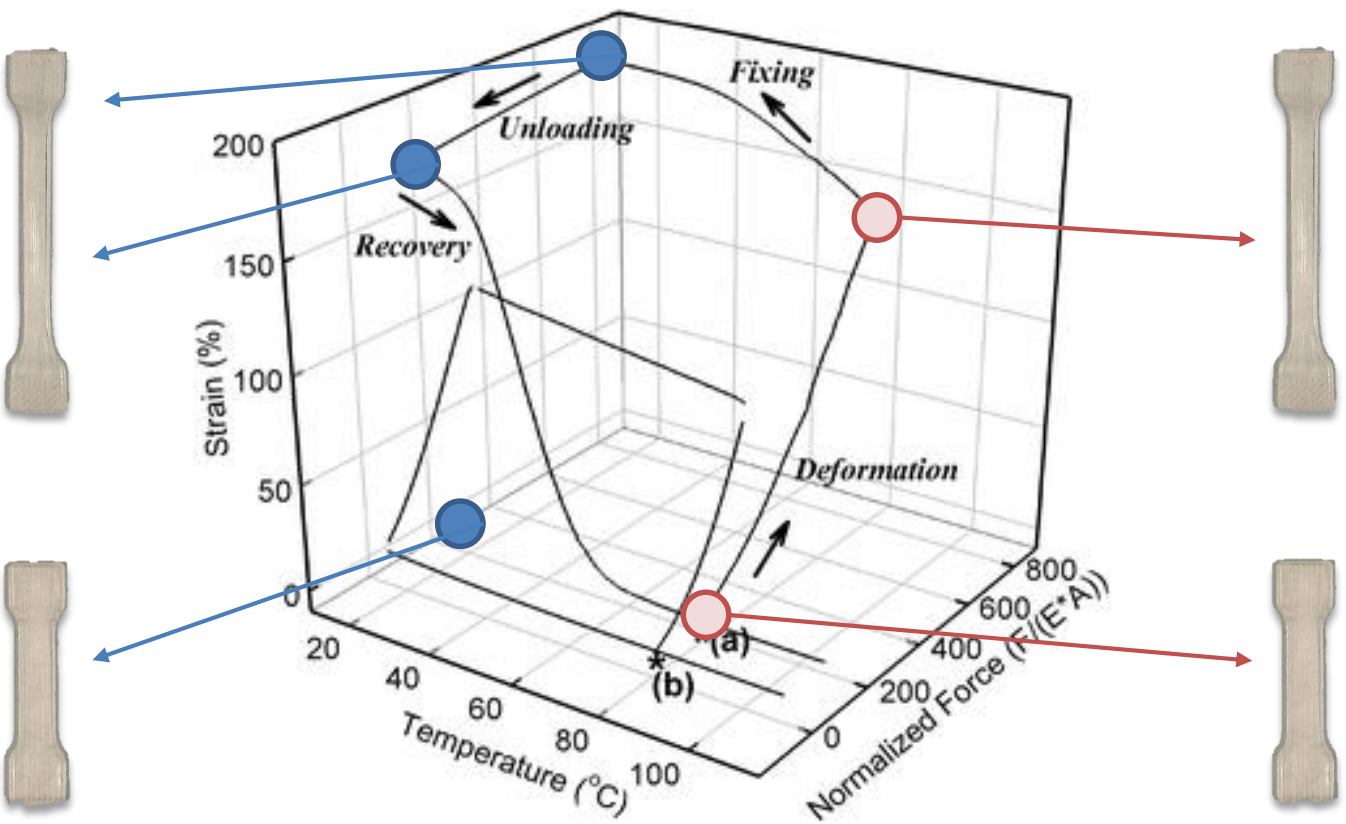
Thermomechanical cycle of SMP

$T = T_{\text{room}}$

$T > T_g$

Temporary shape

Permanent shape



Liu2007

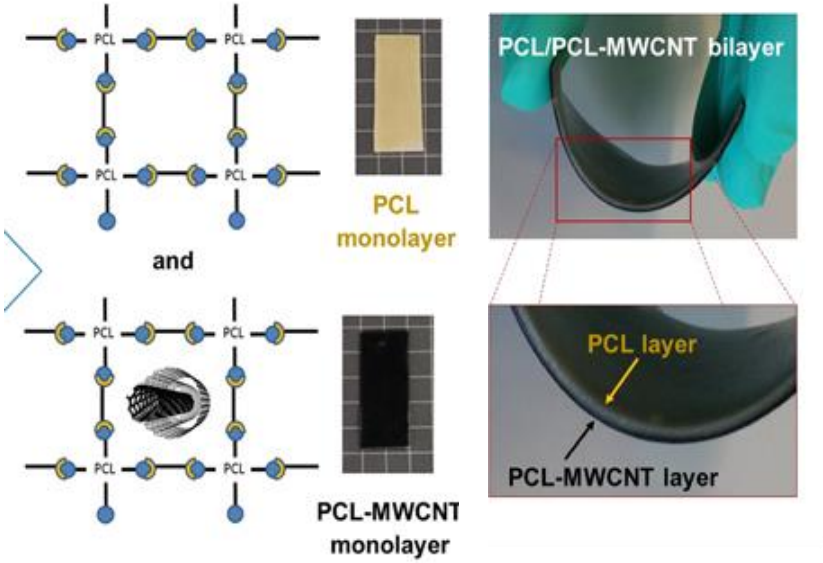
We work also with "home-made" SMP

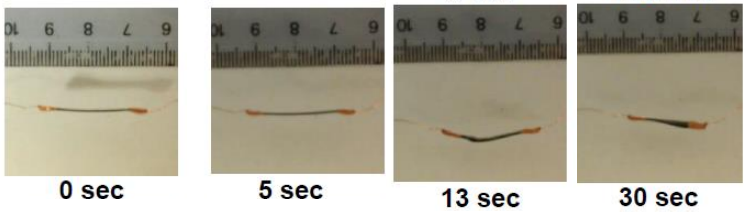
In collaboration with Dr. A. Toncheva

UMONS
Université de Mons

Thermally responsive SMP

with Joule effect

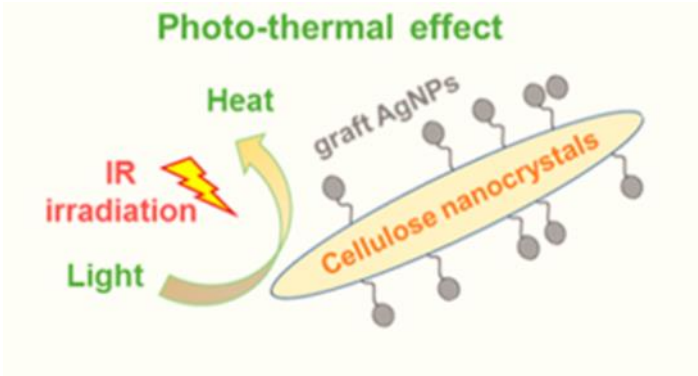




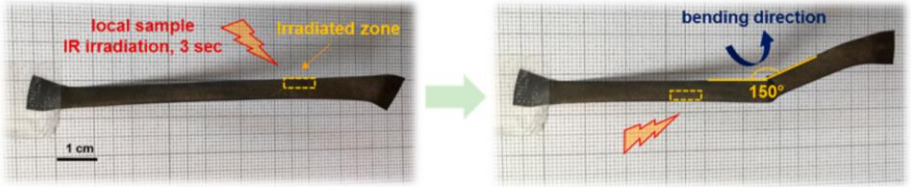
$PCL_4 - CNC_5/PCL_4 - CNT_5$ films,
I=2mA, U=100V

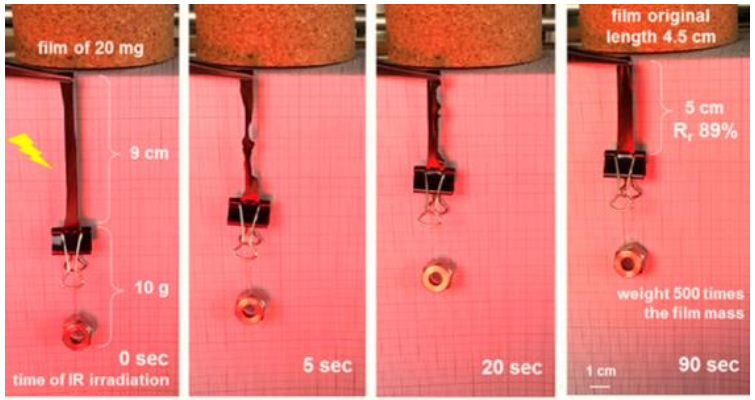
Toncheva2017, J. Mater. Chemistry B

with IR



Controlled PCL_{SMP}/CNC-*g*-AgNPs film bending upon IR irradiation





Toncheva2018, Appl. Mater. Interfaces

Fabrication & characterization

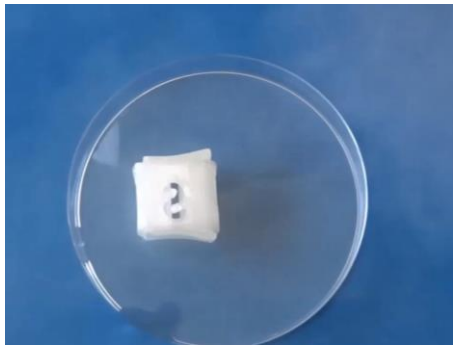
Commercial FDM 3D printer is used

Makerbot Replicator 5th generation

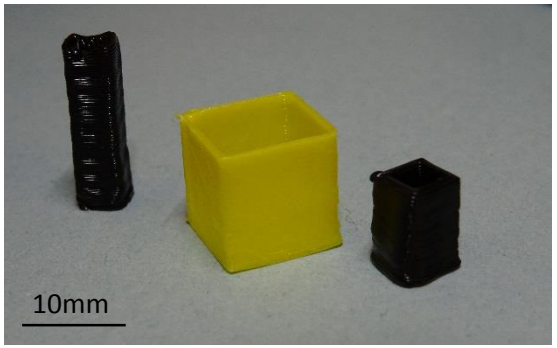
0,2mm -> 0,5mm

3D printing of commercial filament

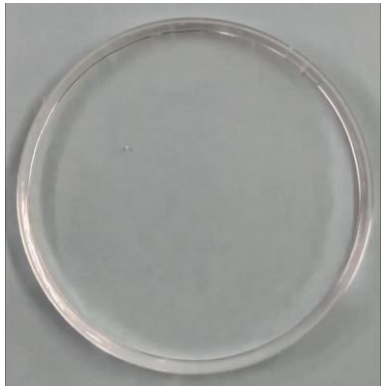
SMP printed at 200°C



PCL printed at 100°C

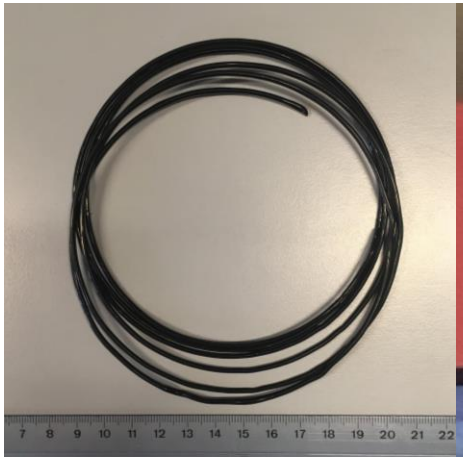
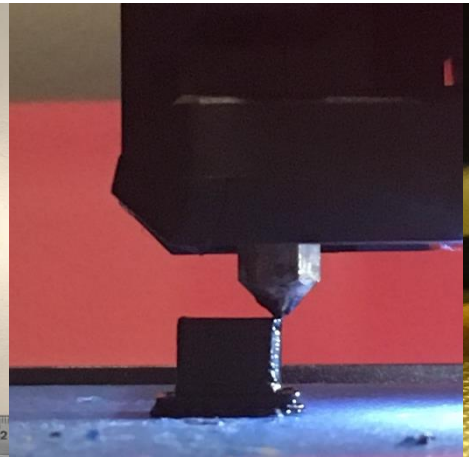
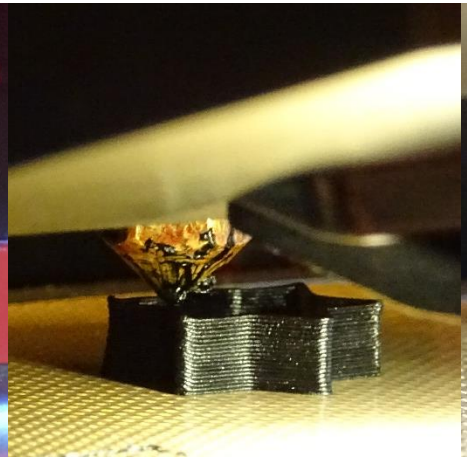
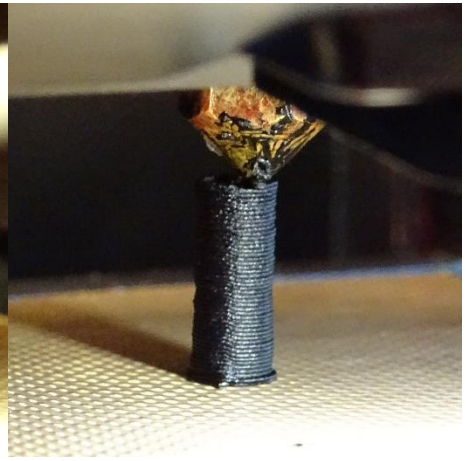


SMP printed at 200°C

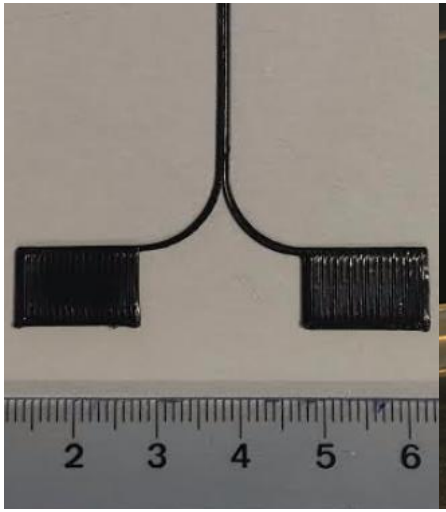
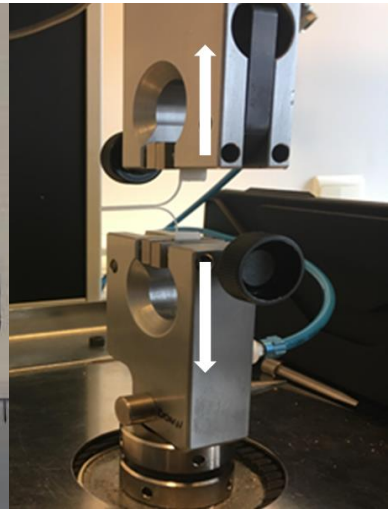


PLA printed at 210°C

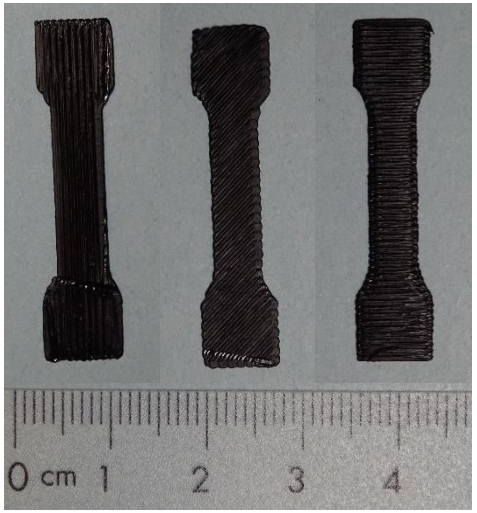
Example of 3D printing of PCL/CNT

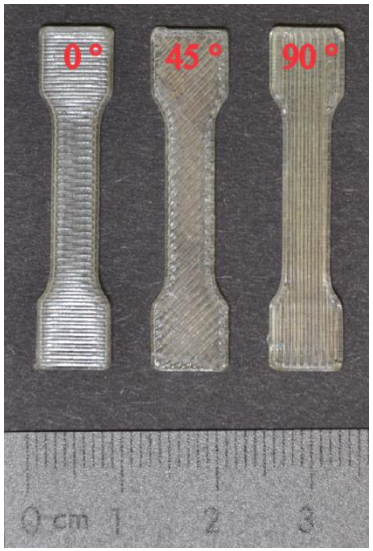
Peeling tests

Tensile tests

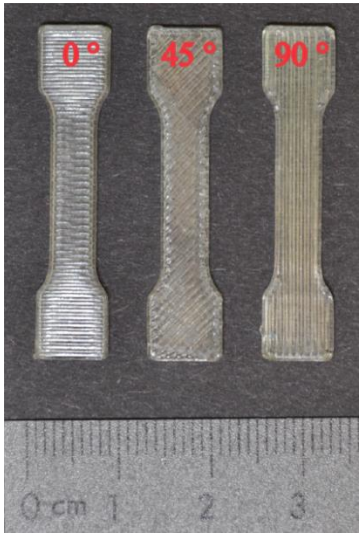


Thermomechanical characterization



The actuation is quantified with the recovery force

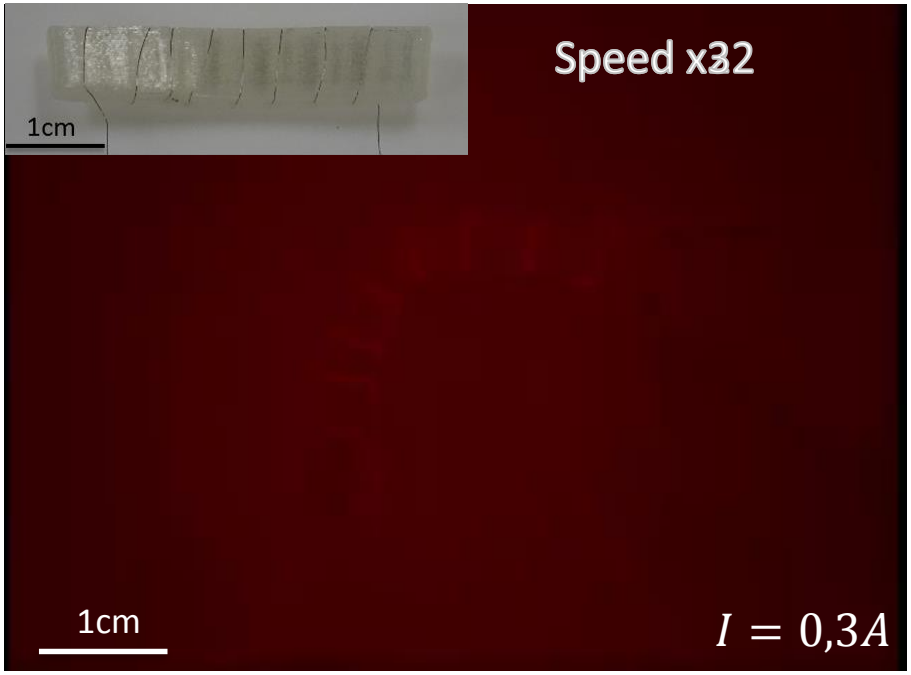
3D printed samples

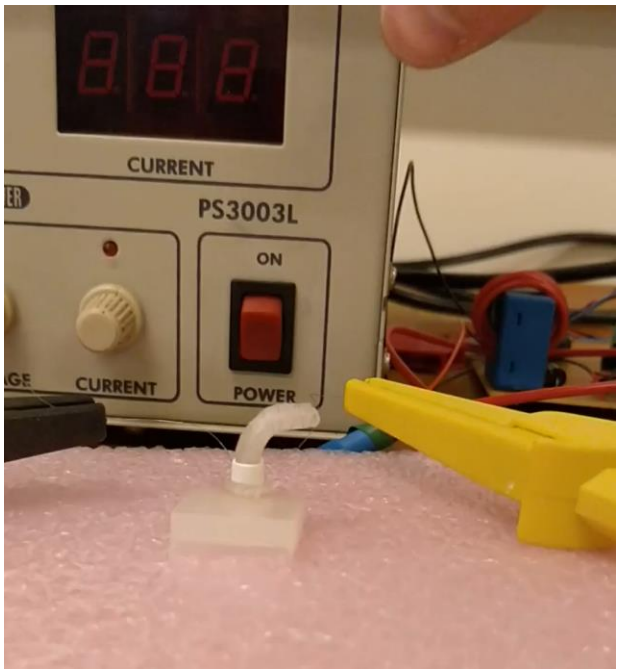


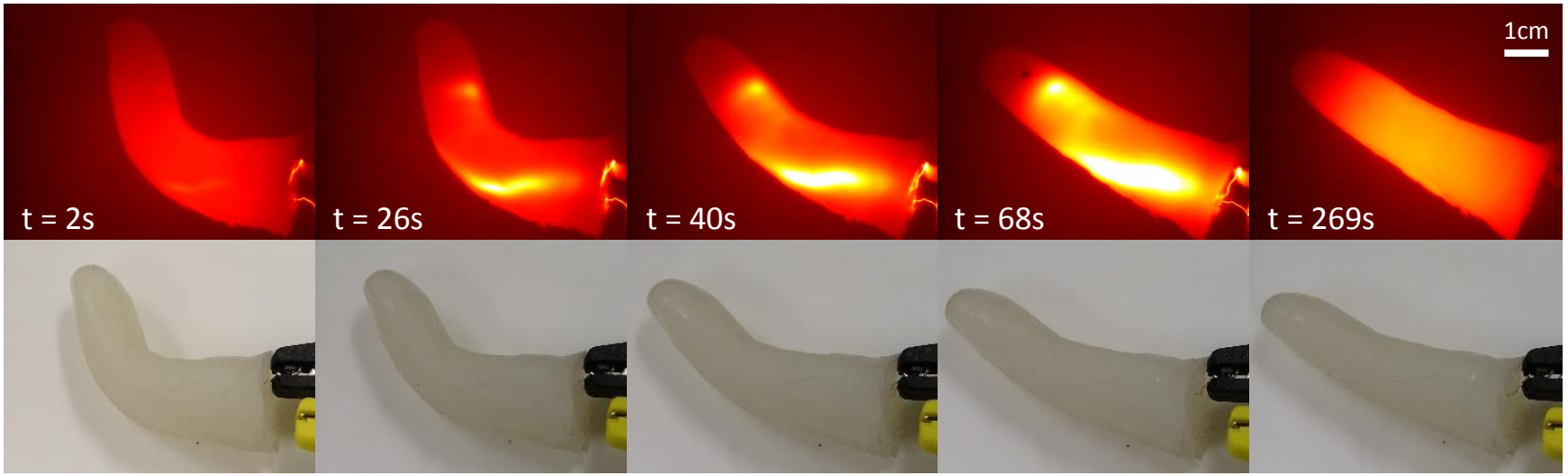
Larrieu2018, PhD thesis ULB

Proofs of concept & challenges

Joule heating of SMP







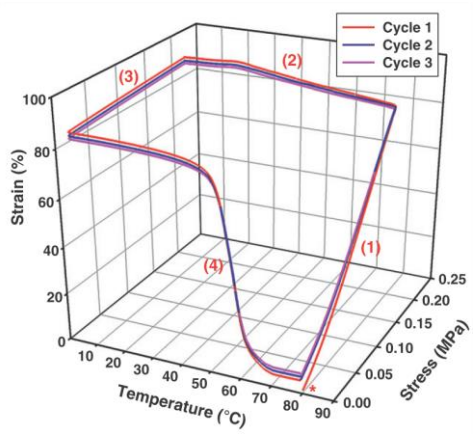
Ongoing challenges

Validation of proofs of concept & embedding stimulus

Manufacturing / miniaturization

Model of SMP

COMSOL



[Luo, 2013]

Special thanks to …

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Prof. A. Delchambre

Prof. J.-M. Raquez & Dr. A. Toncheva

Questions

Presented by Loïc BLANC
October 16, 2018