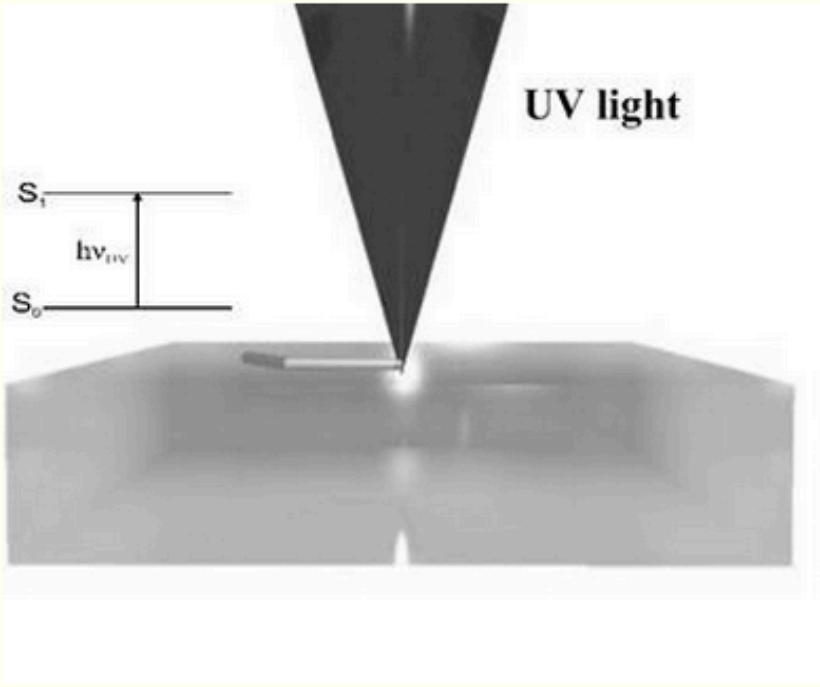
ICONN 2018
INTERNATIONAL CONFERENCE ON NANOSCIENCE AND NANOTECHNOLOGY
29 JAN - 2 FEB 2018 | UNIVERSITY OF WOLLONGONG, AUSTRALIA

3D Fabrication by Multi-photon Polymerisation of Stimuli-Responsive Soft Structures with Sub-200nm Resolution

L. Florea, C. Delaney, A. Tudor, H. Zhang, M. Higgins, D. Diamond

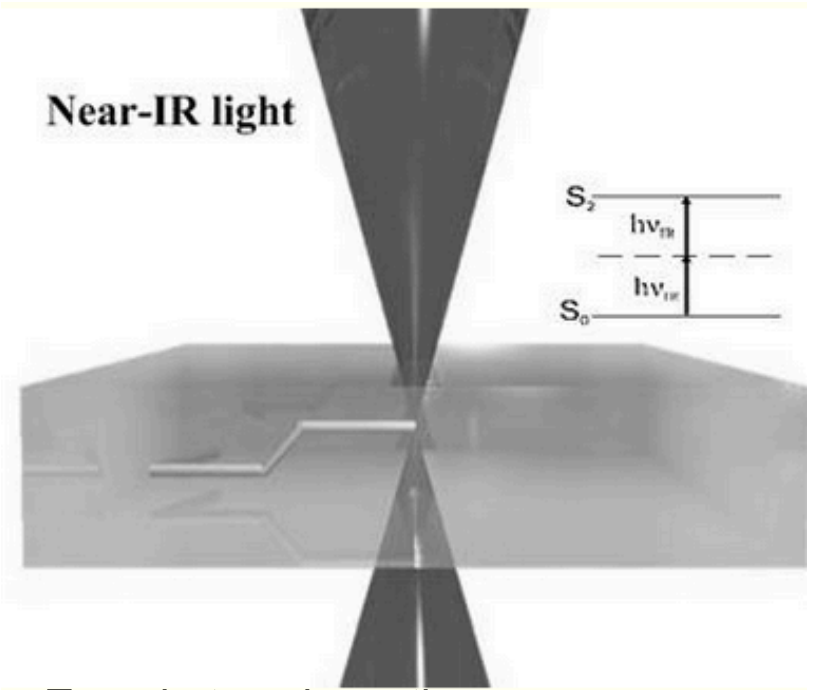
Background

Stereolithography



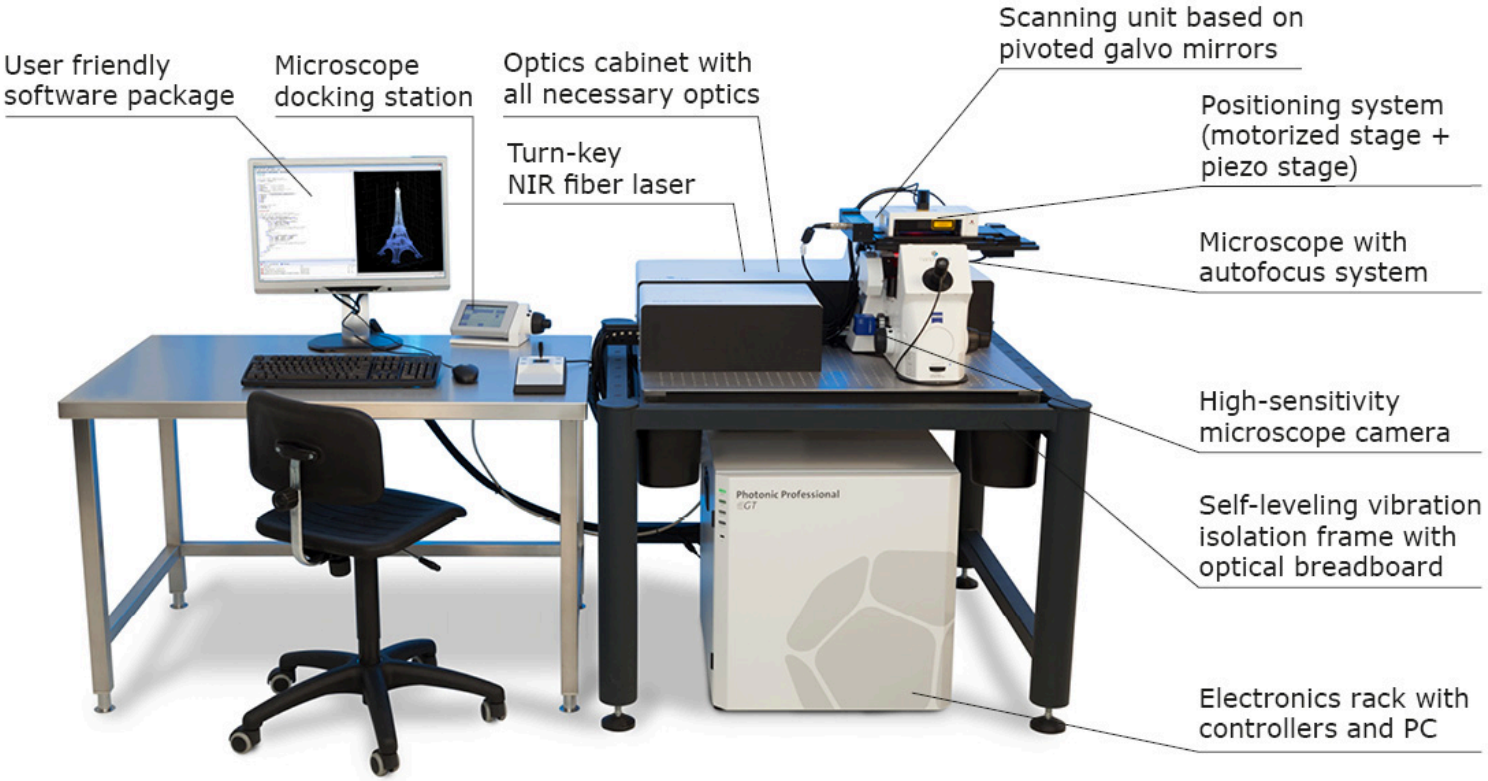
- Single photon absorption
- 2D patterns

Two-photon polymerisation

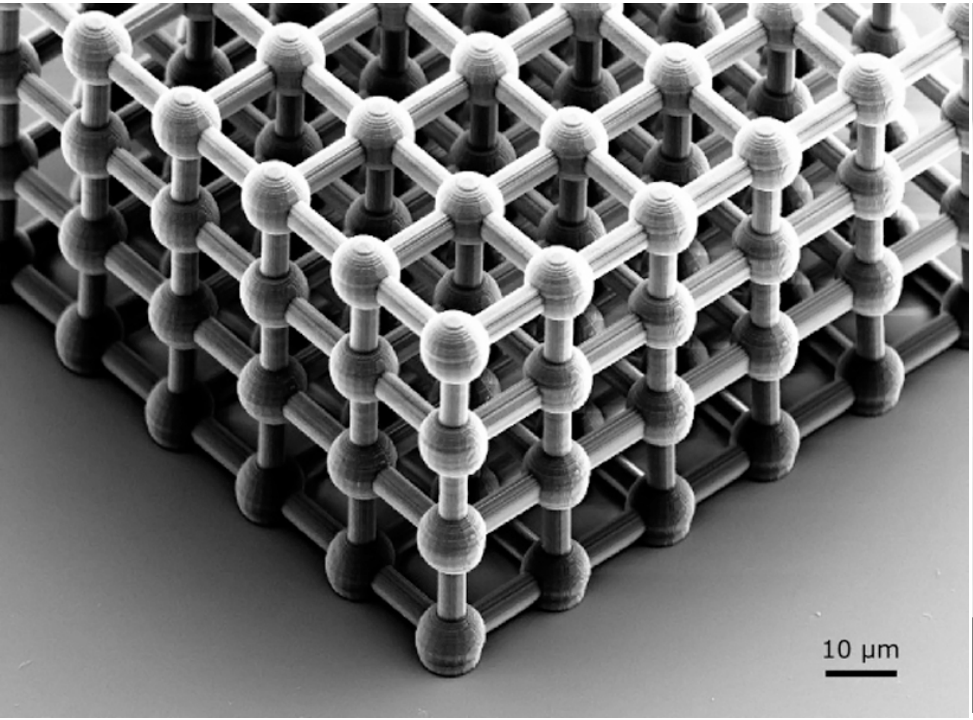


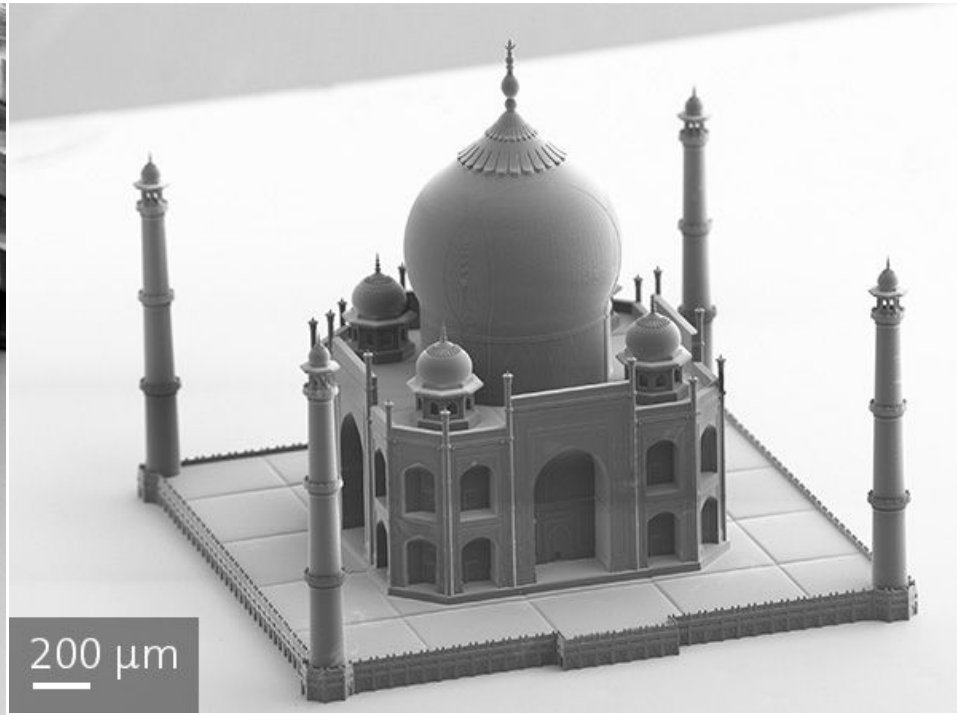
- Two photon absorption
- 3D structures

2-PP

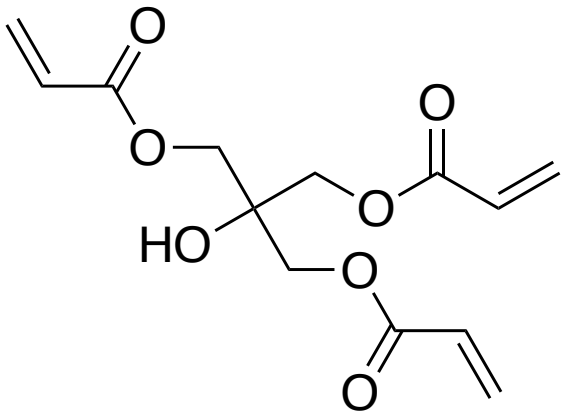

User friendly software package
Microscope docking station
Optics cabinet with all necessary optics
Turn-key NIR fiber laser
Scanning unit based on pivoted galvo mirrors
Positioning system (motorized stage + piezo stage)
Microscope with autofocus system
High-sensitivity microscope camera
Self-leveling vibration isolation frame with optical breadboard
Electronics rack with controllers and PC
Photonic Professional GT

Background

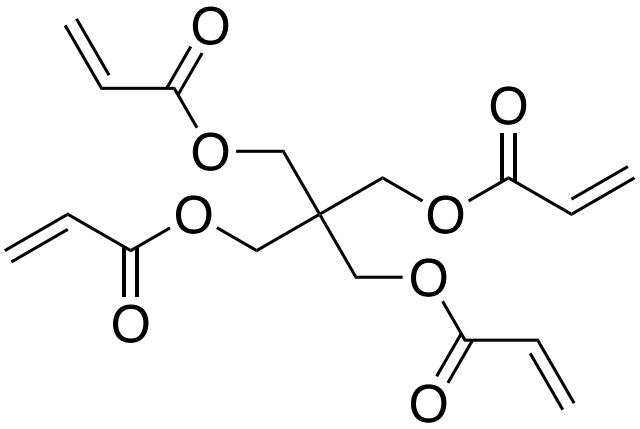




Typical monomers for 2-PP



Pentaerythritol triacrylate



Pentaerythritol tetraacrylate

The world's smallest fiddle?

Soft Stimuli-Responsive Materials

Photo-responsive hydrogels

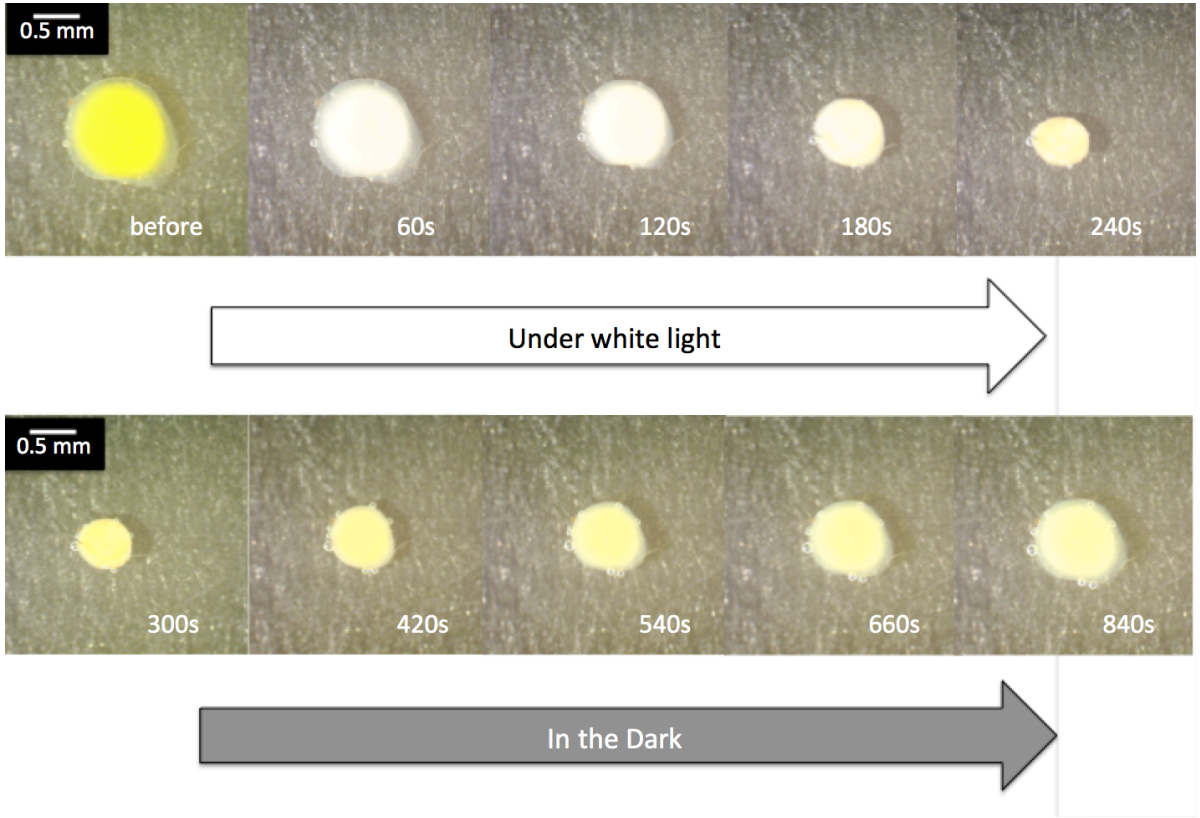
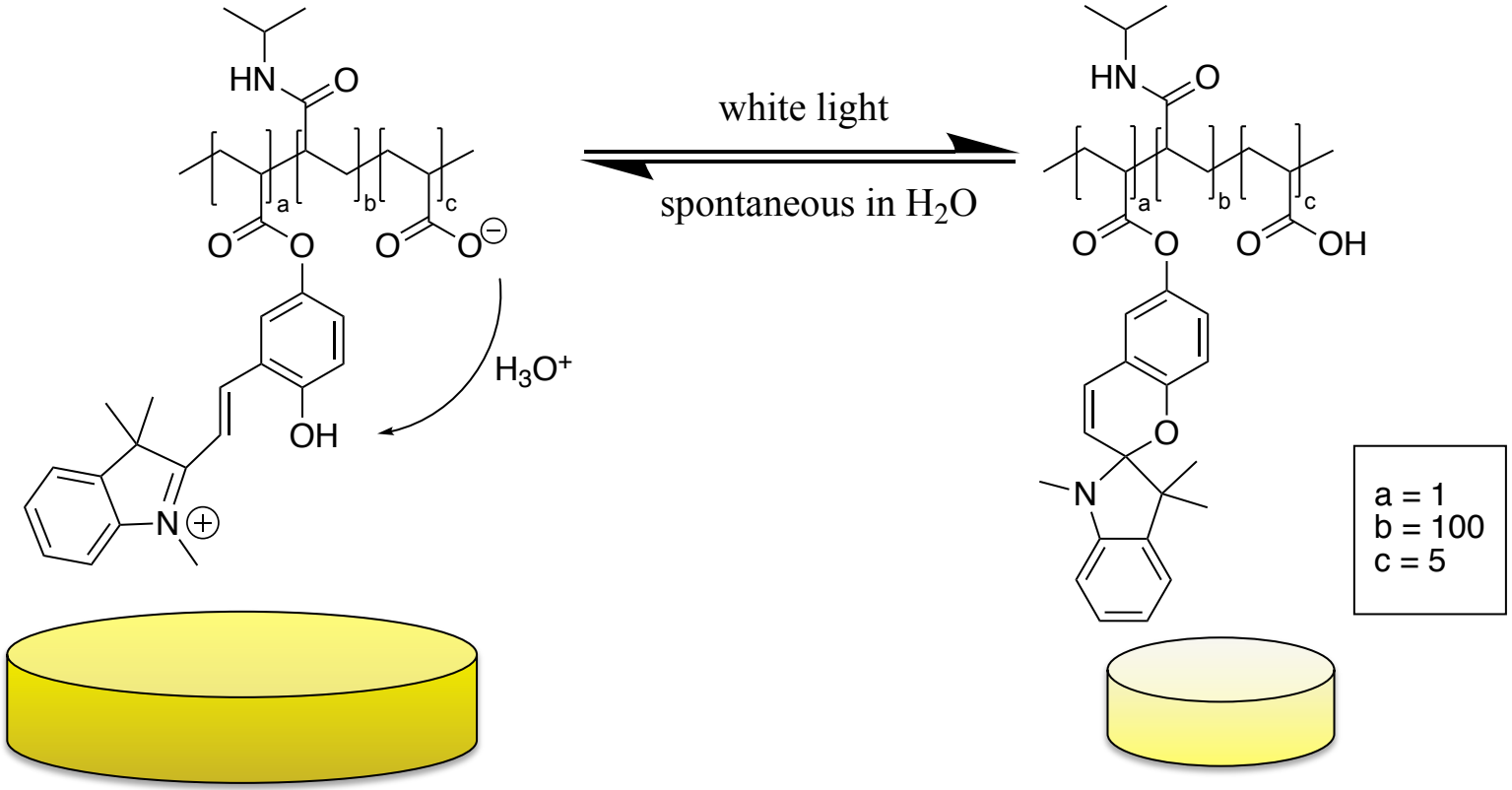


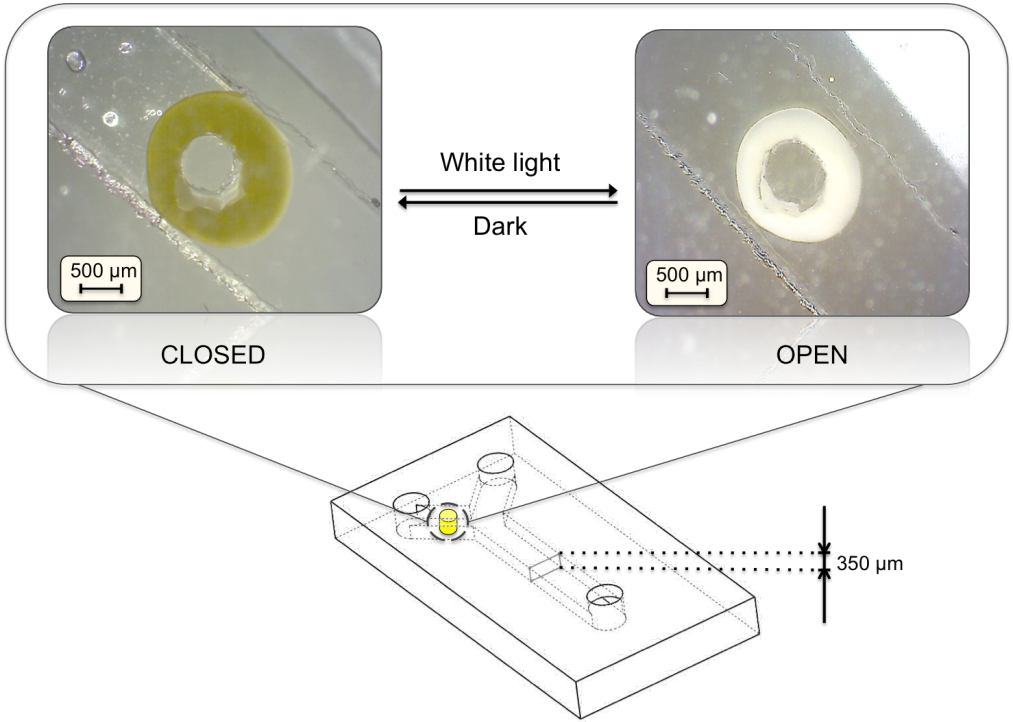
Photo-responsive hydrogels



B. Ziolkowski, L. Florea, J. Theobald, F. Benito-Lopez and D. Diamond, *Soft Matter*, 2013, 9, 8754-8760.

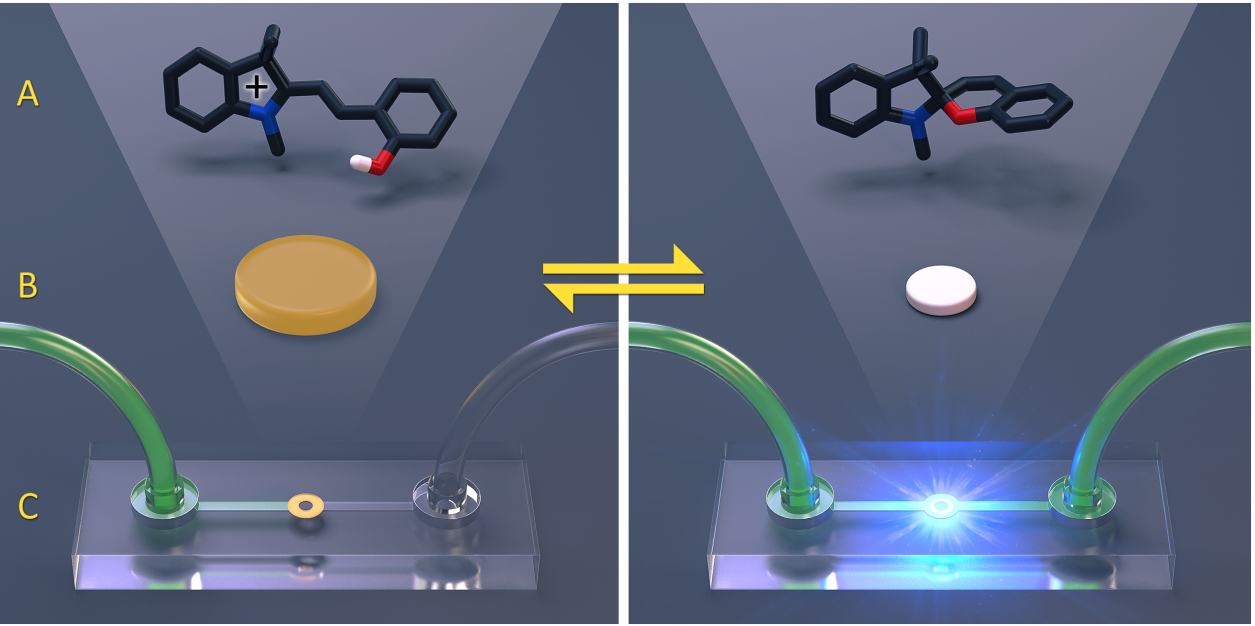
Photo-switchable actuators

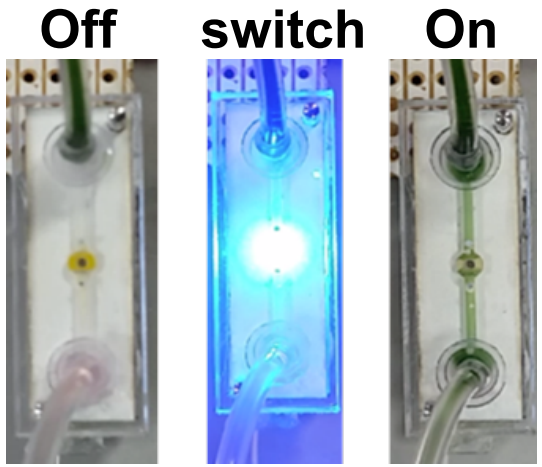
- ON/OFF flow modulation
- photo-control of flow in microfluidic devices

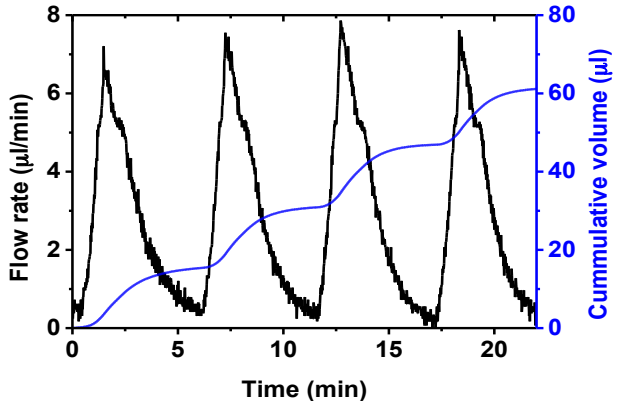


Reversible Photo-Switching of Flow

With Albert Schenning and Dirk Broer, TU Eindhoven

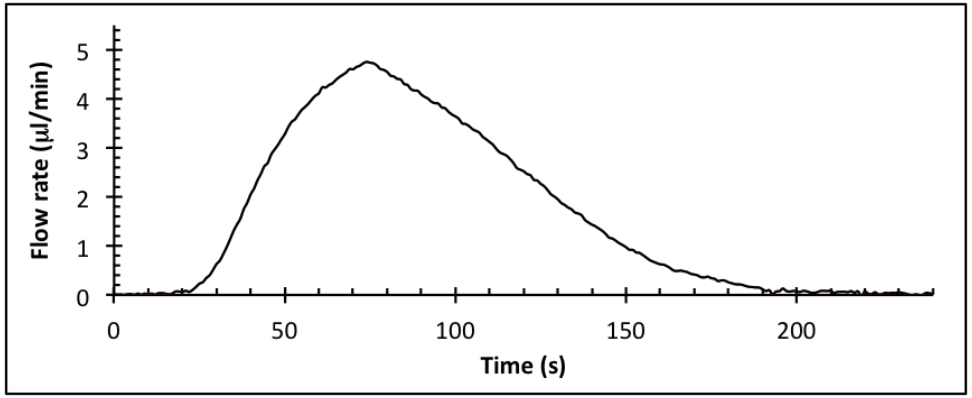




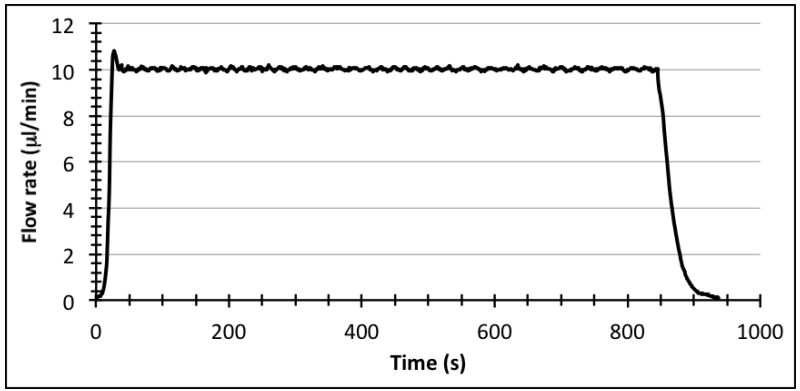


J. ter Schiphorst et al. Chem. Mater., 27 (2015) 5925−5931.

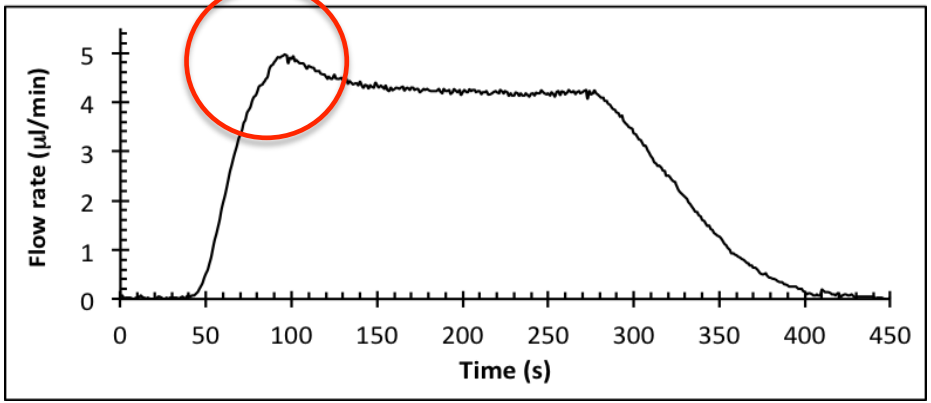
Open and Close



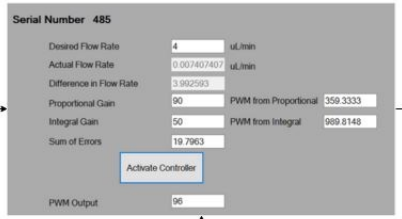
Set Flow Rate



Over shoot



Closed Loop-PID Control

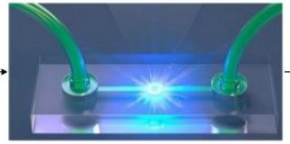


Controller

Arduino

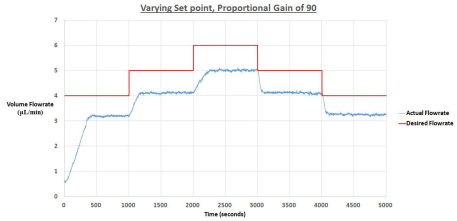
Constant Current LED Driver

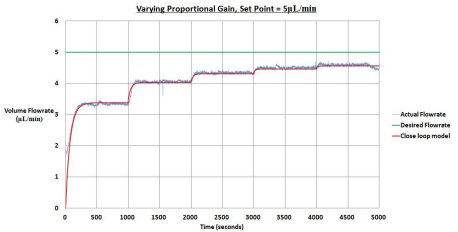
LED

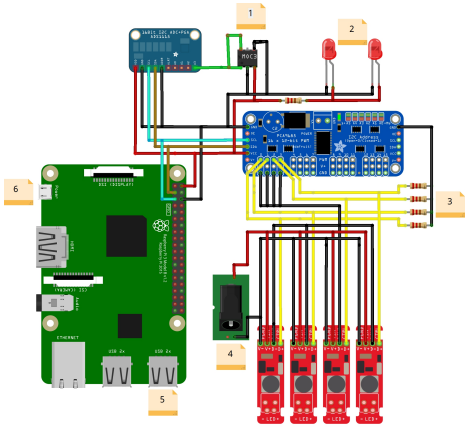


Microvalve

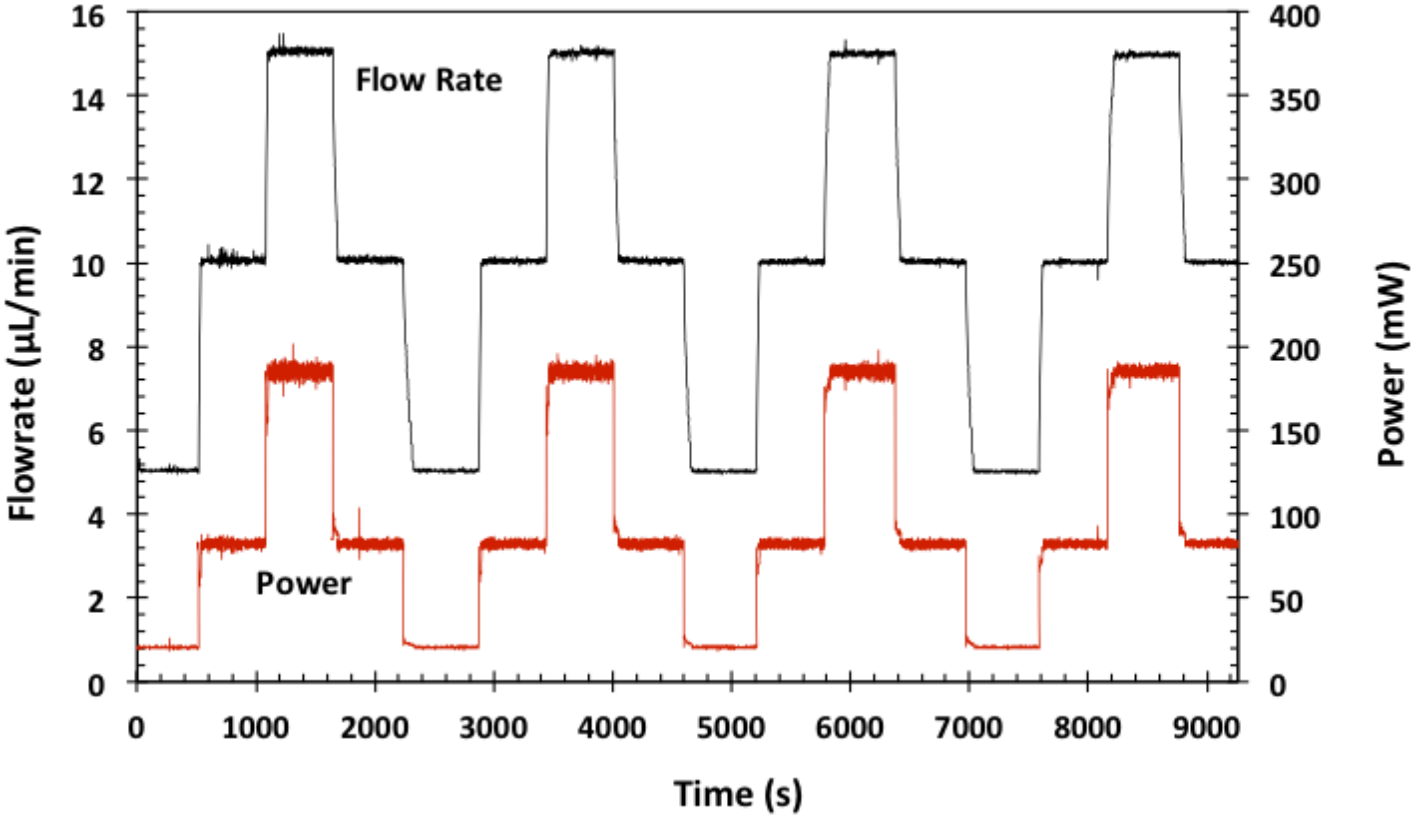
Fluigent Flow Sensor





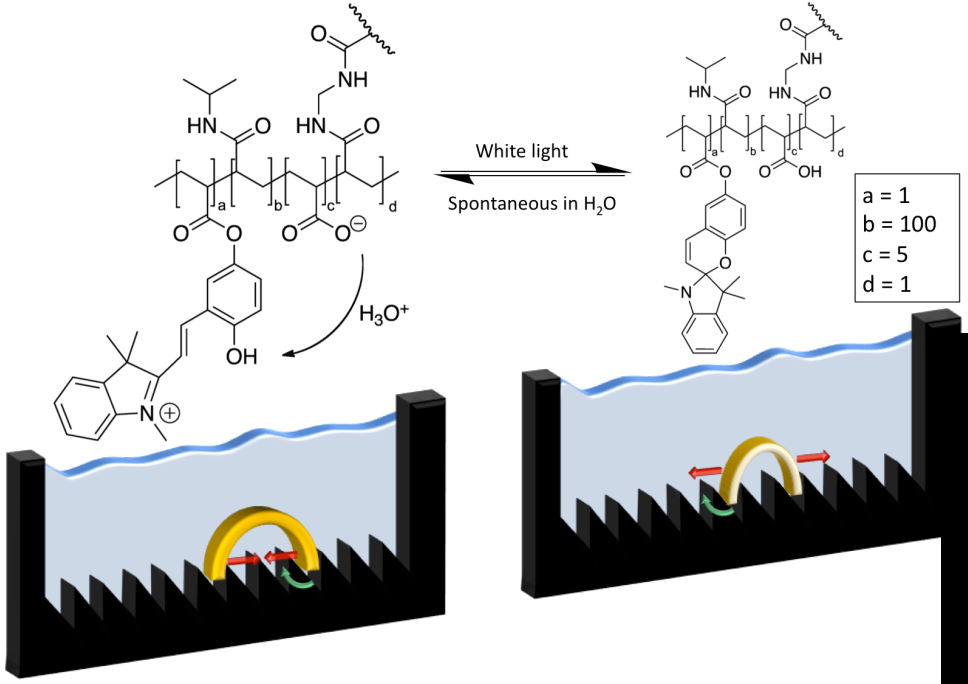


Repeatable Actuation

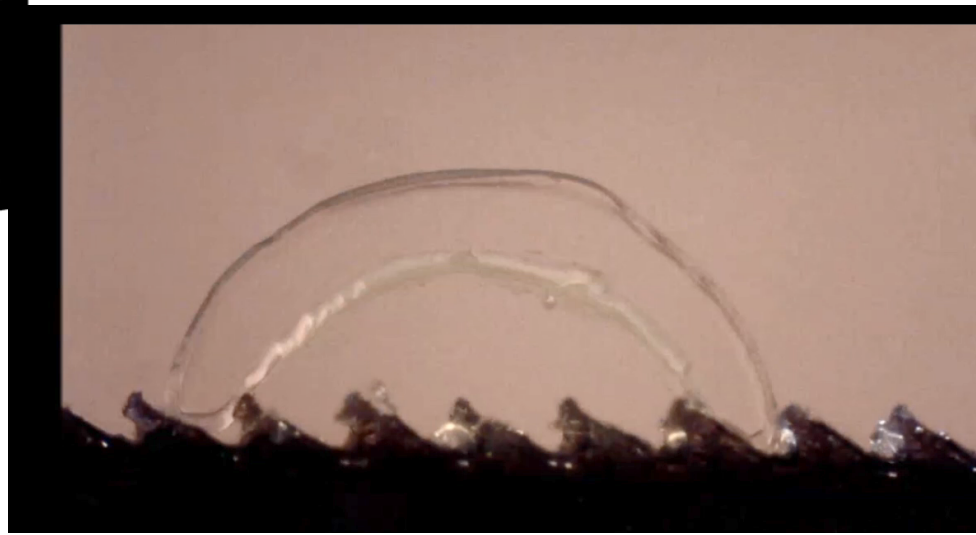


C. Delaney, P. McCluskey, S. Coleman, J. Whyte, N. Kent, D. Diamond, Lab on a Chip, 17(2017) 2013-21.

Photo-Responsive Soft Hydrogels

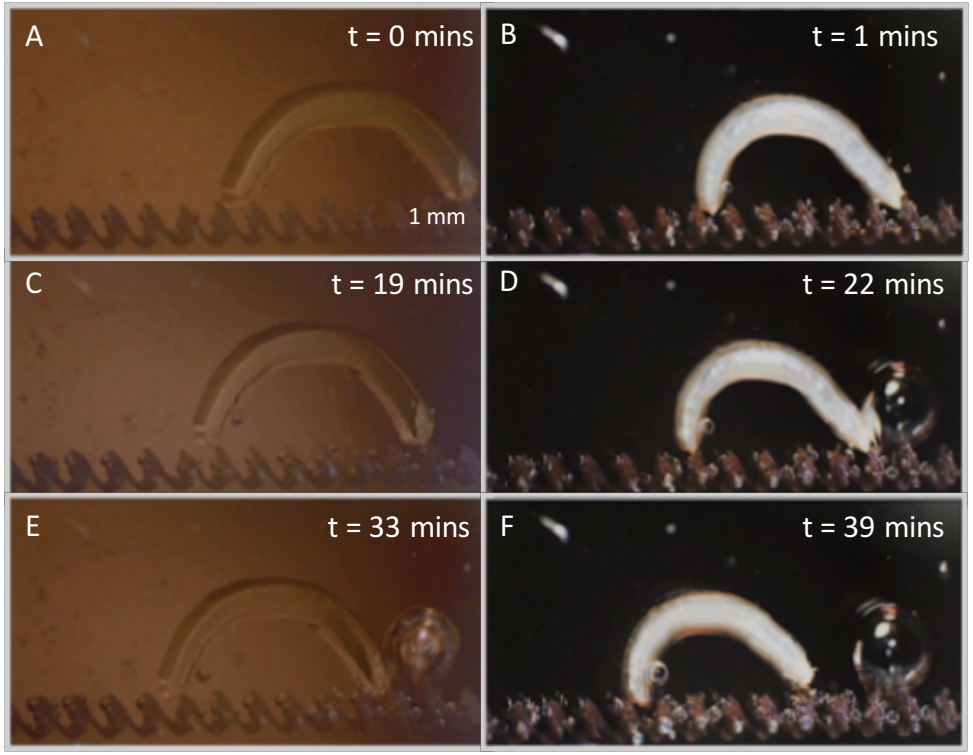


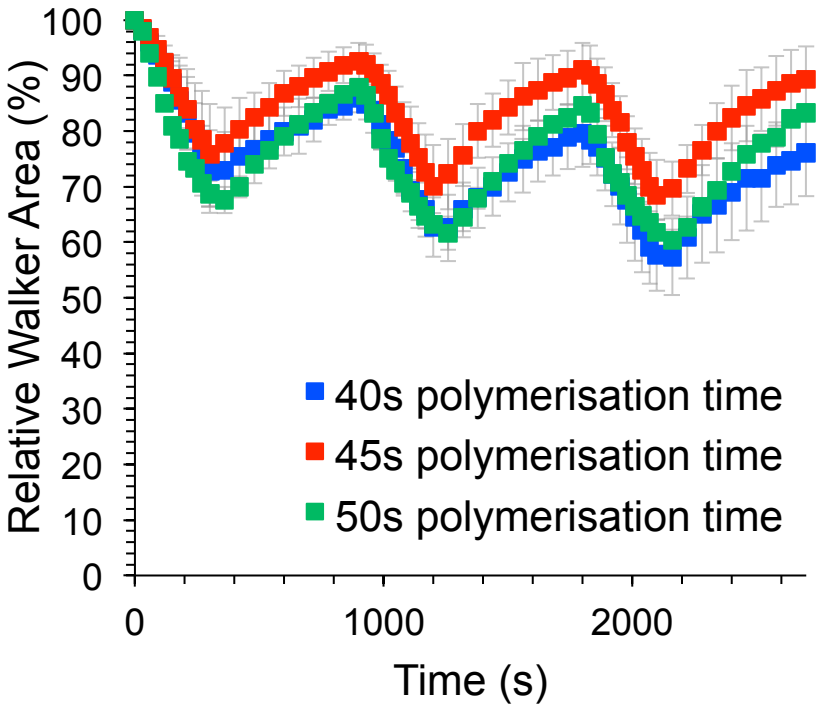
Walking towards the light



W. Francis et al. / Sens. Act. B 250 (2017) 608–616

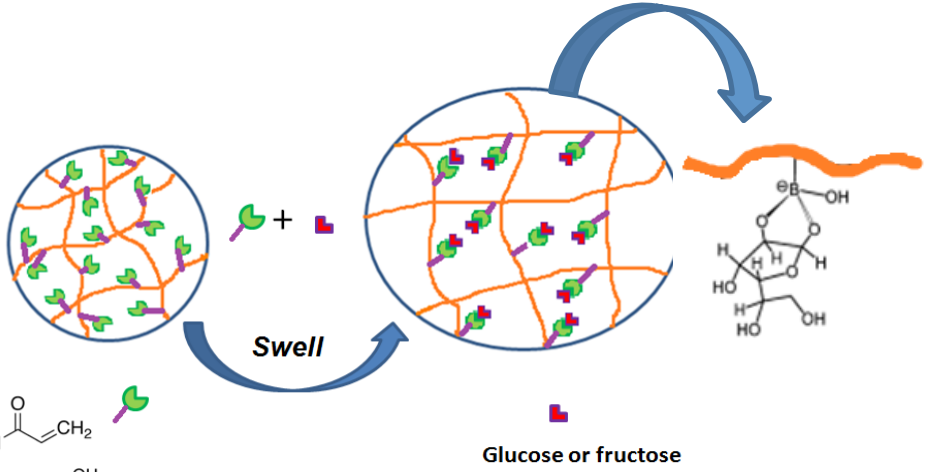
Photo-Responsive Soft Hydrogels

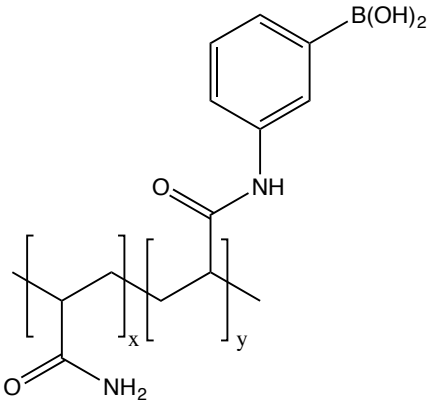


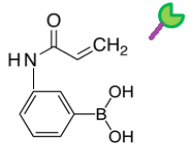


"Walking" Direction

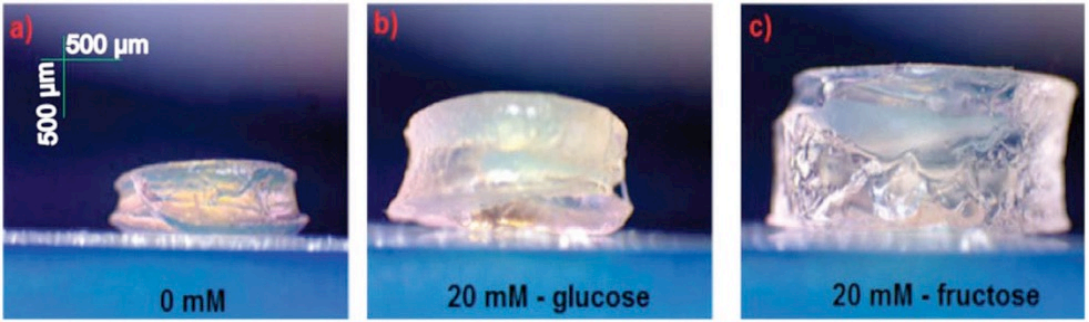
Sugar-Responsive Soft Hydrogels

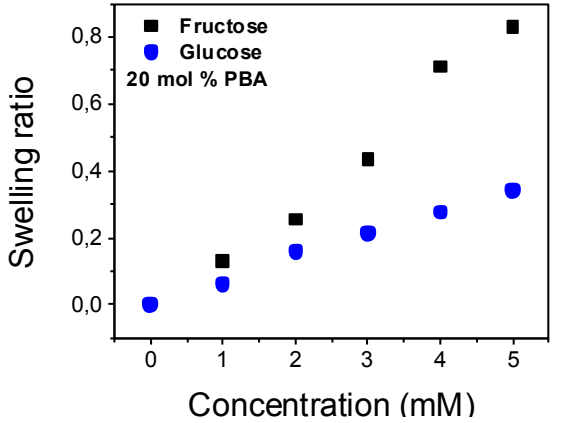






Acrylamide-*co*-PBA Polymer



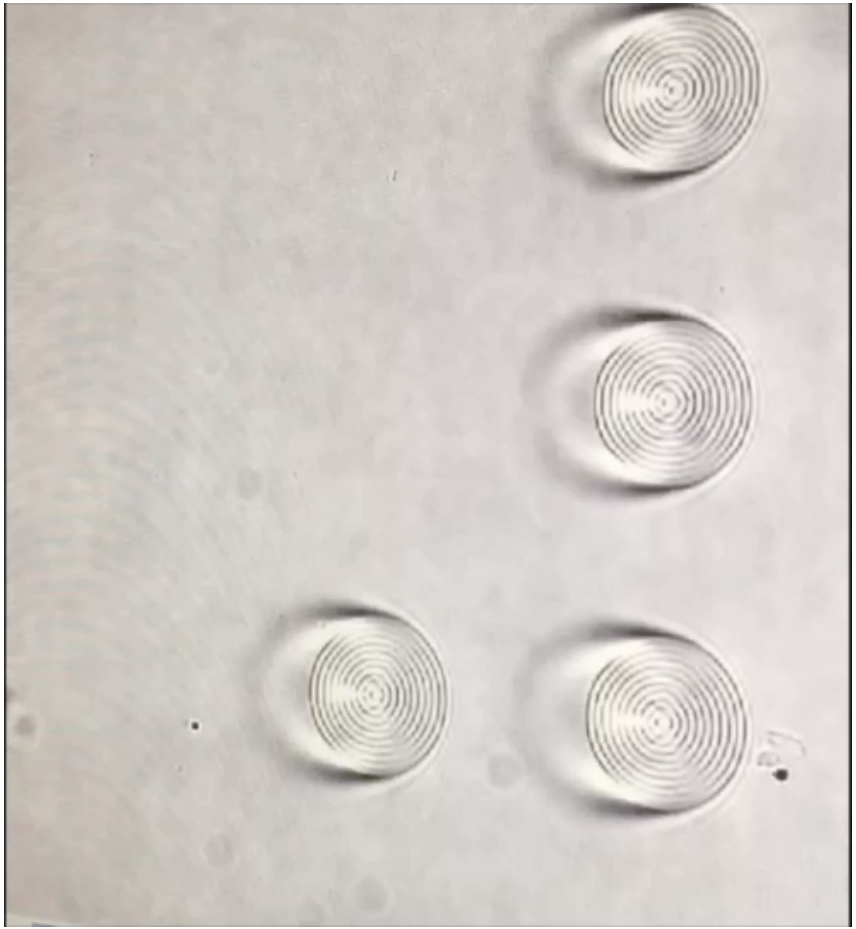


Fabrication of Soft Hydrogel Structures by 2-PP

- 3D Structures
- High resolution (<µm)
- Improved diffusion times
- Improved Swelling/Shrinking Kinetics
- Improved Response Times

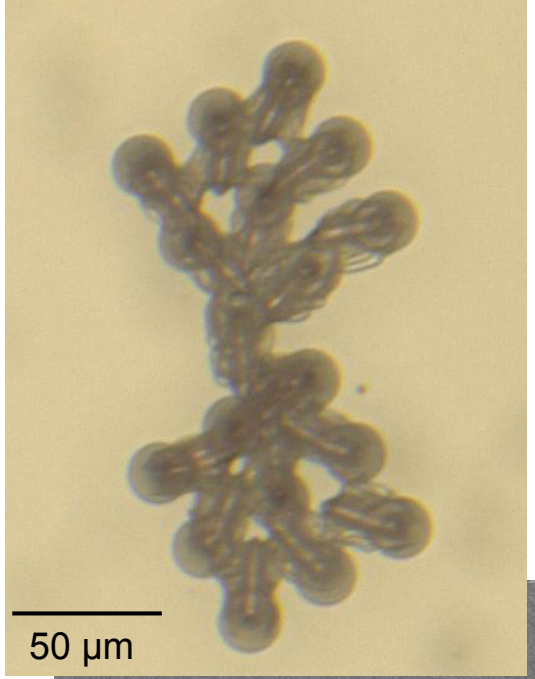
Requirements for 2-PP:

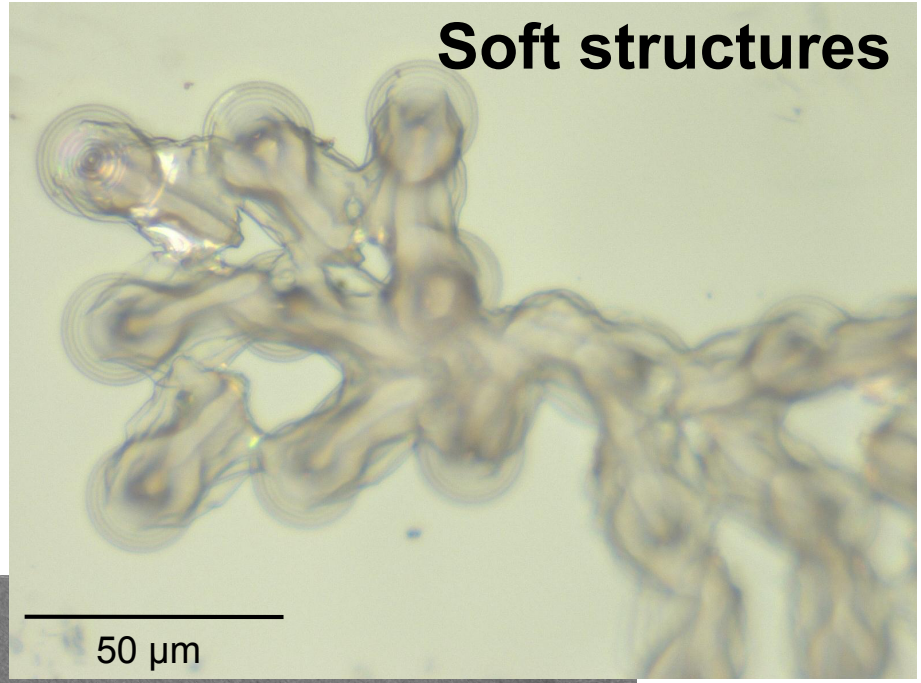
- High monomer concentration → good solvents
- High Thermal Stability
- Low Vapour Pressure
- Tunable Viscosity

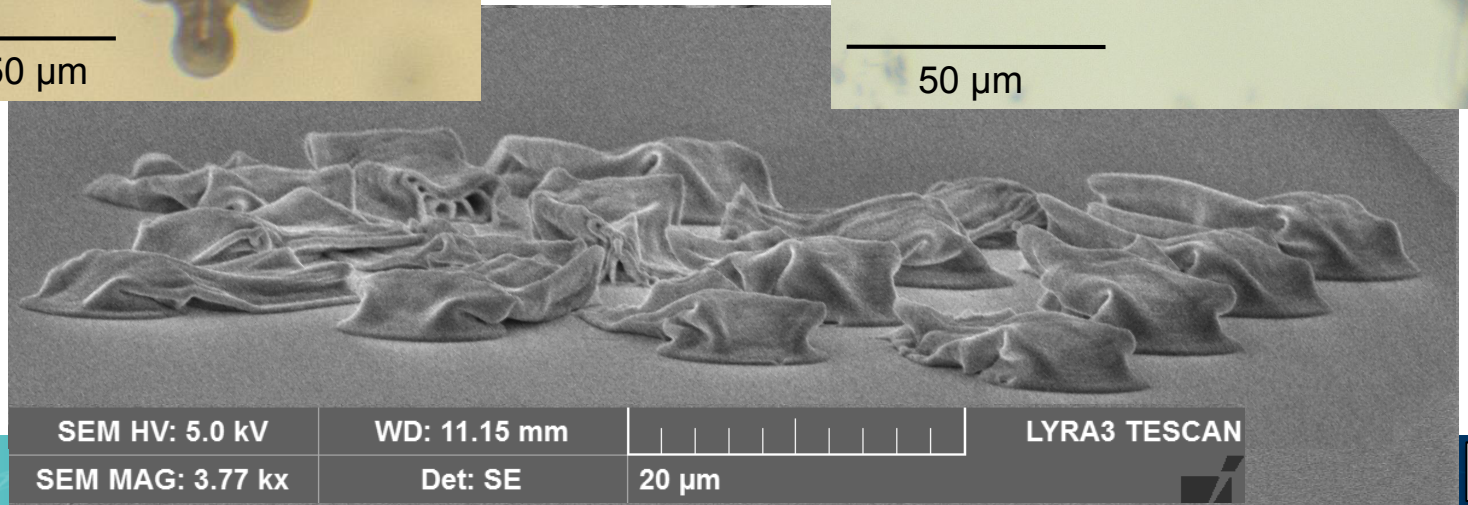


2PP in Real Time of Soft Materials

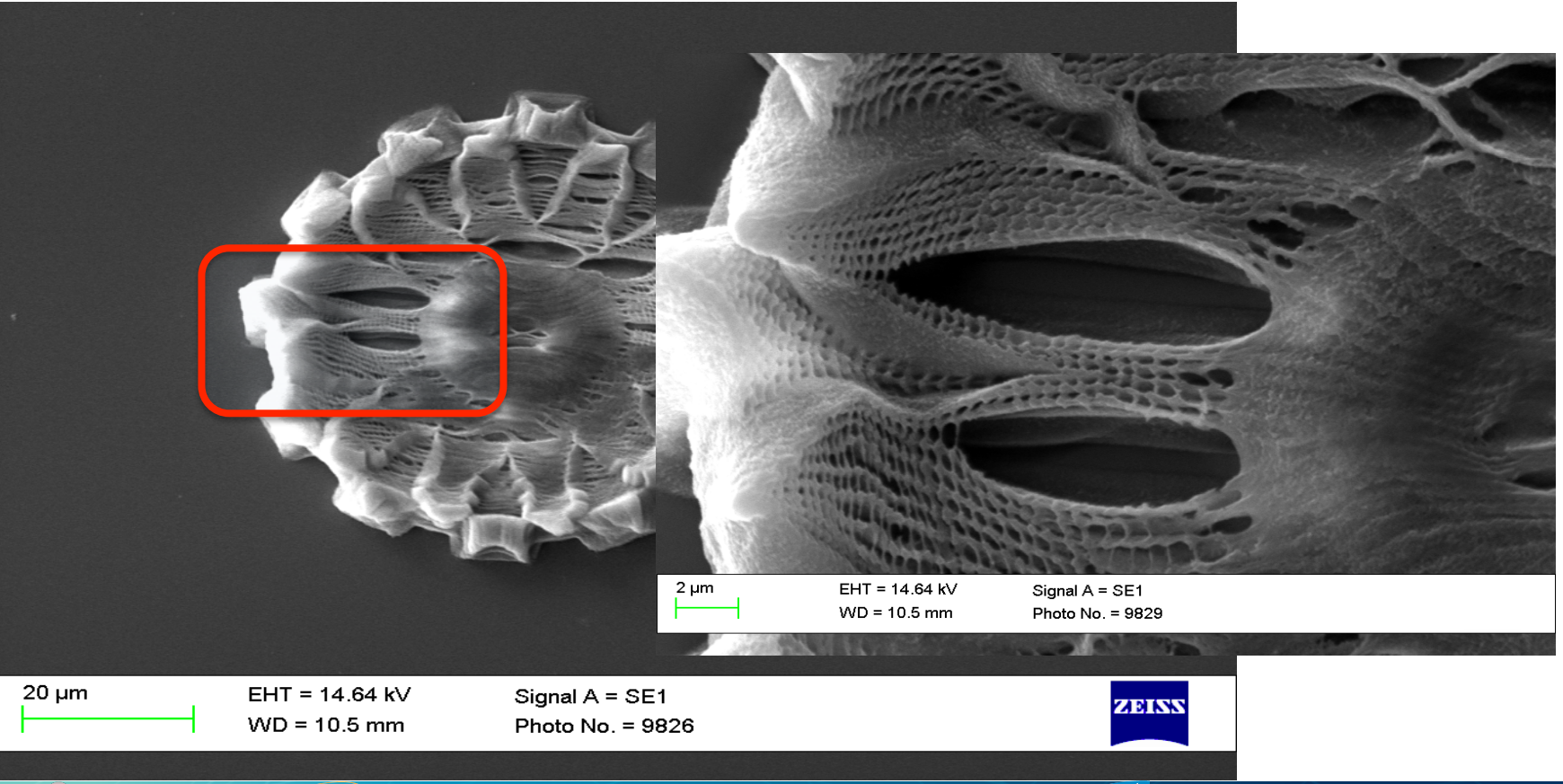
Soft structures



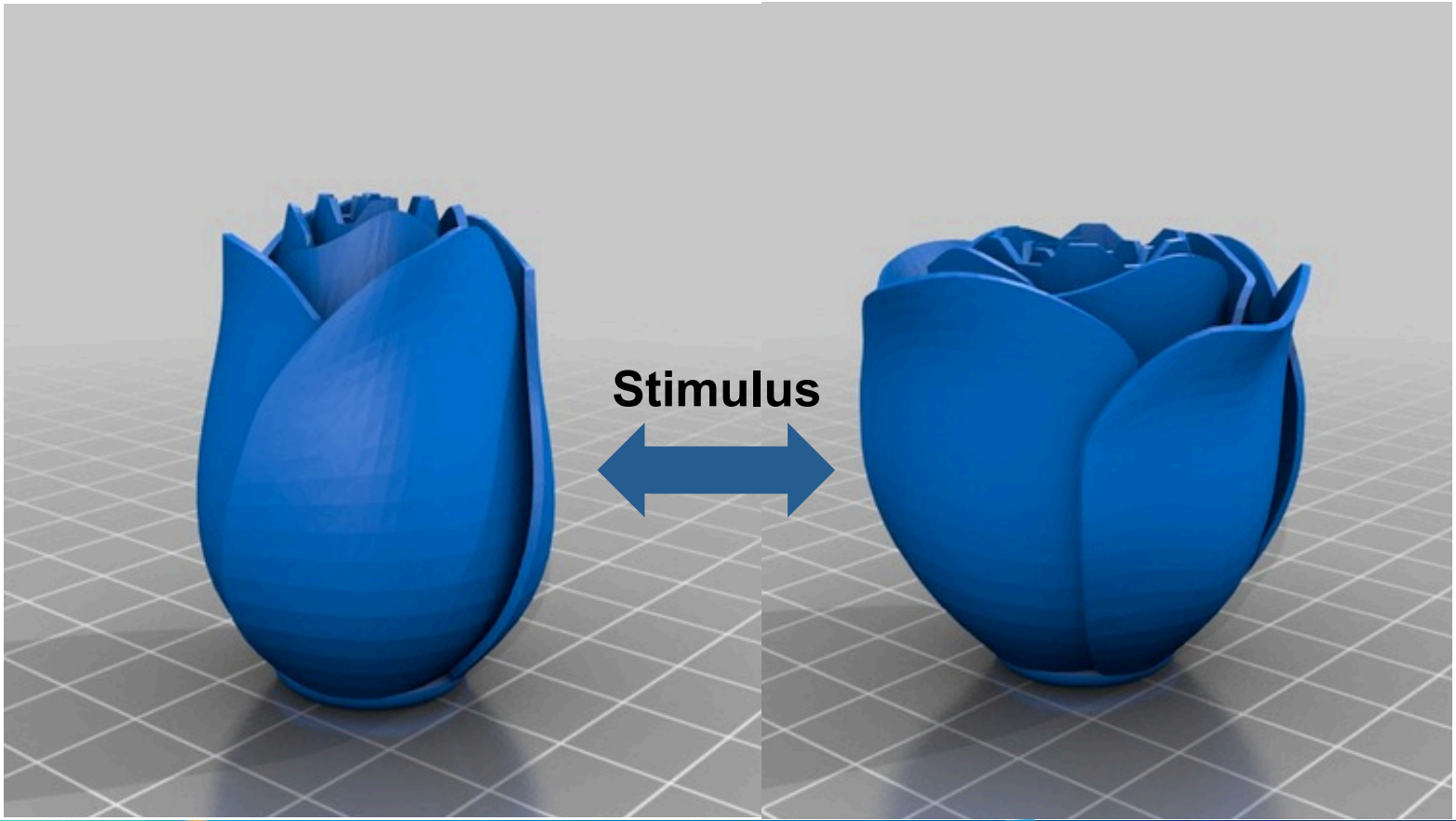




‘Daisy’ – Micro/Nano Scaled Pores

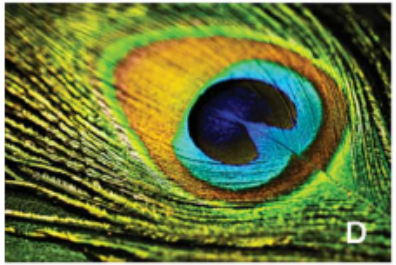


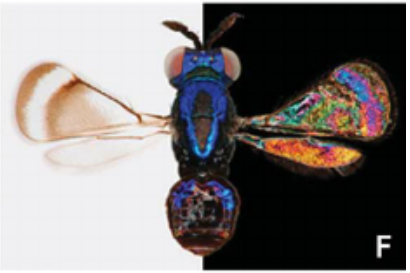
Stimuli-responsive actuators produced by 2PP

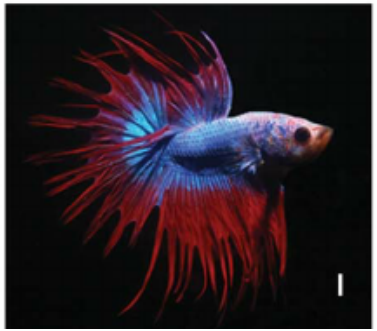


Stimuli-responsive sensors produced by 2PP

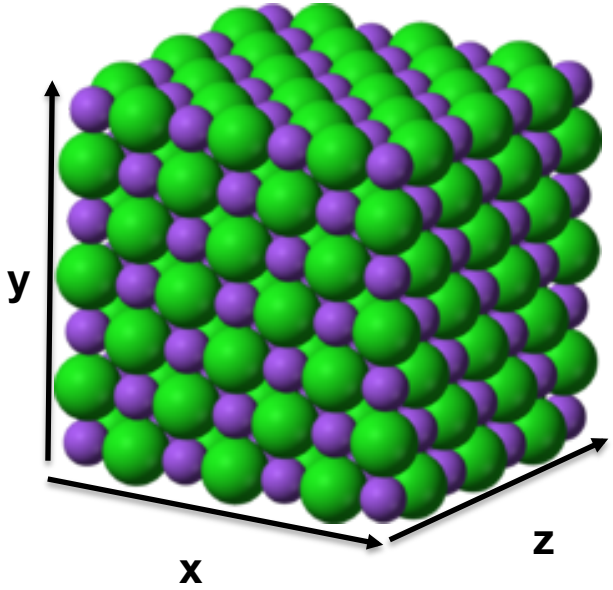
Biomimetic structures



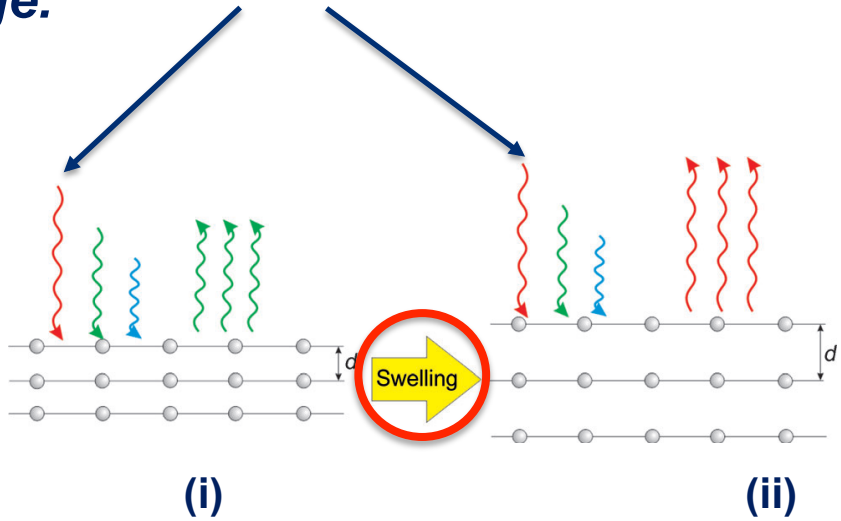




Photonic Crystals



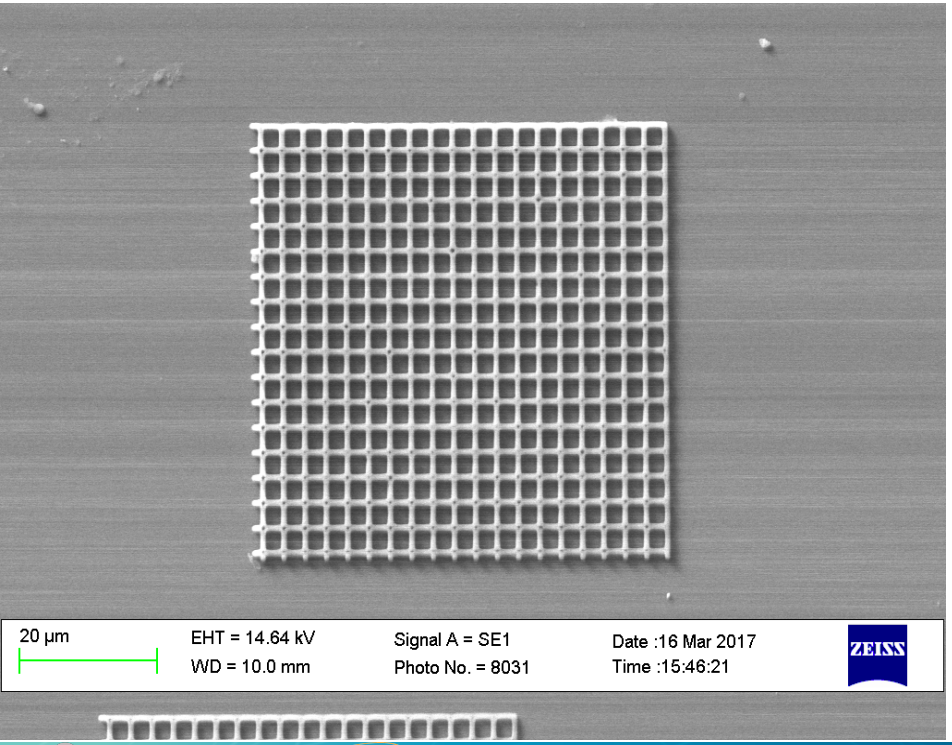
Altered wavelength of reflectance due to change in structure's dimensions (d) caused by a stimulus → colour change.

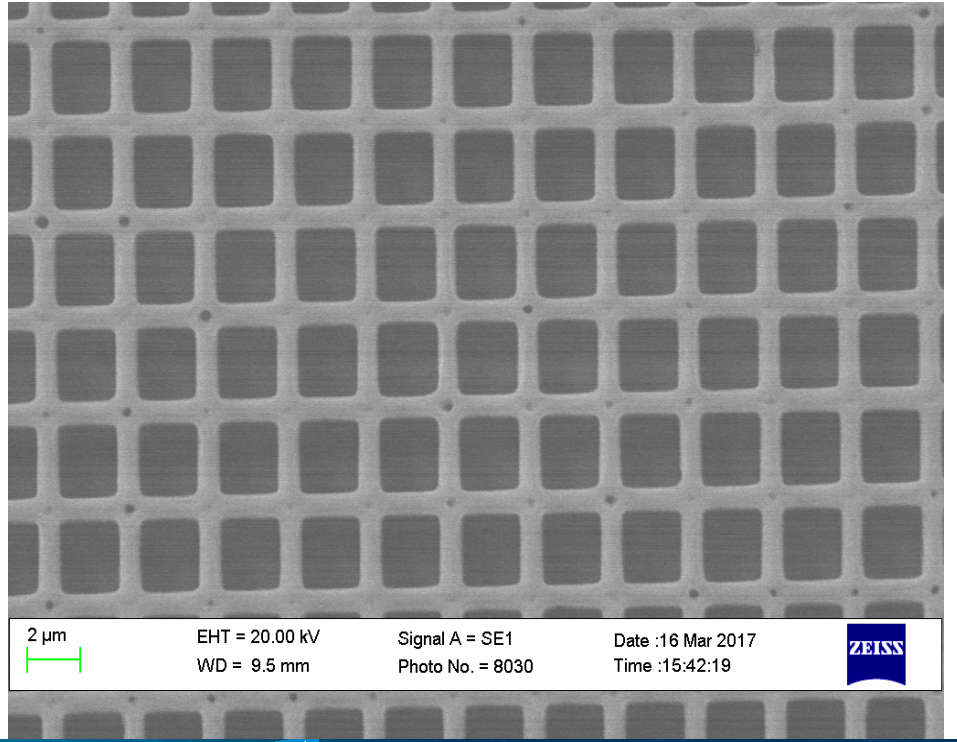


Wavelength of reflectance of this 3D structure is governed by the distance between its layers → Gives structure a specific colour.

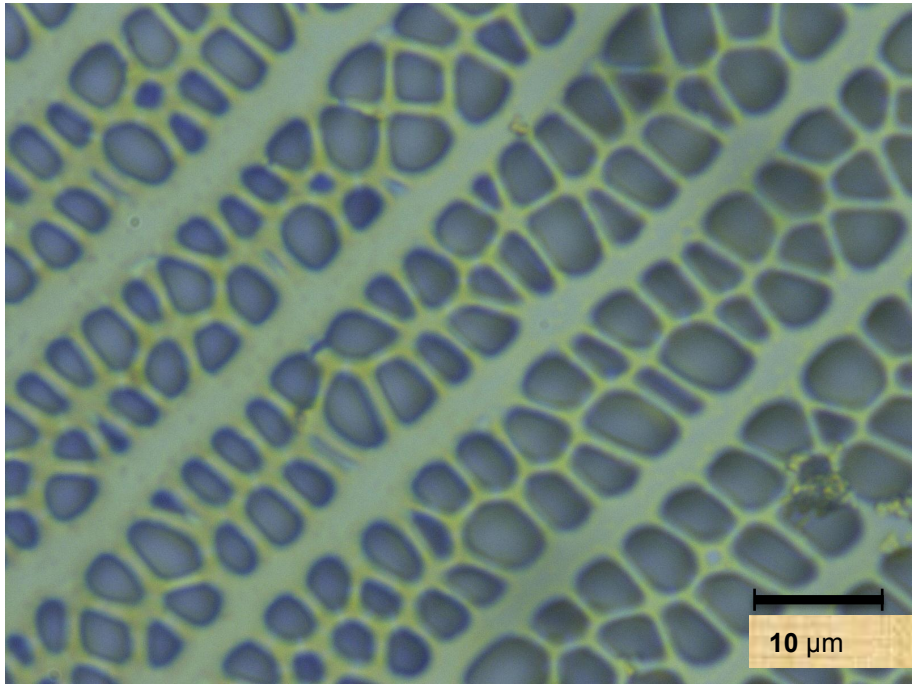
Photonic Crystals for Chemical Sensing and Biosensing, Angew. Chem. Int. Ed. 2014 , 53, 3318 – 3335.

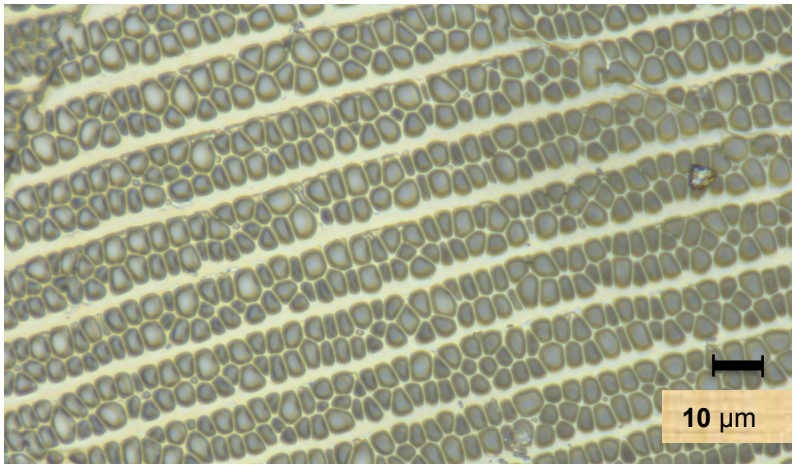
Periodic Hydrogel Structures

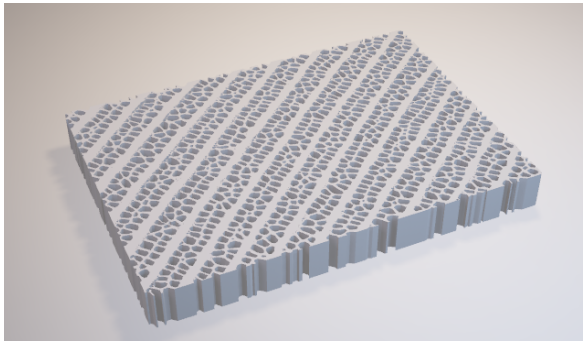




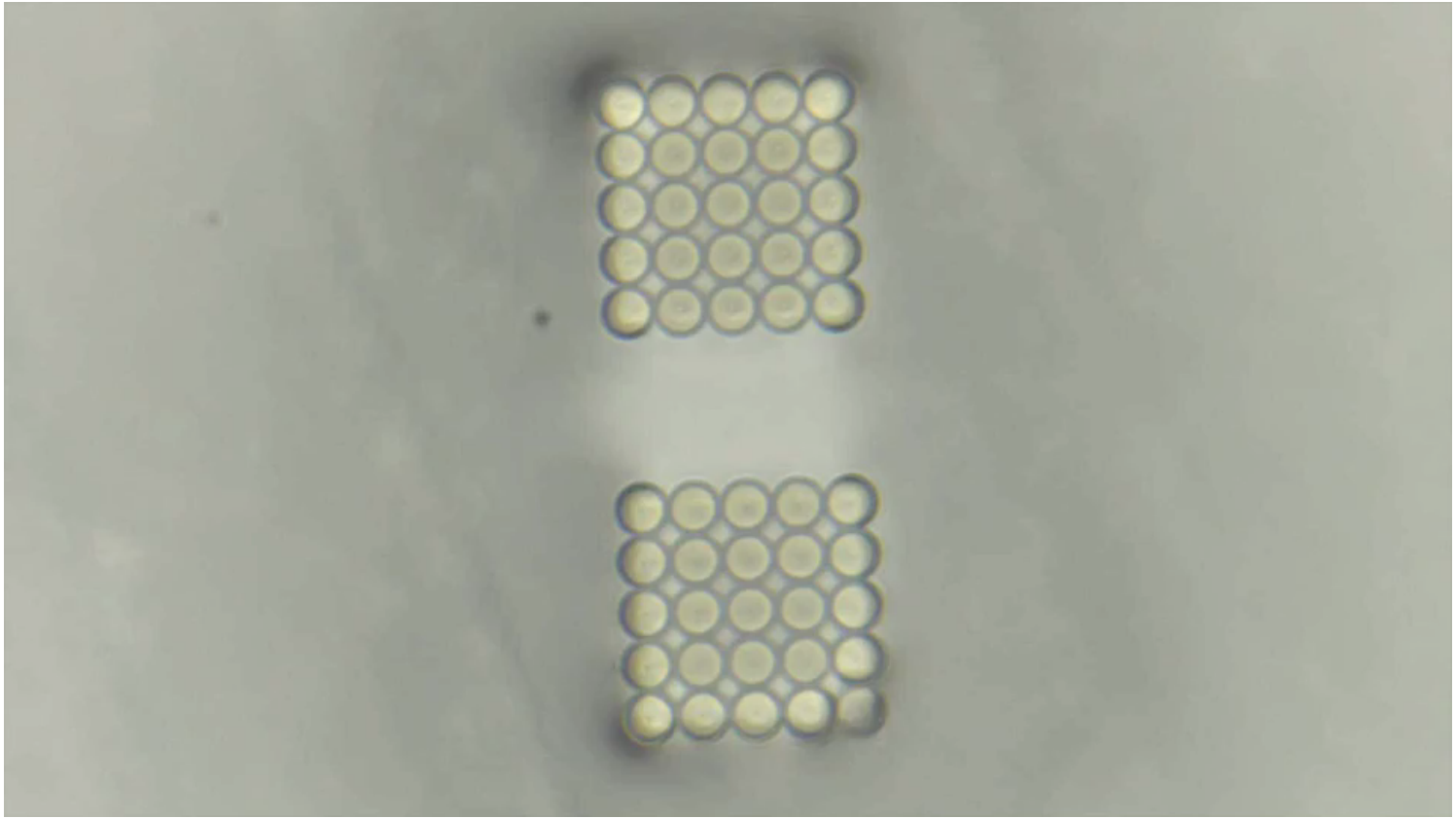
Biomimetic structures - butterfly



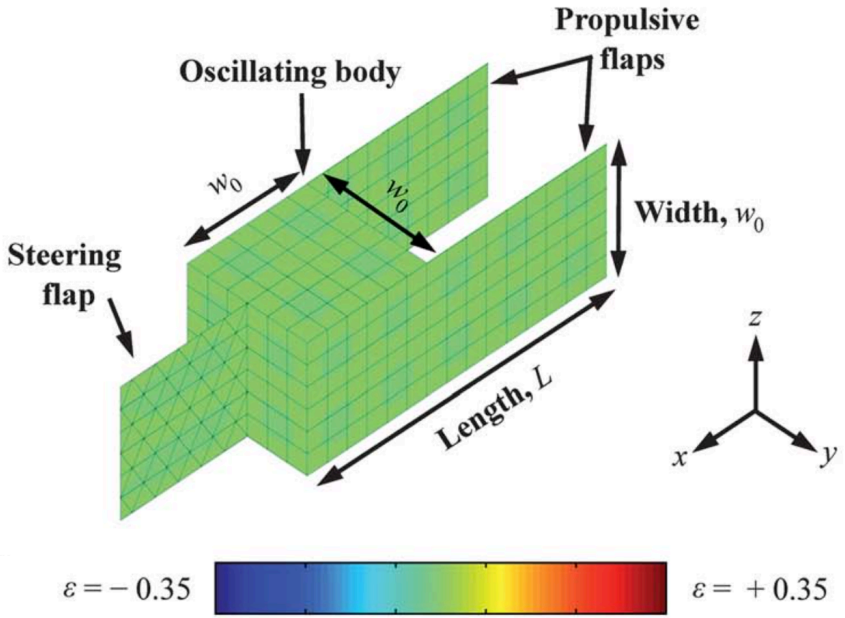


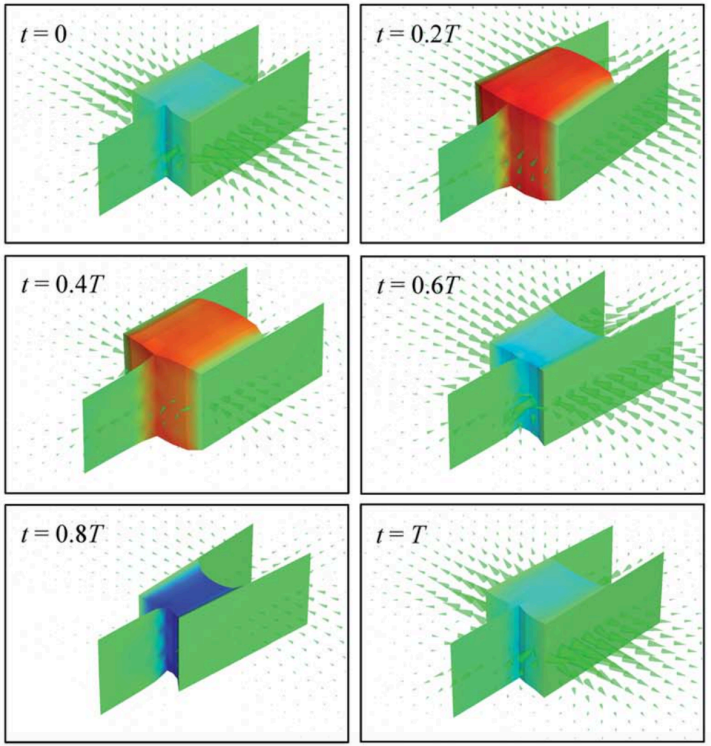


Structure Development



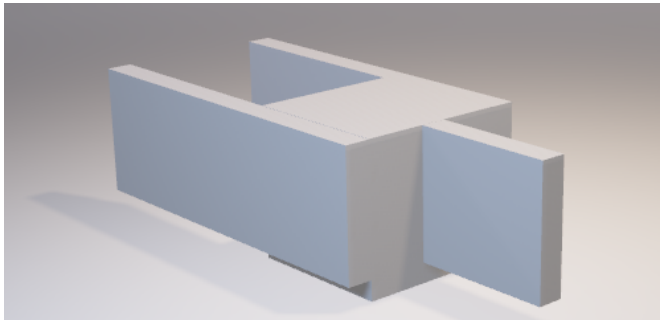
Designing maneuverable micro-swimmers actuated by responsive gel

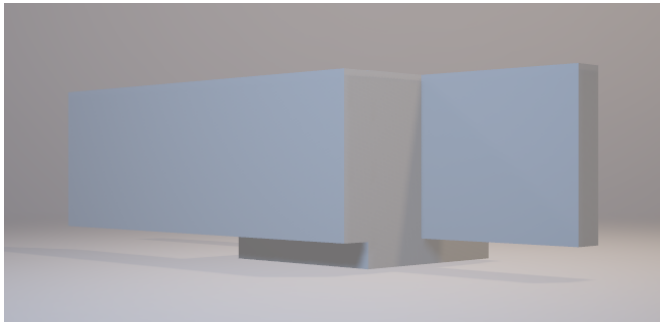


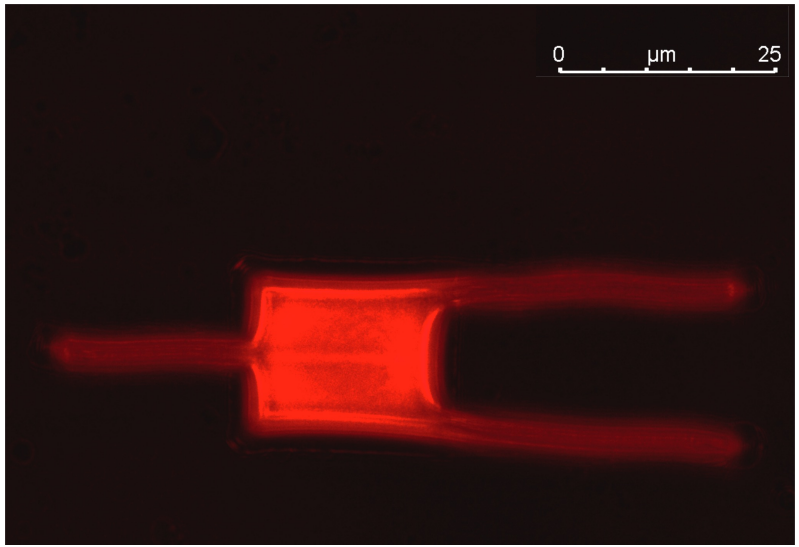


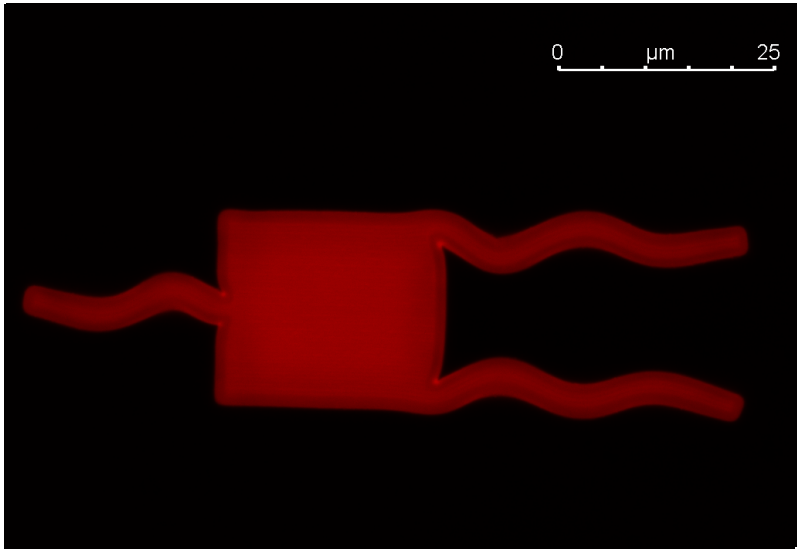
Masoud, H., Bingham, B.I. and Alexeev, A., Soft Matter, 2012, 8(34), pp.8944-8951.

Micro-swimmers actuated by responsive gel



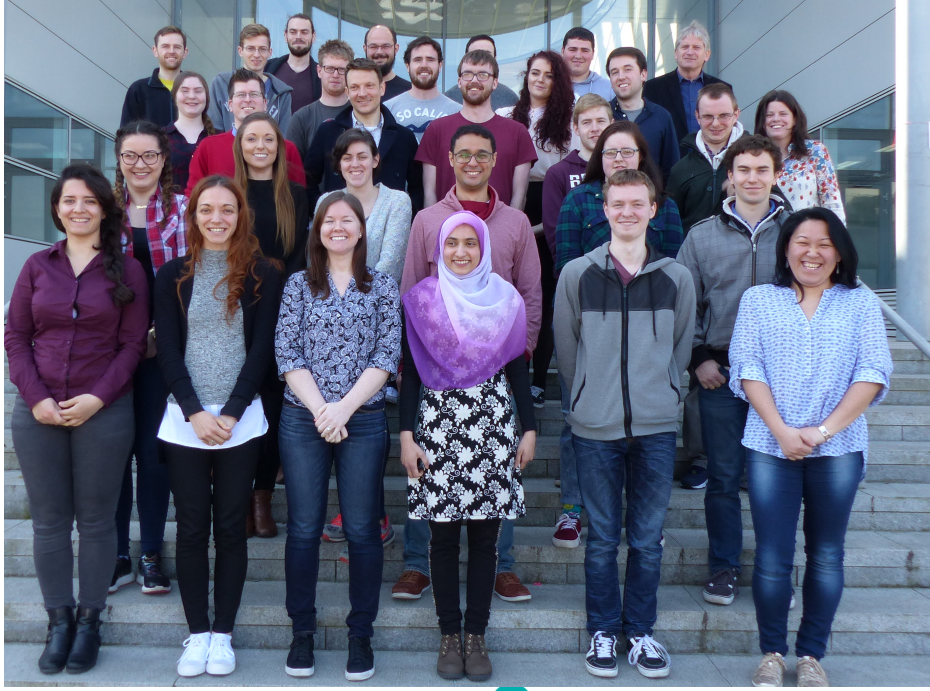






Acknowledgements

Dr. Alex Tudor
Dr. Colm Delaney
Dr. Hue Zhang
Prof. Dermot Diamond
Prof. Michael Higgins
Prof. David Officer
Prof. Gordon Wallace



DCU

MARIE CURIE ACTIONS

sfi Science Foundation Ireland

Insight

NAPES
NEXT GENERATION ANALYTICAL PLATFORMS FOR ENVIRONMENTAL SENSING

SEVENTH FRAMEWORK PROGRAMME

sfi DCU UCC OÉ Gaillimh NUI Galway UCD DUBLIN