BIOCOMPATIBLE, REVERSIBLE PHOTO-ACTUATED HYDROGELS, OPERATIVE IN NEUTRAL ENVIRONMENTS, FOR MICRO-VALVE APPLICATIONS IN MICROFLUIDIC DEVICES

Aishling Dunne*, Wayne Francis*, Larisa Florea*, Fernando Benito-Lopez*,** and Dermot Diamond*

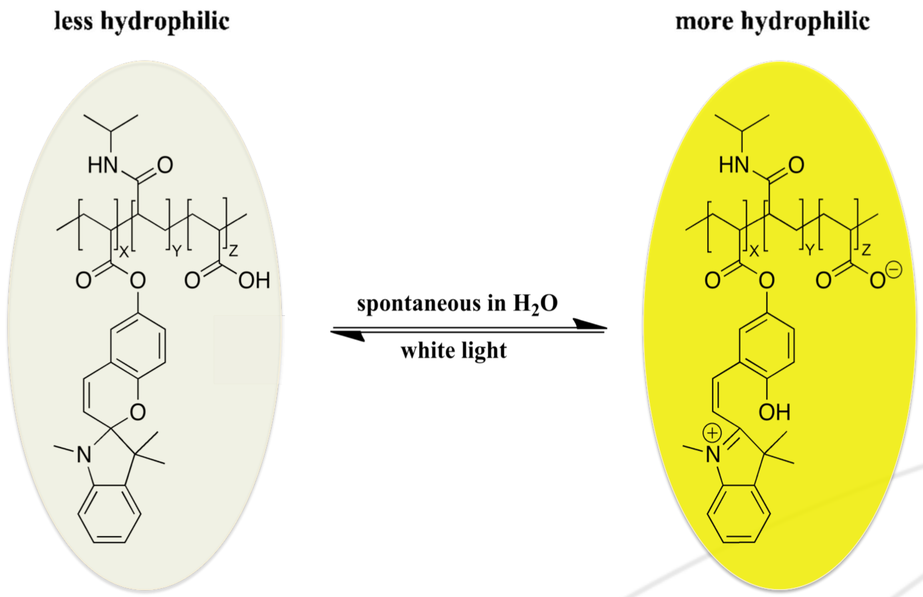
*Insight Centre for Data Analytics, National Centre for Sensor Research, School of Chemical Sciences, Dublin City University, Dublin 9, IRELAND.
**CIC microGUNE, Arrasate-Mondragón, SPAIN.

Introduction

In recent years, a popular way of photo-modulating flow in microfluidic devices has been through the use of acidified hydrogel valves incorporating spiropyran (SP) moieties that needed to be externally protonated with acidic solutions. The approach has significant disadvantages such as (1) the need to expose the contracted gel to strong external acidic solutions, in order to induce re-swelling, (2) slow re-swelling times of up to several hours, making these valves suitable for single use applications only. Herein, we present for the first time, reversible photo-actuation of *N*-isopropylacrylamide, acrylated spiropyran and acrylic acid copolymer p(NIPAAm-*co*-SP-*co*-AA) hydrogel microstructures capable of operating in neutral aqueous environments. The photo-actuation process is successfully reversible in a relatively short time period (seconds to minutes). The hydrogels were incorporated in microfluidic devices as micro-valves for external photo-control of flow.

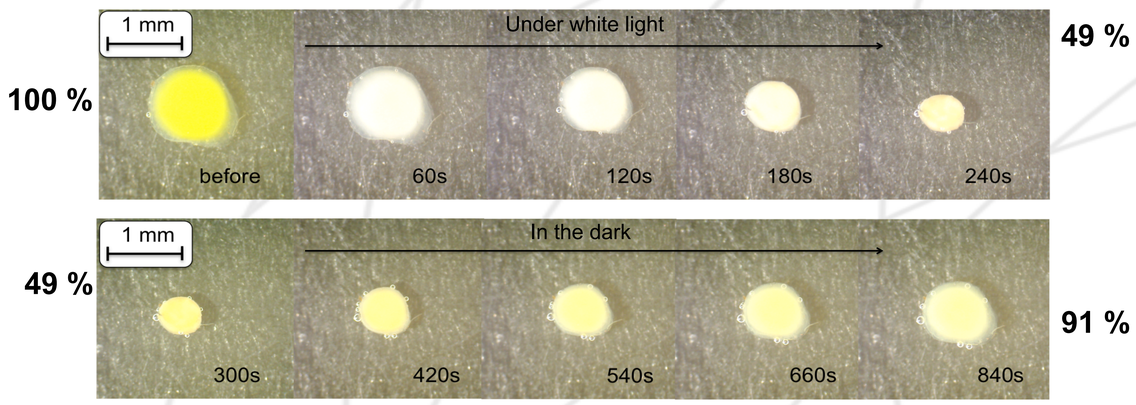
Photo-actuated hydrogels

Actuation mechanism



In water, the acrylic acid comonomer dissociates, resulting in the protonation of the photochromic spiropyran (SP) to protonated merocyanine (MC-H$^+$). This form is hydrophilic allowing the hydrogel to swell. Exposure to the white light promotes isomerisation of MC-H$^+$ form to the less hydrophilic SP form, triggering the hydrogel to contract.

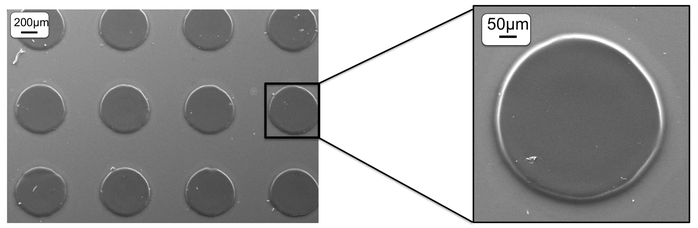
Reversible actuation



Compared to pervious studies of photo-actuation of hydrogels (minutes to hours). This work has resulted in faster photo-actuation times (seconds to minutes). This shrinking and re-swelling cycle can be repeated with great reproducibility.

Micro-patterned hydrogels

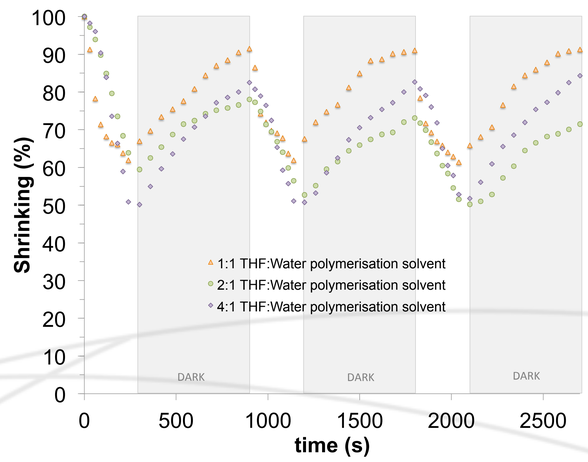
Hydrogel microstructures covalently attached to glass substrates were photo-polymerised through micro-patterned masks using white light.

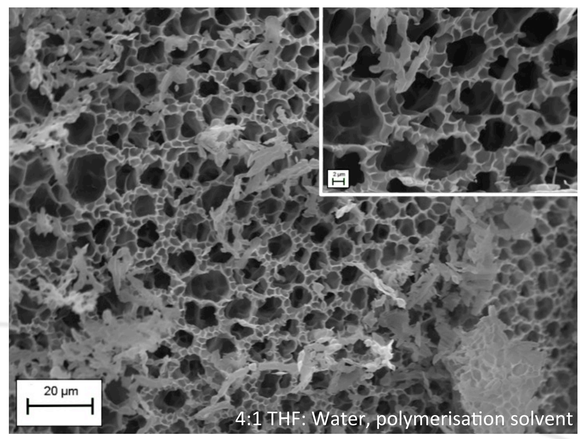


- Circular masks of 1 mm diameter.
- Hydrogel height: 60 µm.
- Polymerisation time: 10-20 s

Hydrogel characterisation

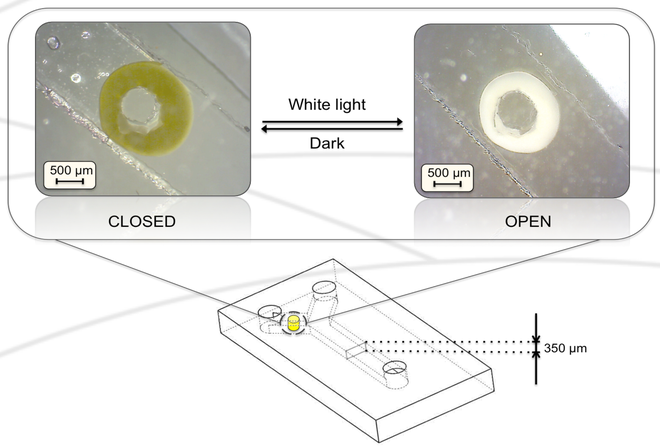
The polymerisation solvent influences the morphology of the hydrogel, by producing highly porous hydrogels of different pore sizes. This has an impact on the diffusion path length for water molecules moving in/out of the hydrogel matrix, thus enabling the swelling and shrinking kinetics of the hydrogel to be tuned.





Hydrogel valve application

Hydrogel microstructures were photo-polymerised *in-situ* inside PDMS/glass microfluidic channels. Exposure to white light causes the valves to contract thus opening the channel, allowing fluid to flow. The opposite was seen when the valve was kept in the dark.



Conclusions

Integration of photo-responsive hydrogels in microfluidic systems provides a new route towards the fabrication of smart, externally controlled systems. These hydrogels can be successfully used as photo-controlled valves in microfluidic systems for repeatable ON/OFF flow modulation in neutral environments.

This project has been funded by Science Foundation Ireland under the Insight initiative, grant SFI/12/RC/2289. FBL wants to thanks the Gobierno Vasco, Dpto. Industria, Innovación, Comercio y Turismo under ETORTEK 2013 with Grant No. IE13-360 and the Ramón y Cajal Programme (Ministerio de Economía y Competitividad).