Reversible photo-responsive hydrogels based on spiropyran

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MRS Spring Meeting – San Francisco 2014

Outline

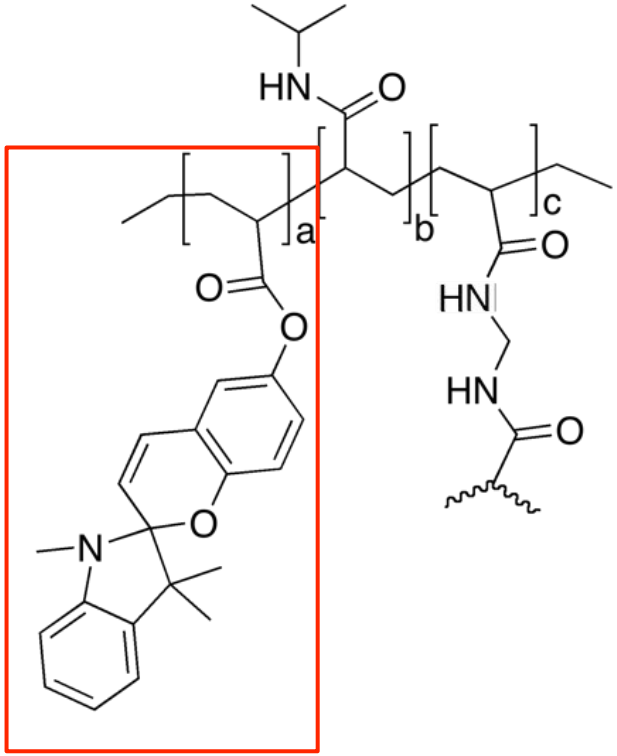
Background

Self-protonating photo-responsive hydrogels

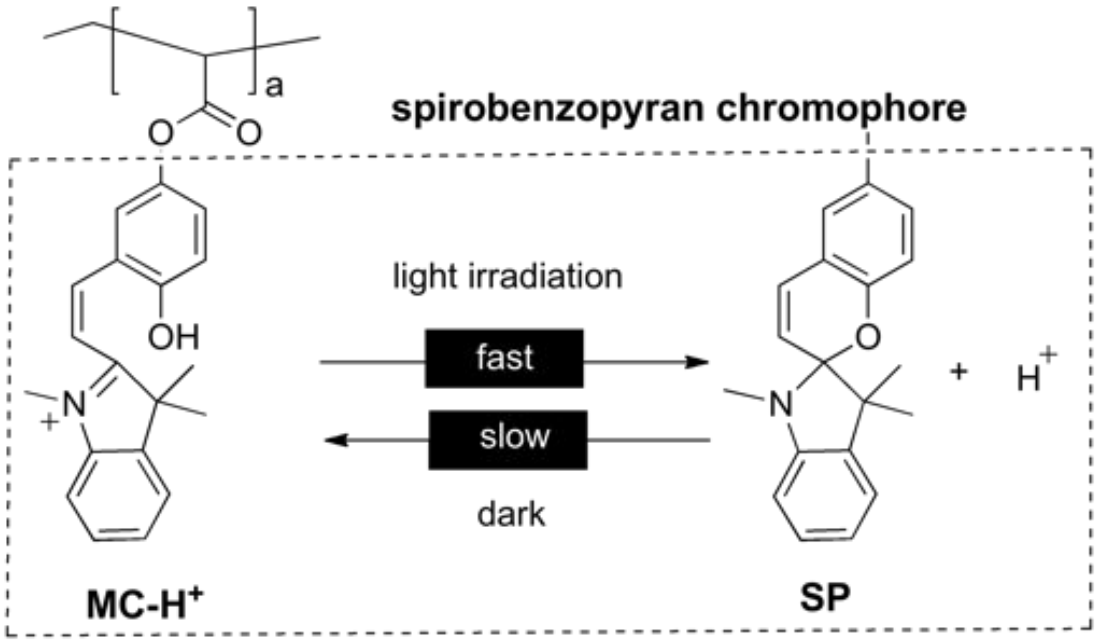
- Hydrogel fabrication
- Characterization
- Optimisation of hydrogel composition
- Photo-actuation properties
- Photo-induced shrinking and reswelling behaviour
- Porous hydrogels for improved reswelling kinetics

Conclusions

Background



- **Spiropyran – Photochromic behaviour**



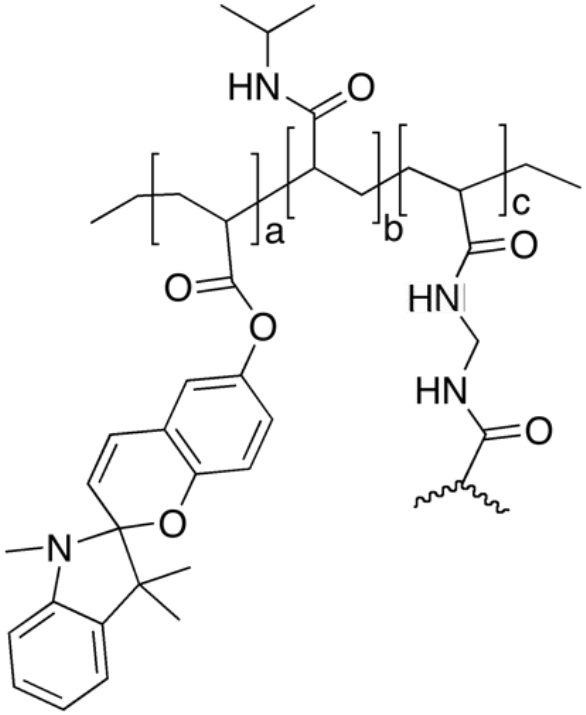
Spiropyran **a = 1**

NIPAAm **b = 100**

MBAA **c = 2**

[1] Sugiura et al., Sens. Act. A, 140 (2007) 176–184

Background



Spiropyran	**a = 1**
NIPAAm	**b = 100**
MBAA	**c = 2**

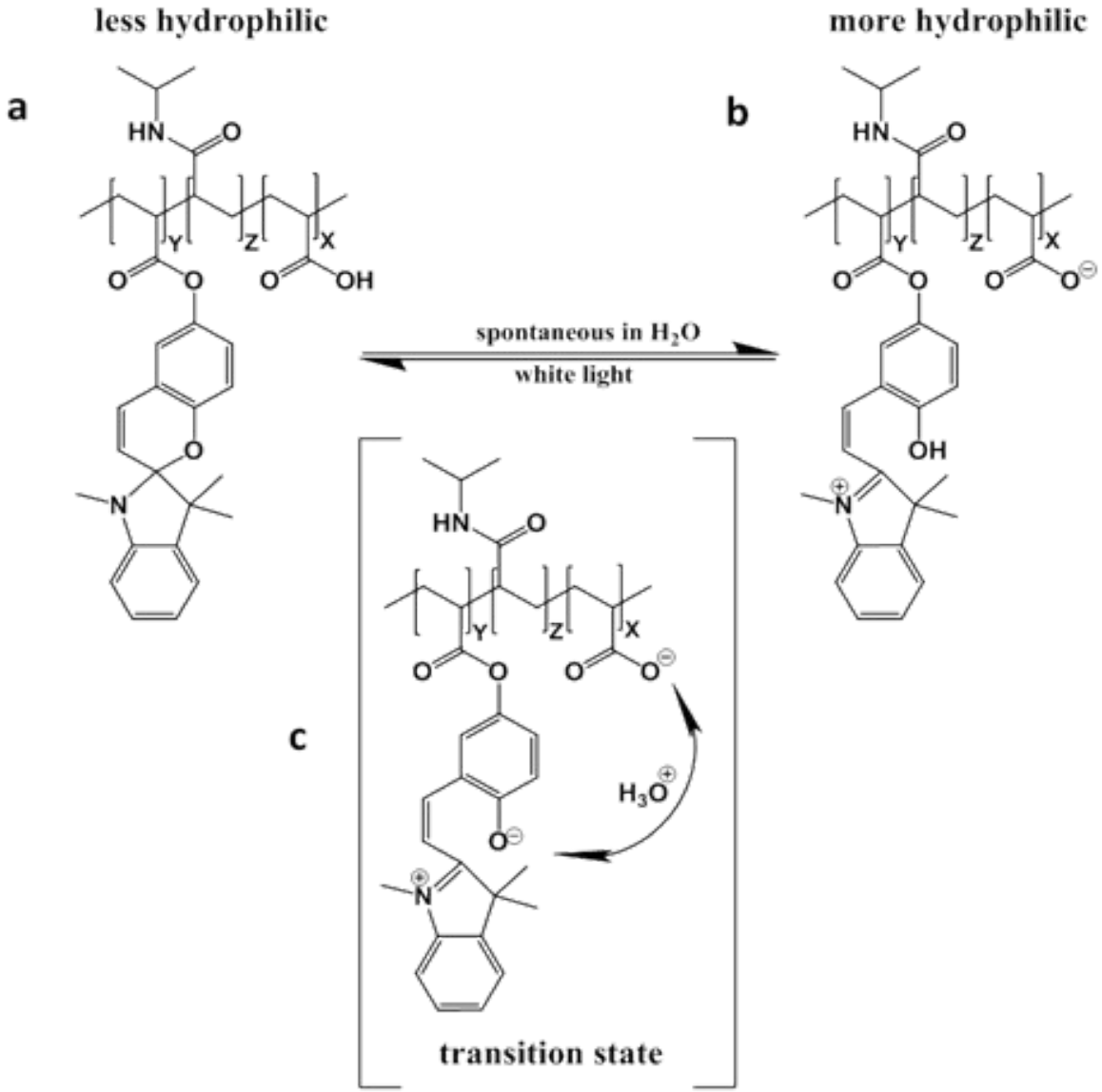
- Size: 120-170 µm [1]
- Shrinking: to 68% of initial size after 120 s
- Maximum shrinking: to 52 % of initial size [1]
- Necessary time for reswelling: > one hour

Drawbacks

- **Gels are soaked in 0.5 mM HCl overnight**
- **Operating only in acidic environment**
- **Suitable for single-use only**

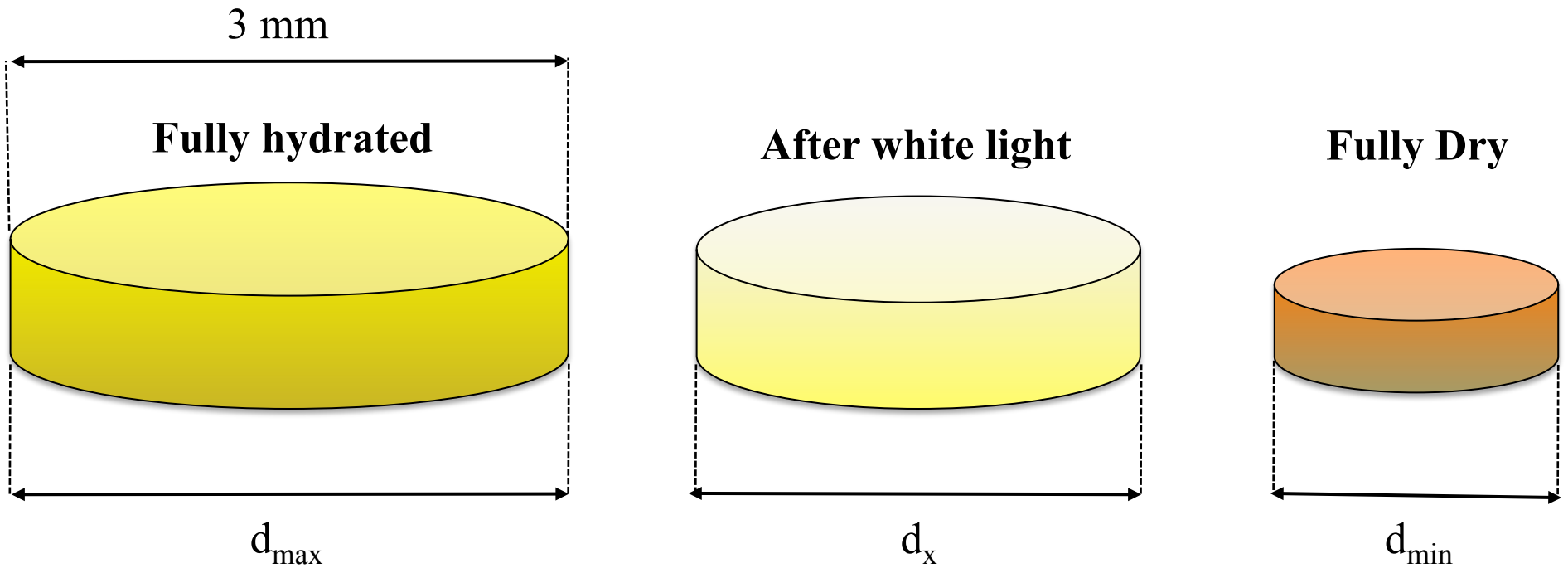
[1] Sugiura et al., Sens. Act. A, 140 (2007) 176–184

Self-protonating hydrogels



Hydrogel fabrication

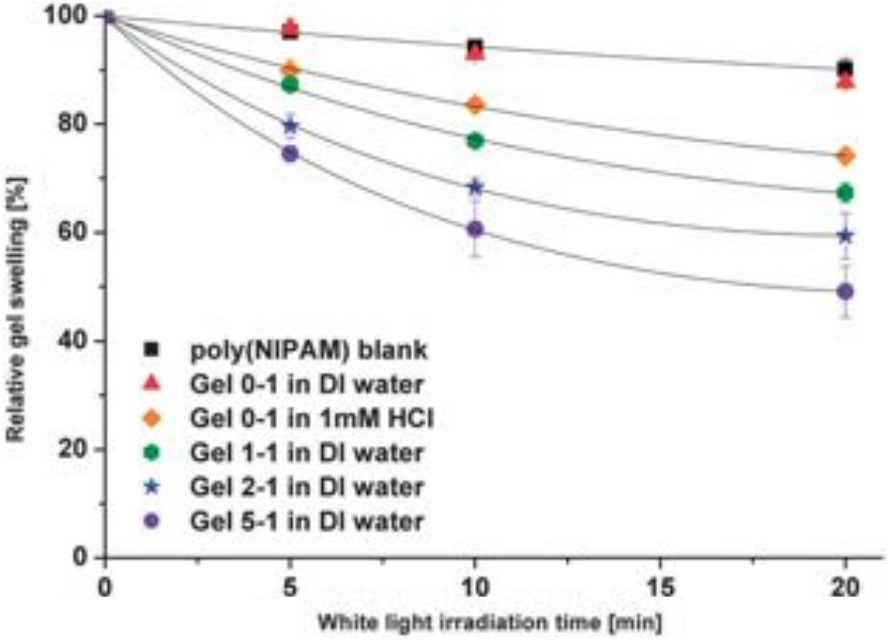
- **Photo-polymerised in circular PDMS moulds**

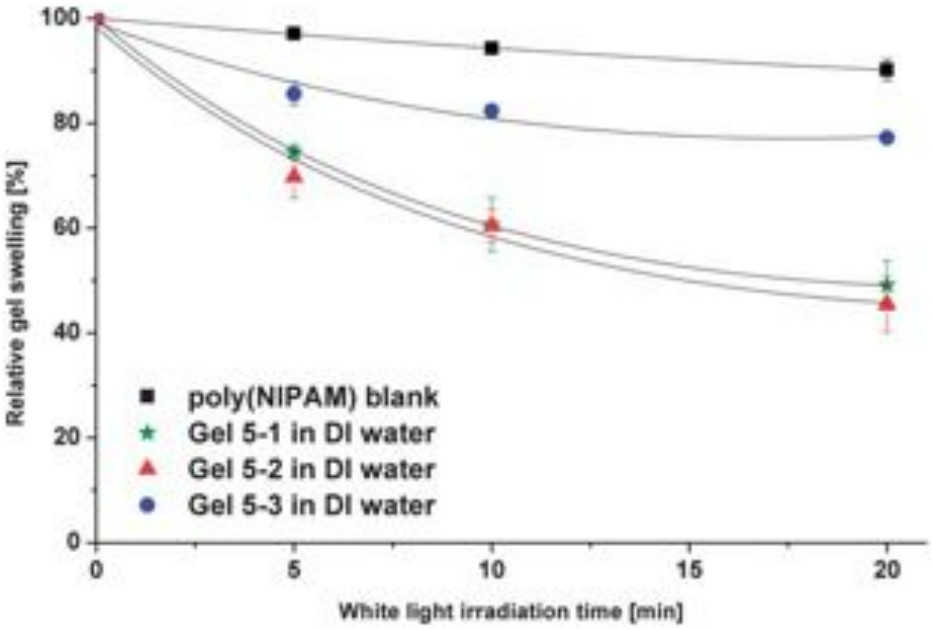


$$D\% = \left[1 - \left[\frac{(d_{max} - d_x)}{(d_{max} - d_{min})}\right]\right] \times 100\%$$

Optimization of hydrogel composition

- **Photo-induced shrinking**

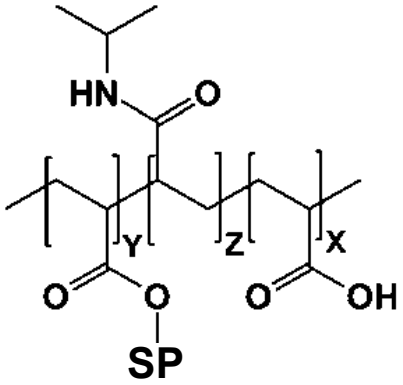




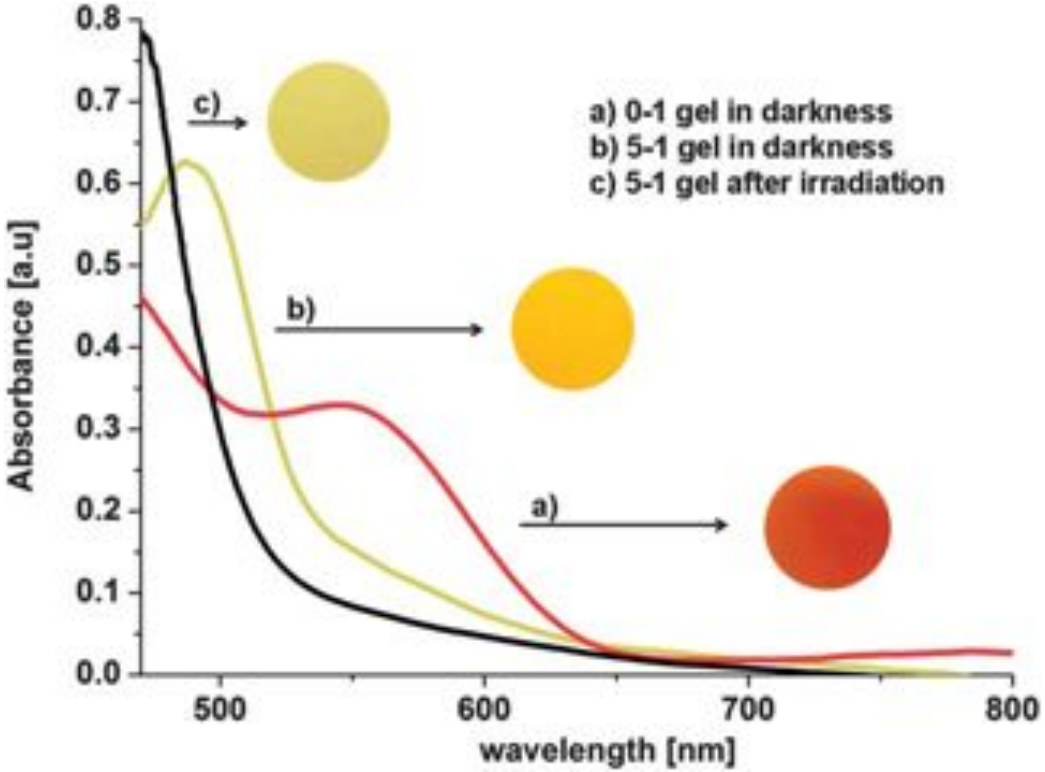
Shrinking/Reswelling Behaviour

sample	20 [min] (Vis. light)	std dev	60 [min] (in darkness)	std dev
poly(NIPAM) blank	87.85 %	1.18	97.44 %	1.60
1 % AA, 1 % BSP-A	67.33 %	1.85	100.45 %	0.64
2 % AA, 1 % BSP-A	59.37 %	4.26	96.48 %	1.34
5 % AA, 1 % BSP-A	49.10 %	4.73	97.35 %	1.93
2 % AA, 2 % BSP-A	61.31 %	5.20	83.69 %	1.27
5 % AA, 2% BSP-A	45.50 %	5.33	82.69 %	3.33
5 % AA, 3 % BSP-A	77.22 %	1.12	76.44 %	1.46

Hydrogel 5-1

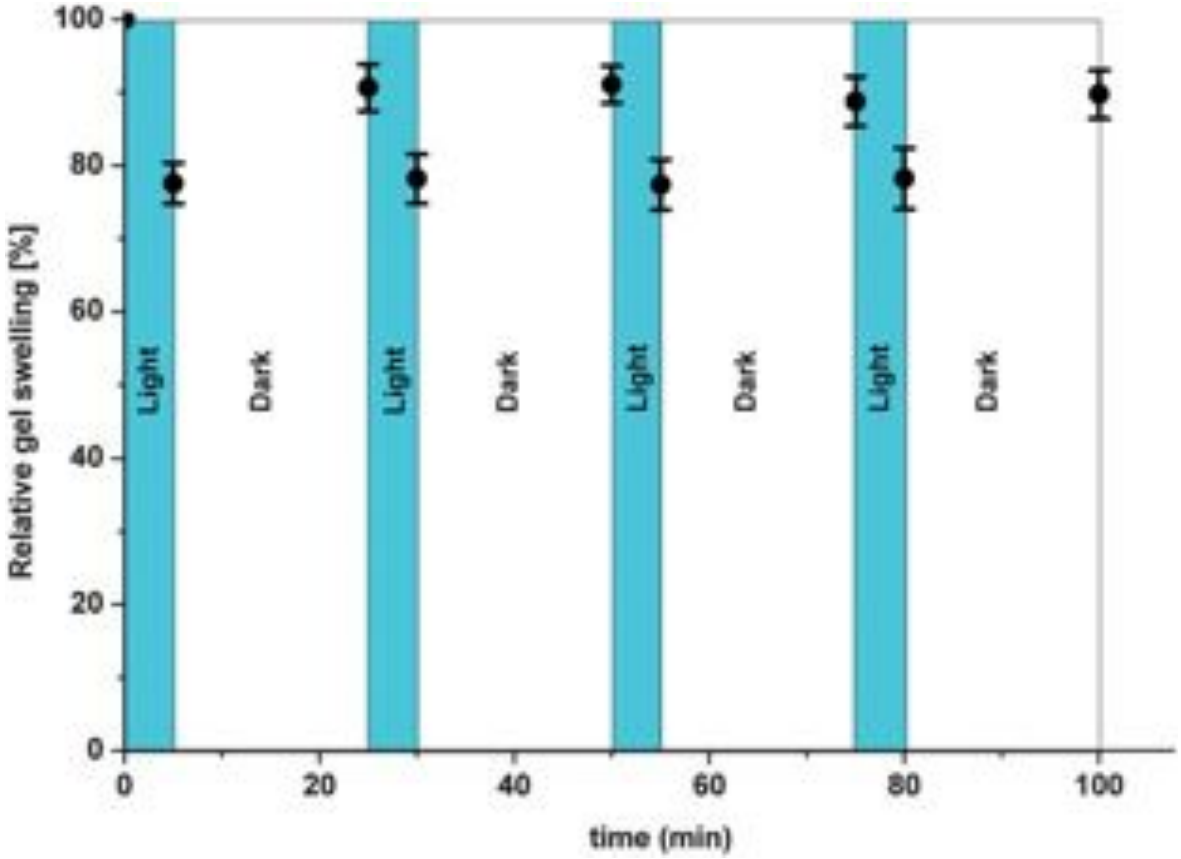


x = 5
y = 1
z = 100



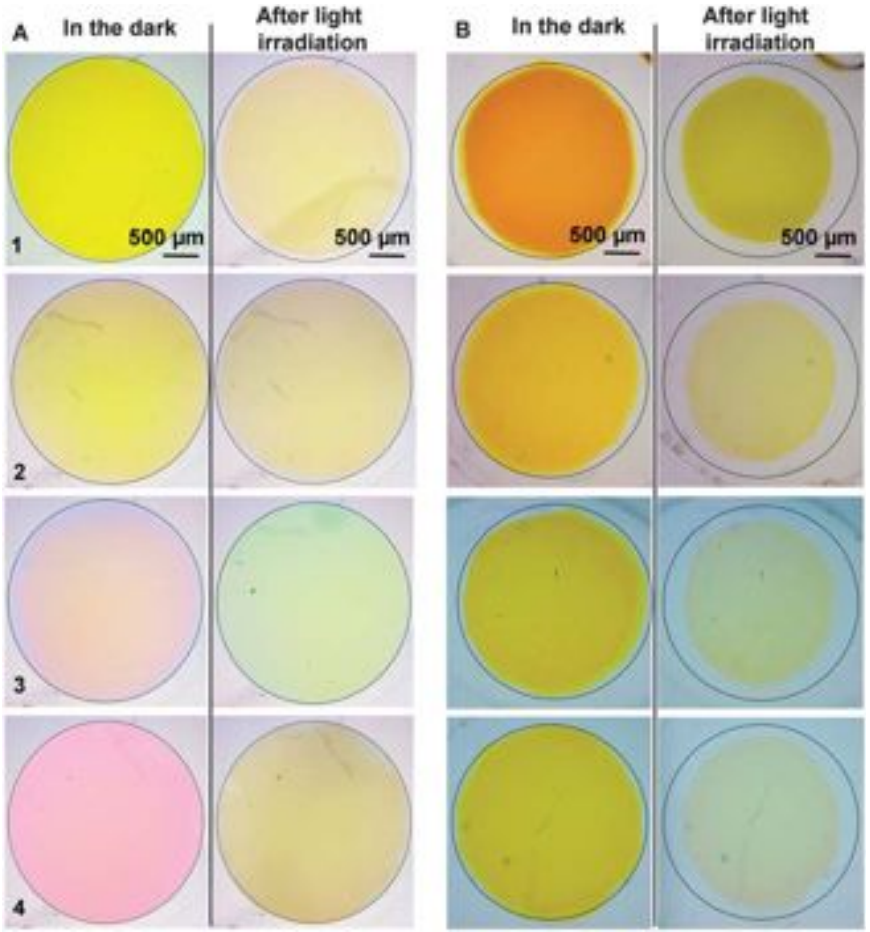
Reproducible actuation

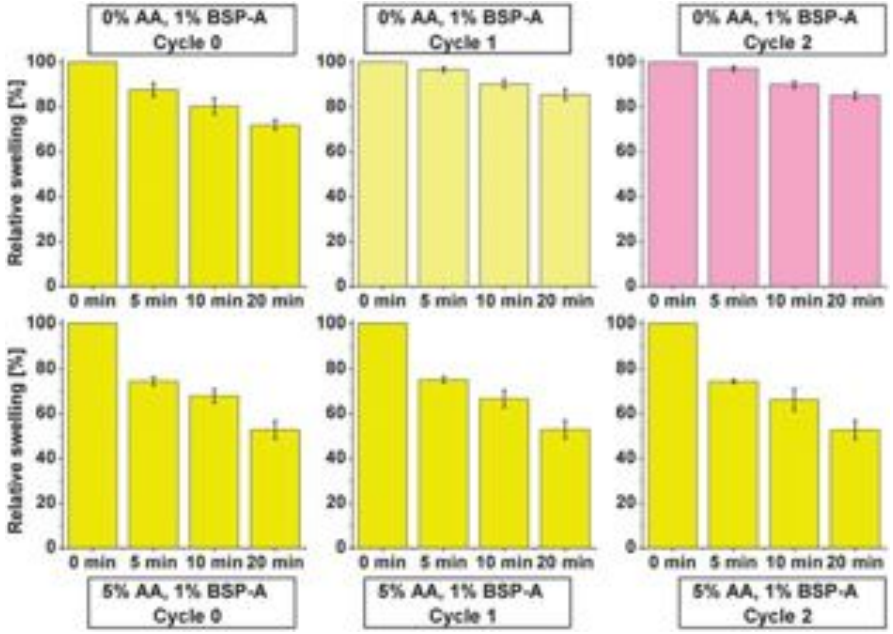
- DI water
- No external proton source



Reproducible actuation

- Comparison between with 5-1 and 0-1 hydrogels



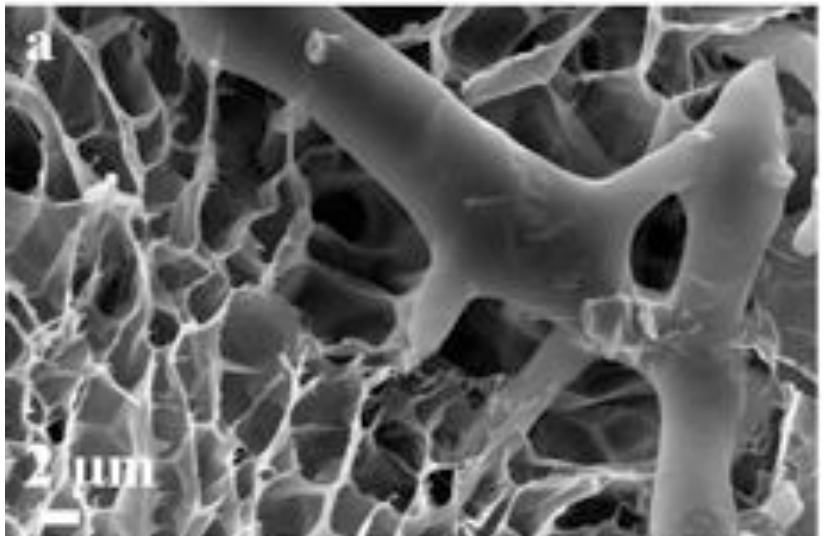


Improved actuation kinetics

- **5-1 Hydrogel**
- **poly(ethylene glycol) M_w = 2000 g/mol**
  M_w = 20000 g/mol

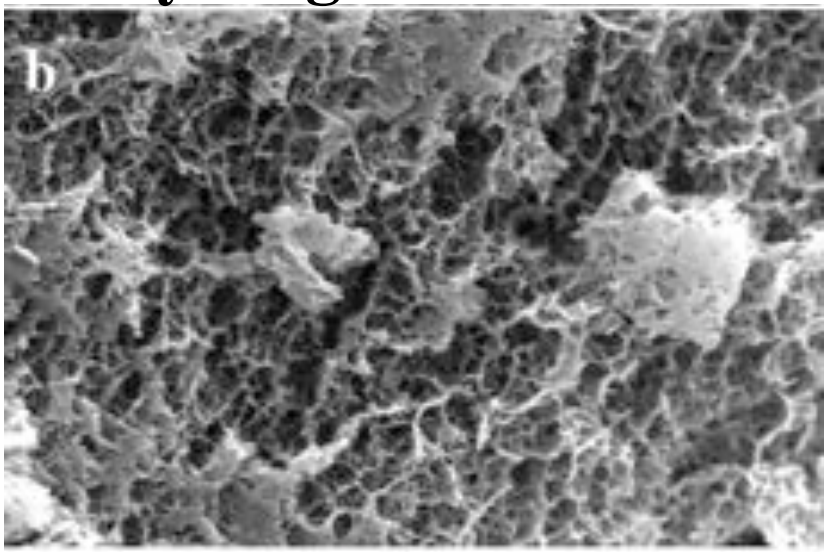
		Blank gel	2k gel	20k gel
AA	[mol %]	5	5	5
BSP	[mol %]	1	1	1
MBIS	[mol %]	3	3	3
PBPO	[mol %]	1	1	1
NIPAM	[mg]	200	200	200
PEG 2k	[mg]	-	400	-
PEG 20k	[mg]	-	-	200
Solvent	[µL]	500	500	500

Porosity control

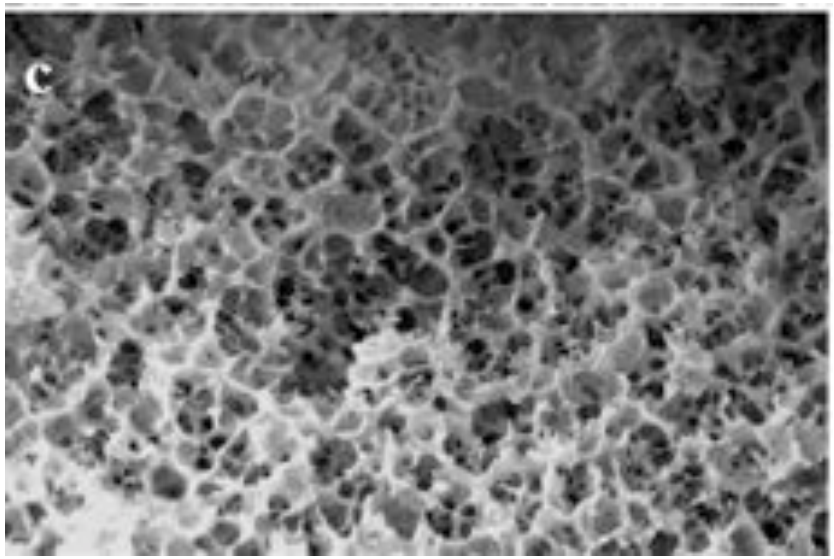


Blank hydrogel

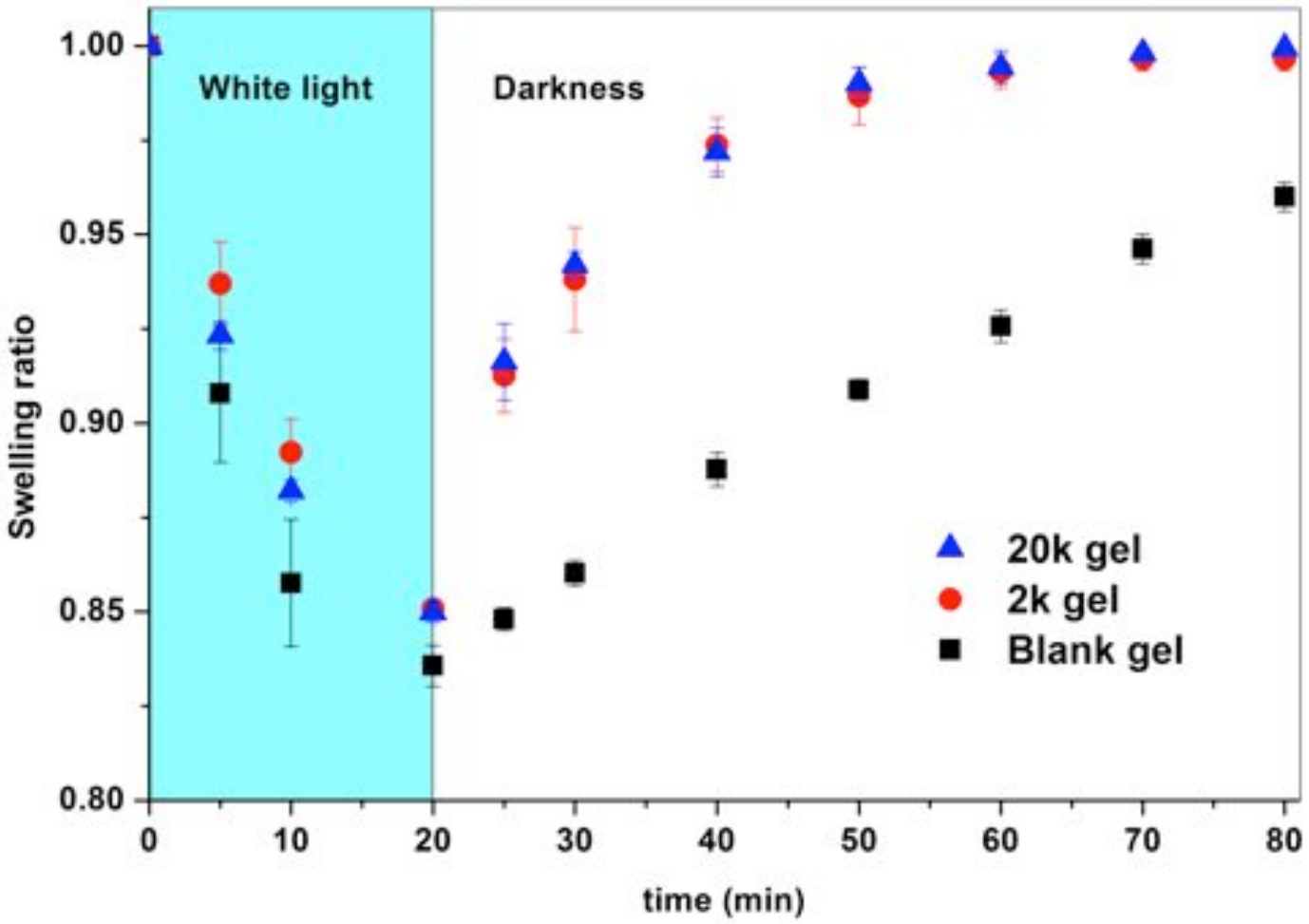
2k hydrogel



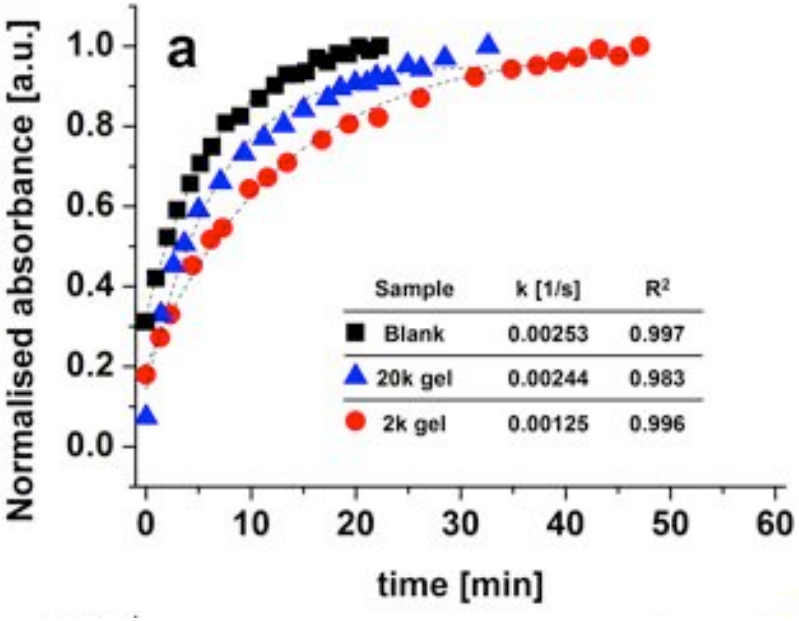
20k hydrogel

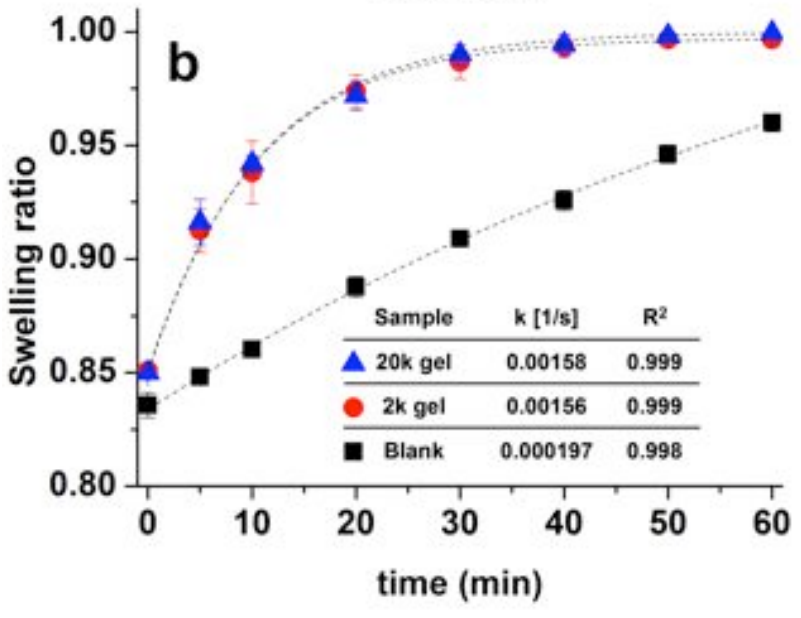


Shrinking/Reswelling Behaviour



Swelling and protonation kinetics





k_{blank} ~ 2.53 x 10^{-3} [s^{-1}]
k_{2k} ~ 1.25 x 10^{-3} [s^{-1}]
k_{20k} ~ 2.44 x 10^{-3} [s^{-1}]

k_{blank} ~ 2 x 10^{-4} [s^{-1}]
k_{2k} ~ 1.6 x 10^{-3} [s^{-1}]
k_{20k} ~ 1.6 x 10^{-3} [s^{-1}]

Conclusions

- ✓ Self-protonating hydrogels
- ✓ Reproducible photo-actuation
- ✓ Capable of performing in DI water and neutral pH solutions
- ✓ Porous hydrogels for improved reswelling kinetics

Acknowledgments

- Jannick Theobald
- Dr. Bartosz Ziółkowski
- Prof. Dermot Diamond
- Adaptive Sensors Group
- Insight SFI award

Thank you!