PHOTO-RESPONSIVE IONOGELS: VERSATILE FLOW CONTROL IN MICRO-FLUIDIC MANIFOLDS

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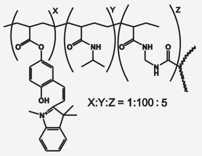
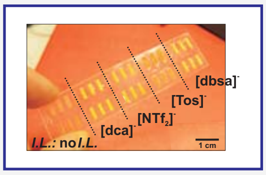
Introduction

Micro-valves are essential for the control and movement of flows in the micro-channels, while simultaneously minimising dead volume. Applications of micro-valves include flow regulation, on/off switching and sealing of liquids, gases or vacuums. [1]

In particular, valves made using photo-responsive gels are of great interest as functional materials within micro-fluidic systems since actuation can be controlled by simple light irradiation, without physical contact, offering improvements in versatility during valve fabrication and actuation.[2]





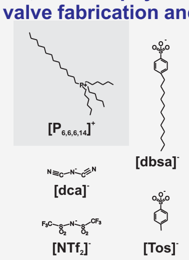


Figure: 1

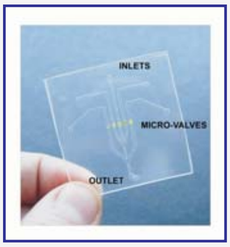
Figure 1: Chemical structure of the photo-responsive ionogel (left), four ionogels polymerised in a (1x5 mm) PMMA mould and trihexyltetradecylphosphonium based ionic liquid chemical structures (right).

A new concept in materials science is the incorporation of ionic liquids (*ILs*) within polymer gels, to produce materials known as ionogels. Through the tailoring of chemical and physical properties of *ILs*, robustness, acid/ base character, viscosity and other critical operational characteristics can be finely adjusted. Therefore, we can tune the characteristics of the ionogels by changing the *IL* and so more closely control the physical and chemical properties of these novel materials (Figure 1). [3]

Chip Fabrication

The micro-fluidic device shown in Figure2 (4 x 4 cm), consisting of five independent micro-channels with a common outlet, was easily fabricated in poly(methyl methacrylate) (PMMA) and pressure-sensitive adhesive (PSA) in four layers using a CO_2 ablation laser.

Figure 2: Picture of the micro-fluidic device.



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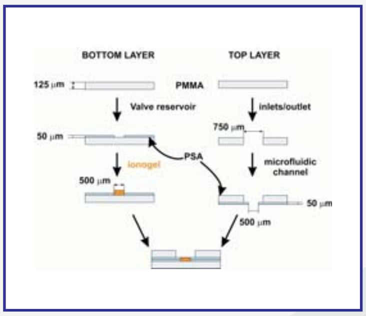

Figure: 3

Figure 3: Schematic representation of the microfluidic device fabrication procedure.

Acknowledgments

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Results and Discussion

Characterization of photo-responsive phosphonium based ionogels

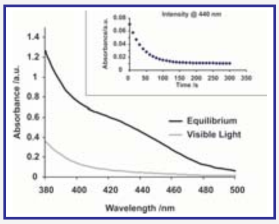
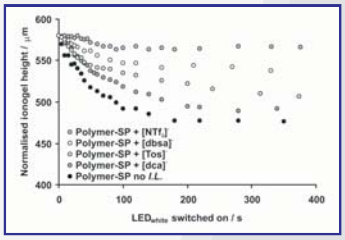


Figure: 4

Figure 4: UV-Vis spectrum of the [dca]⁻ ionogel at equilibrium and after 60 s exposure to visible light. (Inset) First order kinetic plot of absorbance decay at 440 nm under visible light irradiation.

Figure 5: Response kinetics of ionogels upon irradiation with white light. (ionogel height error: ± 5 m).



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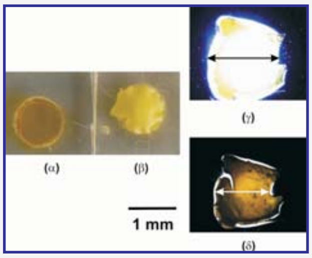

Figure: 6

Figure 6: Photo-responsive polymer gel without (α) and with ionic liquid [dca]⁻ (β) using the same monomer percentage, after immersion of the disks in a 0.1 mM HCl solution for two hours.

Ionogel shrinking process: during white light irradiation (γ), two seconds after white light irradiation (δ), size decreases *ca.* 29% in volume.

Evaluation of photo-responsive phosphonium based ionogel micro-valves

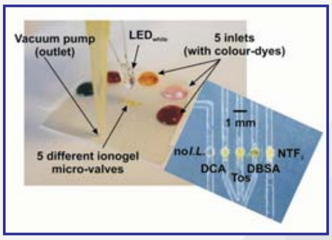

Figure: 7

Figure 7: PMMA:PSA micro-fluidic device coupled to the vacuum pump and LED light source for valve actuation.

Figure 8: micro-valve actuation response times and their errors (average of at least four functional micro-valves), n = 4.

Performance of the ionogel micro-fluidic valves: (**1**) Micro-valves closed; the applied vacuum is unable to pull the dyes through the micro-channels. (**2**) White light is applied. (**3**) 'No I.L.' valve is first to actuate followed by ionogels incorporating [dca]⁻, [Tos]⁻, [dbsa]⁻ and [NTf2]⁻.

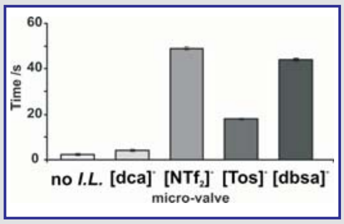

Figure: 8

Conclusions

Novel photo-responsive phosphonium based ionogels were successfully incorporated into a micro-fluidic device as photo-actuated micro-valves.

It was proven that the micro-valve ionogels presented fast actuation responses, and that the micro-valves based on differing *IL* anions opened at particular times under similar white light illumination conditions.

The results demonstrated that localised light irradiation allows the independent control of multiple micro-valves, while the synthesis of ionogels with different *ILs* enables valve actuation at different times under the same illumination conditions.

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2- S. Sugiura, K. Sumaru, K. Ohi, K. Hiroki, T. Takagi and T. Kanamori, Sens. Actuators, A, 2007, 140, 176-184.
3- R. Byrne, K. J. Fraser, E. Izgorodina, D. R. MacFarlane, M. Forsyth and D. Diamond, Phys. Chem. Chem. Phys., 2008, 10, 5919-5924.

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