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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]

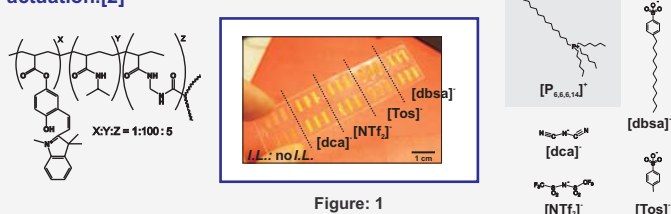


Figure 1

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 Figure 2 (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 CO₂ ablation laser.

Figure 2: Picture of the micro-fluidic device.

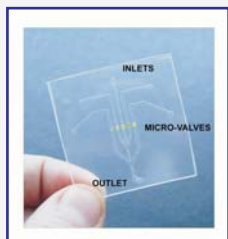


Figure 2

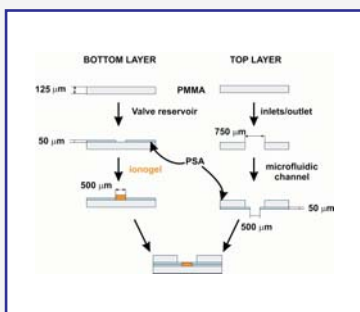


Figure 3

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

Acknowledgments

The project has been carried out with the support of Science Foundation Ireland under grant 07/CE/1147.

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Results and Discussion

Characterization of photo-responsive phosphonium based ionogels

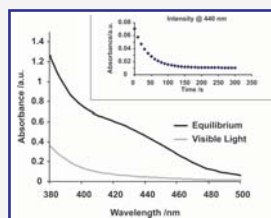


Figure 4

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 μm).

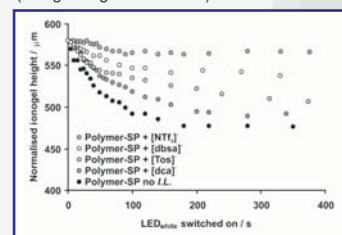


Figure 5

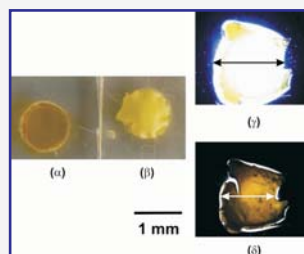


Figure 6

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 (δ), size decreases ca. 29% in volume.

Evaluation of photo-responsive phosphonium based ionogel micro-valves

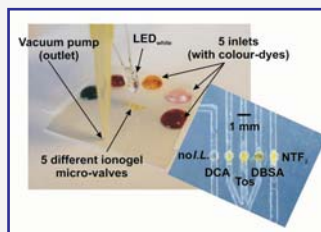


Figure 7

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

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

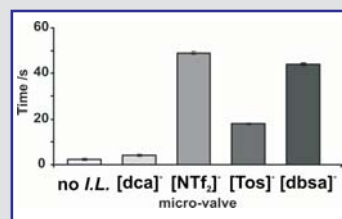


Figure 8

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.

1. K. W. Oh and C. H. Ahn, J. Micromech. Microeng., 2006, 16, R13-R39.
2. S. Sugiyama, K. Sumaru, K. Oh, 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.