NOVEL MULTIFUNCTIONAL MATERIALS BASED ON IONIC LIQUIDS: ON DEMAND MICRO-VALVE ACTUATION FOR LAB-ON-A-CHIP APPLICATIONS

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ABSTRACT

We present the fabrication, characterization and performance as a micro-valve of four novel materials, ionogels, consisting in a polymeric structure with benzospiropyran units and phosphonium based ionic liquids. Each inonogel is photopolymerised in the channels of a poly(methyl methacrylate) microfluidic device generating four different micro-valves. The micro-valves are actuated by simply applying local white light irradiation and each of the micro-valves opens specifically at one particular time. Therefore, flows can be independently controlled by one single light source while the synthesis of ionogels with different ionic liquids enables distinct valve actuation. Moreover, the microfluidic device can be reusable many times.

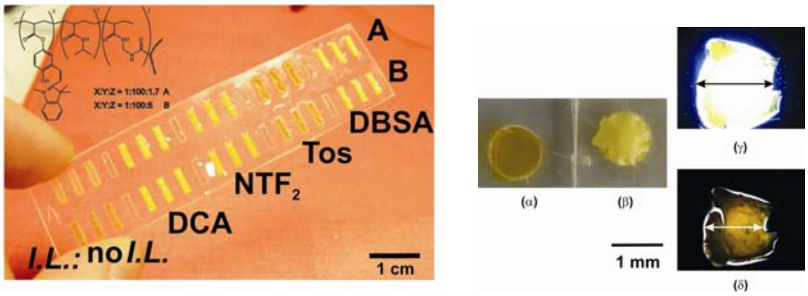
KEYWORDS: microfluidic device; ionic liquids; spirobenzopyran; photoresponsive polymer, micro-valve

INTRODUCTION AND THEORY

When photo-responsive gels are co-polymerised within different IL matrixes, high versatility in the ionogels actuation can be achieved when incorporated in a microfluidic system as micro-valves. It is well known that valve actuation within microfluidic devices is very desirable since precise flow control, provision of exact reagent amounts, contamination prevention between reagents, autonomy, disposability and low-cost manufacture are factors that cannot be found together for micro-fluidic valves.[1-2] Valves made using photo-responsive gels are of great interest as functional materials within micro-fluidic systems since actuation can be controlled by light irradiation. Nevertheless, their poor versatility, slow response times and limited robustness render them currently as scientific curiosities rather than ideally functioning devices.[3] The incorporation of photo-responsive gels with ILs produces hybrid ionogels with many advantages over conventional materials. For example, 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, the characteristics of the ionogels can be tuned by simply changing the IL and so the actuation behaviour of micro-valves made from these novel materials can be more closely controlled.

EXPERIMENTAL

Figure.1a shows the chemical polymerization strategy of four different ionogels at two different photo-responsive monomer concentrations and their physical robustness' structure. The improvement in robustness of the ionogel-based materials ness' structure. The improvement in robustness of the ionogel-based materials compared to the gel without IL is clearly evident (Figure.1b α-β).



(a) (b)

Figure 1. ***(a)*** *Chemical structure of the photo-responsive gel (up-left side of the picture) and four ionogels polymerised in a (1× 2 mm) PMMA mould.* ***(b)*** *Photo-responsive polymer gel without (α) and with ionic liquid (DCA) (b) 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.*

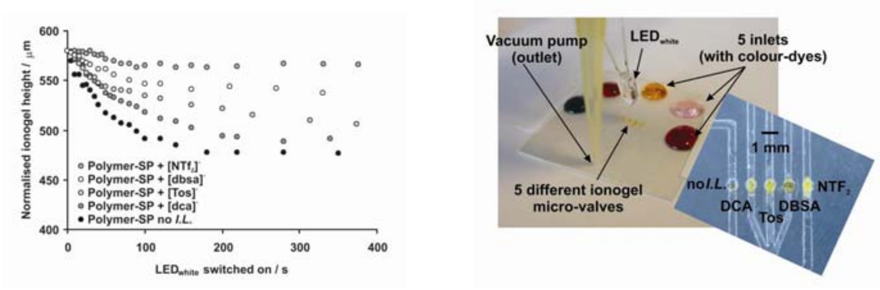
Figure.2a presents the valve actuation of the four different ionogels and the polymer gel (no IL) when white light irradiation from a LED source is applied. Upon exposure to white light, the ring of the merocyanine (hydrophilic) form of the photo-responsive gel closes to the spirobenzopyran (hydrophobic) form (*x* moiety in Figure.1). This ring closing induces a dehydration of the ionogel due to expulsion of the acidic proton generating a much more hydrophobic environment. The accompanying physical shrinkage varies with each IL, as measured on-line by contact profilometer, and by visual observation (Figure.1 γ-δ). The speed of actuation was also found to be different for each of the ionogels.

RESULTS AND DISCUSSION

Photo-control of the micro-valve by localised light irradiation was demonstrated using the micro-fluidic device shown in Figure.2b. A drop of solution containing a strongly coloured dye was placed in each inlet whilst in the outlet vacuum was applied as a fluidic driving force (Figure.3a). Virtually equal amounts of visible light were irradiated to all ionogel micro-valves, and they were found to open at different times as shown in Figure.3b-f: No IL: 2s; DCA: 4s, Tos: 18s; DBSA: 44s; NTF_2: 49s.

CONCLUSIONS

The results demonstrate that local light irradiation allows the independent control of multiple micro-valves, while the synthesis of ionogels with different ILs enables distinct valve actuation. Moreover, it is possible to reuse the micro-valves repeatedly. This approach provides non-contact operation and flexible manipulation of liquid movement in complex micro-fluidic devices as well as parallel control of multiple micro-valves with a single light source.



(a) (b)

Figure 2. ***(a)*** *Ionogels response kinetics upon exposure to white light irradiation (error: ± 5μm).* ***(b)*** *PMMA:PSA micro-fluidic device coupled to the vacuum pump and LED light source for valve actuation.*

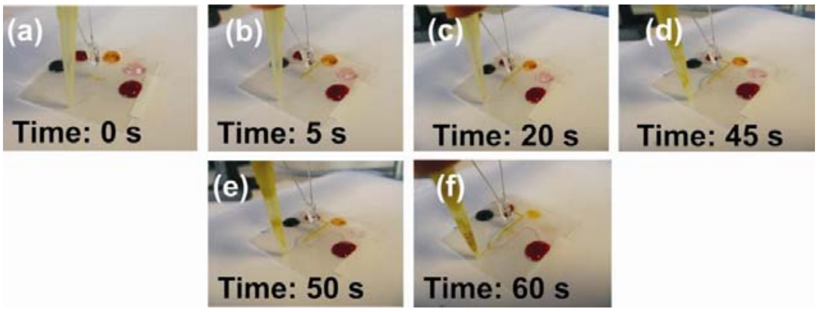


Figure 3. Microvalves closed; vacuum is unable to pull the dyes through the microchannels. White light is applied for the time specified in each picture b) 'No IL' valve is first to actuate followed by DCA, c) Tos valve opens, d) DBSA valve opens, e) NTF2 valve opens; f) all valves are open.

ACKNOWLEDGEMENTS

The project has been carried out with the support of the Irish Research Council for Science, Engineering and Technology (IRCSET) fellowship number 2089, Science Foundation Ireland under grant 07/CE/I1147.

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