Control of Flow Rate in Microfluidic Channels Using Photoresponsive Soft Polymer Actuators

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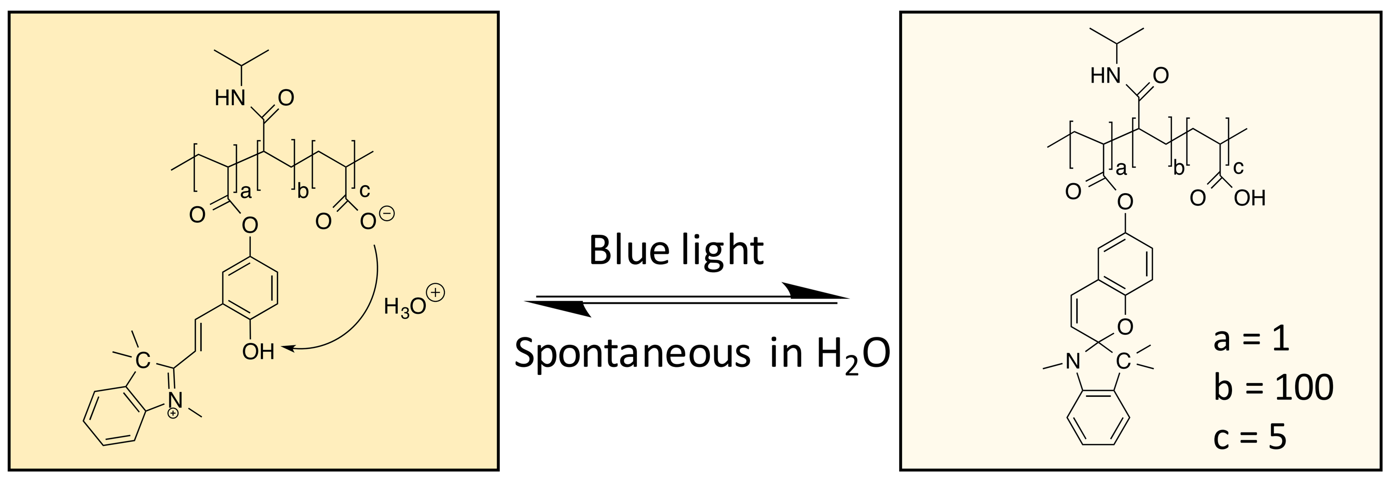
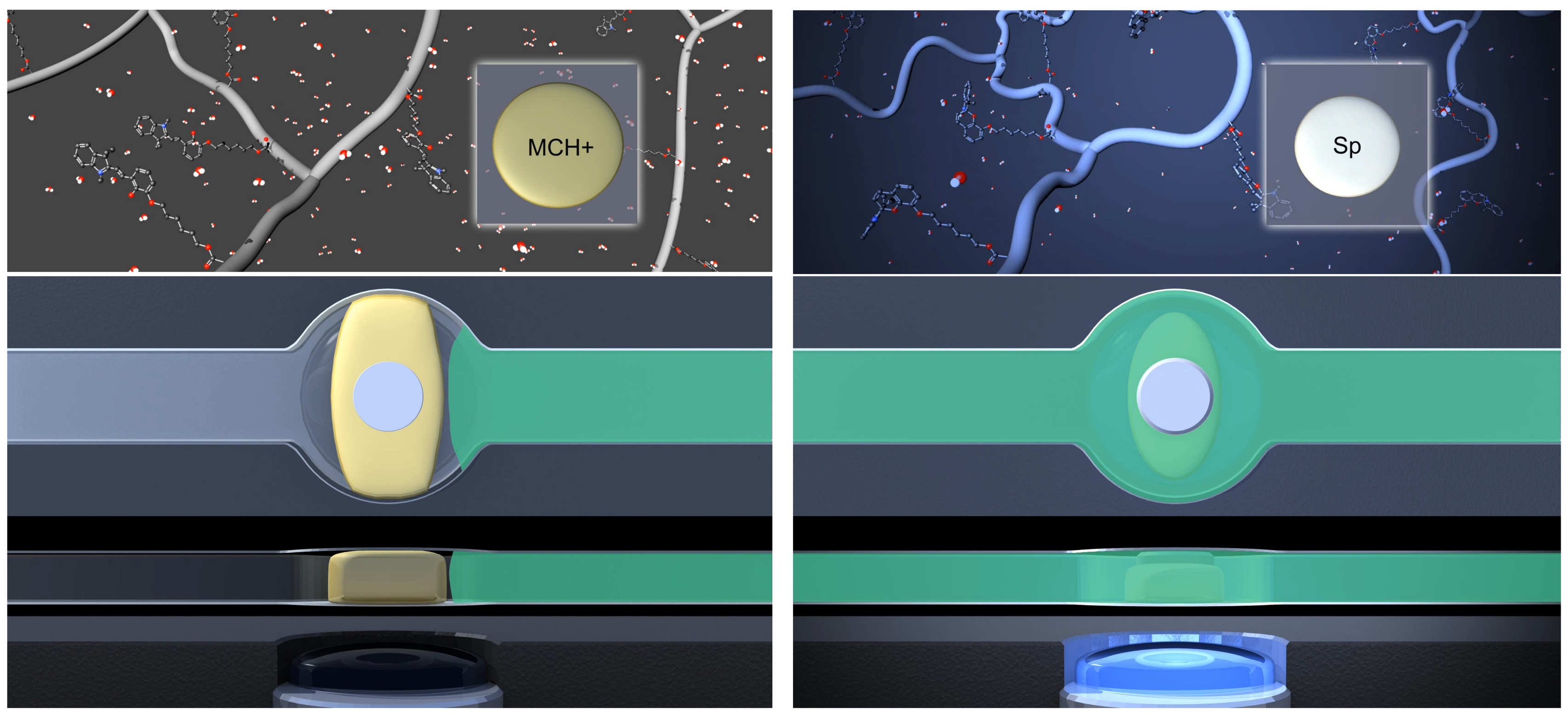
Introduction

Accurately controlling flow, using actuators fully embedded within microfluidic devices, has long been a hurdle within our research community. While inroads have been made, through the use of pneumatic valves based on soft-polymers [1], there still exists a paucity of low-cost and precise actuators. In recent years, several groups have turned to photoresponsive polymers as a means for fluid handling [2].

Photo-actuated Hydrogel Valves

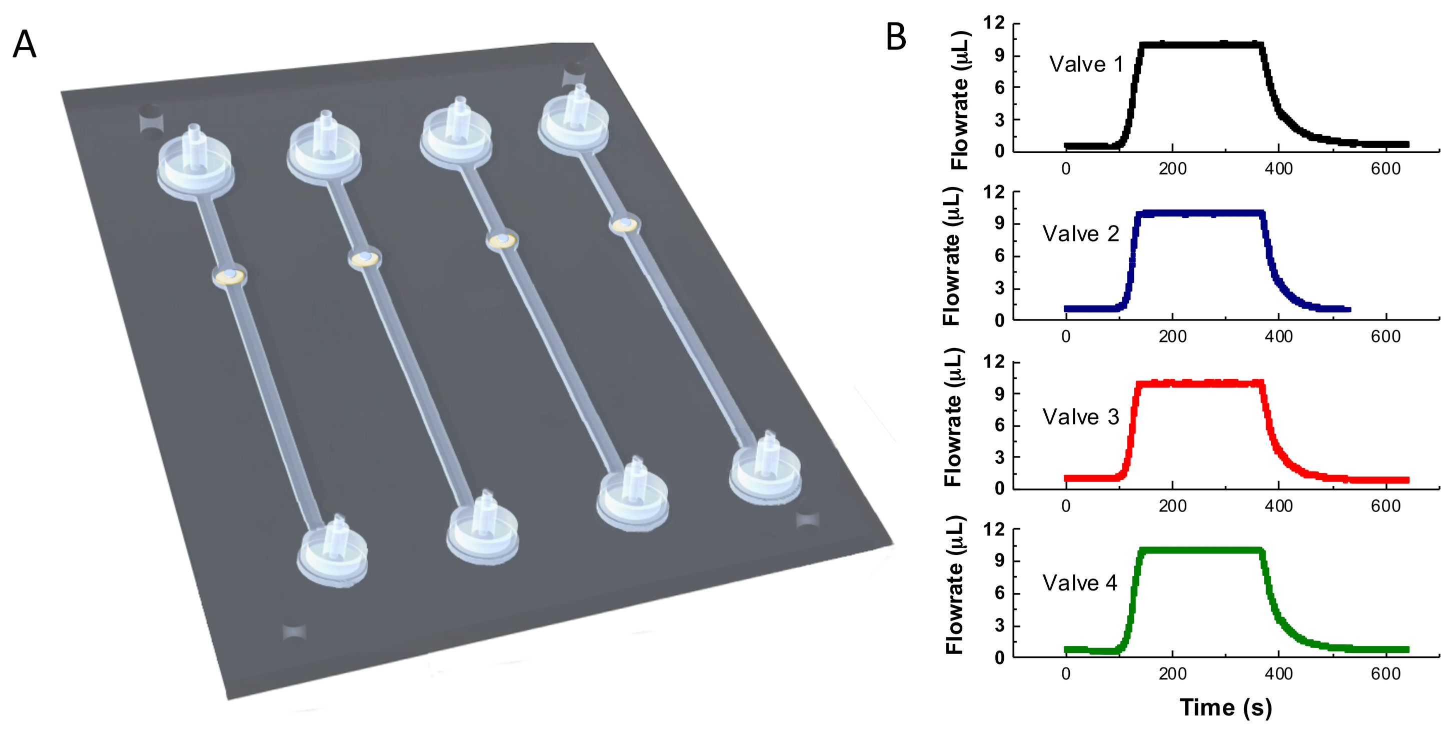
Our group has made significant progress over recent years in the field of photoactuated spiropyran valves, firstly through copolymerization of a proton source and recently through the use of photoactuation platforms [3, 4].





Conversion between merocyanine and spiropyran forms, resulting in open and closed valves.

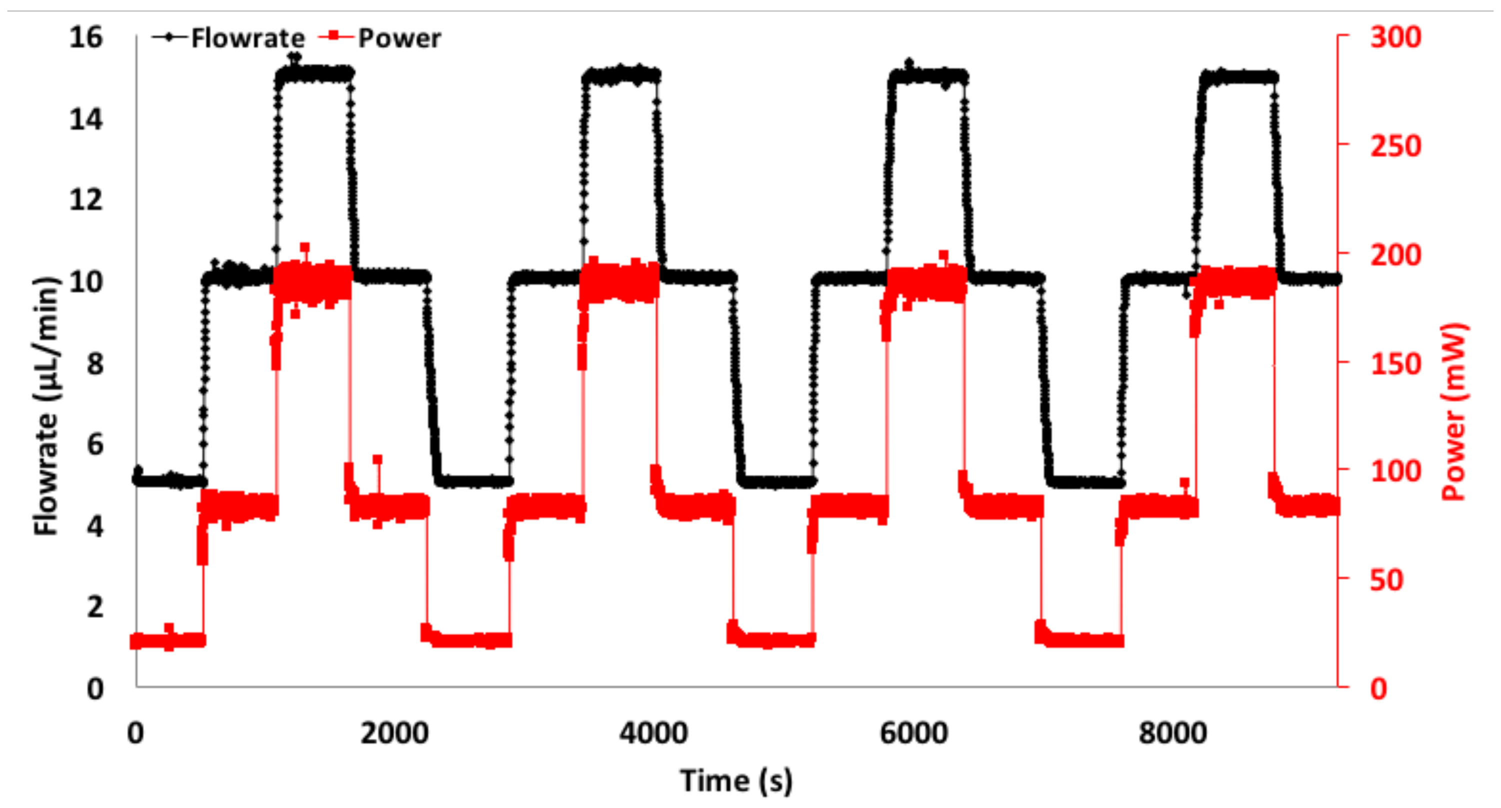
Polymerisation in situ also offers homogeneity between valves. Sequential actuation of four separate valves within a single microfluidic chip shows highly reproducible behaviour, fast actuation times and excellent stability (flow rate = 10 μL/min).



(A) Representation of photo-actuated valves within a microfluidic chip; (B) Actuation profiles (10 μL/min) for 4 valves on a single microfluidic chip.

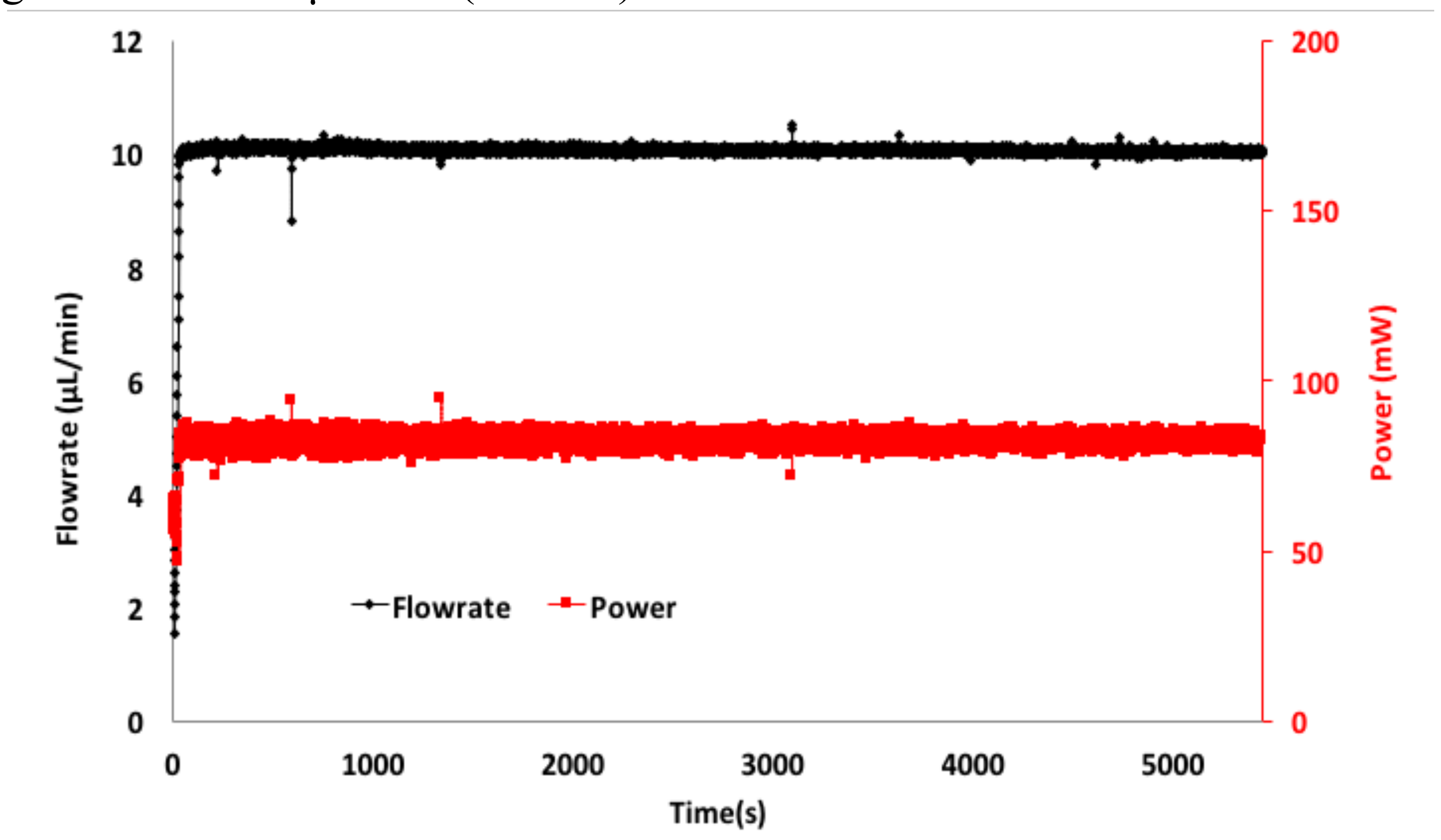
Proportional Integral Derivative (PID) Control

Precise programmable regulation of the relationship between flowrate and LED power has been achieved by using a flow meter to provide feedback to a PID controller. Through optimization of proportional (K_P) and integral (K_I) variables it has been possible to create a system which accurately detects disparity between the measured and set flowrates and which operates autonomously to deliver programmed flow profiles.



Cycles of (5.0, 10.0, 15.0, 10.0, 5.0 μL/min) shown in black (K_P = 10.0; K_I = 0.1), overlaid with power supplied to the LED to achieve actuation in red.

The current design can also be used to maintain a constant flow rate (10.0 µL/min) for extended periods. Once again, the results are impressive, the average flow rate being 10.04 ± 0.032 µL/min (n=1000).



Steady state flow rate (10 μL/min) and power (mW) provided to the LED. The rapid response of the control algorithm is demonstrated by small changes in the flow rate which are accompanied by an immediate response in the LED power.

Conclusions

We have developed a methodology for the production of highly reproducible photo-actuated valves in microfluidic devices [5]. Our results suggest a high correlation between flow rate and LED power, pointing to the possibility of predicting the flowrate of such a characterized system through the LED power, without the need for an external flow-sensor.

References

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