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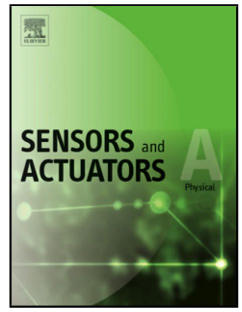

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Pulse Controlled Microfluidic Actuators with Ultra Low Energy Consumption

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Highlights

- Bi-state microactuator with ultra-energy efficiency and state latching capability
- Magnetic field of actuator mechanism controlled using a short current pulse of 120µs
- Actuator with large deflections ranging between 0.3-2.5mm and forces up to 220mN
- 5mJ of energy consumed per actuation with zero energy consumption between actuations
- Wireless power and energy buffering capabilities packaged into actuator

***Abstract*— This paper presents the modelling, simulation, implementation and performance analysis of a novel electropermanent magnet based, bistable wireless microactuator for microvalves with milli Joule level energy consumption. The microactuator is powered wirelessly through inductive power transfer with energy buffered in a supercapacitor bank. Two millimeter sized rods of semi hard and hard magnetic materials are placed side by side with a current carrying coil around them. A 120µs pulse of 15V, 2.5A is applied to the coil, which creates or eliminates the externally available magnetic field. The plunger is either attracted or repelled by this magnetic field to open or close the valve respectively. The theoretical analysis and modelling aligns well with the experimental results. The microactuator consume as little as 0.97-2.5mJ of energy per actuation with no energy consumed between actuations. The actuation pulse width needs to be between 44-150µs. The actuator is capable of delivering large deflections in the range of 0.3-2.5mm, which is much greater than any of the state-of-the-art valves. The maximum holding force of the actuator is 220mN and the attraction force varies between 9.8-98mN. Energy consumption per actuation, actuation speed and deflection of the novel actuator are much better than any state-of-the-art microvalves, with the added advantages of wireless power and control. The momentary peak power requirement of 40W is met by the supercapacitor energy buffer which stores 90J per charge cycle, sourcing 37500 actuations. The energy efficiency and flexibility of this novel actuator can revolutionize the microactuator industry.**

***Index Terms*—microvalves, microactuator, electropermanent magnet actuator, wireless power, energy efficient microactuator.**

1 Introduction

Microfluidic systems are miniaturized fluid channels of micrometre width used to facilitate fast, high throughput, parallel experiments with limited reagent quantities enabling advanced research [1]. They are commonly found in chemical and bio medical applications, fuel cells, inkjet printers etc. and their importance is gaining interest in industries such as oil and gas [2], healthcare [3] etc. Additional microfluidic components such as microvalves, micropumps and micromixers are used to control the fluid flow in these microfluidic systems.

Active microfluidic components which require external energy to operate, are more precise and offer more defined control of the fluids. However, the low energy efficiency of these power supplies often lead to large bulky power packs [4-6] which significantly impact the portability of microfluidic systems. This paper presents a novel bi-state microactuator which is suitable for controlling microfluidic valves which is highly energy efficient. The proposed actuation mechanism uses micro-sized electropermanent (EP) magnets, features wireless power and control and is very versatile. The key advantages are the ultra-low energy consumption during actuation, very fast actuation, zero energy consumption between actuations, large deflection range and wireless power capability.

The remainder of the paper is organized as follows. Section 2 presents a concise literature review of existing microvalve actuators, focusing on the key shortcomings. Section 3 outlines the actuation mechanism proposed, operating principles and material selection. Theoretical analysis, modelling and simulation of the proposed actuator is given in section 4. Section 5 outlines the design and control of the actuator, with experimental results and analysis in section 6. Section 7 compares its performance to state-of-the-art valves with conclusions and future work in sections 8 and 9 respectively.