Review of Polymer Magnetic Nanocomposites for Microfluidics Applications

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Introduction

Magnetic forces in microfluidics have now become commonplace for a wide variety of applications[1]; however, the main application for magnetism in microfluidics remains the manipulation of magnetic beads, cells, or particles for diagnostics and anaylsis[1,2]. While the value of such applications cannot be disputed, the employment of magnetism in other areas of microfluidics (e.g., flow control) has the potential for similarly high impact. Many researchers have already demonstrated successful devices based on magnetic actuation, but the widespread deployment of magnetically-actuated fluidic devices has been slowed by difficult microfabrication and integration of magnetic materials. Relatively new advances in microfabrication of composite polymers offers solutions to these problems. Materials have been demonstrated that can be micropatterned using conventional methods, but are rendered magnetic through the introduction of micro- or nano-particles into a polymer matrix[3,4] and patterned using methods similar to conductive nanocomposites[5]. In this critical review, we discuss emerging microfluidic devices and applications employing magnetic nanocomposite polymers (M-NCP)[6-15], and discuss potential future outlooks for these technological advances.

Magnetic Composites for Microfluidic Applictions

Magnetic actuation offers many potential advantages over other actuation methods for microfluidic devices such as microvalves, pumps, mixers, and assembly. Potential advantages include: combined high force and large distance displacements, local control using on-chip microcoil electromagnets, bi-directional actuation, and location of the actuating element (e.g., electromagnet) external to device. Many ferrofluidic-based devices[16] and mixers[17] and valves[18] based on magnetic particles have been successfully demonstrated. Devices employing embedded[19] or thin film metal[20] miniature magnets have also been demonstrated, but face difficult integration challenges with commonly used polymers. M-NCPs are being increasingly employed by microfluidics researchers as methods of microfabricating them become well developed and understood[6-15]. However, most of these devices feature ferromagnetic soft magnetic materials, rather than hard magnetic rare-earth based materials that can be polarized as permanent magnets. Hard magnetic materials can be advantageous not only for their higher magnetization potetntial, but their ability to be polarized and thus bi-directionally actuated by the same electromagnet through simple current reversal. This review will provide an introduction to magnetics as applied to magnetic composite materials, and discuss the advantages and disadvantages of different dopant particles for example microfluidic devices and applications, including examples from the Microinstrumentation Lab.

Future Outlook

Many novel applications may be expected to result from maturing M-NCP-based microfluidics technologies. Such applications may include new bi-directional mechanisms, and the direct manipulation of biological cells by on-chip magnetic actuators, as well as new fabrication techniques such as printing[21]. The paper will conclude with a discussion of new applications and recent advances at the forefront of M-NCP technological innovation.

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