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Compact Electro-Magnetically Operated Microfluidic System for Detection of sub-200 nm Magnetic Labels for Biosensing without External Pumps

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1. Introduction

Rapid and efficient handling of small volumes of liquids is critical for point of care treatment (POCT), and is currently, this is achieved using microfluidic systems. In particular, the development of biosensing protocols based on the detection of functionalized superparamagnetic beads in microfluidic systems is driven by demand for rapid, high sensitivity, and inexpensive point of care diagnosis of heart disease, cancer, and even testing automobile drivers for the influence of illegal drugs [1]. Typically, functionalized superparamagnetic 'magnetic labels' are attached to target molecules, and detected by magnetic sensors including GMR and Hall effect devices. The diameters of magnetic labels are typically between 200 nm to 3000 nm. However, demands to improve quantification and affinity to target-biomolecules necessitate the use of magnetic labels with sizes comparable to target molecules. However, small concentrations of such sub-200 nm magnetic labels are difficult to detect with magnetoresistive-based sensors. In order to overcome the limitations of GMR and Hall sensors, we have developed a simple procedure for detecting ~130 nm sized magnetic labels for biosensing [2]. In our protocol the magnetically induced capture of micrometer sized superparamagnetic 'columnar beads' by several 130 nm-diameter target beads immobilized on substrates is clearly visible under an optical microscope even though the targets are unobservable optically or electrically.

Conventional microfluidic systems consist of a solid polymer-type of matrix encapsulating micropipes and reservoirs, which are attached to an external pump. Here, we report on the development of an alternative biosensing system based on our previous work that does not require external pumps or etching of microchannels. Pump-free systems offer a compact without peripheral tubes suited for point of care diagnosis.

2.Experimental

Our planar system consists of microchannels were formed by patterning hydrophilic stripes on hydrophobic glass or silicon substrates. Electrodes were formed at both ends of the microchannels as shown in Fig. 1. Superparamagentic micrometer sized 'columnar beads' whose polystyrene surfaces were modified with carboxyl groups were used as probes to detect target labels. An electric field applied across the channels was used to control the flow of the micrometer sized 'columnar beads' in solution. An external magnetic field was applied to the microfluidic chip to detect the magnetic label targets immobilized on the surface of one of the channels (see Fig.1). The electrically manipulated micrometer sized 'columnar beads' only moved over the hydrophilic surfaces of the microchannels, and magnetically self-assembled onto the target labels.

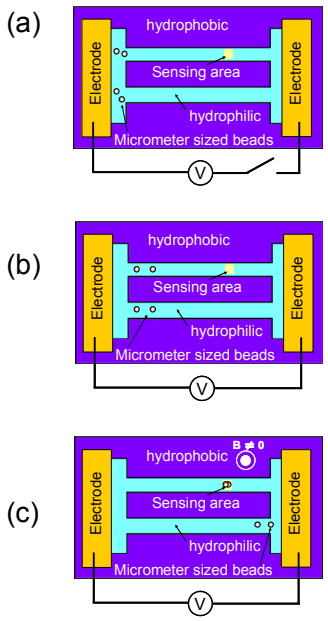

Fig. 1 (a) An aqueous solution containing superparamagnetic micrometer sized columnar beads was dropped into one of reservoirs. (b) An electric field was applied across the channels to manipulate the columnar beads. (c) The external magnetic field was applied to the 130-nm-diameter target beads immobilized on the surface of channels.

3. Results & Discussion

Fig. 2 shows a series of images taken with an optical microscope showing 2.8-μm-diameter superparamagnetic columnar beads being manipulated by the electric field in microchannels, self-assembling at a spot onto which the 130-nm-diameter target beads had been immobilized, under an external magnetic field, and restarting to flow through the microchannels in the absence of the external magnetic field due to the electric force acting on the columnar beads. Our experiments clearly showed that the columnar beads were captured due to magnetic interaction with target beads. More importantly, the columnar beads acting as probes were electrically manipulated without external pumps in order to detect 130-nm-diameter superparamagnetic target beads.

In contrast to conventional microfluidic systems where an aqueous solution containing superparamagnetic beads is injected into microfluidic channels by an external pump, our system is simple, not requiring such pumps. The micrometer sized 'columnar beads' were manipulated by the electric field and captured via magnetic dipole interaction with the target beads. The movement and capture of the 'columnar beads' by the target beads in liquid microchannels was clearly visible under an optical microscope even though the target beads were unobservable optically or detectable by magnetoresistive sensors.

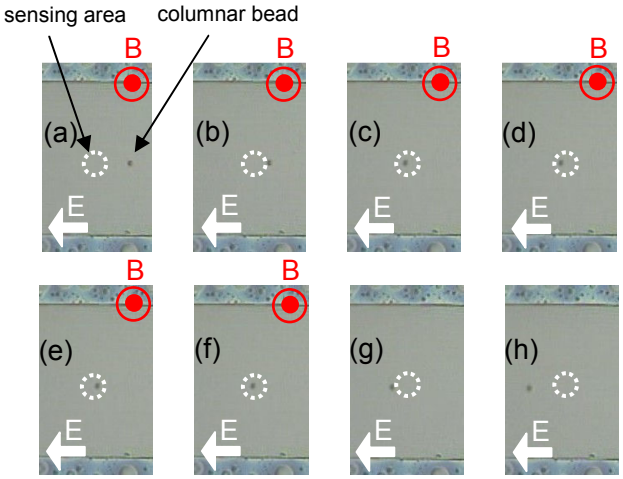

Fig. 2 (a)-(h) Successive optical images showing the transportation of columnar beads in liquid microchannels and detection of 130-nm-diameter target beads via magnetically self-assembly of columnar bead on target beads. [(a) and (b)] Transport of a 2.8-μm-diameter surperparamagnetic bead in a liquid microchannel. [(c)-(f)] The micrometer sized bead was magnetically captured onto target beads. (g) and (h) show that columnar bead restarted flowing the liquid microchannels in the absence of the external magnetic field due to the electric force acting on the columnar bead.

4. Conclusion

We demonstrated a biosensing protocol based on monitoring the electrostatic manipulation and magnetic capture of 2.8-μm-diameter superparamagnetic columnar beads by the 130-nm-diameter target beads in pumpless liquid microchannels. Our experimental setup is simple, and the procedure has potential for the rapid detection of extremely low concentrations of magnetically labeled biomolecules. Low concentrations of target beads were detected by the superparamagnetic columnar beads in the pump-free microfluidic device.

References

[1] A. Sandhu, "Biosensing: New probes offer much faster results," *Nature nanotechnology,* vol. 2, pp. 746-748, 2007.

[2] Y. Morimoto, M. Abe, M. Hatakeyama, H. Handa, and A. Sandhu, "Detection of Magnetic Nanobeads by Self-assembly of Superparamagnetic Microbeads for Biosensing," *IEEE Transactions on Magnetics,* vol. 45, pp. 2871 – 2874, 2009.