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A36: Microfluidic Biosensing System using the Motion of Magnetic Nanoparticles

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The development of hand held, sensitive and fully automated on-chip biosensing systems which directly translate the presence of certain bioanalyte into an electronic signal gain interest increasingly. The integration of a variety of analytical functions on a single chip is enabled by the impressive and rapid progress in micro- and nanotechnology as well as in biotechnology. All necessary sample handling and analysis steps are then performed within the chip [1]. Microfluidic systems are ideally suited for the development of inexpensive and disposable biochips. Once combined with magnetic methods for the manipulation, detection and recognition of bioanalyte they offer a reliable and flexible on-chip solution. Some of the merits of such systems are that magnetic fields can be well tuned and applied either externally or from a directly embedded solution in the biosensing system. In combination with these applied magnetic fields, magnetic nanoparticles (MNPs) are utilized. MNPs can be manipulated inside microfluidic channels by utilizing high gradient magnetic fields, can be detected by integrated magnetic microsensors, and are flexible due to functionalization by means of surface modification and specific binding. Their multi-functionality is what makes them ideal candidates as the active component in miniaturized on-chip biosensing systems.

In this paper, an integrated solution towards an on-chip microfluidic biosensing system using the magnetically induced motion of functionalized MNPs is presented. The innovative aspect of the proposed method is that the induced velocity on MNPs in suspension, while imposed to a magnetic field gradient, is inversely proportional to their volume. Specifically, a velocity variation of suspended functionalized MNPs inside a detection microchannel with respect to a reference velocity, specified in a parallel reference microchannel, indicates an increase in their non-magnetic volume. This volumetric increase of the MNPs is caused by the binding of bioanalyte to their functionalized surface. The new compounds with the increased non-magnetic volume are called loaded MNPs (LMNPs). The magnetic force required for the manipulation of the MNPs and LMNPs is produced by current currying conducting microstructures, driven by a programmable microcontroller [2].

In order to prove the concept of manipulating MNPs inside a microfluidic channel and their velocity decrease due to their volumetric increase we fabricated silver microstructures having a 10 μm width and a distance between each of them of 8 μm. On top of them we fabricated two microfluidic channels using standard photolithography process and a dry photoresist thin film (Ordyl SY355) of 55 μm thickness. The developed microfluidic system with the integrated current carrying microstructures is shown in Fig. 1. One of the microfluidic channels provided the reference velocity of the plain MNPs. Hence, this reference channel was always filled with suspended unloaded/plain functionalized MNPs. In order to form LMNPs we used Micromer®-NH_2 (500 nm of diameter) non-magnetic polymer nanoparticles coated with amino group (-NH_2) and Micromer®-M-PEG-COOH (3 μm in diameter) magnetic microparticles coated with carboxylic acid groups (-COOH). A bond was achieved between magnetic –COOH coated MNPs and non-magnetic –NH_2 coated nanoparticles forming LMNPs and leading to an increased volume. The movement of the LMNPs in comparison to the movement of the plain MNPs caused by the applied magnetic field from the conducting microstructures was demonstrated optically by means of a microscope with a mounted CCD camera. Fig. 2 shows the measurement set-up. Several images and movies of the experiments were obtained. 50 mA current was applied sequentially to the conducting microstructures, employing a programmable microcontroller utilized to drive power MOSFETs; the actuation time depends on the size of the MNP. The optical realization of the experiment is shown in Fig. 3. A promising decrease in the velocity of the LMNPs in comparison to that of the MNPs was measured. Thus, it is the velocity variation which determines the presence of the bioanalyte in the sample fluid.

References

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2. G. Kokkinis, F. Keplinger and I. Giouroudi, *Biomicrofluidics* **7**, 054117; doi: 10.1063/1.4826546 (2013)

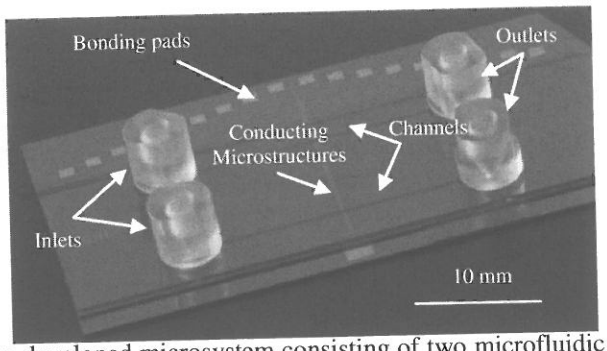

Fig. 1: Photograph of the developed microsystem consisting of two microfluidic channels: the detection and the reference microchannels, the conducting microstructures, inlet and outlet connectors and bonding pads for wire bonding.

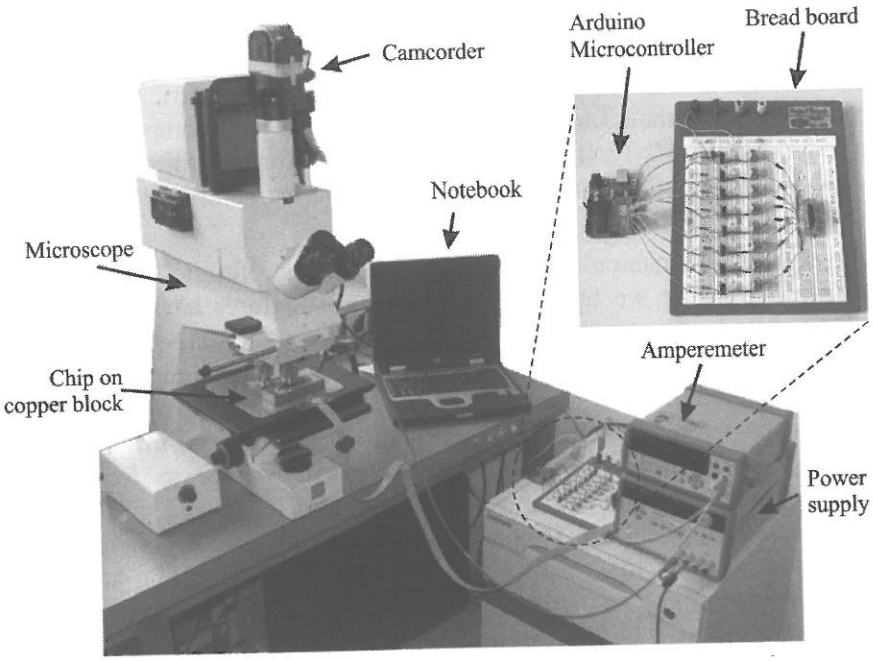

Fig.2: Measurement set-up

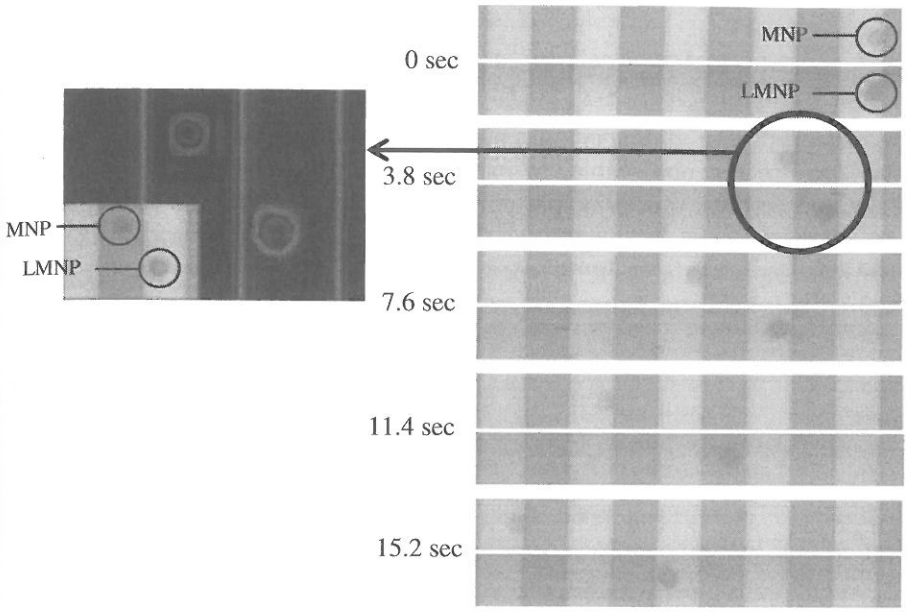

Fig.3: Comparison of the plain micromer®-M-PEG-COOH 3 ìm MNP in the reference channel and the LMNP consisting of 3 ìm MNP conjugated with 500 nm non-magnetic particles travelling in the detection channel, actuated by a current of I = 50 mA. Actuation times are 2.3 sec for the MNP and 3 sec for the LMNP.

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