Electronic Supplementary Material (ESI) for Lab on a Chip.
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Supplementary Information

Article Title:

Magnetofluidic platform for multidimensional magnetic and optical barcoding of droplets

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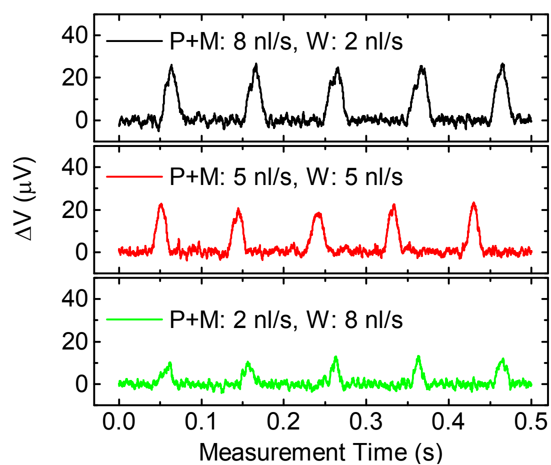

Fig. S1 Real time detection of emulsion droplets with a GMR sensor when an additional channel 3 is used to inject water to further dilute the mixture of fluorescent penicillin and magnetic nanoparticles. The magnetic nanoparticles (M) and fluorescent penicillin (P) inside the droplets are diluted by increasing the flow rates of water (W).

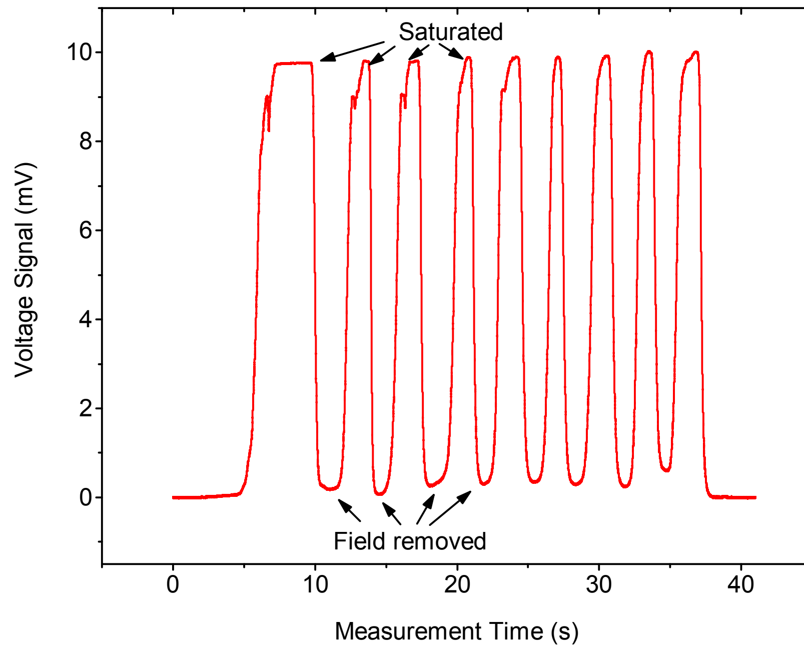

Fig. S2 The response of GMR sensor upon repeated applying and removal of saturating magnetic field to determine the maximum change of voltage signal.

The dynamic range of the device can be estimated by saturating the GMR sensor with external magnetic field and determine the maximum voltage signal. With the current device, the maximum voltage change is about 10 mV and the minimum voltage signal is about 2 μV. Thus the dynamic range of the device can be estimated, which is close to 40 dB.

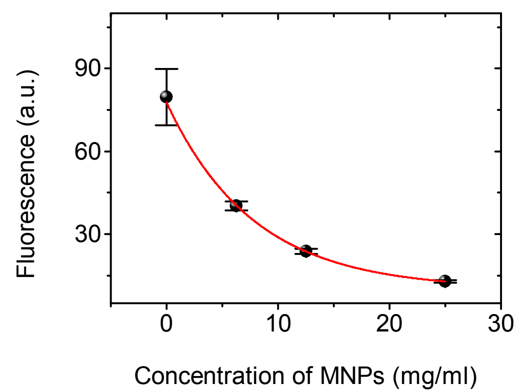

Fig. S3 The dependence of fluorescence intensity of penicillin (50 μg/ml) on the concentration of mixed magnetic nanoparticles (MNPs). Trend line indicates the exponential decrease of fluorescence as MNPs concentration increase.

Protocol of fabrication of GMR sensors

In the following, we provide the fabrication process of GMR sensors of the magnetofluidic platform. We detail two major steps: (A) Preparation of substrates (B) Magnetron sputtering deposition.

A. Preparation of substrates

1. We choose thermally oxidized silicon wafers with 600 nm oxide (CrysTec GmbH) as substrates. The oxide layer is thick enough to avoid any current shunting through the bottom substrate during electrical characterizations.
2. The substrate is cleaned in acetone and isopropanol to ensure subsequent quality of photolithography process. The wafer is rinsed with DI water and baked at 120 °C for 5 min to dehydrate to be ready for lithography.
3. The wafer is placed on to a spin coater, where a photoresist (AZ 5124E) is applied. The wafer is spinning at a speed of 4500 rpm for 30s.
4. **Soft bake**: The spin-coated wafer is immediately transferred to a hot plate with a temperature of 90 °C for 4 min.
5. **Exposure**: After the soft bake, the wafer is transferred to a mask aligner (MJB4, Karl Suss). A chromium coated photo mask with a designed geometry (meander) is used. The photoresist on the wafer is exposed for 2 s to initiate the photoactive compound.
6. **Post bake**: After exposure, the wafer is placed on a hot plate at a temperature of 120 °C for 2 min. This step activates a cross-linking agent. Together with the exposed photoactive compound, the exposed area is insoluble in the developer.
7. After the post bake, the wafer is exposed with a flood exposure (without mask) for 30 s with the mask aligner. The previous unexposed area becomes soluble in the developer.
8. **Development**: Finally, the wafer is dipped in a developer (MIF 726, Microchems) for 1 min to dissolve the soluble area, which reveals a pattern of the photoresist with a designed geometry of the sensor (meander). The wafer is rinsed with DI water and dried with compressed air. A developer time should be well controlled to reveal the best resolution of final pattern.

B. Magnetron sputtering of GMR multilayers

1. The wafer coated with lithographically patterned photoresist is transferred into the deposition chamber of a magnetron sputtering machine. The sputtering machine is installed with required targets (Ta, $Ni_{81}Fe_{19}$, Cu). The deposition rates are calibrated for each target. And the thickness of each layer is optimized to prepare GMR sensors coupled at the 2nd antiferromagnetic maximum.
2. To ensure the film quality, a high vacuum condition is required. Thus, a base pressure of about 5.4×10^{-7} mbar is reached prior to the deposition.
3. During the deposition, we use Ar as the sputter gas. A sputter pressure of about 9.4×10^{-4} mbar and a flow rate of 10 sccm are used for deposition. Each target is pre-sputtered for 5 min remove any contaminants on the target. To deposite each layer, the wafer is transferred under a specific target, a pressure-actuated shutter is used to control precisely the deposition time and the final layer thickness. The whole deposition is remotely controlled and of full automation.
4. After the deposition, the sample is brought out of the chamber for lift-off.

For the lift-off process, the wafer is dipped into acetone (depending on the residual resist on the wafer, the time varies from 1 to several hours; optionally ultrasonic bath can be used to assist the lift-off) to dissolve the photoresist to reveal the GMR sensors with a meander shape, which is subsequently rinsed with isopropanol and dried by compressed air. Afterwards, a second lithography step is used to pattern electrical contacts for the GMR stack. This process is the same as described in **Step A**, except that to pattern the contacts, a different photomask with a designed geometry of contacts is used. The pattern of contacts should be precisely aligned with the previous deposited GMR stack before exposure with the mask aligner. When a second lithography step is finished, the sample is again brought to the magnetron sputtering machine to deposite the contacts. In this case, Ta (5 nm) /Cu (200 nm) /Ta (5 nm) is used as the material.

Datasheet of Magnetic Nanoparticles

The magnetic nanoparticles used in this experiment are purchased from Chemicell GmbH. The corresponding specification is reproduced from [1].

Product: fluidMAG-PAS

Description: Aqueous dispersion of magnetic nanoparticles

Weight of Volume: 25 mg/ml

Core: Magnetite

Matrix: Polyacrylic acid

Size approx.: 50 nm

Number of Particles: ~ 1.3 x 10^{16}/g

Density: ~ 1.25 g/cm3

Type of Magnetization: Superparamagnetic

Functional Group: Sodium carboxylate , -COO- Na

References:

[1] http://www.chemicell.com/products/nanoparticles/docs/PI_fluidMAG-PAS_4110.pdf