Magnetic particles for biotechnology

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This study aims at developing a new type of magnetic particles for biotechnological applications (in particular in-vitro diagnostics).The standard magnetic particles, currently used in biological applications, are chemically obtained and usually spherical. They are superparamagnetic. They have limitations due to their low magnetic susceptibility, their low magnetic moment, the lack of choice of shape, and a poor control of monodispersity. In contrast, our fabrication process is based on a top-down approach taking advantage of all the know-how in magnetic thin films engineering and microelectronic technology. The magnetic nanoparticles that we prepare exhibit magnetization curve having a superparamagnetic-like behaviour (i.e. no remanent magnetization and reversible magnetization variation under field up to saturation). However, their susceptibility are 2 to 3 orders of magnitude larger than conventional particles and their shape and size can be perfectly controlled (see Figure 1).
Our ”top down” approach of fabrication comprises several steps: 1) the patterning of the substrates by nanoimprint and optical lithography, 2) the deposition of original magnetic stacks, 3) biological functionalization, 4) lift-off to release the functionalized particles in a solution (see Figure 2). After release, the functionalized particles are studied in solution. The particles motion under gradient of magnetic field is observed by microscopy imaging.

As a preferred magnetic material, we used sets of multilayered synthetic antiferromagnets with the composition NiFe/Ru0.6nm having different susceptibilities. These stacks present zero remanence and a high isotropic magnetic susceptibility. They imitate very well superparamagnetic particles (see Figure 3). We report, for our particles, magnetic susceptibilities two order of magnitude higher then those of conventional iron oxide based magnetic particles in fields of the order of 10mT. This gives us the possibility of using weaker magnetic fields and/or to apply larger forces on the particles.

Phenomena of self-organization of the particles in suspension were observed related to the magnetostatic interactions between the particles. These phenomena can be controlled and suppressed by changing the magnetic susceptibility of the particles which influences their self-polarization (see Figure 4).

Besides, the intrinsic “flat” shape of the particles yields a weaker viscosity force in the solution as compared to spherical particles.
This approach can yield lot of biological applications in particular related to in-vitro diagnostics.

Figures:

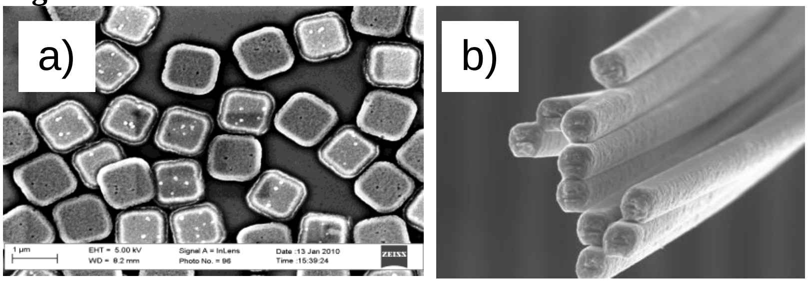

Figure 1. Photos SEM: a) square 1x1µm synthetic antiferromagnetic particles; b) magneto-elastic nanowires 100 nm in diameter

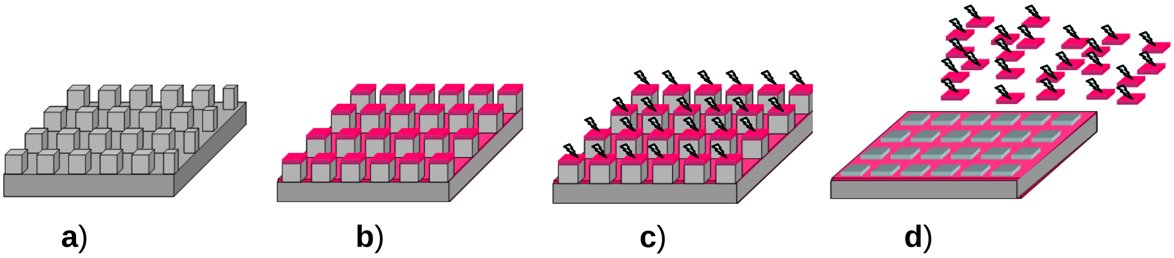

Figure 2. Preparation of micro and nanoparticles; a) Substrate patterning; b) Magnetic stack deposition; c) Biological functionalization; d) Lift-off of the particles

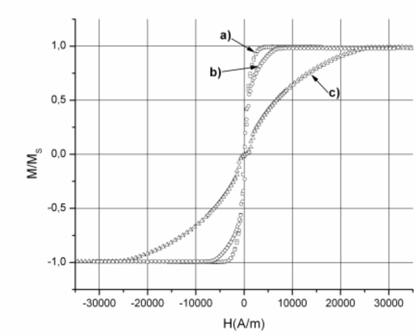

Figure 3. Hysteresis loop for 3 different stacks: a) NiFe60nm/Ru0.6nm/NiFe60nm; b) (NiFe30nm/Ru0.6nm)$_3$/NiFe30nm; c) (NiFe15nm/Ru0.6nm)$_7$/NiFe15nm

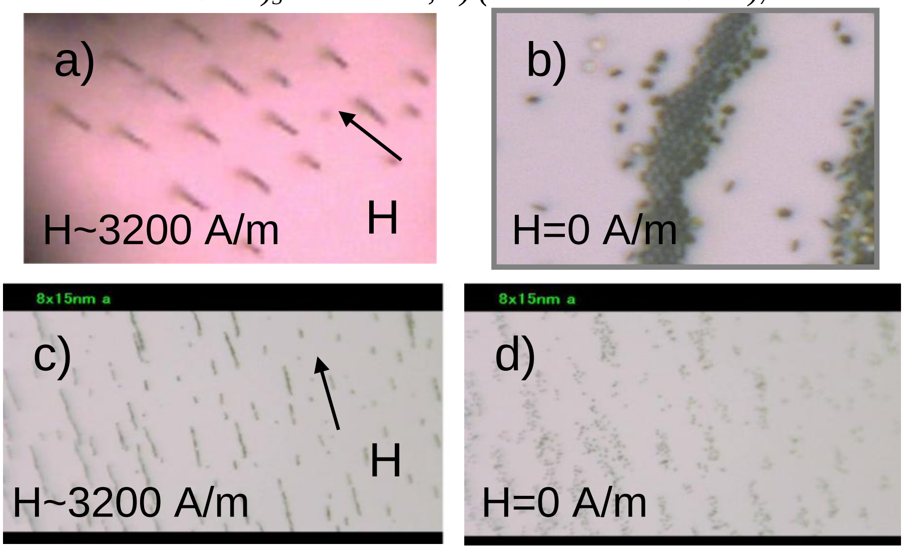

Figure 4. Suppression of self-polarization of super-paramagnetic-like particles; a) and b) particles with high susceptibility; c) and d) low susceptibility particles