Magnetic Lab-on-a-Chip: Magnetic Nanoparticles for Biomedical Diagnostics

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Recent progress in fabrication and characterization of magnetic nanoobjects like rods and beads has triggered many ideas and possible applications in the biomedical field. A magnetic biochip using the combination of both magnetic nanoobjects as markers and magnetoresistive sensors has proven to be competitive to standard fluorescent DNA-detection at low concentrations. Superparamagnetic nanoparticles are detected via giant magnetoresistance (GMR) or tunnel magnetoresistance (TMR) sensors. Their size ranges from a few nm up to few 100 nm and can be reliably reproduced by physical or chemical processes.

Magnetic nanoobjects additionally provide the unique possibility to actively manipulate biomolecules, on-chip, which paves the way to an integrated 'magnetic lab-on-a-chip' combining detection and manipulation. Manipulation can be accomplished either by an external magnetic field or on-chip via currents running through specially designed line patterns on a chip platform. It can be shown that hybridization processes can be accelerated compared to usual thermal activation. A prototype is under development for Sepsis diagnosis. The ultimate goal is the detection of antibodies at the picomolar level at shortest reaction times.

Today's lab-on-a-chip systems are designed in such a way that surfaces play a major role, either as substrate where molecular reaction takes place or as sensor environment for detection, combined with microfluidics. This makes them complicated, slow, and ineffective. Looking forward, a paradigm shift from the 'magnetic lab-on-a-*chip*' to a 'magnetic lab-on-a-*bead*' is discussed as a future device solution. Ferromagnetic nanoobjects are thereby directly used as both molecular recognition sites and detection units. Information about binding events is communicated via characteristic property changes of the nanoobjects which are remotely detected. For this, we envisage a combination of magnetorelaxation and plasmon detection. Symmetry considerations and numerical estimations show that anisotropic magnetic core-shell nanoobjects are best suited for this task. Au-decorated iron oxide nano-spindles were synthesized and investigated for such purposes.