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Diamagnetic trapping of cells above micro-magnets

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Miniaturization of biology-dedicated microsystems, called labs-on-a-chip, provides a better sensitivity for molecular or cellular detection and reduces the volume of solvent and the quantity of handled active principles. However, the resulting small number of molecules or cells and the high surface-to-volume ratio can lead to significant contamination and stiction problems, respectively. Such phenomena raise major issues for samples in the micro- to picolitre (µl-pl) range. For these reasons, contactless handling methods are widely investigated these days.

Diamagnetic levitation is one of the rare natural repulsive forces capable of compensating gravity. Although this kind of repulsion is negligible at our scale, at the microscale (< ~1 mm) it becomes significant and diamagnetic levitation of micro-objects above micro-magnets can be achieved. Widely investigated at the macroscale with superconducting coils [1] or bulk magnets [2], diamagnetic levitation has been little explored at the microscale, mainly because of the difficulty to obtain strong non-uniform magnetic fields. Recent advances made in the micro-patterning of hard magnetic films [3] hold much potential for MEMS compatible applications based on diamagnetic contactless manipulations.

The contactless confinement (Fig. 1.A-B) of Jurkat cells (T lymphocytes) in a paramagnetic medium was successfully achieved above NdFeB micro-magnets (Fig 1.C). Experiments were made with an extremely low concentration of contrast agent (GdDO3A) (C=5-10mM - $\delta\chi$ ~ 4-3 µSI). Cytotoxicity testing (Live/Dead cell viability assays) shows that such low concentrations have no impact on cell viability. However, after a few dozens of minutes diamagnetic trapping is lost and the cells sediment on the edge of the magnets. Such a phenomenon could be explained by the internalisation of the paramagnetic salt by endocytosis [4]. This study opens broad and attractive alternatives for contactless cell arraying and sorting based on their size, magnetic susceptibility and endocytosis capabilities. Such methods are being investigated further, and could be applied for sorting cancer, stem and blood cells.

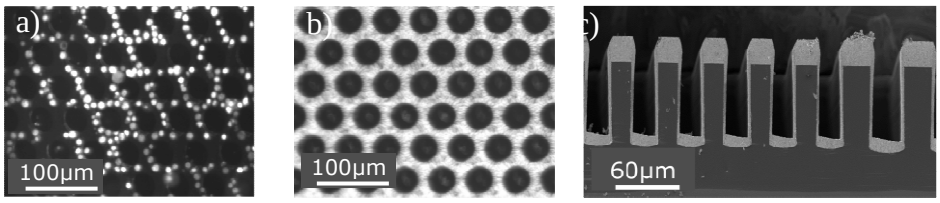

Fig 1 : , a) Micropositioning of Jurkat cells in a paramagnetic medium above this magnetic film, b) Plane-view optical image of a hard magnetic NdFeB film containing an array of micro-holes c) SEM image of the cross-section of NdFeB micromagnets.

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