Magnetic nanobeads used for the development of structured biocompatible surfaces to induce cell differentiation

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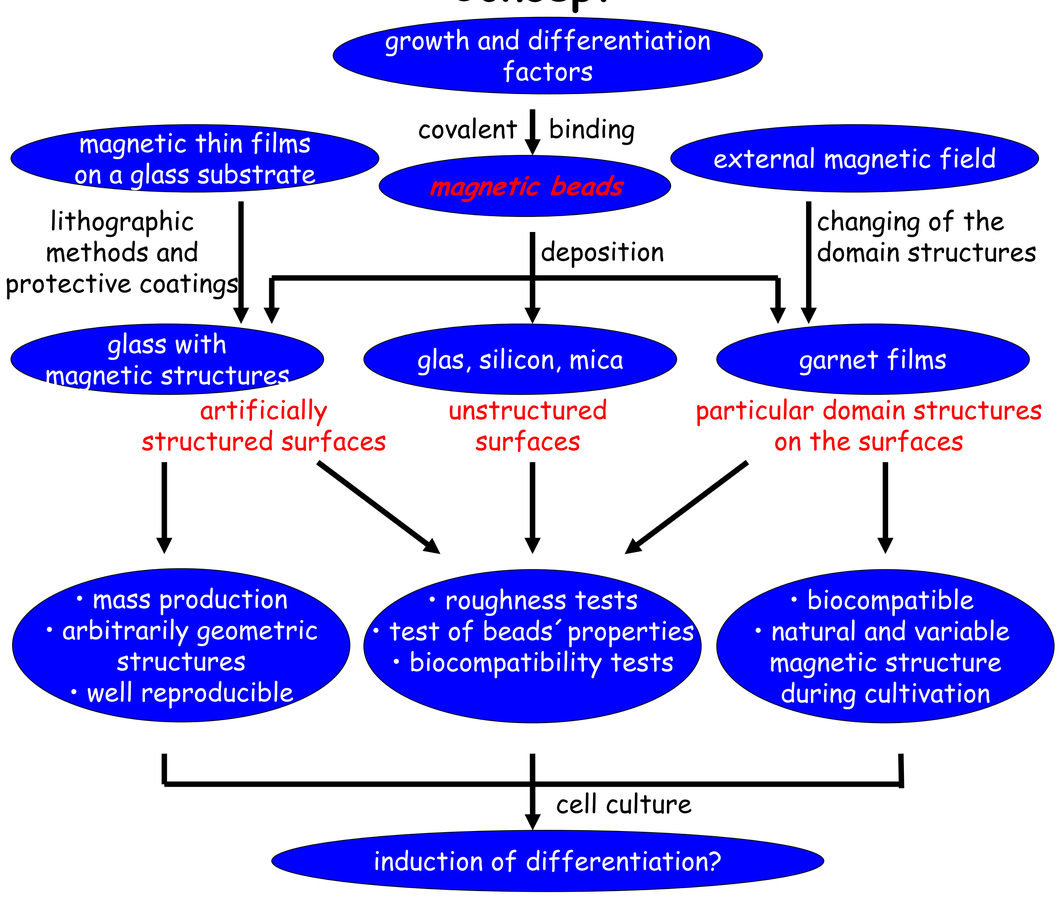
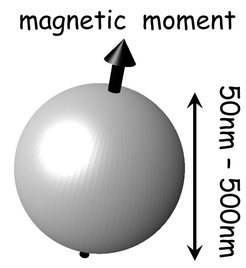
CellPROM Cell Programming by Nanoscaled Devices

Concept



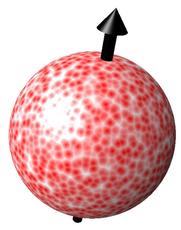
Beads



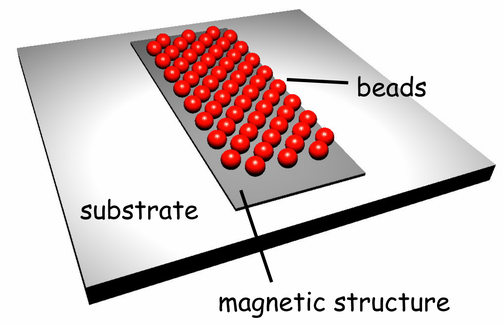
- superparamagnetic
- commercially available with different chemical properties (NH_2, COOH, fluorescent dyes)
- magnetite particles embedded in a dextran matrix

Differentiation (growth) factors

- TGF β1 (NHDF)
- FGF4, HGF and others (MAPCs)
- NDF (PC12-cells).

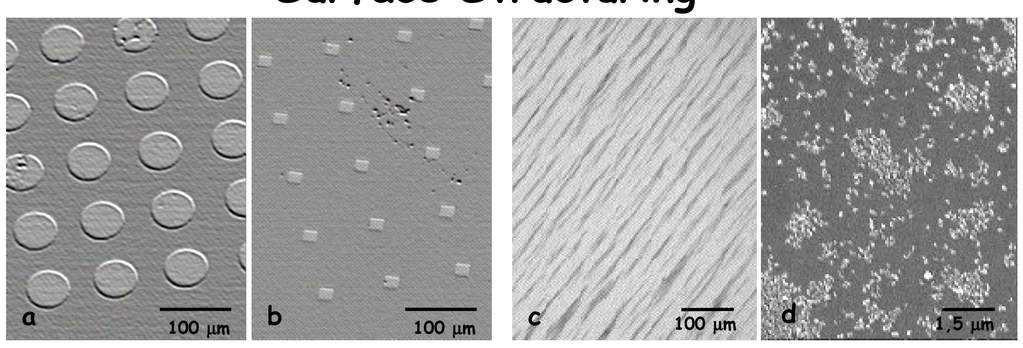


- functionalized bead with covalently bound molecules



Deposition of the beads onto the surface. Interaction between beads and magnetic structures increases adhesive forces. Beads bind to the surface in the regions of highest field gradients.

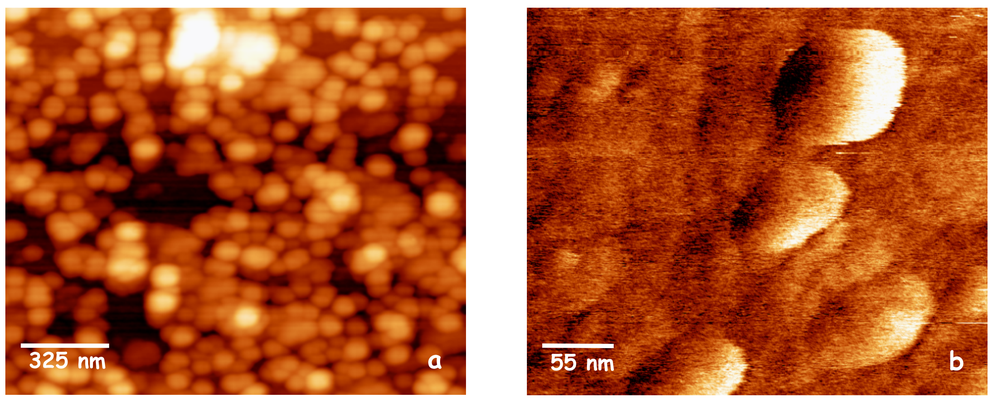
Surface Structuring



Magnetic thin films (here Permalloy, FeNi, 30 nm thick) can be structured by e-beam-lithography or contact lithography (not shown).
(a) circles, ϕ 60 µm , (b) squares, 20x20μm^2

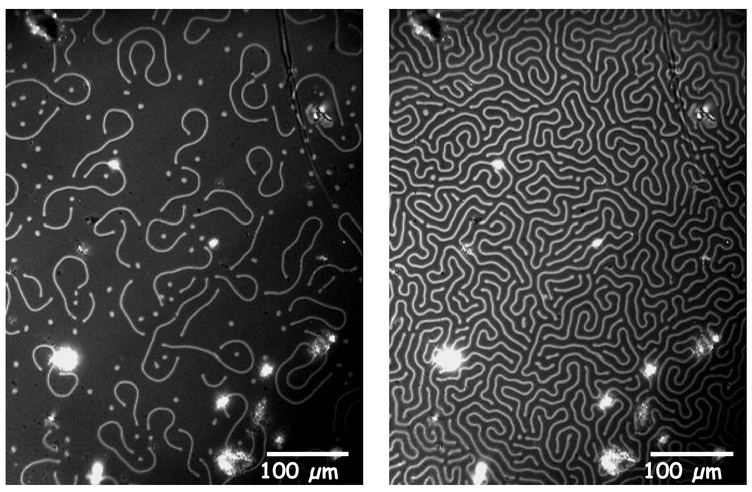
Beads deposited on glass.
(c) light microscopic images, structures obtained by using a magnetic stirrer. Turning off the stirrer results in "freezing" of the structure.
(d) SEM images, varying the beads´ amount changes the concentration of the functionalization molecules

Bead Visualization

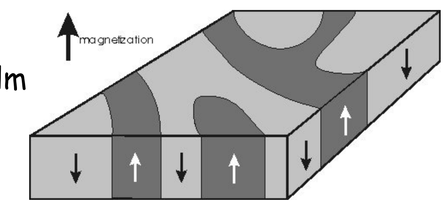


Magnetic force and atomic force microscopy are used to visualize single magnetic beads. The MFM technique gives information about the magnetic properties (stray field) of the beads or magnetic surface structures (not shown).
(a) AFM, Tapping Mode, $f_{resonant}$ = 70 kHz
(b) MFM, 50 nm mean distance to the surface, same cantilever, coated with 30 nm CoCr

Garnet Films



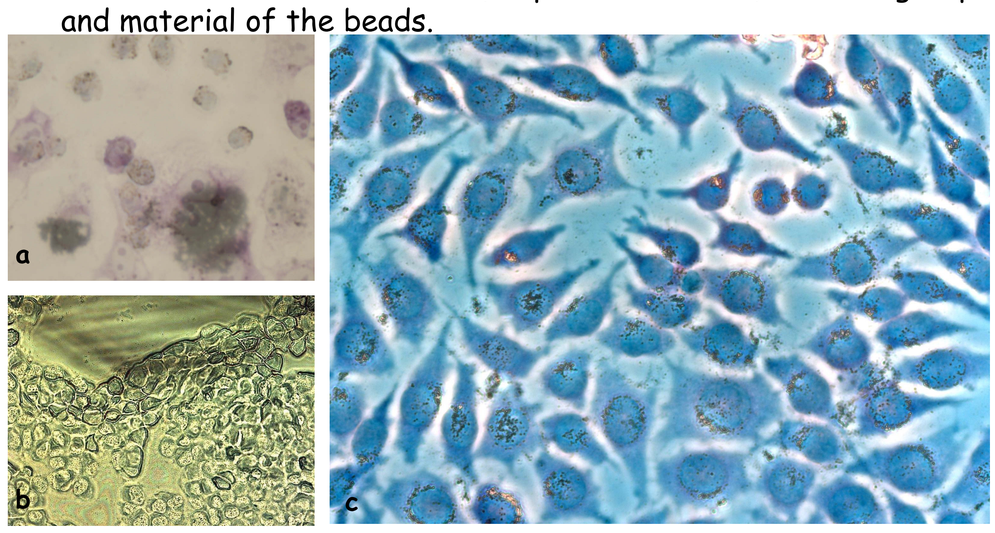
Faraday microscopy of a garnet film under the influence of different external magnetic fields



- Y Sm Bi Ga Fe
- white/dark contrast ⇔ antiparallel magnetization
- beads can be deposited between white and dark areas (field gradient)

Biocompatibility

All surfaces must be testet for biocompatibility. This was performed with L929 Mouse Fibroblasts and HuTu cells, respectively.
(a) HuTu on Permalloy after three days. The magnetic material peels off under cultivation conditions ⇨ protective coating.
(b) L929 on a garnet film after five days. Cells grow well to confluency.
(c) L929 with 100nm beads added to culturing media. Endocytosis: Cells collect beads around the core, dependent on size, reactive groups and material of the beads.



Summary

A highly variable set up for a straightforward change of the chemical and topographical properties of a substrate for inducing cell differentiation is presented. The usage of functionalized magnetic beads allows to combine topographical with chemical (biomolecules) conditions.

Acknowledgment

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