Self-Assembly of Linear Nanoparticle Arrangements guided by Prestructured Surfaces

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The control the dimension and orientation of nanopatterns is important for the construction of functional nanodevices. It is possible to control the arrangement of nanoparticles with nanoimprint soft lithography\(^1\). We use the nanoimprint procedure to prepare linear arrangements of nanoparticles. To obtain the linear pattern, we apply masters of DVD-R and BD-R structures\(^2\). We are using pre-structured silicon stamps of poly(dimethylsilane) (PDMS), which are manufactured by molding the master structure and covering whose pattern. Furthermore, it is possible to embed nanoparticles inside prestructured glass surfaces, which were obtained by the same imprint technique. One obtain highly ordered linear arrays. The rotational GISAXS experiment is used for investigation of the linear, highly ordered arrays of nanoparticles on the surface.

![Figure 1: SEM images of FeO\(_x\)-nanoparticles (15 nm) embedded in a prestructured glass-surface with distances of 320 nm (a) and 740 nm (b)](image)

After uncovering the optical rewriteable media (DVD-R and BD-R), the exposed structures were used to form a negative replica in silicone stamps. These stamps were pressed into the particle solution and afterwards the solvent evaporates. The remains on the substrate are highly ordered, free standing, linear arrays of the nanoparticles. Another routine applies the same nanoimprint technology to form a structured glass substrate using tetramethyl orthosilicate (TMOS) as precursor. In a second step, nanoparticles were embedded into the superstructure by using coating techniques. The results are presented in Figure 1a/b.

We investigated the structured FeO\(_x\)-nanoparticle patterns with synchrotron radiation in GISAXS experiments at experimental station BW4 (HASYLAB). The sample was rotated around its normal axis. Figure 2 shows the vertical reflections (q\(_z\)) of a 1D-lattice (superstructure, 740 nm, DVD-R) and horizontal reflections (q\(_y\)) of embedded nanoparticles. The vertical distance of the q\(_z\)-reflections depend on the repeating units of the superstructure and on the used incident angle. The distances between the reflections change by rotation (Figure 2). At 90° the vertical projection of the linear superstructures becomes small, which leads to larger distances in the reflection in reciprocal space, explained in the tilted 3D-AFM-micrographs.
Figure 2: GISAXS images of the rotational experiment of embedded nanoparticle arrays into linear superstructure and 3D-AFM micrographs\textsuperscript{[3]}. Out of plane cuts along $q_y$ at the critical angle of substrate give information about the type of arrangement and interparticle distance of the linear arrangements. At $0^\circ$ (beam parallel to the linear structures) the GISAXS image shows a nonpointed beam reflection. Although there are reflections in $q_y$ of the nanoparticles.

Figure 3: (a) the possibilities of the incoming beam passes the nanoparticle arrays and (b) intensity profiles of the $q_y$-reflections

Figure 3a shows the situations how the primary beam passes the structure. This explains the different distances between the reflections ($q_y$) at $30^\circ$ and $60^\circ$, demonstrated in the intensity profile in figure 3b. The scattering position of the first and second $q_y$-reflections change due to the rotation of the 2D-hexagonal array. The scattering patterns of embedded nanoparticle arrays are presented in figure 4.

Figure 4: Scattering patterns of embedded FeO$_x$-nanoparticle arrays into linear superstructures\textsuperscript{[3]}

These measurements demonstrate that we are able generate single crystalline, linear particle superstructures.

References