The realization of block copolymer films with nanoscopic unit cells down to a few nanometre and quasi long range crystalline order over arbitrary large length scales [1] stimulates the fabrication process of ordered nanostructure via the hierarchical self-assembly method. Although applicable in a variety of branches, particularly interest is given to block copolymer based magnetic nanostructure with the potential to boost the capacity of future hard drives.

Here we investigate a special case where a nanoscopic PS-b-PMMA template with a flat surface morphology is transformed into a highly ordered 3D structure by thermal deposition of FePt at elevated temperatures (see one example in Fig. 1). Atomic force microscopy allows to detect the surface morphology but the buried structure in the polymer matrix can not be determined thus avoiding to understand the origin of this transformation phenomena as well as to determine the extension of the magnetic nanostructure. For this we use grazing incidence small angle x-ray scattering (GISAXS).

The experiment was performed at the beamline BW4 using a photon energy of 10 keV and a focussing of the beam to 30 μm x 60 μm at the sample position. A series of data sets were taken at different incident angles and at different lateral orientations of the sample relative to the photon beam. Two of the GISAXS pictures are displayed in Fig. 2.

Figure 1. AFM images of structurally transformed polymer templates after nominal MBE (molecular beam epitaxy) deposition of 7 nm of FePt at elevated temperature. A drastic change of the surface morphology from a plane to a highly ordered, canted lamellar structure can be seen. Even sensitive to the surface morphology the AFM images don’t allow to determine where the magnetic material is deposited. GISAXS investigations were made to clarify this question.

A 2D simulation of the scattering pattern was made with the data evaluation software IsGISAXS [2] to get a full picture of the structural and ordering parameters of the nanostructure. The main results are presented in Fig. 3. The simulation shows that a homogenous FePt is formed on an anisotropic pyramid like structure. The thickness is reduced by 35% compared to the nominal thickness of the deposited material. This effect is obviously due to the increased surface area of the nanostructured polymer film compared to that of a plane film. However, from the results (FePt is exclusively deposited on top of the polymer) it is concluded that the drastic change of the polymer
structure (from a hexagonal arrangement of upright PMMA cylinders in a plane PS matrix into the pyramid like lamellar surface morphology) is finished before the FePt deposition started.

Figure 2. GISAXS images of the polymer templates after nominal deposition of 20 nm and 7 nm of FePt. The exposure time at BW4 was around 60 s for each picture.

Figure 3. Sketch of selected results extracted from the 2D GISAXS simulation for the 7nm deposition. The evaluation shows that the plane PS-b-PMMA polymer template transformed into an anisotropic polymer pyramid structure on a polymer film on which the FePt formed a homogeneous film of slightly reduced thickness compared to the nominal FePt deposition (7nm).

Thus, this effect is probably mainly due to the thermal treatment before the actual metal deposition started. Future investigation will focus on the magnetic properties of this pyramid like FePt structure.

References