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Structural investigation of ultrathin Pt/Co/Pt trilayer films with perpendicular magnetic anisotropy induced by extreme ultraviolet light irradiation

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The ultrathin Pt/Co/Pt trilayer films with tunable magnetization direction are of particular importance for spintronics. It was previously evidenced that the out-of-plane to in-plane magnetization reorientation can be induced in this system by light irradiation. Femtosecond laser pulses (in visual range) driven transition from in-plane into out-of-plan magnetization state has been recently reported [1]. Similar effect induced by extreme ultraviolet (EUV) light pulses also exists in Pt/Co/Pt. Structural study of EUV modified nanostructures is the goal of this presentation.

Investigations were performed on the MBE fabricated layered system containing ultrathin (3 nm) cobalt layer grown on 5 nm thick Pt buffer layer and covered by 3 nm thick second layer of Pt. Nanostructures were irradiated with EUV pulses (about 3ns duration and 11nm light length) from plasma source operating with gas target Kr/Xe/He excited with an optical laser. The structural characterization has been done by X-ray diffraction (XRD) methods with use of the synchrotron radiation at the P-08 beamline of Petra III at DESY as well as the laboratory diffractometer X'Pert PRO MPD Panalytical configured for Bragg-Brentano diffraction geometry, equipped with a strip detector and an incident-beam Johansson monochromator.

The diffraction patterns of the as grown samples show only thickness fringes related to the total thickness of the multilayers (~10 nm). Direct observation of the diffraction peaks from the individual layers were not possible due to their very small thickness. The detailed analysis of the patterns allows to estimate the position of the 111 diffraction peak from the Pt layers (total thickness ~8 nm) and to calculate the value of the lattice spacing d_{111}, which is very close to that characteristic for Pt. Unfortunately, the diffraction signal from the Co layer (~3 nm) is not visible.

The thickness fringes from the irradiated places of the samples show pronounced changes in the films structure. More detailed insight suggests creation of substitutional alloy $Pt_{1-x}Co_x$ with the interplanar distance d_{111} of the layer system significantly smaller than that for as grown samples.

The grazing-incidence diffraction recorded at an angle of incidence of 0.5° has shown a polycrystalline phase component in platinum film, both in as grown and irradiated places.

After the X-ray measurements the morphology of the samples was examined by transmission electron microscopy methods (TEM) using the FEI Titan CUBED 80-300 microscope. It was confirmed that irradiation leads to complete intermixing of the cobalt film with the platinum covers resulting in substitutional $Pt_{1-x}Co_x$ alloy.

From the experiment at P-08, it has been found that outside of EUV irradiated spot the X-ray beam footprints on the surface of the samples, visible as a slightly darker areas. We performed special tests explaining the beam influence on the formation of these features. Our observations suggest that the effect of "discoloration" may appear due oxidation of the sample induced by ozon generated by high energy density of photons flux. As a result outside of EUV irradiated spot sample losts his ferromagnetic properties. Comparison of measurements with synchrotron radiation and with laboratory diffractometer, where this discoloration does not appear, showed that the general features of the diffraction patterns at intermediate 2θ angles, with thickness fringes, stays unaffected.

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