P-57

XMCD studies of Pt/Co/Pt nanostructures modified by Ga^+ ion irradiations

P. Mazalski[1,2], I. Sveklo[1], Z. Kurant[1], K. Olefs[3], A. Rogalev[3], F. Wilhelm[3], J. Fassbender[4], A. Wawro[5] and A. Maziewski[1]

[1]*Faculty of Physics, University of Białystok, Ciolkowskiego 1 L, 15-245 Białystok, Poland*
[2]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Niezapominajek 8, 30-239 Kraków, Poland*
[3]*European Synchrotron Radiation Facility, B.P.220, F-38043 Grenoble Cedex, France*
[4]*Helmholtz Zentrum Dresden-Rossendorf, PO Box 510119, Dresden 01314, Germany*
[5]*Institute of Physics, Polish Academy of Sciences, Al. Lotnikow 32/46, Warszawa 02-668, Poland*

Keywords: synchrotron radiation, magnetic anisotropy, ion irradiation

*e-mail: piotrmaz@uwb.edu.pl

Magnetic anisotropy of ultrathin films are usually tuned by varying the film thickness, chemical composition or structure. Increasing Co film thickness d above d_{RPT}(~2nm) transition from out-of-plane into in-plane magnetization state is observed. It was discovered [1,2] that He ions irradiation also induces transition to in-plane state for $d>d_{RPT}$. However it was recently reported [3,4] a new effect - Ga^+ ion irradiation drives multiple both vanishing and creation of perpendicular magnetic anisotropy (PMA). Two branches of PMA were reported on the 2D maps (d, F) Co thickness and Ga ions fluence F. Possibilities of ion driven modification of magnetic nanostructures are important for patterning [5] especially by focus ion beam technique, where Ga ions are used.

The Co films with different buffer (Au or Pt) and overlayer (Au or Pt) were deposited by molecular beam epitaxy technique and magnetooptically studied for different d and F. Magnetooptical studies show strong influence of the Au and Pt on magnetic anisotropy changes ploted as a (d, F) maps. For the following sapphire/Pt(20nm)/Co(d=3nm)/(Pt or Au (5nm)) trilayers were selected for XAS/XMCD measurements: non-irradiated and two uniformly irradiated with fluences F_1 and F_2 corresponding to the first and second PMA branches, respectively. Synchrotron studies were performed in ID12 ESRF beamline using XAS and XMCD techniques on Co K-edge and Pt $L_{2,3}$ edges. XAS studies for both irradiated samples showed: (i) changes of the spectra shapes and (ii) big changes of the spectra amplitude for the fluence F_2 connected with etching process. Changes of shape spectra are probably related to the mixing of the layers at the interfaces which forces a modification of the 3d and 4p shells of the Co atoms. The electronic structure of transition metals is very sensitive to changes of their local environment. Higher number of Pt atoms in the nearest vicinity of Co atoms modifies their d and p shells due to hybridization with the d-states of Pt atoms. Above mentioned process create very good conditions for the Co-Pt alloy formation in irradiated samples – shape of obtained spectra on Co and Pt absorption edges are similar to those for Co-Pt alloy [6].

XMCD spectra for both Pt and Au cap layer in non-irradiated samples obtained at the Co K-edge are similar to the XMCD spectra obtained for a pure hcp Co layer. For the samples irradiated with fluences F_1 and F_2 it is possible to distinguish two additional peaks located energetically in the same position like for $Co_{0.5}Pt_{0.5}$ alloy with well developed $L1_0$ structure. This results is an indication that the Co–Pt alloy is formed and probably responsible for the enhanced magnetic anisotropy in branches 1 and 2. However in samples with Au cap layer effect is weaker because of presence only one Co/Pt interface - mixing of Co and Au does not have influence on magnetic changes.

XMCD Pt $L_{2,3}$-edge studies revealed increase of the spectra amplitude for samples irradiated with fluences F_1 and F_2 in relation to the non-irradiated sample. This fact reflects the appearance of magnetic moments at the Pt atoms which are induced by the magnetic moments of adjacent Co atoms because of Co-Pt alloy formation. However amplitude of the spectra for sample with Au cap layer is smaller than for Pt cap layer because of smaller number of Pt atoms close to Co in the Au/Co/Pt - only at the one interface Co–Pt alloying take place. Such behaviour is also visible in magnetic moments of Pt atoms obtained from the sum rules calculations. The moments at the Pt atoms in Pt/Co/Au are slightly smaller than in Pt/Co/Pt. This might be related with different number of Pt atoms in the Co surrounding. However for both irradiated systems the magnetic moment is larger than in the non-irradiated sample.

Acknowledgments: This work was supported by FUGA project financed by the Polish National Science Centre, DEC-2015/16/S/ST3/00450

[1] C. Chappert et al., *Science* **280** (1998) 1919.
[2] T. Devolder and H. Bernas, *Material Science with Ion Beams,edited by H. Bernas, Topics in Applied Physics*, 116 (Springer-Verlag, Berlin, 2010).
[3] A. Maziewski et al. *Phys. Rev. B* **85** (2012) 054427.
[4] P. Mazalski et al., *J. Appl. Phys.* **113** (2013) 17C109.
[5] J. Ferré and J.-P. Jamet, *Handbook on Magnetism and Advanced Magnetic Materials* (H. Kronmüller & S.-J. Parkin, Wiley,Chichester, UK, 2007), Vol. 315.
[6] Y.S. Lee, J.Y. Rhee, C.N. Whang, Y.P. Lee, *Phys. Rev. B* **68** (2003) 235111.