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Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** XAS, XMCD studies of ions irradiation driven magnetization orientation in Pt/Co/Pt nanostructures.	**Experiment number**: **HC-961**
Beamline: ID12	**Date of experiment**: from: 12.11.2013 to: 16.12.2013	**Date of report**: 21.02.2014
Shifts: 11	**Local contact(s)**: Andrei Rogalev, Fabrice Wilhelm	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

The main aim of current experiment was to study the structural (XAS) and magnetic (XMCD) changes in Pt (20nm - buffer)/Co (3nm) /Pt (5nm – cap layer) trilayers irradiated with 30 keV Ga^+ with a two doses corresponding to the appearance of perpendicular magnetic anisotropy (PMA). Besides it, the similar studies were done on other set of samples in which Pt(5nm) cap layer was replaced with Au(5nm). Thus we can check the influence of miscibility of upper interface on irradiation process. Preliminary magnetooptical studies have shown a strong difference in magnetic properties of irradiated Co films with Pt and Au cap layer.

The studied trilayers were prepared by MBE grown techniques with the following structure: single crystal sapphire (0001) substrate was covered with Pt(20nm – buffer layer)/Co(Co d_{Co}=3nm or linear wedge 0-5nm)/(Pt(5nm) or Au(5nm) as a cap layer). Wedge samples were used for experimental definition of irradiation doses required for PMA appearance in a similar way as it was done in [1]: these wedge shaped trilayers were irradiated with 30 keV Ga^+ ion beam with monotonically increasing fluence F while direction of cobalt thickness gradient was perpendicular to the fluence gradient. Polar magnetooptical Kerr studies of the whole Co wedge sample enabled to determine the magnetic and magnetooptical properties as a function on d_{Co} and F. As a result, on 2D maps of magnetic and magnetooptical parameters one can find that in the case: a) Pt/Co/Pt – the appearance of two elongated areas – ("branches") with enhanced perpendicular magnetic anizotropy and out-of-plane component of magnetization; b) Pt/Co/Au – the appearance of two branches with enhanced perpendicular magnetic anizotropy but out-of-plane component of magnetization was only present for high irradiation fluence branch 2. After the determination (performed on the wedge samples) of irradiation fluences corresponding to the appearance of branch 1 and branch 2 for 3 nm Co thickness, flat Pt/Co 3nm/Pt and Pt/Co 3nm/Au samples were irradiated with fluences corresponding to the branches 1,2 for XAS/XMCD studies.

Evolution of the amplitude with the applied ion fluence of the XAS spectra measured at Co and Pt absorption edges is a common feature of the both studied systems. The amplitude is proportional to the number of absorbing atoms in the sample. For as-deposited sample and irradiated one with fluence branch 1 the amplitudes at cobalt K-edge are practically the same, whereas for the fluence branch 2 it drastically decreases. Such behavior observed for high fluence is related with smaller amount of Co atoms remaining in the sample. Simple comparison between the spectra amplitude shows that signal for the sample irradiated with the highest fluence is about 45% less (1.8 times smaller) than for as-deposited one. It means that almost half of the cobalt atoms were removed from the sample during irradiation process at branch 2. Similar

behavior – decrease of platinum L_3 absorption edge for branch 2 irradiation fluence was noticed too. However the decrease by 18% is much smaller in comparison to Co (1.2 times smaller). This difference is related with initially different amount of the Co and Pt atoms in the sample.

The results of the Co K-edge and Pt L_3-edge (L_2-edge was also measured) XMCD spectra of the irradiated trilayers with the fluences corresponding to the branch 1 and branch 2 and as-deposited trilayers for samples with Pt and Au cap layer are shown in Fig.1 a), c) and Fig.1 b), d), respectively. The XMCD spectrum of the as-deposited samples depicts the shape and amplitude typical of pure metallic Co films or nanoparticles [2, 3]. However, XMCD spectra of the irradiated samples for both branches show different shapes in comparison to pure metallic cobalt. This proves that irradiation leads to a significant change of the Co atoms electronic structure due to the different nearest neighbor configuration rearrangement resulting in the formation of $Co_{1-x}Pt_x$ alloys. The XMCD spectra for an ordered $Co_{0.5}Pt_{0.5}$ $L1_0$ thin film reference sample is presented in Fig.1 a). The similarities between this spectrum and those for irradiated (branch 1 and branch 2) samples with Pt and Au cap layer are a strong indication that formation of Co-Pt alloy is responsible for enhanced PMA in branches 1 and 2. Therefore, we interpret the XMCD spectrum of the irradiated sample as the superposition of pure Co and CoPt alloy contributions. The comparison of XMCD spectra for irradiated Pt/Co/Pt and Pt/Co/Au samples suggests that upper interface is more subjected to irradiation mixing. In samples with Au cap layer alloy connected features are smaller. This is confirmed on Pt L_3-edge spectras for both systems presented on Fig. 1 c) and Fig. d), respectively. Au cap layer induces smaller mixing on the Co/Pt interface (amplitude is smaller), induced magnetic moments on Pt atoms also is smaller because of smaller number of Co atoms located in the neighborhood to the Pt atoms (e.g. [4]).

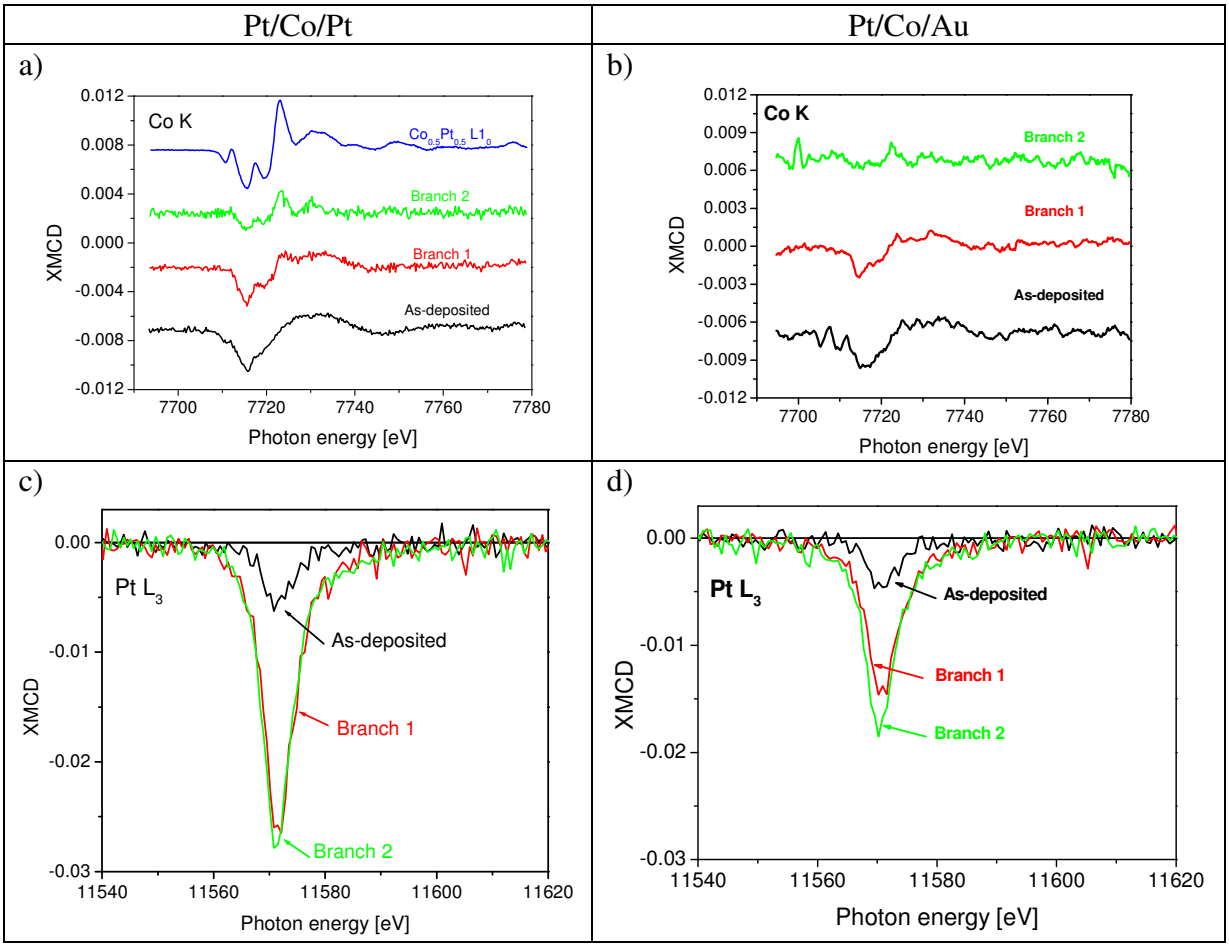

Fig.1. Room temperarture XMCD spectra obtained for Pt/Co/Pt and Pt/Co/Au trilayers at: a ,b) Co K-edge; c, d) Pt L_3-edge. In a) XMCD spectra for reference sample with $Co_{0.5}Pt_{0.5}$ $L1_0$ ordered film is shown as blue line.

In summary, we show that (i) ion driving etching at: branch 1 is negligible, but at branch 2 cap Pt layer with significant part of Co layer are removed; (ii) top Co-Pt interface mixing is more important for formation of the Co-Pt alloy than bottom one.

Results were presented by Piotr Mazalski as a contributed talk on Magnetic Materials under Extreme Conditions Workshop associated to the ESRF Users' Meeting 2014, 3-5.02.2014, Grenoble (Francce), "*XAS/XMCD studies of Ga^+ ions irradiation driven magnetization changes in ultrathin cobalt films*". Manuscript of the paper "*XAS and XMCD studies of magnetic properties modifications of Pt/Co/Au and Pt/Co/Pt trilayers induced by Ga^+ ions irradiation*" with results obtained during HC-961 is under preparation.

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