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Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

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The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

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All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

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 and XMCD studies of Ga+ irradiation driven magnetization reorientation transitions in Pt/Co/Pt nanostructures.	**Experiment number**: **HE-3673**
Beamline: ID12	**Date of experiment**: from: 02.11.2011 to: 08.11.2011	**Date of report**: 30.03.2012
Shifts: 18	**Local contact(s)**: Andrei Rogalev, Fabrice Wilhelm	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Andrzej Maziewski[1], Piotr Mazalski[1], Andrzej Wawro[2]

[1] Faculty of Physics, University of Bialystok, Lipowa 41 street, 15-424 Bialystok,
[2] Institute of Physics, Polish Academy of Science, Al. Lotnikow 32/46 street, 02-668 Warszawa

Report:

The aim of the proposal was investigation of the magnetic and structural ordering of a Co film in MBE deposited Al2O3/Mo(20nm)/Pt(20nm)/Co(3.3nm)/Pt(5nm) trilayers irradiated by a 30 keV Ga^+ ion beam. In the performed experiment we have observed in the studied samples remarkable oscillations of the magnetic anisotropy between: in-plane and out-of-plane orientations with increasing irradiation fluence F, extending our previously performed research [1]. From the polar magnetooptical Kerr studies we have distinguished in 2D diagramas (d_{Co}, F) two clear branches with enhanced perpendicular magnetic anizotropy (PMA).For comparison the investigations were performed on Ga irradiated Pt/Co/Pt nanostructures deposited by sputtering technique. Also in this case we obtained similar results, which prove that the observed effects are reproducible features of the irradiated samples. For deeper insight into magnetic properies the all samples were studied by means of the Co K-edge X-ray Absorption Spectroscopy (**XAS**) and X-ray Magnetic Circular Dichroism (**XMCD**) spectroscopies. We have tried to explain an origin of irradiation-induced increase of magnetic anisotropy. As a reference a MgO/CoPt sample with the perfectly ordered $L1_0$ phase was investigated to check a hypothesis that the Ga^+ ion irradiation driven $L1_0$ phase creation is responsible for out-of-plane branch existence.

Results of the Co K-edge XAS and XMCD spectra of the irradiated film with the fluence $F = 2.8 \bullet 10^{14}$ ions/cm^2 (branch 1) and non-irradiated film are shown in Fig.1a. The XMCD spectrum of the as-deposited sample depicts the shape and amplitude typical of pure metallic Co films or nanoparticles [2, 3]. Conversely, the XMCD spectrum of the irradiated sample shows a drastically different shape. This proves that irradiation leads to a significant change of the Co atom's electronic structure due to the different nearest neighbor configuration rearrangement resulting in the formation of ordered $Co_{1-x}Pt_x$ alloys with enhanced PMA. In order to confirm the presence of a chemically ordered CoPt alloy, we have compared the XMCD spectrum of the irradiated sample (Fig. 1) to that of an ordered $Co_{0.5}Pt_{0.5}$ $L1_0$ thin film reference sample. There are striking similarities between these two spectra eventhough the amplitudes of some features are slightly different.

However, all the characteristic peaks are present in both spectra at exactly the same energies. Therefore, we interpret the XMCD spectrum of the irradiated sample as the superposition of pure Co and $L1_0$ CoPt alloy contributions. Similar results we have obtained on Ga irradiated Pt/Co/Pt nanostructures deposited by sputtering technique.

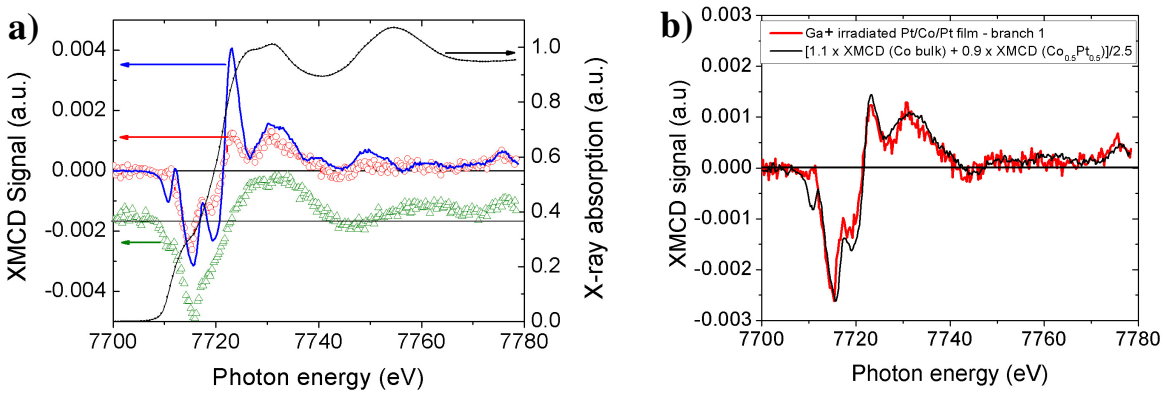

Fig.1. (**a**) Room temperature absorption spectrum (XANES) (black solid line) of the Ga^+ irradiated film (branch 1) and Co K-edge XMCD spectra in a magnetic field for: the non-irradiated film (green triangles), the irradiated film (red circles), reference CoPt $L1_0$ phase film (blue line); (**b**) comparison of the supreposed non-irradiated Co film and reference CoPt $L1_0$ phase film (black) with the irradiated film from branch 1 film (red)

These results have already been presented at few international conferences and workshops (e.g. Users' Meeting 2012 & Associated Workshop, Magnetic Materials under Extreme Conditions at ESRF Grenoble in February 2012) and have been recently published in a paper "*Tailoring of magnetism in Pt/Co/Pt ultrathin films by ion irradiation*" appeared in Physical Review B [4]

Unequivocal interpretation of XAS/XMCD study of the out-of-plane magnetization appearing as branch 2 in the irradiated sample requires more detailed studies. Obtained signal is much weaker and it is difficult to achieve well grounded information from this measurement. Higher contribution of Pt atoms and probably also the presence of the Ga ions seems to be important for this branch existence.

In summary we confirmed our hyprothesis related to formation of the CoPt ordered $L1_0$ phase for sample with branch 1 and this result is published in [4]. But there are still open questions concerning physics of branch 2 creation and these are the subject of our new proposal.

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[2] S. Pizzini, A. Fontaine, C. Giorgetti, E. Dartyge, J.-F. Bobo, M. Piecuch and F. Baudelet, Phys. Rev. Lett. **74**, 1470 (1995).

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