Experimental Report

(Please follow remarks as specified in the report guidelines; use font Arial, 11 pt)

Experiment number:	Project type:	Date(s) of experiments (from/to)	Date of report:
2014-021-01	Short term	28-30.07.2014	05.09.2014

Title:

Ar^+ irradiation of Pt/Co/Pt – ion induced perpendicular magnetic anisotropy (PMA)

Name(s) and affiliation(s) of applicant(s): (* indicate main user / experimenter):

Marcin Jakubowski*, Institute of Physics Polish Academy of Sciences, Warsaw, Poland
and Department of Physics, University of Białystok, Białystok, Poland

Local contact and/or other supporting HZDR staff involved in the experiment:

Dr. Roman Boettger, Dr. Kay Potzger, Franziska Nierobisch

1 Objectives

Post-growth ion irradiation effects on magnetic properties of Pt/Co/Pt system have been investigated. In particular, induced out-of-plane magnetisation vector regions by enhancing perpendicular magnetic anisotropy (PMA) was a main subject of this study. Previously reported [1] work concentrates only on relatively high energies (30keV) with full ion beam penetration through Co layer. Moreover, this effect is sensitive to total ion fluence and can be diminished or restored, creating two so-called “branches” on the “Co thickness/ion fluence” dependency maps. In order to gain an insight into such behaviour we proposed experiment where by varying ion energy of ion bombardment thereby an ion depth penetration, an effectiveness of layer intermixing, total surface etching depth (surface recession) and selective mixing of top interface Pt/Co (low energy) can be tuned.

Within this project, maps of “Co thickness/ion fluence” relationship were obtained – in particular for three different ion beam energies: 1.2, 5, 30keV of Ar^+. Moreover, non-irradiated reference stripes were left at the end sides of the irradiation area for measurements of etching effects (top part of the samples) and second reference zones intentionally covered from ion irradiation (bottom part of the samples) as a non-irradiated virgin sample reference. With the knowledge of fine fluence parameters a further irradiation experiments can be planned for local chemical/structure investigations.

2 Experimental

Samples were grown by MBE (Pt $_{350Å}$ / Co $_{0\text{-}44,7\ Å\ +\ Å\ 50\ Å\ +\ 100\ Å\ (two\ steps)}$ / Pt $_{50\ Å}$) in IoP PAS, Warsaw. Thickness of the cobalt layer was monitored during the growth using quartz balance and evaporation rate was stabilised. Smooth Pt seed/buffer layer was deposited using procedure where surface with 2-4 terrace steps were observed (STM). Co wedge and Pt cap layer was deposited at RT.

Then, three samples were irradiated in such manner, where steps of incremental wedge fluence (73 micron steps) was aligned parallel to the Co thickness gradient wedge. Ion fluence applied to the samples was in range of $2*10^{13}$-$1.9*10^{16}$ ions/cm^2.

Irradiated nanostructures were investigated in University of Białystok with special construction of optical microscopy system using polar magnetooptical PMOKE effect sensitive for out-of-plane magnetization component. Preliminary MOKE images where obtained in remanence state. Further examination is the subject of ongoing work.

3 Results

PMOKE studies of irradiated nanostructures enabled determination of remanence figures (see Figs.1,2.3). Brightness level is related with out-of-plane magnetization state. Bottom part of the samples was left for reference as a virgin samples. In sample P0093B & C the reference region was also left at top sample edge. Zones of irradiation with linear recursion of parameters were constrained by green lines. Co wedge is from left to right and ion fluence changes are aligned vertically from bottom to top part of the images.

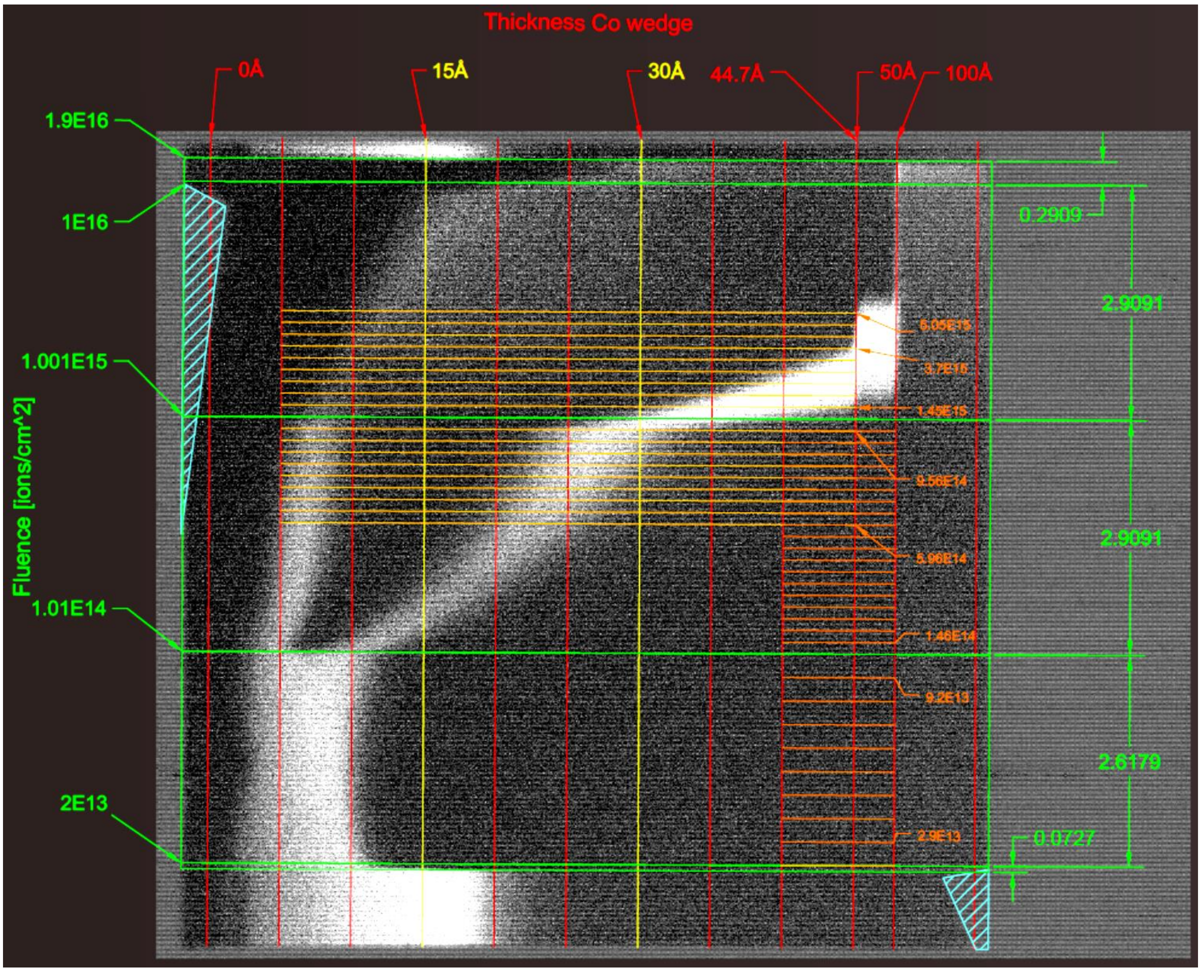
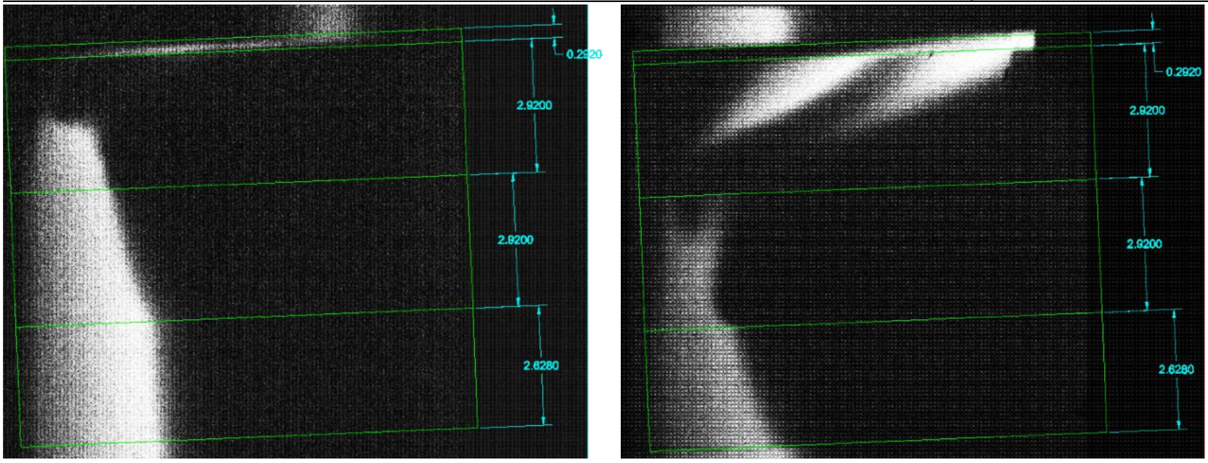


Figure 1: Rush version of Ion fluence/Co thickness map on remanence image of Irradiated P0093C sample using 30keV@Ar^+ beam.



1.2 keV **5keV**

Figure 2, 3: Remanence images of Irradiated P0093C (30keV@Ar^+) and P0093B (5keV@Ar^+).

Prior to the experiment, TRIDYN software calculations were used for simulation and determination of in-depth profile Co concentration changes, surface recession and fluence range selection. Two chosen plots of the Co layer 3 nm thick (see one of yellow vertical lines on fig 1) and represent two various ion energy dependent scenarios of intermixing.

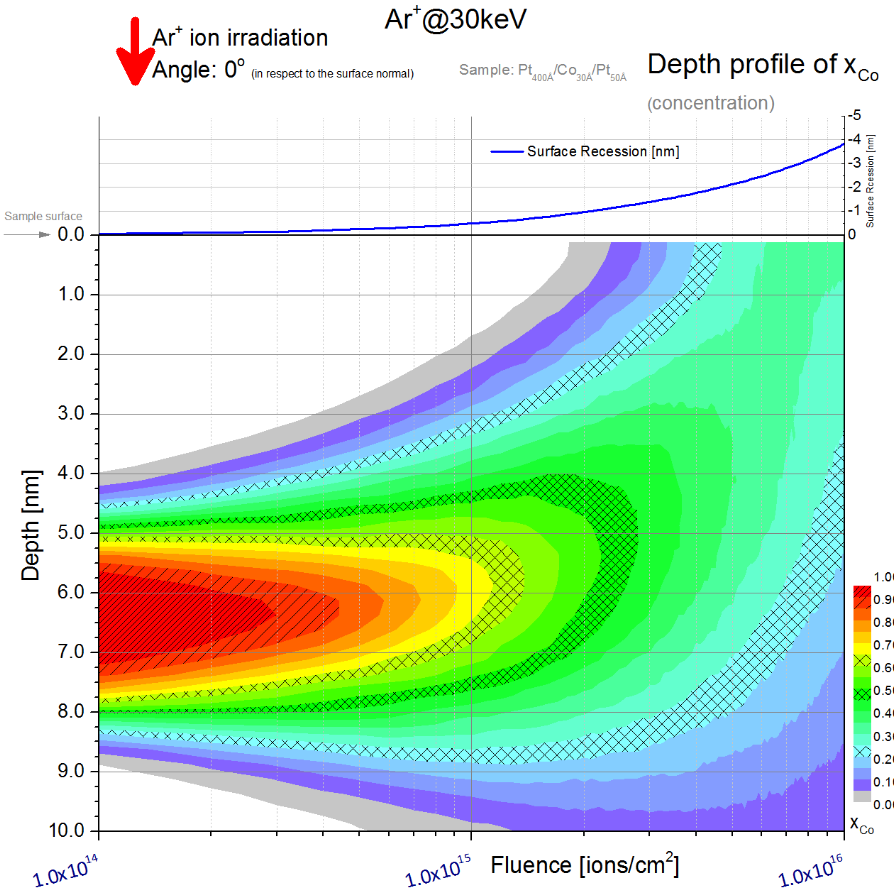


Figure 4: Plot of x_{Co} depth profile simulated using TRIDYN software. Beam energy: 30keV.

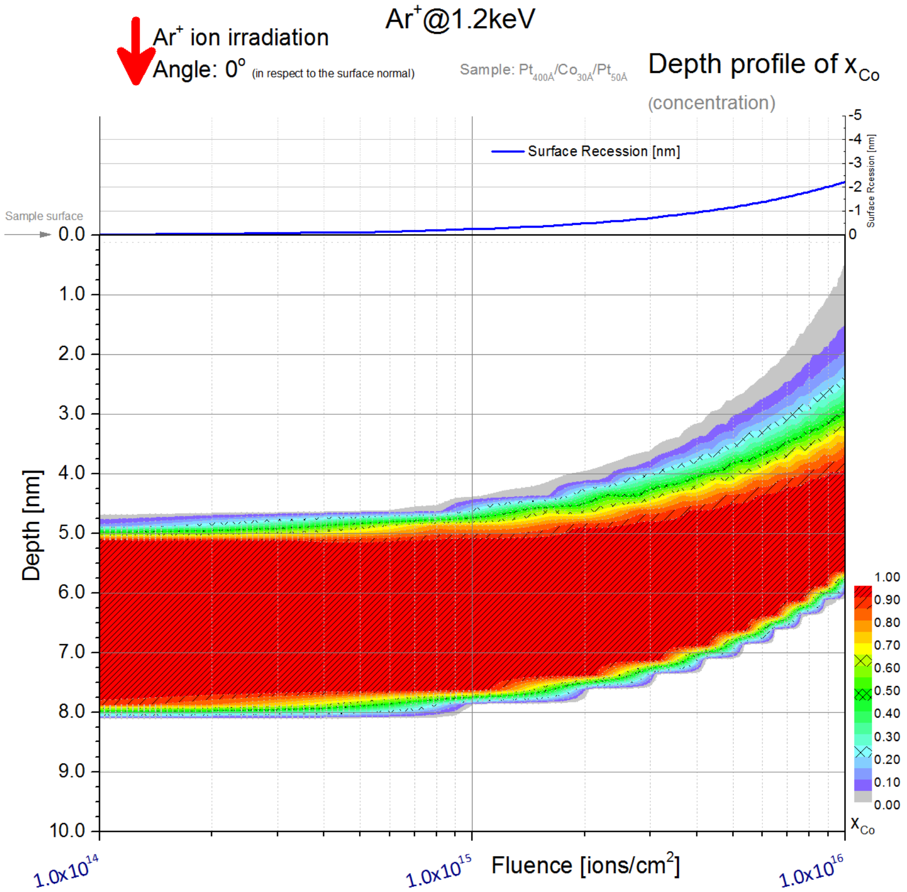


Figure 5: Plot of x_{Co} depth profile simulated using TRIDYN software. Beam energy: 1.2keV.

4 Conclusions

Two “branches” of magnetisation vector out-of-plane are clearly visible in 30keV and 5keV maps. For 1.2keV irradiation, two faint traces are visible but repeat irradiation with better resolution of the fluence should by proceeded to reveal more details. As predicted from TRIDYN simulations, fluence shift of the “branches” in contrast to previous Ga+ irradiations is confirmed. For more complex analysis further experiments must be preceded. At this point, we can therefore try to speculate about mechanism that induces the SRT transitions present in Pt/Co/Pt system irradiated by ions on the basis of Tridyn simulation and our recent work.

Firstly, initial irradiation lowers the PMA by interface smoothing and slightly increasing the total thickness of Co layer in the meaning of initial rarefaction of Co phase by Pt atoms. As result of that, out-of-plane magnetisation shifts to region with initial thinner Co layer. In the case of “I branch”, when out-of-plane magnetisation is induced by further increasing the ion dose, appearing of SRT can be address to that situation where a thin residual and diluted Co layer is between two PtCo thicker quasi gradient layers. Further irradiation mixes entirely Co layer and thickness of gradient PtCo phase is getting thicker (TRIDYN) eventually lowers the PMA and induces SRT to some complex quasi “in-plane” magnetisation. Finally, “II branch” is a result of getting thinner mentioned gradient PtCo phase, which is a result of further rarefaction of Co and surface etching. Regions with initial thin Co layer exhibit more “fainter branches”, because magnetisation is probably not entirely out-of-plane due to the situation when Co is quickly diluted. Possible local alloying of PtCo in $L1_0$ structure may occur but temperature during irradiation doesn't exceed 40°C, so random ordering formation is more probable.

We plan a further studies and measurements of these samples (profile of etching, more detailed measurements using Kerr effect) but first obvious move is to enhance the resolution of the fluence wedge, especially of 1.2keV irradiation, thus we want carry out further irradiation experiments in a range 10^{15}-$3*10^{16}$ of fluence [ions/cm2].

5 Publications / Presentations

[1] A. Maziewski, P. Mazalski, Z. Kurant, M. O. Liedke, J. McCord, J. Fassbender, J. Ferre, A. Mougin, A. Wawro, L. T. Baczewski, A. Rogalev, F. Wilhelm, and T. Gemming., Phys. Rev. B 85, 054427 (2012)

Presented results are not published yet.

6 Acknowledgements

This research is supported by the “Statistics and dynamics of magnonic and magnetophotonic crystals - SYMPHONY” project* of the Foundation for Polish Science TEAM program, co-financed by the European Union from European Regional Development Found (ERDF).

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
FNP
Foundation for Polish Science
EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND