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Low energy ion irradiation induced modifications in Co/Pt bi-layers

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Abstract : We report on 150 keV Ar and 250 keV Kr ion-irradiation induced modification of Pt(8 nm)/Co(85 nm)/Si bilayers. X Ray diffraction, Rutherford backscattering spectrometry and magneto optical Kerr effect measurements have been performed to study the changes in structural and magnetic properties of the technologically important Co/Pt bi-layer system due to low energy ion irradiation The combined result from XRD and RBS measurements strongly indicate that ion beam induced mixing takes place across the Co/Pt interface leading to the formation of Co–Pt phase and simultaneous sputtering of the Pt atoms from the top most layer Magneto optical Kerr effect data reveal the corresponding changes in the magnetic properties due to the formation of Co–Pt alloy

Keywords : Low energy ion irradiation, Pt/Co bilayers, XRD, RBS, MOKE.

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1. Introduction

The fundamental understanding of ion beam induced interface modification of new materials is not yet sufficient and thus it is of recent interest among the researchers. It can be mentioned that ion beams play an important role not only in atomic mixing across the interfaces but also in materials modification and phase formation [1–4]. Low energy ((~keV/amu) ion irradiated atomic mixing in materials is an interesting phenomenon, which is predominantly governed by elastic collisions of ions and target nuclei with nuclear energy loss S_n.

According to the investigations done on uniformly irradiated Co/Pt system [5–9], the structural properties of ultrathin magnetic films and layered structures can be purposefully modified by light ion irradiation in an energy range of 5–150 keV. The basic motivation for ion irradiation of Co/Pt system arises from the possibility of modifying the perpendicular magnetic anisotropy (PMA) through irradiation-induced intermixing at the interfaces [10,11]. Also, these investigations are of interest for future applications to ultra high-density magnetic recording media since this technique may be a way to produce magnetic nanostructures with strong PMA without affecting the

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surface topography. We should mention here that for Co/Pt bi/multi-layers, apart from the composition, crystallinity, and the grain sizes; the magnetic properties are often strongly dependent on surface and interface structures [12]. Based on the above facts, one can approach towards systematic tailoring of the magnetic properties of the Co/Pt layered structures by low energy ion irradiation induced interface modification.

In this paper, we present the correlation of changes in structural and magnetic properties of 150 keV Ar and 250 keV Kr irradiated Pt(8 nm)/Co(85 nm) bilayer samples grown on native oxide covered Si substrates. The samples were characterized by X-ray diffraction (XRD), Rutherford backscattering spectrometry (RBS) and magneto optical Kerr effect (MOKE) measurements. The results are attributed to the ion beam induced interface modification of Co/Pt bi-layers.

2. Experimental

[Pt (8 nm)/Co (85 nm)/Si] thin films were deposited using ion beam sputtering technique under a vacuum of $\sim 10^{-6}$ mbar. The films were irradiated by 150 keV Ar and 250 keV Kr ions obtained from an electron cyclotron resonance (ECR) ion source at Inter University Accelerator Centre. RBS was performed using 1.7 MeV He^+ ions at IOP. XRD was employed for phase analysis, while MOKE was used for studying magnetic properties of the Co/Pt system before and after ion irradiation.

3. Results and discussion

All irradiation induced significant changes are systematically shown in Figures 1 and 2 (for XRD), Figures 3 and 4 (for RBS), and Figure 5 (for magnetic studies).

Careful analyses of the XRD patterns (for both the ions) clearly show that with irradiation some new peaks evolve, which match well with those corresponding to the $CoPt_3$ phase. This strongly indicates the formation of Co–Pt phase as a result of ion

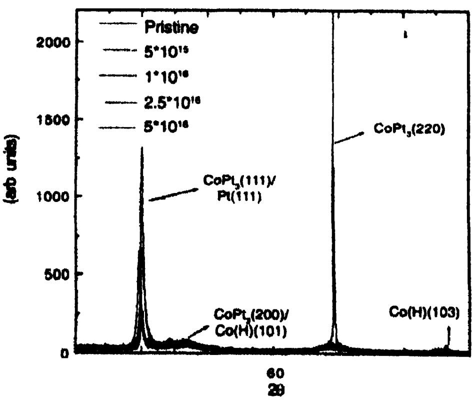

Figure 1. XRD patterns of Co/Pt bilayers irradiated with 250 keV Kr ions showing crystalline peaks of old and new phases with fluence.

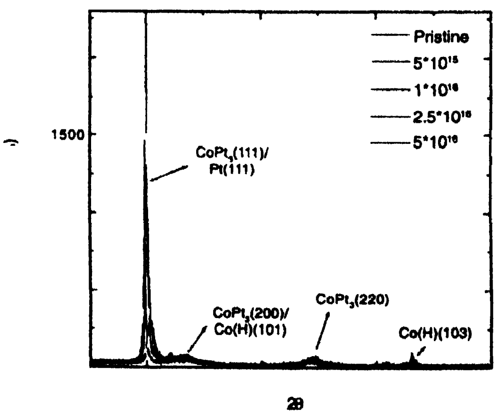

Figure 2. XRD patterns of Co/Pt bilayers irradiated with 150 keV Ar ions showing crystalline peaks of old and new phases with fluence.

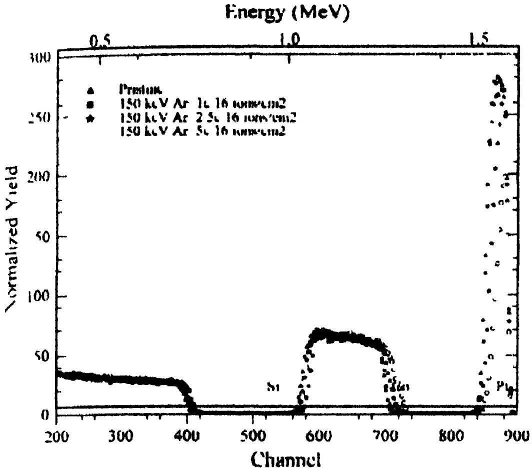

Figure 3. RBS spectra for 150 keV Ar ion irradiation.

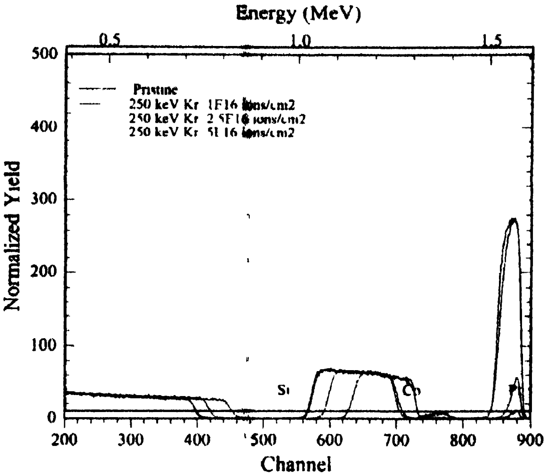

Figure 4. RBS spectra for 250 keV kr ion irradiation.

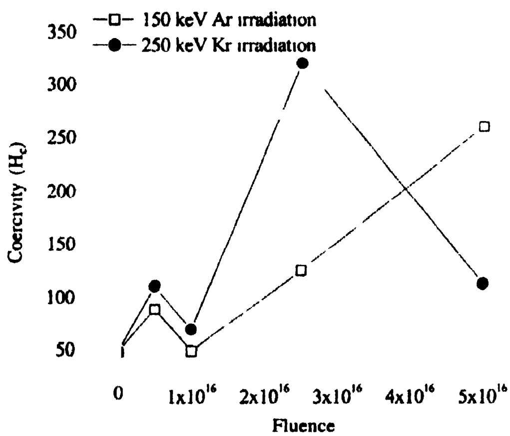

Figure 5. Coercivity with fluence for both the ions.

induced mixing of the Co and Pt atoms across the interface. From SRIM [13] simulation it is seen that both the ions stop deep in the Si substrate penetrating both Pt and Co layers. The irradiation process, therefore, involves recoils of Pt and Co atoms, which are limited to one or two atomic distances leading to the substitution of Co→Pt, Pt→Co [12]. Thus, if we consider this process as a "soft" irradiation process then the original crystallographic structure and the microstructure should remain nearly unaltered. From the XRD patterns, it is observed that although some new peaks have evolved due to mixing across the interface, the original peaks still remain unaltered. Therefore, it can be inferred that although short range motions are most likely due to irradiation, the appearance of the new XRD peaks confirm that long range motions also take place giving rise to new phase formation due to mixing. Essentially to have a better understanding of the mixing process, we need to consider the probability of chemical effect superimposed on the pure ballistic ion mixing. It has already been reported [11] that Pt and Co atoms are being miscible, which favours atomic mixing across the interface. However, at this stage we are unable to provide the exact information whether any chemically ordered $L1_0$ or $L1_2$ phase has been formed or not.

Let us now go on to discuss our RBS results (Figures 3 and 4) where we clearly notice that alloy formation is accompanied by the drastic loss of Pt atoms with increasing ion mass and fluence. There are also shifts in the Si and Co signals. All the observed changes in the RBS spectra are indicative of the fact that Pt atoms get sputtered. Now if we try to understand the ion irradiation effects on the Pt layer, we can consider the following two possibilities : (a) sputtering of Pt atoms leads to a situation so that it is present only in the form of Co–Pt alloy, (b) reduction in Pt thickness from the top layer accompanied by the formation of Co–Pt alloy. However, combining the results of XRD and RBS, we observe that the XRD patterns do show the presence of Pt, which essentially rules out the first possibility mentioned above. These observations match well with the SRIM simulation towards calculation of the sputtering yield of Pt due to Ar and Kr ion-irradiation.

To correlate the structural properties with the change in magnetic properties of uniformly irradiated Co/Pt bi-layer films, we have employed MOKE measurements to study the hysteresis loop as a function of ion fluence. The dependence of coercivity on the ion fluence has been plotted in Figure 5.

These plots show that there is a definite increase in both the values. The origin of the hysteresis loop is expected to be due to the strong magnetic nature of the Co atoms. It is also known that the value of coercivity saturates for Co layer of 40 nm or 50 nm [12]. Therefore, increase in coercivity, could result only due to the formation of the Co–Pt phase. Together increase in coercivity and in remanence may be interpreted as a direct consequence of interface mixing of Co atoms and Pt atoms. However, formation of chemically ordered phase is expected to give rise to a large increase in coercivity value, which is not observed in our case. This reveals that although Co–Pt alloy is formed, it is not in a chemically ordered state.

4. Conclusions

In conclusion, 150 keV Ar and 250 keV Kr ion-irradiation of Pt(8 nm)/Co(85 nm) grown on Si substrates lead to the formation of Co–Pt alloy phase through ion beam mixing across the interface. This is followed by the increase in coercivity and remanence, which can also be attributed to the formation of Co–Pt alloy phase. Further studies are underway to understand the change in magnetic properties in the context of structural evolution in the Co/Pt bi-layer system with ion irradiation under varying parameters.

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