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STRUCTURAL AND MAGNETIC PROPERITES OF Xe ION IRRADIATED Co/Si BILAYERS

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Abstract. Polycrystalline cobalt layers, deposited on Si(110) wafers via electron beam evaporation to a thickness of 55 nm, were irradiated at room temperature with 200 keV Xe ions to fluences of up to 15×10^{15} ions/cm^2.The atomic and magnetic force microscopy (AFM and MFM) were used to investigate the changes in the roughness and magnetic properties of the Co/Si bilayers. Ion beam induced structural changes were correlated with magnetic properties.

1. INTRODUCTION

Tailoring thin films of new materials by ion bombardment of layered structures appears as an interesting alternative to physical or chemical vapor co-deposition, pulsed laser deposition, and other methods of thin-film technology.

Based on the need to tailor shallow $CoSi_2$ junctions as contact metallization, the Co–Si system (Cheng and Chen 2008) has been investigated in much detail, with respect to thermal and ion-induced mixing (Mayer et al. 1981), implantation through metal doping (Bouilla et al. 2006), nano-patterning via focussed ion beams (Mitan et al. 2001) and low-energy and swift heavy-ion mixing (Bhattacharya et al. 2002). Nonetheless, the correlations existing between the microstructural properties of ion-irradiated or ion-mixed metal/silicon bilayers and their magnetic properties (in the case of 3d elements) is far from being understood. Phase transformations in Xe-irradiated Co and Co/Fe films have recently been studied by Zhang and collaborators (2003).

Led by these considerations, we have carried out a series of experiments, in which cobalt films of 55 nm thickness were deposited on crystalline Si wafers and irradiated at room temperature with 200 keV Xe ions to fluences of up to 15×10^{15} ions/cm^2.

2. EXPERIMENTAL PROCEDURE

Co thin films were deposited on Si (100) substrate by e-beam evaporation at the TESLA facility (Bibic et al. 2002). The substrates were cleaned by means of standard procedure, rinsed in diluted HF and in deionized H_2O, and prior to deposition they were sputter-cleaned with a high-intensity 1,5 keV Ar ion beam. The pressure in the chamber during deposition was maintained 1×10^{-6} mbar, and the Co deposition rate

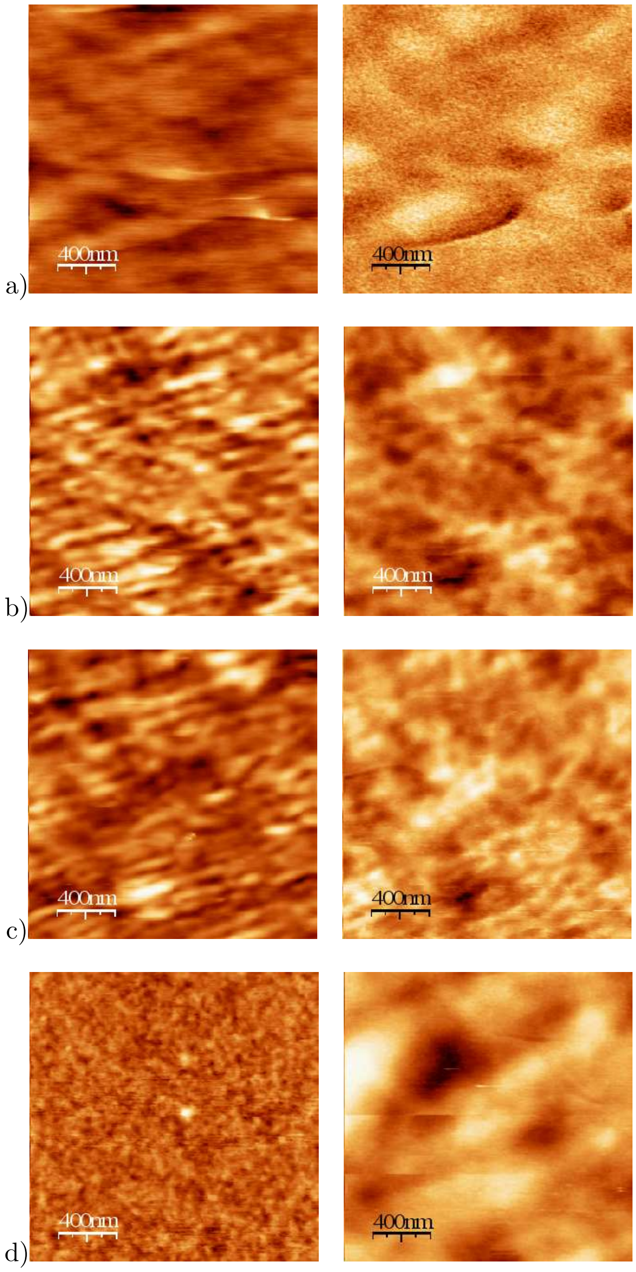

Figure 1: (a-d) Topography(AFM) images (left) and MFM images (right) of Co/Si bilayers: (a) as deposited; (b) irradiated to $5{\times}10^{15}$ ion/cm^2; (c) $10{\times}10^{15}$ ion/cm^2 and (d) $15{\times}10^{15}$ ion/cm^2.

at 0,5 nm/s. The IONAS implanter was used for ion irradiation. A sample area of 1×1 cm^2 was implanted homogeneously at a beam current of 2,5 $\mu A/cm^2$. The Co/Si layers were irradiated to (5, 10, 15) × 10^{15} ions/cm^2 with 250 keV Xe at 550 °C.

The SPM studies were caried out on VEECO MultiMode Quadrex IIIe in the lift mode. In the first step cantilever was tapping the surface and gives topography. In second step cantilever was lifted for 60 nm and it oscilated under the magnetic forces. Changing the oscilating frequency magnetic domains were obtained. Cantilever type is standard MESP-Veeco production. Tip was magnetized in external magnetic field in N direction along vertical axis. Scaned area was 2×2 μm for the all samples.

3. RESULTS AND DISCUSSION

The results of AFM and MFM analyses of Co/Si bilayers before and after irradiation are shown in Figure 1. Topography image(AFM) taken from as deposited Co/Si bilayer clearly show that the mean grains size is about 30 nm, and z-range 9 nm (Fig. 1a left). The specific pattern with the bright and dark regions represents magnetic domain structures (Fig. 1a right). The MFM image indicates that the magnetic domains are in the range of 50 nm.

After irradiation of Co/Si bilayers with 200 keV Xe ions to fluence of 5×10^{15} ion/cm^2 the surface roughness increases to 15 nm z-range (1b left), but the grain size decreases to 25 nm. The MFM image shown in Figure 1b right suggests that Xe ion irradiation induces the change of the local magnetic structure. In fact, the magnetic domains increased to 75 nm (1b right).

Images shown in Figure 1c are from the sample implanted to 10×10^{15} ion/cm. Analysis of this sample in AFM mode showed that the z- range was 22 nm, indicating also slightly smaller grains size of about 20 nm (Fig. 1c left). In this case, the increase of the magnetic domains to 100 nm was observed (Fig. 1c right).

At a highest Xe ions fluence of 15×10^{15} ion/cm^2, the smoothing effects occurred, as shown in Figure 1.d. Namely, the mean grains size is about 15 nm and z-range 8 nm (Figure 1d left). This suggests that high concentration of irradiation induced defects may enhance the atomic mobility, which can result in a change of the crystalline structure. As a consequence the magnetic domains increased to 170 nm (Figure 1d right).

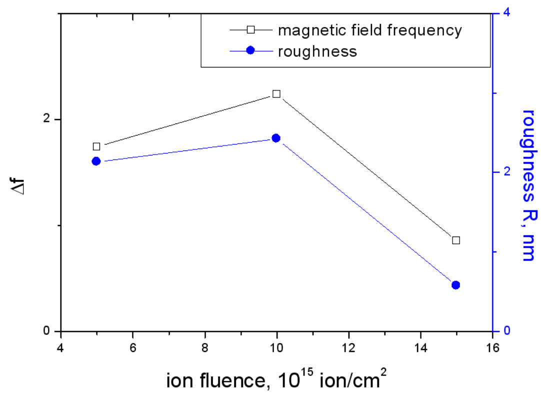

Figure 2: The Xe ion fluence dependence of magnetic frequency (Δf) and roughness (R) of Co/Si bilayers irradiated with 5×10^{15} ion/cm^2, 10×10^{15} ion/cm^2 and 15×10^{15} ion/cm^2.

Figure 2 displays the fluence dependence of magnetic frequency (Δf) and roughness (R) for irradiated Co/Si bilayers. Both curves show very similar behavior. A dramatic change occurred after irradiation to a highest fluence of 15×10^{15} ion/cm^2. This is consistent with the possible changes of the crystalline structure induced by Xe ion irradiation.

4. CONCLUSION

In conclusion, the results obtained with AFM and MFM analyzing techniques are consistent with the changes of crystalline structure in Co/Si bilayers irradiated with 200 keV Xe^+ ions. A possible explanation of this phenomenon has been associated with a high concentration of irradiation induced defects.

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