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SELECTED AREA ELECTRON DIFFRACTION STUDY OF MAGNETRON SPUTTERED OF $Co_{80}Sm_{20}$ THIN FILMS DEPOSITED ON ZIRCONIUM UNDERLAYER

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ABSTRACT

The structure of $Co_{80}Sm_{20}$ thin films deposited on zirconium underlayer and without zirconium underlayer using dc magnetron sputtering technique was investigated based on selected area electron diffraction (SAED) in Transmission Electron Microscopy (TEM). The use of zirconium underlayer between magnetic thin film and Si (100) substrate increases the coercivity of the film by about two times compared to that for the film deposited directly on Si (100) substrate. The film deposited directly on a Si (100) substrate shows a larger loop squareness compared to that for the film deposited on zirconium underlayer. The high coercivity observed in the films deposited on thicker (100 nm) zirconium underlayer is discussed. X-Ray Diffraction (XRD) pattern shows no crystalline diffraction peaks from any of the $Co_{80}Sm_{20}$ thin film deposited on zirconium underlayer. Moreover, XRD result reveals preferred (10.0) and (00.2) orientation. Electron diffraction patterns reveal diffused rings for thicker zirconium undelayer. No diffraction peak from $Co_{80}Sm_{20}$ thin film can be observed from these electron diffraction patterns.

Keywords: sputtering; magnetic; structural properties; selected area electron diffraction; $Co_{80}Sm_{20}$ thin film.

INTRODUCTION

The relationship between structural and magnetic properties in magnetic materials in the form of thin films with their magnetic recording media density has long been a subject of interest research. According to [1], high-density magnetic data storage with low noise requires materials that have high magnetic anisotropy and consisting of small and magnetically isolated grains. One of the magnetic materials that can fulfill these requirements is Co_5Sm [2]. In small grain sizes of about 2.3 nm, high magneto crystalline anisotropy is needed in order to achieve a high magnetic recording density of 10 T bit/inch^2 [3].

There are several methods [4, 5] that can be used to fabricate thin films of cobalt alloy such as CoSm alloy with certain composition. However, thin films with controlled geometry and surface smoothness as well as composition can be prepared by the magnetron sputtering method [6]. One of the advantages of this method compared to other methods is that sputtering method can produce thin films with uniform thickness and composition.

It is well known that magnetic properties of thin films have been affected by several parameters such as preparation conditions, [7, 8] films fabrication methods and utilization of underlayer materials [9]. In order to obtain high density magnetic data storage it is necessary for thin films to have high coercivity and loop squareness. Therefore, understanding structural relationship with coercivity is one of the important steps in further development of high density magnetic data storage. Thin films of CoSm with high coercivity and high magnetic anisotropy have been studied by previous researchers [10]. It has been found by other researchers that depositing Co_5Sm thin film on Si (100) can lead to epitaxial growth with high coercivity values [11].

The magnetic properties of cobalt samarium thin films are determined by their microstructure. However, controlling the microstructure of growing films is difficult. There have been several attempts to improve the magnetic properties of cobalt samarium films such as using an appropriate underlayer materials, that is the layer between the substrate and magnetic layer, [9] as well as depositing the film at high substrate temperature [12-14]. Recent studies [15] reported that high coercivity can be obtained when $Co_{80}Sm_{20}$ thin films are deposited on the niobium underlayer. Several underlayer materials such as Ti, V, Cu and Cr have been used between the substrate and magnetic layer in order to control the Co alloy grain size and epitaxy [9]. They found that $Co_{85}Sm_{15}$ thin films deposited on Cr underlayer had a coercivity value of the order of 3600 Oe, which was larger than the coercivity value in the films deposited on Ti, V and Cu underlayers. In this study, we investigated the effects of zirconium underlayer thicknesses on the magnetic and structural properties of the $Co_{80}Sm_{20}$ thin film.

EXPERIMENTAL PROCEDURE

The sputtering chamber was evacuated to the pressure of $5x10^{-8}$ mbar prior to the sputtering process. The deposition was carried out at the argon pressure of $8x10^{-3}$ mbar. Zirconium underlayer with different thicknesses (40 nm to 100 nm) was deposited directly on Si (100) substrate. $Co_{80}Sm_{20}$ thin film was grown on zirconium underlayer and without zirconium underlayer. $Co_{80}Sm_{20}$ thin film was deposited from elemental target of Sm and Co. The atomic composition of the CoSm thin films was controlled by adjusting the sputtering power of Sm and Co targets. The sputtering powers of Co and Sm targets were 100W and 16W, respectively. The 15 nm overlayer of Au was deposited to protect the films from oxidation. The compositions of the CoSm thin films were

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determined using energy dispersive x-ray spectroscopy (EDX). The crystallographic structure of the films was studied by X-Ray diffractometer (XRD) and selected area electron diffraction (SAED) mode in transmission electron microscope TEM. Magnetic properties of the films were studied using alternating gradient force magnetometer (AGFM) in the applied magnetic field up to 4000 Oe.

RESULTS AND DISCUSSIONS

Structural Properties

The Structural properties of $Co_{80}Sm_{20}$ thin films deposited zirconium underlayer was studied using XRD with CuKα radiation of wavelength λ = 0.15405 nm and selected area electron diffraction (SAED) mode in Transmission Electron Microscope (TEM). Figure-1 shows the x-ray diffraction (XRD) pattern of $Co_{80}Sm_{20}$ thin films deposited on 40 nm thick zirconium underayer. It can be seen that the three clear maxima from (10.0), (00.2) and (10.1) planes of hexagonal zirconium are clearly observed. The *d*-spacing values for these lines are 0.277 nm, 0.259 nm, 0.235 nm. No crystalline diffraction peaks can be observed from any of the $Co_{80}Sm_{20}$ thin films suggesting that the crystal size of the films is too small to show well defined peaks. From these results, it can be noticed that fractions of the film may show preferred (10.0) and (00.2) orientation. It was reported by Okumura *et al*. [9] that the x-ray diffraction patterns for $Co_{85}Sm_{15}$ films deposited on Ti, V, Cu and Cr underlayers result from the underlayer materials. No crystalline diffraction peaks were observed from the $Co_{80}Sm_{20}$ film. This result is due to the lower crystalline order in the magnetic layer suggesting that the films deposited on these underlayer materials have an amorphous structure.

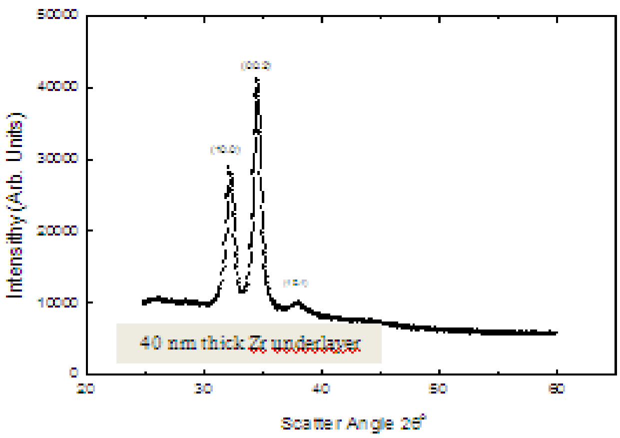


Figure-1. X-Ray Diffraction pattern for $Co_{80}Sm_{20}$ film deposited on 40 nm thick zirconium underlayer.

Figure-2 shows the electron diffraction rings of $Co_{80}Sm_{20}$ films deposited on zirconium underlayer for two different thicknesses namely 40 nm and 100 nm and deposited directly on silicon (100) substrate.

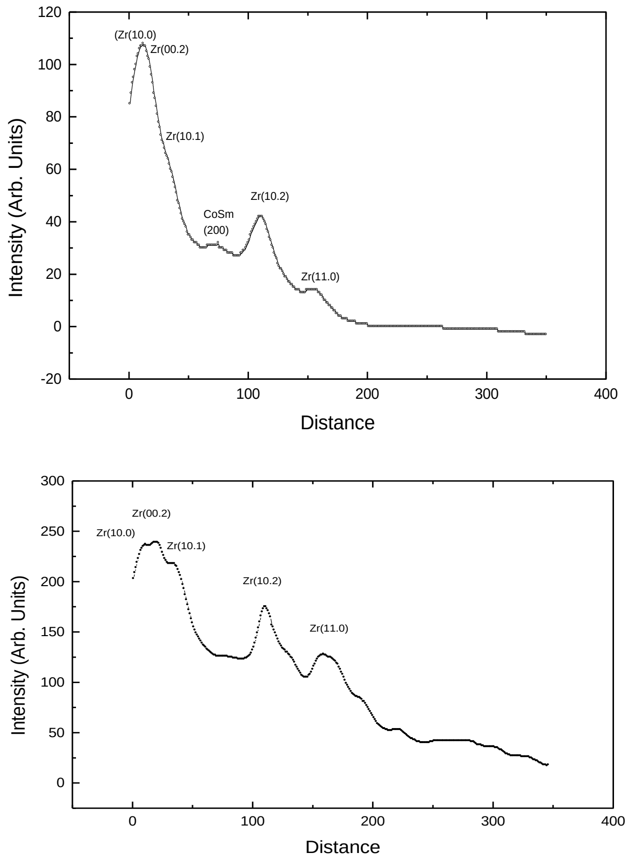


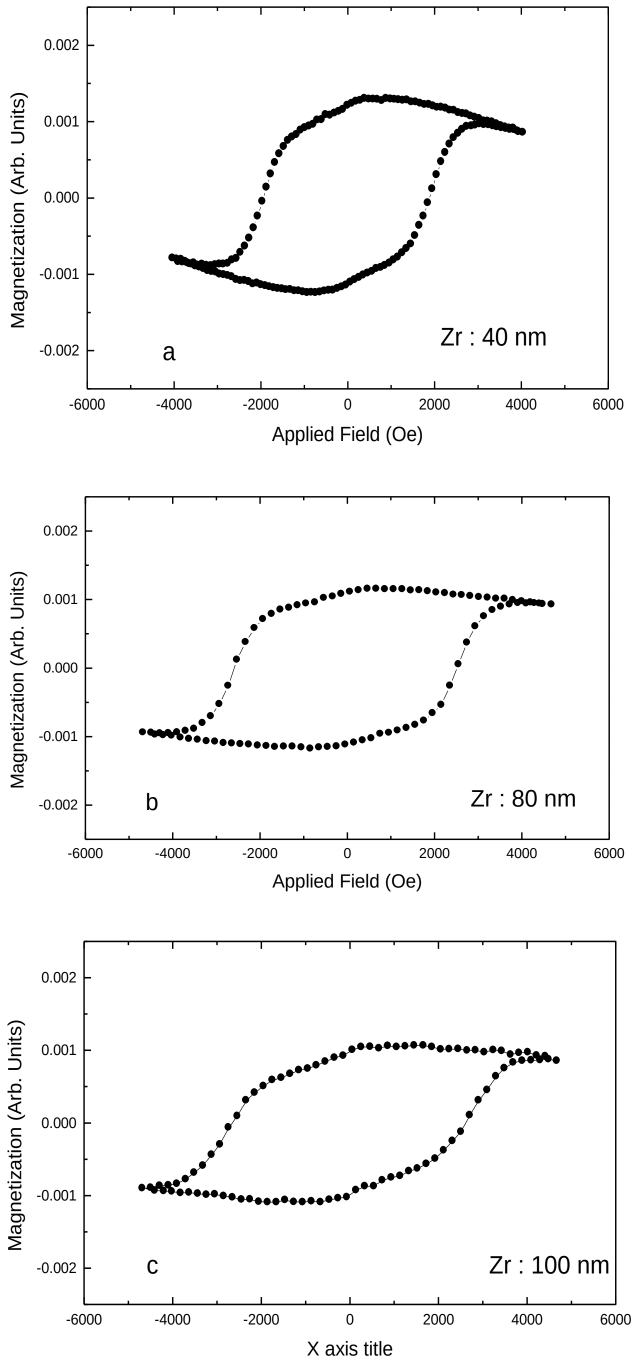
Figure-2. Selected area electron diffraction for $Co_{80}Sm_{20}$ film deposited on zirconium underlayer (a) 40 nm thick, (b) 100 nm thick and the inset pattern below shows the diffraction rings of $Co_{80}Sm_{20}$ film without zirconium underlayer.

Figure-2 shows a series of electron diffraction patterns, together with their density scans, taken from $Co_{80}Sm_{20}$ thin films deposited onto zirconium underlayer for the thickness of (a) 40 nm, (b) 100 nm and the inset pattern in Figure-2(b) shows the diffraction rings of $Co_{80}Sm_{20}$ film without zirconium underlayer. In this analysis, the negative films of the diffraction patterns were scanned using an optical scanner. The length of the density scan was chosen to be 350 (Arb. Units) for the negatives of the diffraction patterns. The horizontal axis represents the scan length. The camera length for each electron diffraction pattern was 150 cm. The incident electron beam is directed perpendicular to the films. Si (100) reflections were used as a reference scale for indexing of the films reflection rings. The electron diffraction pattern of zirconium underlayer, inset of Figure-2(a) shows an hcp structure with (00.2) preferential crystalline direction, which is agreed well with the XRD result shown in Figure-1.

The inset pattern in Figure-2(b) reveals clearly that the film is characterized by f.c.c. structure, exhibits broad halos. The first order diffraction rings in the pattern have *d*-spacing of 0.240 nm, 0.208 nm, 0.146 nm, 0.125 nm and 0.118 nm which correspond to (111), (200), (220), (311) and (222) planes respectively. In this composition the diffraction rings, especially for the first and second ring, are broader and less intense. This result suggests that the nanocrystalline film is approaching the amorphous state. The diffraction rings of the $Co_{80}Sm_{20}$ films deposited on zirconium underlayers show an hcp structure although a large fraction of the film was amorphous. Moreover, The $Co_{80}Sm_{20}$ films deposited on thinner zirconium underlayer namely 40 nm, Figure-2(a) the electron diffraction patterns show weak and diffuse rings and correspond to the hcp structure. Depositing film on thicker zirconium underlayer (100 nm) produces the electron diffraction in Figure-2(b) which shows one set of crystalline diffraction lines that is from (10.0), (00.2) and (10.1) planes of hexagonal Zr. The *d*-spacing values for these lines are 0.277 nm, 0.259 nm, 0.235 nm. No diffraction peak from $Co_{80}Sm_{20}$ thin films can be observed from this diffraction pattern. This is consistent with the XRD results which shows (10.0), (00.2) and (10.1) reflections shown in Figure-1. As discussed in other article, [9] attempts to observe the structure of the CoSm thin films with X-ray diffraction have not been successful. This is probably due to the small $Co_{80}Sm_{20}$ crystal/grain size. This result is consistent with other observation of CoSm thin films by Zhang *et al*. [16]

Magnetic Properties

Figure-3 shows the hysteresis loops for $Co_{80}Sm_{20}$ thin films deposited on (a) 40 nm, (b) 80nm (c) 100 nm zirconium underlayer thickness and (d) without zirconium underlayer. As seen, the coercivity of the film increases for more than two times compared to that for film deposited on 100 nm. However, the saturation magnetization (M_s) of the films deposited on zirconium underlayer is smaller than that for the film directly deposited on silicon (100) substrate. The decrease of the saturation magnetization might be due to the diffusion of zirconium atom from the underlayer into magnetic layer ($Co_{80}Sm_{20}$ thin film). It also can be noticed that the hysteresis loop for $Co_{80}Sm_{20}$ thin film deposited without zirconium underlayer shows higher loop squareness (*S*) of 0.94. When zirconium underlayer is introduced, the coercivity increases and therefore, the loop squareness decreases as zirconium underlayer thickness is increased. This is associated with decreasing intergranular exchange interactions. [17] It is worth noting that in this hysteresis loops, the squareness is much less then unity and contrasts strongly with that for film deposited without zirconium underlayer indicated in Figure-3(d). From Figure-3, it is clear that increasing the zirconium underlayer thickness causes the coercivity to increase. The increase of the coercivity of $Co_{80}Sm_{20}$ films deposited on thicker zirconium underlayers could be due to reduction in the exchange interaction between the grains. [17] Deposition of film on thicker zirconium underlayer namely above 100 nm reduces the coercivity value and this could be indicative that the grain size of zirconium underlayer is past the optimum. [18] The hysteresis loops of $Co_{80}Sm_{20}$ thin films deposited on zirconium underlayer exhibit a small kink in both field directions i.e., near zero field, indicating the presence of either a second soft phase or low field nucleation phenomena that initiates magnetization reversal. [19] Notice also the diamagnetic contribution to the loops from the substrate at higher applied field.



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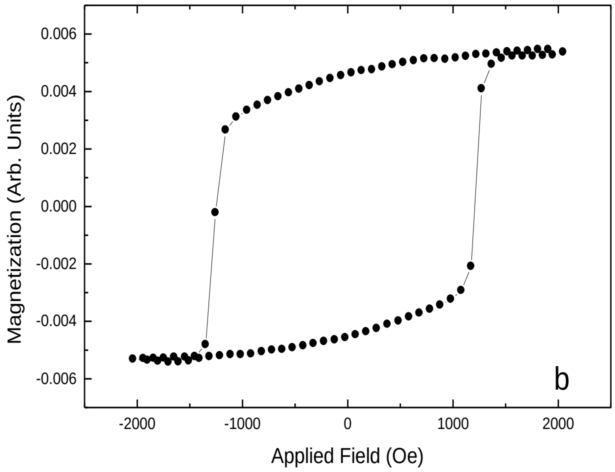

Figure-3. Hysteresis loops of $Co_{80}Sm_{20}$ films deposited (a) on 40 nm, (b) on 80 nm and (c) on100 nm zirconium underlayer and (d) without zirconium underlayer.

CONCLUSIONS

The structural and magnetic properties of $Co_{80}Sm_{20}$ thin film deposited on zirconium underlayer with different thicknesses (40, 80, and 100 nm) and without zirconium underlayer have been analyzed. This study shows that the application of the zirconium underlayer plays an important role in enhancing magnetic properties of the film. The coercivity of the film deposited on 100 nm thick zirconium underlayer increases for more than two times compared to that for film deposited without zirconium underlayer. There are three clear maxima from (10.0), (00.2) and (10.1) planes of hexagonal zirconium in electron diffraction patterns from TEM and no crystalline diffraction peaks can be observed from XRD pattern suggesting that the crystal size of the films is too small.

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