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ELECTRON DIFFRACTION STUDY OF $Co_{80}Sm_{20}$ DEPOSITED ON NIOBIUM UNDERLAYER FOR HIGHER DENSITY MAGNETIC RECORDING MEDIA

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ABSTRACT

The effects of niobium underlayer on magnetic properties of $Co_{80}Sm_{20}$ thin films deposited on silicon substrates have been studied based on electron diffraction. The films were fabricated using dc magnetron sputtering technique. Transmission electron microscope (TEM) was used to study the structural properties of the films based on selected area diffraction (SAD). The TEM study shows that the diffraction rings of film becomes less well defined for the films deposited on the thicker niobium underlayers. The coercivity of the films increases with increasing niobium thickness up to 100 nm. Further increase of the niobium thickness leads to a decrease of coercivity. The decrease of coercivity value for films deposited on thicker underlayers i.e., 120 nm indicated that the grain size of the niobium underlayer is past the optimum value. Thus the increase and decreases of the coercivity of the films with increasing niobium thickness is discussed.

Keywords: magnetic, structural properties, electron diffraction, magnetic thin films.

INTRODUCTION

Over the last decades, interest in CoSm alloys in the form of thin films has increased very significantly. This is due to high value of magneto crystalline anisotropy constant of 1.1 x 10^8 erg/cm^3 that possessed by these alloys especially with cobalt and samarium composition ratio of 5:1 [1]. Fundamental research studying various microstructure with corresponding magnetic properties have utilized thin films of cobalt samarium alloys for various applications namely high density magnetic recording media [2, 3, 4, 5], electromagnetic micro actuators [6] and microwave devices [7]. According to *Murdock et al.* [8] thin films for high-density magnetic recording media require a material consisting of small and magnetically isolated grains of about 10 nm or below. Several methods [9, 10, 11] have been reported for fabrication of thin films for high density magnetic recording media. However, thin films with controlled geometry and surface smoothness as well as composition can be prepared by the magnetron sputtering method.[12] One of the advantages of the sputtering technique compared to other techniques is that it is capable of producing thin films with uniform thickness and composition over large areas.

The magnetic properties of cobalt samarium thin films are determined by their microstructure. However, controlling the microstructure is quite difficult. Deposition of cobalt samarium films at room temperature or lower results in an alloy with an amorphous structure which has low magnetic anisotropy. [13] There have been a number of significant attempts to improve the magnetic properties of cobalt samarium films. These have included the use of appropriate underlayer materials that is the layer between the substrate and magnetic layer, [14] as well as depositing the film at high substrate temperature. [15, 16] Recently, several underlayer materials such as bcc alloys of Cr, including CrCo, [17] and CrMo, CrTi and CrV [18] have been used between the substrate and magnetic layer in order to control the Co alloy grain size and epitaxy. In this work, we investigated the effects of niobium underlayer thicknesses on the magnetic and micro structural properties of the cobalt samarium thin films.

EXPERIMENT

Thin films of $Co_{80}Sm_{20}$ deposited on niobium underlayer have been fabricated using dc magnetron sputtering technique. The atomic ratio of 5:1 for Co and Sm was obtained by adjusting the magnetron power in which cobalt and samarium magnetron power was kept constant at 100 watt and 25 watt respectively. The pressure of sputtering chamber prior to deposition process was 5 x 10^{-8} mbar, while argon gas during the film fabrication was 8x10^{-3} mbar. The thickness of niobium underlayer was varied from 20 to 120 nm. The films were protected using gold over layer. Magnetic properties were studied using alternating gradient force magnetometer (AGFM) in the applied magnetic field up to 3000 Oe. The film composition was determined using energy dispersive x-ray spectroscopy (EDX). The structural properties of the films were examined using selected area diffraction (SAD) in transmission electron microscope TEM.

RESULTS AND DISCUSSIONS

Selected area diffraction (SAD) mode in TEM has been employed to study the structural properties of $Co_{80}Sm_{20}$ deposited on niobium underlayer. Figures below show the electron diffraction of $Co_{80}Sm_{20}$ films deposited on various niobium underlayer thicknesses.

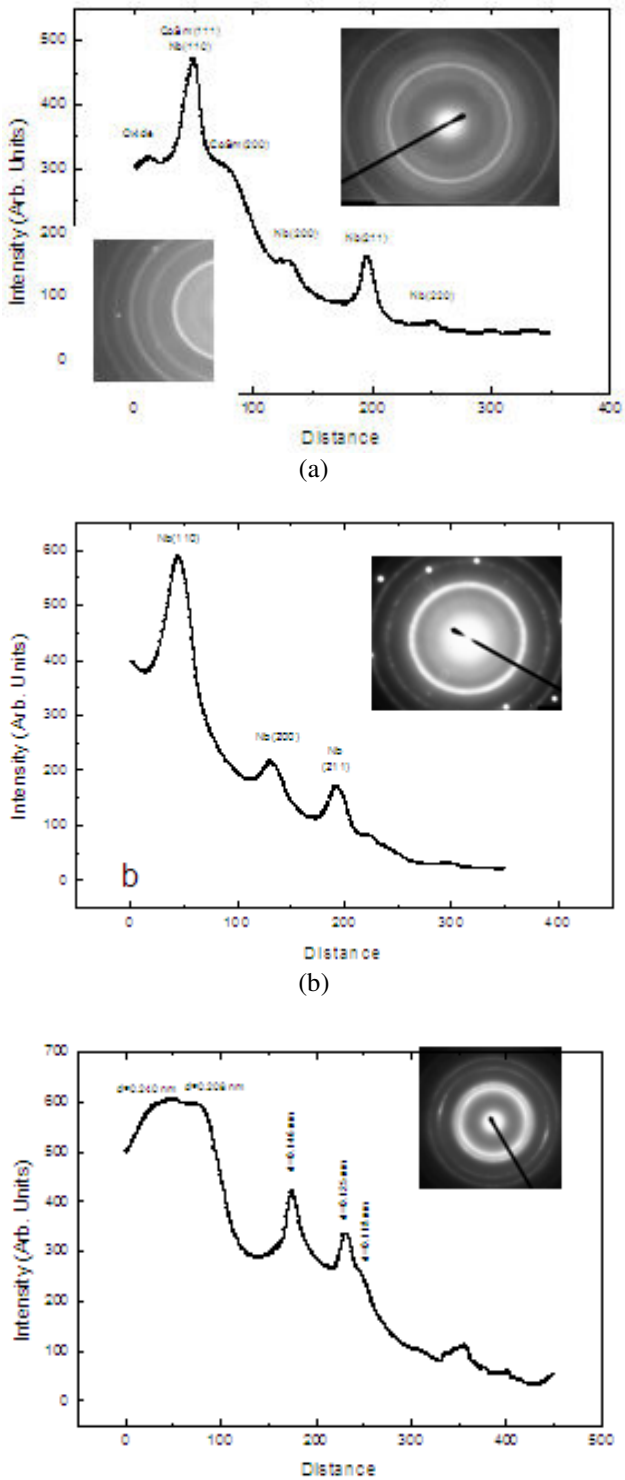


Figure-1. Selected area diffraction (SAD) for $Co_{80}Sm_{20}$ films deposited on various niobium underlayer (a) 40 nm thick, (b) 120 nm thick and (c) without niobium underlayer.

Figure-1 shows the electron diffraction patterns, together with their density scans, for $Co_{80}Sm_{20}$ deposited on niobium underlayer. In this analysis, the negatives of the diffraction patterns were scanned optically. The length of the density scan was chosen to be 350 (Arb. Units) for each negative film. The horizontal axis represents the scan length. The camera length for each electron diffraction pattern was 150 cm. It can be seen that all the $Co_{80}Sm_{20}$ films deposited on niobium underlayers can be characterized by a face centered cubic (f.c.c) structure although a large fraction of the film was amorphous.

The electron diffraction patterns for films deposited on 40 nm and 120 nm thick niobium and without niobium underlayer are shown in Figure-1 (a), (b) and (c) respectively. A niobium electron diffraction pattern is included in Figure-1(a) for comparison. An oxide peak was observed in these diffraction patterns. This is due to more reactive nature of niobium with oxygen compared to that of Cr and Zr. [19] Only a few first order reflection rings from $Co_{80}Sm_{20}$ films were observed. These electron diffraction rings were (111) and (200) and corresponding to *d*-spacings of 0.235 nm and 0.202 nm respectively, other reflections from $Co_{80}Sm_{20}$ films are virtually absent. It is noted that the (111) reflection ring from $Co_{80}Sm_{20}$ films overlaps with the reflection from (110) niobium in the underlayer. Attempts to observe the structure of the 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*. [21]

The composition of the cobalt samarium film fabricated using magnetron sputtering under the condition in which cobalt and samarium magnetron power of 100 watt and 25 watt was examined by EDX in SEM. The composition of the film is $Co_{80}Sm_{20}$ which is close to the composition of Co_5Sm. The magnetic properties especially coercivity of the films are affected significantly by the presence of the underlayer materials. The coercivity of the films increases monotonically with increasing niobium thickness up to 100 nm. Further increase of the niobium thickness leads to an apparent decrease of coercivity. The decrease of coercivity value for films deposited on 120 nm thick underlayers could be indicative that the grain size of the niobium underlayer is past the optimum. [22] In general, the enhancement of the coercivity of the films deposited on this underlayer material could be due to enhanced topography-induced isolation and increased size of the magnetic grains.

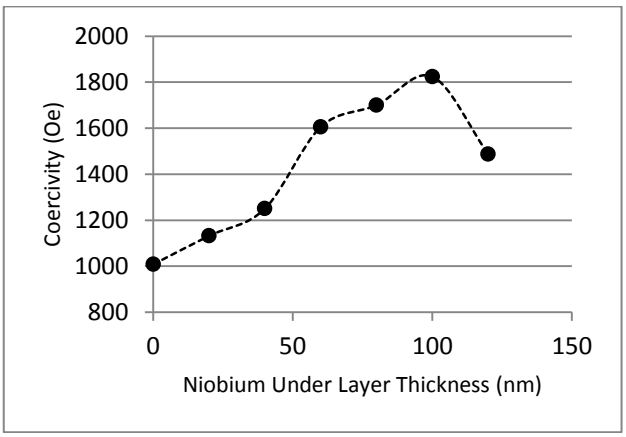
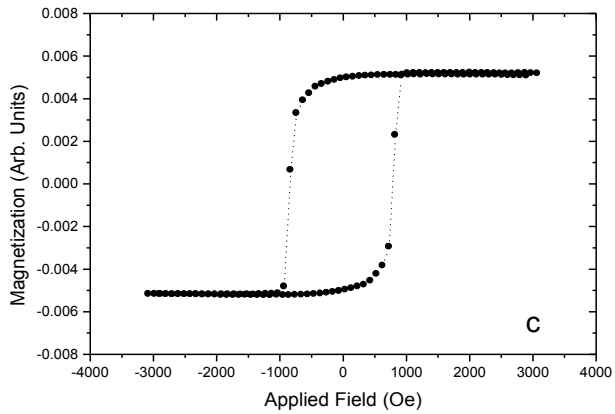


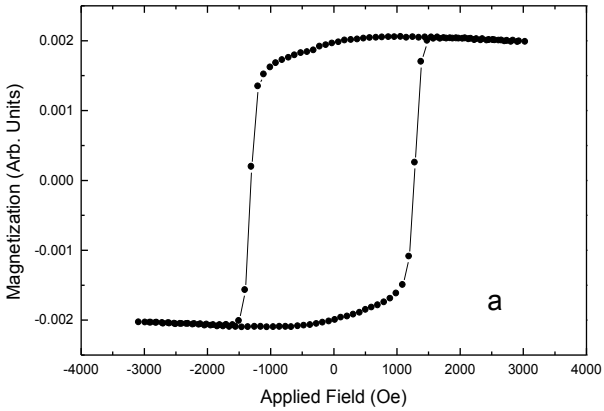
Figure-2. The coercivity values of cobalt samarium thin films deposited on various niobium underlayer thicknesses.

Figure-3 shows hysteresis loops for $Co_{80}Sm_{20}$ thin films without niobium underlayer and with niobium underlayer. It is clear that the coercivity increases and the remanence or loop squareness (M_r/M_s) of these films decreases from 0.95 to 0.90 as the underlayer thickness increases from 40 nm to 100 nm. The reason for the increase of the coercivity of $Co_{80}Sm_{20}$ films deposited on thicker niobium underlayers could be due to more separation between grains, as shown in SEM micrographs (Figure-6). The increase of the coercivity value is also indicated by a reduction of the exchange interaction between the grains, as indicated in Figure-5. The hysteresis loops for films deposited on niobium underlayer exhibit a small kink in both field directions i.e., near zero field as shown in Figure-4 (b) and (c), indicating the presence of either a second soft phase or low field nucleation phenomena that initiates magnetization reversal. [23] Notice also the diamagnetic contribution to the loops from the substrate at higher applied field. Moreover, the hysteresis loop squareness of films deposited on niobium decreases as underlayer thickness is increased. A similar result in hysteresis loop squareness is observed in ternary alloys, such as Co-Ni-Pt thin films deposited on NiP/Al substrates and on Cr underlayers [24] and attributed to a reduction of grain separation. [25]

It also can be noticed that the coercivity values of the films deposited on niobium underlayer with the thickness of 100 nm, the coercivity of the films was more than 1.5 times larger than those without underlayers. This enhancement in coercivity values could be due to the microstructure of the $Co_{80}Sm_{20}$ films, which is different for different underlayers thicknesses



(a)



(b)

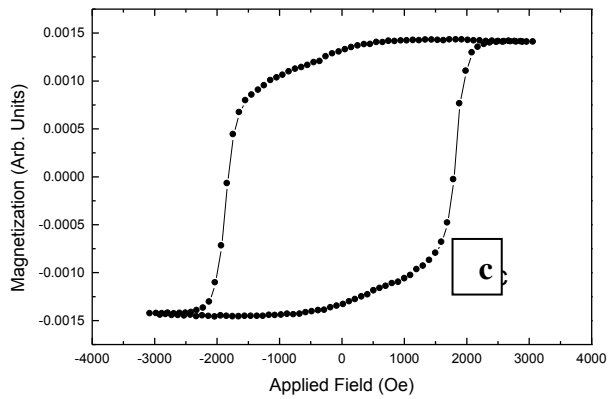


Figure-3. Hysteresis loops of $Co_{80}Sm_{20}$ thin films (a) without niobium underlayer (b) deposited on 40 nm niobium underlayer and (c) deposited on 100 nm niobium underlayer.

CONCLUSIONS

The magnetic properties were found to depend on the underlayer thickness. In general, an increase in the underlayer thickness leads to a large increase in the coercivity. Further increase of the niobium thickness leads to a decrease of the coercivity values. This could be due to the optimum size of the niobium grains. The coercivity of the films deposited on niobium underlayers was enhanced

by a factor of nearly two compared to the coercivity of films deposited directly on a Si substrate.

Only two electron diffraction rings observed, they are (111) and (200) reflection and corresponding to *d*-spacings of 0.235 nm and 0.202 nm respectively, other reflections from $Co_{80}Sm_{20}$ films are virtually absent, implying that the crystal size in the films is too small to show well defined peaks.

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