Microstructural and Magnetic Studies on Ag/Co bilayer thin film Prepared by Ion Beam Sputtering Technique

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Abstract. Bilayer nanocomposite films composed of two different metal atoms possess unique physical and chemical properties due to their nanosize and tailored structure. In the present study a magnetic (cobalt) and a nonmagnetic (silver) atom has been selected for forming the bilayer. In the earlier reports Cobalt (Co) has been used as underlayer while the silver (Ag) has been used as overlayer. In the present study, the bilayer has been designed with Ag as underlayer and Co as overlayer. Ion beam sputtering (IBS) was used to deposit 4nm layer of Ag on pre-cleaned float glass substrate. An overlayer of 10nm of Co was also deposited using IBS over the Ag layer. The bilayer film was characterized using GIXRD and MOKE. The GIXRD pattern showed peaks belonging to cobalt which indicate formation of FCC phase. Interestingly Ag peaks are also seen clearly, although Ag is the underlayer. The particle sizes of Ag and Co as evaluated by Scherrer formula are found to be 5.5nm and 4nm respectively. The magnetic property was studied by MOKE which showed presence of well-defined hysteresis loop with coercivity of about 116 Oe. The results are described in light of interaction of the two metals.

INTRODUCTION

Bilayer nanocomposite systems composed of two different metal atoms are interesting as they possess unique physical and chemical properties due to their low dimensionality and extra-periodicity whose structure can be tailored.[1-3] Among all the metals, Silver (Ag) exhibits the highest electrical and thermal conductivities. It also possesses unique optical and catalytic features. On the other hand Cobalt (Co) is known for its ferromagnetic property. Furthermore, Cobalt (Co) nanoparticles exhibit large surface and high chemical reactivity. A good synergy effect can be produced upon combination of these two metals, thus enhancing their physical-chemical properties.

There are various reports on Co, Ag bilayer systems where Co is the underlayer and Ag is the overlayer. Co and Ag are immiscible and these bilayers show interesting properties depending on the layer thickness, the method of preparation and also on the substrate. [4-7]

To the best of our knowledge, there is no report on Co-Ag bilayer system with Ag as underlayer and Co as overlayer. In the present study we have prepared Ag/Co bilayer system on float glass by ion beam sputtering (IBS) technique. The Ag layer is 4nm thick with an overlayer of 10nm of Co. The microstructure and magnetic properties of this film have been studied using GIXRD and MOKE and the results are discussed in this paper.

EXPERIMENTAL

Sample preparation

A bilayer of Ag/Co was deposited sequentially on pre-cleaned float glass substrate using ion beam sputtering technique. The system was evacuated to a base pressure of 2×10^{-6} Torr. Pure silver (99.995%) and cobalt are used as cathodic targets. Ag and Co were sputtered onto float glass substrate to produce a 4 nm layer of Ag and a 10 nm overlayer of Co.

Characterization

The structural studies of materials play a prominent role as their physical properties depend a lot on their structure. The knowledge about the structure of the material is very important to understand and predict the nature of the materials. The microcrystalline structure of nanomaterials is found to have a high influence on the structural, optical, magnetic and other properties. The structural measurements were done using Grazing incidence X-ray diffraction (GIXRD) technique with Cu-Kα radiation at a grazing incidence of 0.5°. The GIXRD measurements were performed on Bruker D8 Discover diffractometer, operated at 40KV/40mA. The GIXRD records were taken over a 2θ range of 10°- 80°.

The in-plane magnetization behavior of Ag/Co film sample was studied with the help of magneto optical Kerr effect (MOKE) where the polarized light from He-Ne laser (λ=6328Å) got reflected from the sample (Field = 1.5 kOe and frequency = 50 kHz) using M/S Evico Magnetics, Germany.

All the measurements were performed ex-situ at room temperature.

RESULTS AND DISCUSSION

GIXRD measurements

The GIXRD pattern of the sputtered Ag/Co is reproduced in Fig. 1. Five prominent peaks at 2θ = 38.37°, 44.05°, 53.19°, 64.30° and 75.83° can be observed. The peaks at 2θ = 38.37°, 64.30° and 75.83° can be attributed to (111), (220) and (311) planes of Ag (FCC) respectively. The interplanar distance (d) is calculated using Bragg's law

$$2dSin\theta = n\lambda \quad (1)$$

Where n is order of diffraction, λ is wavelength of x-rays, d is interplanar distance and θ is the Bragg's angle.

The values of interplanar spacing (d) are consistent with JCPDS record for Ag (card no. 87-0597). The crystallite size was calculated using Scherrer formula

$$L = k\lambda/\beta Cos\theta \quad (2)$$

Where L is crystallite size, k is Scherrer constant (0.9), λ is wavelength of x-rays and θ is the Bragg's angle.
The average crystallite size for Ag is calculated as 5.5 nm. The values of lattice constant a can be calculated using formula

$$a = d(h^2 + k^2 + l^2)^{1/2} \quad (3)$$

Where 'a' is lattice constant; h, k, l are the Miller indices.

The peaks at 2θ = 44.49° and 52.13° can be attributed to (111) and (200) FCC planes of Co respectively. The average particle size was estimated as 4 nm. The values of lattice constant, d-spacing dislocation density and strain are listed in Table 1. The value of lattice constant for Co matches well with the early reported values (JCPDS card no. 89-4307). It is important to mention that even though Ag was deposited prior to Co, yet there exist a distinct signature of Ag in the GIXRD pattern which is an interesting observation. There are no other peaks indicating that the Ag and Co both are present in the pure metallic form.

The origin of strain is related to lattice "misfit" that depends upon the growing condition of nanoparticles. The strain **ε** have been calculated using the following formula [8]

$$\varepsilon = \beta Cot\theta/4 \quad (4)$$

Where θ is Bragg angle; β is the Full width at half maxima.

The x-ray line profile analysis has been used to determine the intrinsic stress and dislocation density. The dislocation density (δ) in the sample has been determined by using the following expression.

$$\delta = 1/D^2 \tag{5}$$

Where, D is the size of the nanoparticle.

Table 1. Particle size, d-spacing, lattice constant, dislocation density and strain of Ag/Co thin film prepared by IBS

Element	2θ (degrees)	d-spacing(Å)		Lattice constant a(Å)		hkl	Particle size (nm)	Dislocation density (lines/m^2)	Strain
		Present study	Reported	Present study	Reported				
Ag	38.37	2.34	2.36#	4.059	4.086#	111	5.5	0.033	0.019
Co	44.15	2.05	2.05+	3.549	3.544+	111	4.0	0.061	0.022
Co	53.19	1.72	1.77+	3.440	3.544+	200			
Ag	64.30	1.45	1.44#	4.093	4.086#	220			
Ag	75.83	1.25	1.23#	4.156	4.086#	311			

 # JCPDS Card No. 87-0597
+ JCPDS Card No. 89-4307

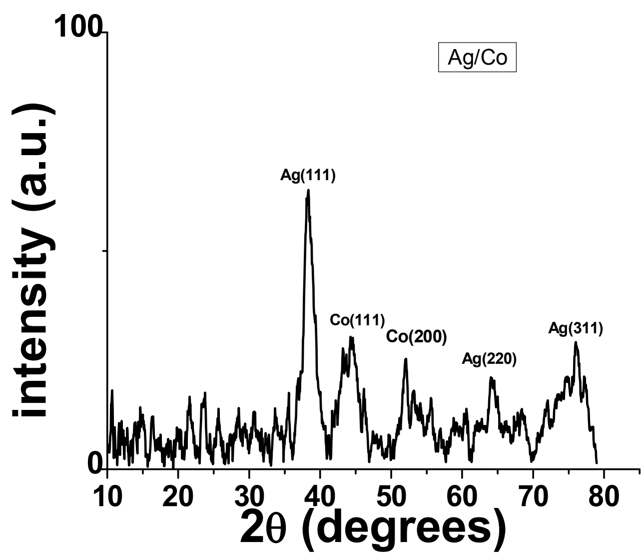

Fig. 1. GIXRD pattern of Ag/Co thin film.

3.2 MOKE measurements

The magnetic behavior of the as-deposited Ag/Co film has been investigated using magneto-optical Kerr effect (MOKE). The in-plane measurements at room temperature were made by applying the magnetic field parallel to the sample. From the record of this measurement, one can see well defined hysteresis loop Fig. 2. The value of the coercivity Hc is found to be about 116 Oe from the measurement whereas the value of saturation field Hs is found to be 378 Oe indicating soft ferromagnetic behavior.

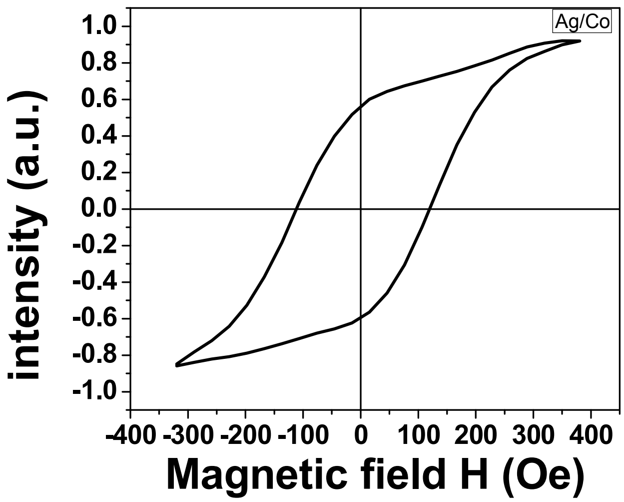

Fig. 2. Magnetization behavior of Ag/Co film as recorded using MOKE.

CONCLUSION

Ag/Co bilayer nanocomposite has been prepared using ion beam sputtering technique. Microstructural properties of the deposited Ag/Co nanocomposite system are studied using GIXRD technique which shows fcc phase for both Ag and Co metals. The values of lattice constant for Ag and Co are found to be 4.06 Å and 3.55 Å respectively. MOKE measurements show the soft magnetic behavior of the film. The ion beam sputtering technique is simple, cost effective and time effective technique for producing good quality Ag/Co film as confirmed by GIXRD and MOKE study.

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