Structural and Magnetic Study af Ion Beam Sputtered Iron Thin Film on Polyvinyl Alcohol

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Abstract. Poly vinyl alcohol (PVA) is a versatile polymer which can act as a good host material with good film forming ability and is bio friendly. In this paper PVA film has been used as matrix for depositing Fe nanoparticles to obtain light weight and flexible polymer-metal nanocomposite film with magnetic properties. PVA was deposited on float glass substrate by solution casting method. Ion Beam sputtering method (IBS) was used to sputter Iron (Fe) onto PVA to obtain Fe Deposition with nominal thickness of 30 nm. The nanocomposite film was characterized using Grazing Incident X-ray Diffraction (GIXRD) and magneto-optical Kerr effect (MOKE). In the GIXRD pattern, the prominent peak at 19.6° confirms the presence of PVA crystalline peak. The desirable BCC phase responsible for the magnetic property was detected even in the iron/polymer film. The particle size of Fe nanoparticles is found to be about 6.24 nm. MOKE pattern shows well defined hysteresis loop with coercivety of the order of 20.76 Oe indicating soft ferromagnetic property of the nanocomposite film.

1. INTRODUCTION

Iron (Fe) is one of the most useful magnetic material. The magnetic properties of iron have made it a popular choice for use in magnetic recording material system. This is now a major force behind the development of nanoscale iron but the greatest weakness of the iron is its reactivity with oxygen and water, this weakness is greatly multiplied with the decreases of the size of nanoparticles (NPs). One solution to this problem is to embed the Fe NPs in polymer matrix, Incorporation of magnetic atoms in suitable polymer matrix likely to make it magnetic material. There are very few reports on metal NPs embedded in polymer. Suzuki and Lisfi[1-2] reported study on Co NPs embedded in PI (polyamide) and PET (Polyethylene Terephthalate). studies on Co embedded in PVA has been reported by our group earlier[3-5] which shows that PVA protects Cobalt (Co) from oxidation and the nanocomposite shows good magnetic property.The versatility and dependability of polyvinyl alcohol (PVA) polymer is established from the fact that they have attractive properties like lightweight, good mechanical and optical properties. Polyvinyl alcohol is also considered to be a good host material where dopants can modify its physiochemical properties. The PVA films can be peeled off to form self-standing films. To the best of our knowledge , there is no report of iron deposited on PVA films by IBS technique.in the present paper, Fe has been sputtered onto PVA by Ion Beam sputtering technique .The prepared films have been characterized by Grazing Incident X-ray Diffraction (GIXRD) and magneto-optical Kerr effect (MOKE) and the results are discussed.

2. EXPERIMENTAL DETAILS:

Fe thin films have been deposited by Ion beam sputtering technique (IBS) onto PVA coated glass. PVA (Mol. Wt. 72 kDa, E. Merk, Germany) was dissolved in double distilled water at 60 °C with continuous stirring on a magnetic stirrer. After obtaining required viscosity, film of PVA was deposited by solution casting method on precleaned Float glass. A 30 nm layer of Fe nanoparticles was deposited in PVA film by ion beam sputtering method using Kaufman gun maintaining a base vacuum of ~2×10^{-6} Torr. The deposition rate was 27.1 Å/min.

Structural properties have been studied by means of the Grazing incident X-ray diffraction (GIXRD). The GIXRD pattern for the films was recorded using Siemens D-5000 diffractometer using Cu Kα radiation of 1.54Å at grazing incidence of α =0.5° .The magnetic properties of the films were measured with Magneto-Optic Kerr effect (MOKE) (M/s Evico magnetics, Germany). Domain structure and the hysteresis loops were recorded simultaneously using magneto-optical Kerr microscope. All measurements were done at room temperature.

3. RESULTS AND DISCUSSION:

3.1. GIXRD

Figure 1 represents the GIXRD pattern of PVA/Fe film. Figure shows well-defined peaks For the PVA/Fe sample first peak observed at 2θ = 19.66° can be attributed to the (100) plane of PVA the corresponding interplanar distance was evaluated using Bragg's law given in equation (1) and is found to be 4.52 Å which agrees well with the reported value[6] and the broad peak appeared at 2θ= 40.85° also belongs to PVA.

$$n\lambda = 2d\sin\theta \quad \text{---------- (1)}$$

Where n is the order of diffraction, λ is the wavelength of incident X-ray, d is the interplanar distance, θ is the Bragg angle. The peak found at 2θ= 44.47° can be attributed to the (110) plane of Fe in BCC (body centered cubic) Phase. The interplanar distances d were determined by Bragg's equation (1) and found to be 2.02 Å which matched well with the earlier reported value (JCPDS Card No.87-0721) No other peak is observed indicating that there is no oxide formation of these metal nanoparticle and Fe is present in its metallic state inside PVA. The lattice constant was estimated using the formula given in equation (2) and found to be 2.87 [6].

$$d = \frac{a}{(\sqrt{h^2 + k^2 + l^2})} \quad \text{---------- (2)}$$

Where a= lattice constant and h, k, l are miller indices

The observed interplanar distance and lattice constant matched well with the reported value in JCPDS Card No.87- 0721.

The particle size was estimated through Scherrer formula given below

$$D=0.9\lambda/B\cos\theta \quad \text{---------- (3)}$$

Where λ is the wavelength of x-ray used, B is the full width at half maximum (FWHM), θ is the Bragg angle. The particle size of the Fe nanoparticles is found to be 6.24 nm.

3.2 MOKE Microscopy

The magnetic measurement of the prepared PVA/Fe film was carried out using MOKE microscopy technique at room temperature. In plane measurements were taken by applying magnetic field parallel to the samples. From the record of this measurement, one can see well defined hysteresis loop (Figure 2a). The value of the coercively (H_c) is found to be 20.76 Oe, The value of saturation field ($H_{s)}$ is found to be 60.30 Oe indicating soft ferromagnetic property with squareness ratio around 0.97. The earlier work reported on Fe deposited on glass by IBS technique[7] shows Hc value of 2.5 to 5 Oe for Fe layer thickness of 300-350nm. Hence one can see that PVA is a good substrate and host, which is conducive for the growth of Fe nanoparticles resulting in better magnetic property. Figure 2b

shows the magnetic domain structure at room temperature. The sample was photographed under Kerr-effect microscope. It can be seen that PVA has facilitated growth of Fe NPs, which shows good magnetic property.

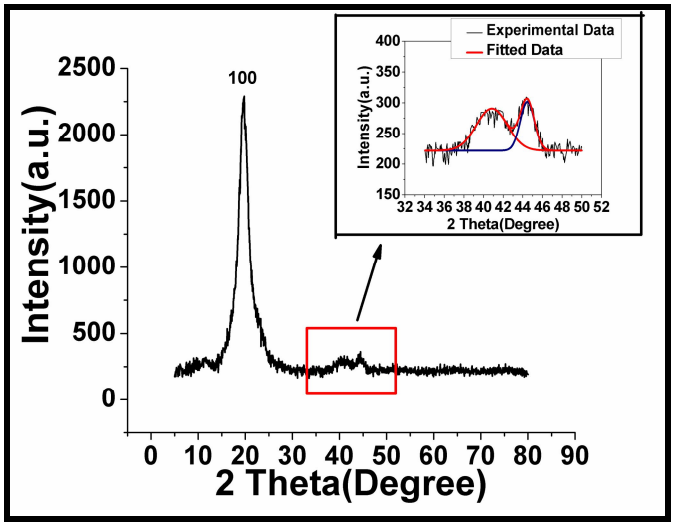

FIGURE 1. GIXRD pattern of Fe deposited on PVA where t_{Fe}= 30 nm. The inset shows close look at Fe peak and smaller PVA peak

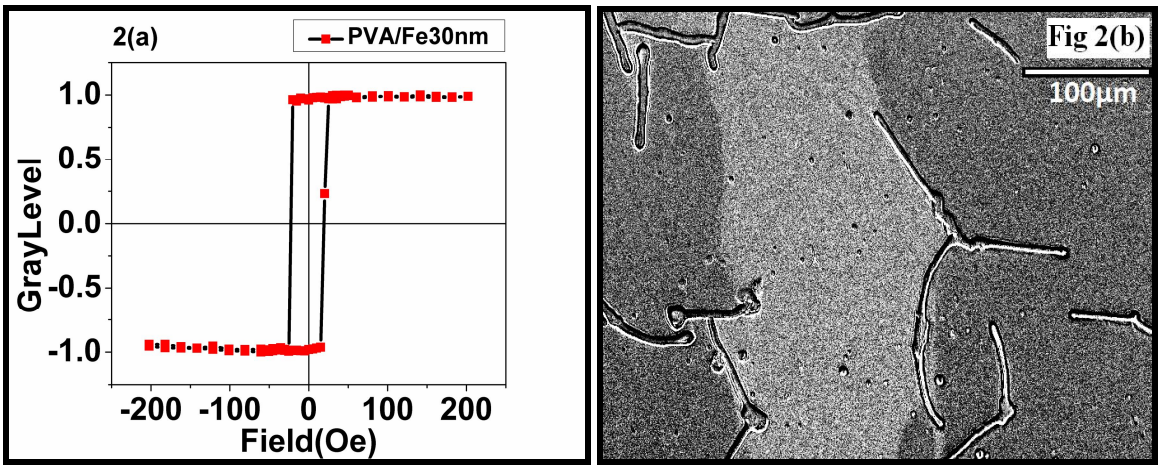

FIGURE2.2 (a) Magnetization behavior of PVA/Fe30nm as recorded using MOKE 2(b) domain evolution along the easy magnetization axes i.e., 0°

4. CONCLUSION

Iron films on polyvinyl alcohol have been deposited by IBS technique and their structure and magnetic properties have been studied. It was found that the magnetic behaviour and structural studies are in good agreement. Our results show that Ion Beam Sputtering can be a good method to produce high-quality magnetic Fe/polymer nanocomposite film and PVA is a good host for Fe NPs.

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