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Influence of sputtering pressure on the structure, giant magnetoresistance in Ni substituted Fe-Cu granular films

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1. Introduction

Granular thin films are nanocrystalline magnetic grains embedded in an immiscible nonmagnetic metallic matrix or an insulator exhibiting giant magnetoresistance (GMR) have attracted researchers due to their interesting fundamental properties and potential applications in magnetic sensors and read heads [1, 2]. We have studied the effect of Ni substitution on the magnetoresistive properties of Fe-Cu system for two sputtering pressures 5 and 20 x 10^{-3} mbar. Since Ni is miscible to both Fe and Cu lattices, the formation of Fe-Ni and Cu-Ni intermixed alloy is possible. In this paper, we present the structural and magnetoresistive properties of Fe-Cu-Ni granular films sputtered at two different sputtering pressures. This research work is in the continuation of our interest to investigate various granular films [3, 4].

2. Experimental

Fe-Cu-Ni granular films were deposited by dc magnetron sputtering onto glass substrates at the sputtering pressures of Ar, p_{Ar} = 5 and 20×10^{-3} mbar. Seven series of samples were prepared at both the sputtering pressures. The targets were of 75 mm diameter and they consisted of semicircular split-targets of one half FeNi and other half Cu as described by Barnard *et al.* [5]. The method of preparation and the parameters used for all the characterizations are reported elsewhere [3].

3. Results

The concentrations of the Fe, Cu and Ni in the Fe-Cu-Ni films deposited at a sputtering pressures of 5 and 20×10^{-3} mbar of Ar can be shown either by ternary diagram or concentration versus substrate position in linear array. The atomic concentration of Ni (Fe) increases (decreases) as we go from series 1 to series 7. The atomic concentration of Cu lies between 40 to 80 % for all series of samples.

XRD measurements carried out on the samples in the angular range 2Θ = 20- 120º reveal only one peak from the (111) planes of the Cu grains, for each sample. The absence of Fe peak in Fe-Cu system have also been reported [6]. Separate Ni peaks can not be detected because Ni dissolves either in Fe or Cu lattice.

The systematic shift of the d-spacing d_{111} (hereafter d_{111}^{Cu}) determined from the Cu(111) peaks towards smaller d-spacings when we go from series 1 to series 7.

The MR curve for each series shows a maximum around a certain composition for series 1 to 6, for both the sputtering pressures. The concentration value corresponding to the position of the maximum shifts gradually when we go from series 1 to 6. It is interesting to see that the maxima were obtained for almost same concentration 60% of Cu. The maximum value of MR for each series remains almost between 0.8 to1.3%, and 0.5 to ~2.0 % respectively for 20 and 5 x 10^{-3} mbar, indicating that the MR has not been significantly affected by large substitution of Ni.

4. Discussion

The systematic increase (decrease) in the concentration of Ni (Fe) as we go from series 1 to series 7, indicates the systematic Ni substitution in Fe-Cu granular system. The concentration range of ~ 20-25 at. % for Cu in a particular series shows maxima in that interval.

The d_{111}^{Cu} decreases with increasing Fe whereas it decreases with decreasing Cu, for series 1. Such a decrease in the d_{111}^{Cu} is due to the partial mixing of Fe atoms in the Cu lattice. In our samples, we expect that the Ni atoms occupy both the Fe and Cu lattices, the systematic shift is due to the presence of Ni in the Cu grains thereby forming CuNi alloy grains. For CuNi alloy, it is known that the lattice parameter decreases almost linearly with increasing Ni content following Vegard's law [7]. Therefore, the variation in d_{111}^{Cu} observed by us can be assumed to signify the amount of dissolved Ni atoms in the Cu lattice. We also notice that the d_{111}^{Cu} versus Fe shift systematically towards smaller d values even though Fe concentration decreases as we go from series 1 to series 6. If Fe atoms occupy Cu lattice, the d_{111}^{Cu} is expected to show an increasing tendency towards its bul value when Fe desreases. The opposite trend supports that the shift in the d_{111}^{Cu} is mainly due to the presence of Ni in the Cu lattice.

The peak values for series 1 agree well with that reported for the Fe_xCu_{1-x}system by various authors [8-10]. The peak value of MR for samples sputtered at 5 x 10^{-3} mbar is higher as compared to the samples sputtered at 20 x 10^{-3} mbar due to the role of residual gas impurities in the films that decreases with decreasing sputtering pressure. The peak value of MR remains almost between 1.5% and 2% (0.8 to 1.3 %) for sputtering pressure 5 x 10^{-3} (20 x 10^{-3} mbar) indicating that the MR in this case as well has not been significantly affected by the large substitution of Ni.

5. Conclusion

The variation of d_{111}^{Cu} indicates that the Ni atoms dissolve in the Cu grains of the Fe - Cu - Ni system. Furthermore, the structure of these films does not depend on the sputtering pressure. The peak values of MR observed for series 1 to series 5 is larger for the samples sputtered at 5 x 10^{-3} mbar. Interestingly, the peak values of MR have not been significantly affected by the large amount of Ni impurities in the Cu lattice.

6. Reference

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