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A Study on Magnetic Properties of Fe-Ni-N monolayer and Fe-Ni-N/Cu multilayers Films

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1. Introduction

Iron nitrides have received much attention by virtue of the excellent magnetic properties in combination with significantly improved corrosion and wear resistance over pure iron. It has been found that the chemical stability and the mechanical ductility of the Fe_4N compound can be improved by the substitution of Ni[1]. The investigation of thermal expansion and force magnetostriction of Fe3NiN showed similarities with the Fe-Ni Invar alloys. In this paper, Fe-Ni-N films with soft magnetic properties and a new series of Fe-Ni-N/Cu multilayers were prepared on Si(111) substrates by DC magnetron sputtering method. The effects of nitrogen on the structure and magnetic properties of Fe-Ni-N films and the interlayer exchange coupling on the multilayers been investigated.

2. Experiment

DC magnetron sputtering system was used in sample fabrication, together with a hybrid target consisting of Ni chips placed on a 99.9 % Fe disc covering 9.9 % of the disc surface. The size of deposit plane is approximately 8 mm in diameter on a Si(111) of square-type of 10 x 10 mm. The sputtering was carried out at an Ar and N2 gas pressure of 2mTorr and DC Power of 50 W. The substrate temperature was held at approximately 240 °C throughout the experiment. The deposition rate was approximately 4 and 6 nm/min for FeNiN and Cu, respectively. The crystal structure was investigated by using an X-ray diffraction with *Cu-Kα* radiation in θ-2θ geometry. The film composition deduced from Energy Dispersive X-ray Spectrometer. Magnetic properties were measured by vibration sample magnetometer in maximum magnetic field of 100G at room temperature. The spin waves were studied by Brillouin light scattering (BLS) and SQUID.

3. Result and Discussion

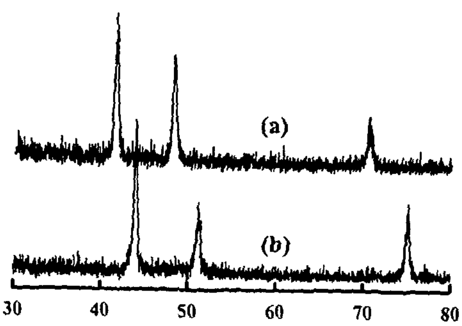

Fig. 1 XRD patterns: (a) Fe-Ni-N deposited on Cu buffer layer and (b) Fe-Ni deposited on Si(111) at T= 240°C.

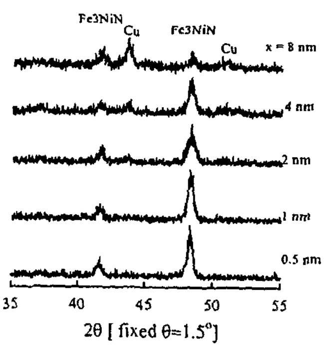

Fig. 2. Variation of XRD patterns of multilayered films for films with various tcu. Multilayered films were composed of 12[Fe-Ni-N(5 nm)/Cu(x nm)] bilayers.

The crystal structure of the films obtained was confirmed by XRD. Figure 1 gives the XRD patterns for the Fe-Ni-N(a) and Fe-Ni(b) film obtained at 60 nm thicknesses and performs using a glancing angle x-ray diffractometer. The results of XRD show that the films have a crystal structure of fcc without any other crystal phase, which is in good agreement with the value of JCPDS card. Fig. 2 shows the variation of standard θ-2θ XRD patterns of multilayered films with various tcu. These patterns implied that the preferential orientation of crystallites in Fe-Ni-N and Cu layers were so sensitive to t_{cu}<4 nm for t_{FeNiN} of 5 nm. It seemed that the (100) orientation of Fe-Ni-N and Cu crystallites were enhanced at t_{cu}<4 nm. The enhancement of the (100) preferential orientation seemed to follow certain periodicity.

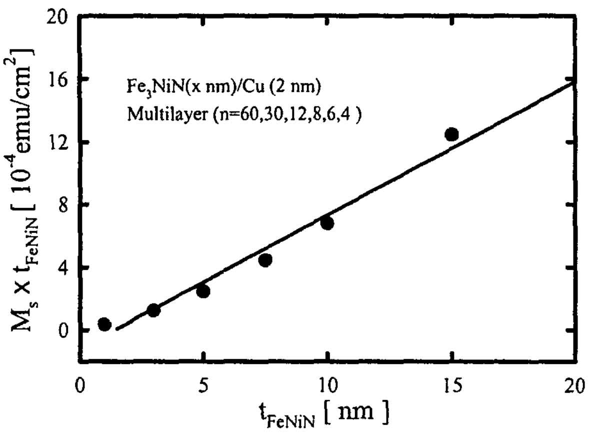

Fig. 3. The variation of the product $M_s \times t_{FeNiN}$ as a function of thickness t at T=300K.

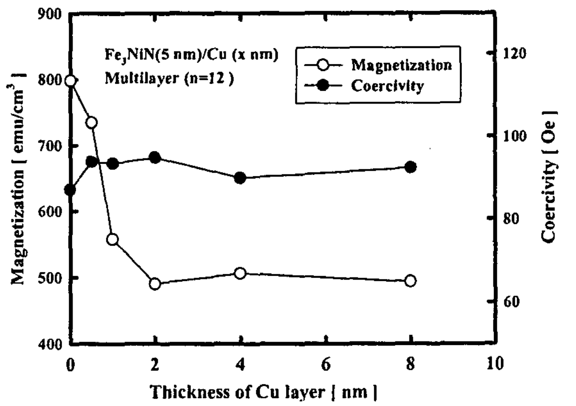

Fig. 4 The magnetization and coercivity per Fe-Ni-N volume of 12[Fe-Ni-N(5 nm)/Cu(x nm)] bilayers as a function of Cu layer thickness at room temperature.

As shown in Fig. 3, the magnetization is found to decrease with the decreasing FeNiN layer thickness. This indicates that we have a non- or weak-moment magnetic alloy at interface. It is known from the dead layer model that, the magnetization M of multilayers can be written as follows[2]: $M = M(0)(1 - 2\delta / t_{FeNi})$, where M(0) is bulk value of FeNiN and δ the dead layer thickness. From linear fits to data we find M(0) = 850 emu/cm^3 which is close to the bulk FeNiN magnetization and the dead layer thickness δ = 0.7 nm. The origin of this dead layer can be explained on the basis of the local environment effect on FeNiN. This also shows that there is no apparent moment on the Cu atom. In Fig. 4, the dependence of the magnetization on Cu layer thickness t_{cu} at T=300K of FeNiN/Cu multilayered films with a FeNiN layer thickness of 5 nm is displayed. It is seem that M decreases rapidly with increase of t_{cu} for t_{cu} up to 2 nm, and keeps approximately unchanged when t_{cu} >2 nm. Generally, this behavior of magnetization has been attributed to the formation of interdiffusion near the interface, which leads to a reduction of magnetic moment[3].

4. Conclusions

In conclusion, we have studied the magnetic properties of Fe-Ni-N/Cu multilayered films in detail, and observed: (1) The (100) orientation of Fe-Ni-N and Cu crystallites in the multilayered films were enhanced at t_{cu}<4 nm. (2) Magnetization decreases rapidly with increase of Cu layer thickness when t_{cu}<2 nm. (3) The Fe-Ni-N layer thickness dependence of magnetization suggests three atomic layer of Fe-Ni-N at interfaces to be nonmagnetic.

5. Acknowledgments

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6. References

[1] S. K. chen, S. Jin, T. H. Tiefel, F. Hsieh, E. M. Gyorgy, and D. W. Johnson, Jr., J. Appl. Phys. **70**, 6247(1991).
[2] L. Driouch, R. Krishnan, M. Porte, K. V. Reo, and M. Tessier, J. Appl. Phys. **81**, 4745(1997).
[3] Chubing Peng, Yang Cao, and Daosheng Dai, J. Appl. Phys. **71**, 3457(1992).