Structure and magnetic properties of thermally annealed (Ni80Fe20)1-XMnX

Y. Oh, K.K Kim, C. -S. Yoo, C.S. Yoon, C. K. Kim[1]

[1]*Hanyang University, Department of Materials Science and Engineering, Seoul, Korea*

Introduction and Experimental Procedure

Granular ferromagnets consist of nanometer-sized ferromagnetic grains embedded in a non-magnetic maxtrix. Granular ferromagnets have been extensively studied due to their giant magnetoresistance which was reported in different granular metal alloys including Co-Cu,Co-Ag, Fe-Ag, NiFe-Ag.1 Bulk NiFe and Mn are miscible2 and Mn was readily accommodated in the NiFe lattice in the annealed multilayer thin film stack.3 In this research, we showed that the sputtered NiFe-Mn thin films, however, formed a metastable fcc solid solution which dissociated into NiFe and Mn upon annealing. The annealed film exhibited an inverse magnetoresistance.

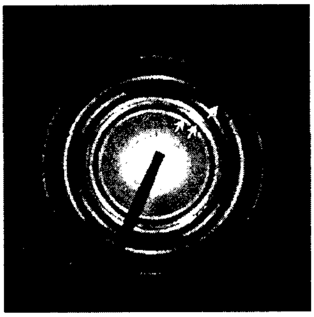
150 ~200-Å-thick (Ni80Fe20)1-xMnx thin films with $0.05 < x < 0.6$ were deposited using dc magnetron sputtering at room temperature on 10-Å-thick Ta underlayer to prevent the silicide formation during annealing. To obtain different Mn compositions, a number of Mn chips (Aldrich, 99.98%) were placed on the NiFe sputtering target in a mosaic pattern. Thin films were annealed at 400°C under vacuum (10-5 torr) for 3 hours.

Results and Conclusion

The changes in the saturation magnetization, *Ms*, before and after annealing the (Ni80Fe20)1-xMnx thin films are summarized below.With increasing Mn content, the saturation magnetization, *Ms* continuously decreased. The trend is in agreement with the bulk Ni-Fe-Mn alloy with similar composition, whose *Ms* dropped with addition of Mn.2 Upon annealing, the (Ni80Fe20)1-xMnx films regained their magnetization. In fact, the change for the films with $x > 0.3$ was quite dramatic as the films which appeared to be antiferromagnetic prior to annealing changed to being ferromagnetic after annealing at 40 0℃. It is also observed that above x ~0.3, the *Ms* for the annealed fims appeared to plateau. The result suggests, after annealing at 400℃, a phase separation of the alloy film itno Mn and NiFe phases. Transmission electron microscopy (TEM) showed no evidence for other phases.

The electron diffraction pattern from the as-deposited film showed that the fcc lattice of the permalloy was well maintained even at high Mn contents although NiFe(111) and Mn(330) peaks were broadened due to the small grain size and strains arising possible inhomogeneous alloying. The electron diffraction pattern from the $(Ni_{80}Fe_{20})_{0.7}Mn_{0.3}$ film annealed at 400℃ (Mn peaks indicated by arrows) is shown below. Phase separation of Mn can be clearly seen as peaks corresponding to α-Mn were observed. As the Mn content increased, a strong crystallographic texture began develop in the annealed thin films as evidenced by discontinuous rings in the diffraction pattern. The texture development could be attributed to the volume expansion and subsequent development of strain in the thin film arising from the phase separation. Bright field TEM images of the annealed films suggested that the phase separation also suppressed the coaresening of the grains so that grain size of the $(Ni_{80}Fe_{20})_{0.5}Mn_{0.5}$ was suppressed below 10 nm even after annealing at 400℃ for 3 hours.

The phase separated structure of the thin film resembled the granular magnetic alloy and exhibited an inverse magnetoresistance ratio of 0.5 % at low fields as shown on the left. In spite of the predicted phase stability, the annealed $(Ni_{80}Fe_{20})_{1-x}Mn_x$ alloy film separated into a discontinuos granular structure when annealed above 400℃, exhibiting a inverse magnetoresistance behavior.



References

[1] A.E. Berkowitz, J. R. Mitchell, M.J. Carey, et al, Phys. Rev. Lett. **68**, 4593 (1997); A. Tsoukatos, H. Wan, G.C. Hadjipanayis, K.M. Unruh, Z.G. Li, J. Appl. Phys. **73**, 5509 (1993); J.S. Jiang, J.Q. Xiao, C. L. Chien, Appl. Phys. Lett. **61**, 2362 (1992); M. Kitada, K. Yamamoto, N. Shimizu, J. Magn. Magn. Mater. **124**, 243 (1993).

[2] R. M. Bozorth, *Ferromagnetism* (D. Van Nostrand Co. Inc., Princeton, NJ, 1963), p.180.

[3] J. B. Youssef, D. Spenato, H. L. Gall, J. Ostoréro, J. Appl. Phys. **91**, 7239 (2002).