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Correlation between Giant Magnetoresistance and Magnetization in Fe-Ag-Ni films with Log-normal Distribution of Nanoparticles

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1. Introduction

Magnetic granular systems composed by nanometer sized particles of a magnetic metal (Fe, Ni, Co and their alloy) dispersed in a non-magnetic metallic matrix (Ag, Au, Cu) are attractive because of their unique electronic and magnetic transport properties [1, 2]. It is known that the GMR effect in granular films originates from the spin dependent scattering of conduction electrons at the interfaces between the ferromagnetic granules and the nonmagnetic matrix as well as within the ferromagnetic granules, and has a close relationship with granule size. The granules with different sizes can display different magnetic property under applied fields, giving rise to different effects on the spin-dependent scattering related to GMR effect [3-5]. In this article, we present the correlation between the magnetoresistance and magnetization by taking account of lognormal distribution of ferromagnetic entities in ternary granular system $Fe_xAg_yNi_z$.

2. Experimental

The $Fe_xAg_yNi_z$ granular films were grown on glass substrates by a dc magnetron sputtering at sputtering pressure, P_{Ar}= 1 x 10^{-3} mbar. The target were of 75 mm diameter and they consisted of semicircular split-targets. This method of preparation is the same as described by us in the previous articles [6]. The samples exhibiting the maximum value of giant magnetoresistance in each series are taken for our study. The parameter of all the characterizations on these samples are also reported elsewhere [6]. Magnetization measurement with magnetic field parallel to the film plane were carried out using Quantum Design's Physical Properties Measurement System.

3. Results

Magnetic hysteresis curve and magnetoresistance were measured at room temperature foreach sample. The magnetic field was in the plane of the sample. The magnetization and magnetoresistance curves do not saturate even at 20 kOe. The remanence, coercivity are nearly zero and the small area of the measured loop and slow approach to saturation, indicating the occurrence of superparamagnetic phase. The non-saturation behavior is characteristics of a superparamagnetic phase. This kind of non-saturation behavior is reported by various authors [7, 8].

4. Discussion

To evaluate the size of the magnetic particles and to understand the correlation of the magnetization and magnetoresistance, Langevin equation was used to fit the magnetization and magnetoresistance curves measured at temperatures above the blocking temperatures.

The curve fitting parameters were chosen assuming spherical particle shapes with negligible interactions between them. We used log normal distribution, since single and two particle fitting did not fit to the magnetization and magnetoresistance curves in our sputtered $Fe_xAg_yNi_z$ films.

(1) $M = M_S \sum_{i=1}^{25} f(D_i)\left[\coth(x_i) - \left(\frac{1}{x_i}\right)\right]$, (2) $\frac{\Delta R}{R} = C\sum_{i=1}^{25}\left(\frac{2r_o}{D_i}\right)^n f(D_i)L^2(x_i)$

Where $f(D_i) = \frac{1}{\sqrt{2\pi}D_i \ln\sigma}\exp\left[-\frac{(\ln(D_i/D_0))^2}{2(\ln\sigma)^2}\right]$ is the log-normal distribution function and $x_i = \frac{\mu\left[\frac{4\pi}{3}\left(\frac{D}{2}\right)^3\right]H}{kT}$.

M_S is the saturation magnetization of the magnetic grains, D_i is the diameter of the ith magnetic particle, $f(D_i)$ the weighting factor representing the population of the ith magnetic particle with the diameter D_i, the saturation magnetization in bulk form for the same composition of the magnetic entities, H the applied magnetic field, k Boltzmann constant and T the temperature. For computations, we have taken the summation over twenty five particles for convenience such that $\sum_{i=1}^{25} f(D_i) = 1$. We have used the constant interval of 5 Å while the particle diameters. The MS is fitting parameter, D_0 is the average particle diameter and $\sigma$the standard deviation from the average diameter in the particle distribution. A good agreement between experiment and simulation was observed when fitted with lognormal distribution. We have also compare the deviations from the well established correlation $-A(M/M_S)^2$.

5. Conclusion

The correlation between magnetization and magnetoresistance was establish assuming the log-normal distribution of superparamagnetic ferromagnetic entities. The average diameters calculated from the log-normal distribution were between 3 to 6 nm and their standard deviation between 0.1 to 0.2 nm for our sputtered Fe-Ag-Ni films.The value of $n > 1$, indicates that there is a certain degree of magnetic bulk scattering in addition to the spin dependent scattering at the interface. This analysis clearly indicates that the magnetic properties depend on the microstructure of the film.

6. References

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