Magnetic intergranular interaction in nanocomposite $\text{Co}_\chi\text{Pt}_{100-\chi}:\text{C}$ thin films

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Magnetic intergranular interaction in nanocomposite Co$_x$Pt$_{100-x}$:C thin films

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Magnetization reversal and intergranular interactions have been studied in composite Co$_x$Pt$_{100-x}$:C thin films using several magnetic characterization techniques. The intergranular interactions, as determined by $\Delta M$ curves, were strongly dependent on the ratio of Co and Pt concentration. For films with high Co content, the intergranular exchange coupling was predominant, while dipolar interactions were exhibited in the film with the equiatomic concentration of Co and Pt. Magnetic intergranular interaction was directly observed using magnetic force microscopy. There is a strong correlation between the value of $\Delta M$ and magnetic correlation length obtained from the magnetic domain images. © 2002 American Institute of Physics. [DOI: 10.1063/1.1453353]

The areal density in magnetic recording has been increasing from 40% to 60% per year due to the introduction of the magnetoresistive head, and recently, has been increasing driven to 100% per year by introduction of giant magnetoresistive media. The areal density in magnetic recording has been increasing from 40% to 60% per year due to the introduction of the magnetoresistive head, and recently, has been increasing driven to 100% per year by introduction of giant magnetoresistive media. The areal density in magnetic recording has been increasing from 40% to 60% per year due to the introduction of the magnetoresistive head, and recently, has been increasing driven to 100% per year by introduction of giant magnetoresistive media.

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The magnetic properties of two samples are shown in Table I. Sample 1 is equiatomic concentration of Co and Pt and sample 2 has a higher Co concentration. $H_{cr}$ and $H_{cr'}$ are the remanence coercivity obtained from the dc demagnetization (DCD) curve and isothermal remanent magnetization (IRM), respectively. IFF is the interaction field factor. Hysteresis loops for those two samples are shown in Fig. 1. The different shape of the hysteresis suggests that the two samples have different magnetization reversal mechanisms. For sample 2, a squarer loop with a higher saturation squareness $S$, and coercive squareness $S^*$ suggests that grains are exchange coupled and magnetization reversal is realized through reversed domains. For sample 1, the round hysteresis loop indicates less intergranular exchange coupling for this sample. Reduced exchange coupling could be expected to result in the formation of smaller domains. In this case the magnetic grains may be reversed individually and a more rounded hysteresis loop is exhibited.

Two types of remanence curves, the IRM and the DCD, provide information about the irreversible magnetization changes which have taken place. Figure 2 shows the IRM and DCD curves for those two samples. From those DCD and IRM curves, two remanence coercivities $H_{cr}$ and $H_{cr'}$ can be determined. For sample 1, the value of $H_{cr}$ is smaller than that of $H_{cr'}$ while for sample 2 the value of $H_{cr}$ is larger than that of $H_{cr'}$. Corradi and Wohlfarth described the interaction field factor defined by $\text{IFF} = (H_{cr} - H_{cr'})/H_{c}$, where $H_{c}$ is coercive field obtained from the $M$ vs $H$ hysteresis loop. As shown in Table I, the value of IFF is negative 0.017 for Co$_{50}$Pt$_{50}$:C films and the value of IFF is positive 0.031 for Co$_{57}$Pt$_{43}$:C films. Although it is not clear how the magnitude of IFF is related to the intergranular coupling strength, the difference of sign indicates that the nature of the coupling is changed. According to O’Grady et al., the granular interactions could be described by the differential of the IRM and DCD curves. The IRM differential, $\chi_{ir} (H)$, is related to the energy barrier distribution of the pinning sites. Because the IRM curve measures from a demagnetization state, existing domains are increased in size by the usual domain-wall movement process. The DCD differential susceptibility,
The process starts with the material already saturated, measures the energy barrier to domain nucleation in the first instance, and then examines the mechanism by which reversal proceeds. For a system without interaction, the relation of \( x_{irr}^i(H) \) and \( x_{irr}^d(H) \) should be \( 2x_{irr}^i(H) \approx x_{irr}^d(H) \). The \( x_{irr}^d(H) \) and \( x_{irr}^i(H) \) curves for Co:50 Pt:50 and Co:57 Pt:43 films are shown in Fig. 3. The dotted lines in Fig. 3 show the \( 2x_{irr}^i(H) \). Our data show that the energy barrier distribution narrows and is shifted to a lower field for the Co:57 Pt:43 film. Because the shape of the SFD is governed by intergranular exchange or dipolar coupling, these results suggest that the grains in the Co:57 Pt:43 film are more exchange coupled, while grains in the Co:50 Pt:50 film have weak interactions.

\( \Delta M \) curve measurement is a common method to directly obtain the information about magnetic intergranular interactions in recording media. Large-scale numerical micromagnetic models have confirmed the interpretation of the \( \Delta M \) plot, where a positive value of the curve indicates intergranular exchange coupling and a negative \( \Delta M \) profile indicates dipolar interaction. Figure 4 shows \( \Delta M \) curves for those two samples. It is seen that the \( \Delta M \) plot shows both the positive and the negative peaks for the Co:57 Pt:43 film. This suggests that interactions are complex due to the presence of intergranular exchange coupling. However, the higher positive peak implies that intergranular exchange coupling is predominant for this sample. For Co:50 Pt:50, the negative peak indicates that only a small amount of dipolar interactions are present, which is a characteristic of isolated single-domain particles.

MFM images have been used to analyze the magnetization reversal and recording bit patterns. Here, we use MFM images to observe the exchange coupling strength directly.
Granular coupling ($\Delta M$) and coupling length measured from MFM.

In summary, we have shown that the intergranular interactions in nanocomposite CoPt:C films are strongly dependent on the film composition. The nature of granular interactions can be controlled by adjusting the Co concentration. MFM images have been shown to clearly correlate with intergranular interactions, which demonstrates a new way to directly observe exchange coupling.

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