Effect of Evaporative Deposition Angle on Anisotropy in Co-MgF2 Nanocomposite Soft Magnetic Materials

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EFFECT OF EVAPORATIVE DEPOSITION ANGLE ON ANISOTROPY IN Co-MgF_2 NANOCOMPOSITE SOFT MAGNETIC MATIERIALS

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Granular metal-nonmetal nanocomposite materials can exhibit excellent soft magnetic properties. Particularly notable is their high resistivity of hundreds of micro-ohm centimeters which, when combined with strong anisotropy, allows them to maintain permeability up to very high frequencies (sometimes over 1 GHz). High resistivity also allows extremely low loss in lower frequency applications such as power converters, even if a large film thickness of several microns or more is used. Space limits preclude including in this digest references to the large body of excellent recent work on these materials.

Most soft granual metal-nonmetal materials are deposited by reactive sputtering or by sputtering a composite target. Anisotropy is usually induced by applying a magnetic field during depositon. Evaporative deposition can also be used. For example, co-evaporating Co and MgF_2 has been used to produce similar materials [1]. This alternative could allow increasing the thickness of the film, because of reduced stress and high deposition rates; thicker films are particularly attractive for applications to integrated high-frequency power converters.

In this paper we report strong anisotropy found in films deposited by co-evaporation of Co and MgF_2 with no magnetic field applied during deposition. Anisotropy is important for both RF and power applications: to raise the ferromagnetic resonance frequency in RF applications, and to ensure very low coercivity in the hard-axis direction for low losses in power applications.

Fig. 1(a) shows two *M-H* loops measured in perpendicular directions on the same sample, deposited without a magnetic field applied during deposition. The directions of the hard and easy axes consistently appear in the same orientation relative to the configuration of the deposition apparatus, as shown in Fig. 1(b). In the plane of the film, the axis parallel to the line between the two sources exhibits hard-axis behavior while the axis perpendicular to that exhibits easy-axis behavior. This magnetic anisotropy is believed to result from shape anisotropy of the 3 to 5 nm Co particles in these granular films. It represents a practical application of the shape-anisotropy behavior observed in co-evaporated Co-Cu films in [2]. TEM (transmission electron microscopy) does not show uniform particle shapes and alignment, but anisotropy can be visually confirmed by comparing the two images in Fig. 2, which are the same image, but rotated 90 degrees. To quantitatively assess the anisotropy visible in TEM images, image data has also been examined by fast fourier transform (FFT) analysis, which confirms indicates a small difference in the two axes. Resistivity measurements in two perpendicular axes also show slight anisotropy, consistent with the hypothesis that Co particle shape causes the magnetic anisotropy.

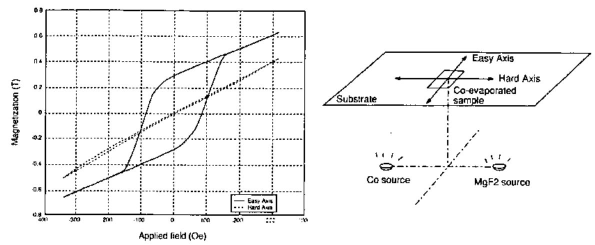

Fig. 1. (a) (left) Easy-axis and hard-axis *M-H* loops of a film deposited with no magnetic field applied. The anisotropy is found to be determined by the angles of evaporative deposition, as shown in (b)(right).

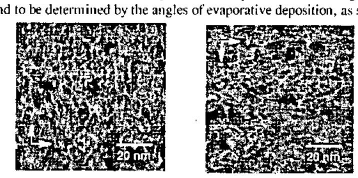

Fig. 2. TEM image of an Co-MgF_2 sample deposited with no magnetic field applied. The image is presented twice; once rotated by 90 degrees. The anisotropy can be seen by comparing the two images.

The shape effect is stronger than the effect of an applied field during deposition. A field perpendicular to the long axis of the Co particles typically cannot override the shape anisotropy, but a field applied in the parallel direction enhances magnetic anisotropy and can result in low coercivity along the hard axis of Co-MgF2 granular thin films.

Further investigations of the relationship between the shape anisotropy and the incident angle of Co flux, to be included in the full paper, are used to develop a suggested geometry to maximize the induced anisotropy.

Partial List of References

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