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Influence of Microstructure on the Magnetic Properties of Co Alloy Thin Films for 100 Gbit/in^2 Longitudinal Recording

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The microstructure of magnetic thin films for longitudinal recording dictates the ultimate data storage density of the media. Grain size distribution is perhaps the most important parameter since smaller grains produce sharper transitions between data bits. However, thermal stability is a critical issue for high data density with the minimum stable grain size determined by the super-paramagnetic limit. The ratio of the switching energy over the thermal energy, K_uV/kT, should be greater than 60 to maintain stability [1]. The term, K_uV, is the product of the uniaxial anisotropy energy density and the switching volume. For magnetically isolated columnar grains, V equals the grain area times the film thickness. In sputtered Co media with relatively large Cr content (16-22 at%), segregation of Cr to grain boundaries breaks the magnetic exchange between grains and depletion of Cr increases the magnetocrystalline anisotropy of the grain interiors (a factor of 2 increase in K_u with a 7 at% decrease in Cr) [2]. This current study is part of the National Storage Industry Consortium (NSIC) 100 Gbit/in^2 Program. Samples of the NSIC reference media were characterized using energy-filtered transmission electron microscopy (EFTEM) for grain size and Cr distribution. These results have been used in micro-magnetic models for thermal stability and magnetic exchange in order to understand the ultimate data-density limits for longitudinal recording.

Magnetic thin films of $Co_{71}Cr_{17}Pt_8Ta_2Nb_2$ were D.C. magnetron sputtered onto NiP plated Al substrates with 60 nm of NiAl and 7.5 nm of CrMo as a seed-layer. Samples with magnetic layer thicknesses ranging from 15 to 30 nm were characterized for grain size and Cr distribution. Plan view samples for EFTEM were prepared by back-thinning with the final ion milling produced by a single gun at 4 keV and 12°. The EFTEM was performed using a 300 kV Philips CM30, with a LaB_6 cathode and a Gatan Image Filter (GIF) [3]. Grain size measurements were made by using Cr elemental maps to expose the Cr-enriched grain boundaries. Quantification of the Cr grain boundary profiles utilized intensity-ratio images where the Cr map was divided by the Co map to minimize the effects of diffraction contrast, sample thickness variation, and illumination differences. The quantitative analysis is simplified by experimental observations from x-ray energy-dispersive spectroscopy, that the Nb, Ta and Pt atoms have a homogeneous distribution [3].

FIG. 1 shows Cr/Co intensity-ratio images from the 30 nm and 15 nm thick films. An advantage of using the Cr grain boundary segregation for grain size measurements is that only grains with significant magnetic isolation are considered in the grain size distribution. FIG. 2 presents the intrinsic coercivity and the average grain area as a function of magnetic layer thickness. As the film thickness decreased, the average and median grain size also decreased. The 22-nm-thick sample exhibited the maximum coercivity, while coercivity was reduced in the thinnest samples owing to thermal instabilities from smaller switching volumes. The intensity-ratio image in FIG. 1b was used for quantitative Cr distribution analysis from the 15-nm-thick sample. Although the CrMo underlayer is evident in the thicker part of the foil (bottom-left corner), ion milling from the backside has isolated the magnetic layer near the edge of the sample for even the thinnest magnetic layer. A t/λ ratio of 0.1 in the area of FIG. 1b indicates that the actual TEM foil thickness, t, was only ~10 nm since the mean free path for inelastic scattering, λ, is ~100 nm for Co alloys. Independent of magnetic layer thickness, EFTEM analysis of Cr grain boundary segregation revealed Cr levels of 20-33 at% with an average of 24 at %. Intragranular Cr levels, which ranged from 11-16 at% were not related to grain size. However, the intragranular Cr content did correlate with adjacent intergranular Cr segregation, i.e., grain boundaries with greater Cr levels produced larger intragranular Cr depletion.

References

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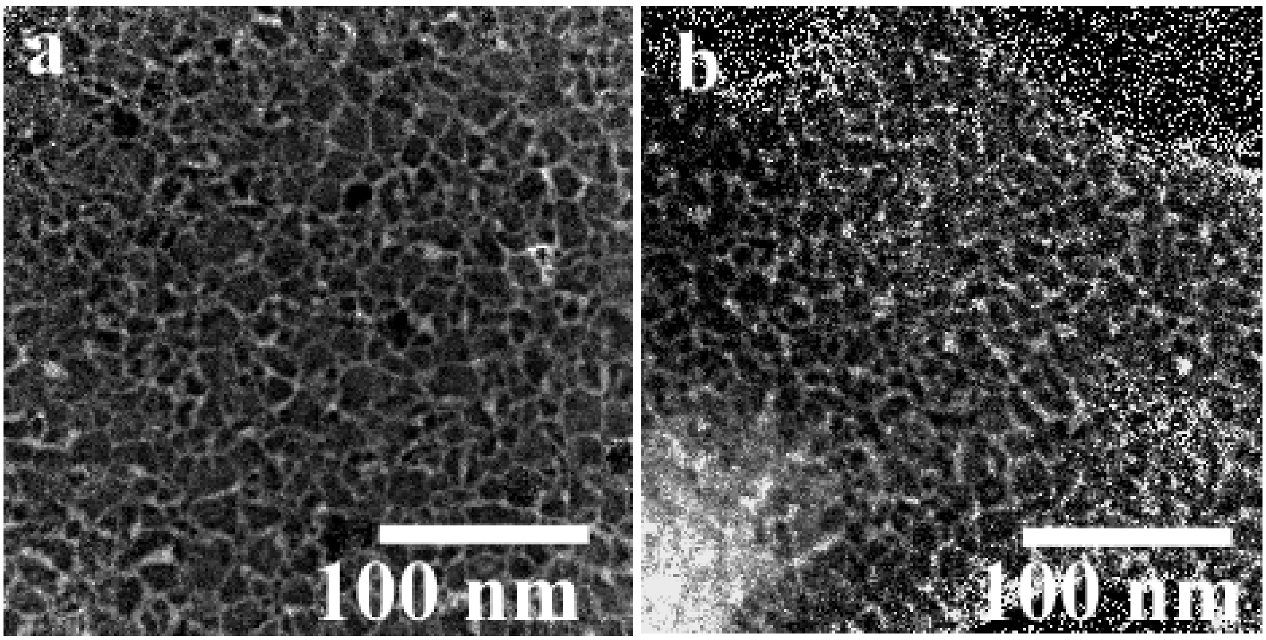
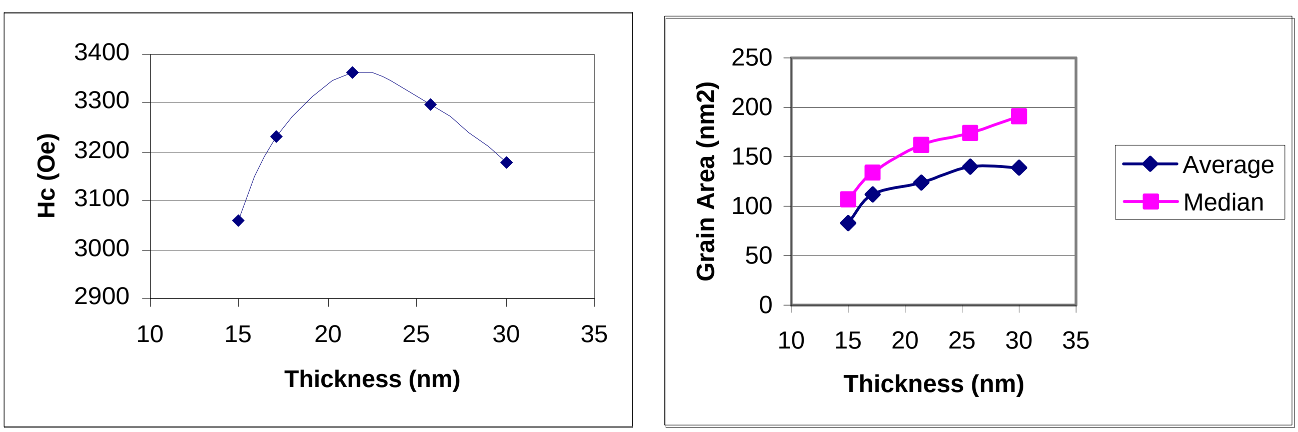


FIG. 1. Dividing the Cr map by the Co map produced the EFTEM intensity-ratio images for grain size measurements and quantitative Cr composition data from (a) the 30-nm-thick film and (b) the 15-nm-thick film.



a **b**

FIG. 2. (a) Intrinsic coercivity versus thickness for the five magnetic layers. (b) The average and median grain area decreased as the magnetic layer thickness decreased.

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