Effect of target processing on CoCrPtTa thin-film media

S.D. Harkness IV,[a] and W. Lewis[b]
Intevac VSD, Santa Clara, California 94054

M. Bartholomeusz and M. Tsai
Heraeus MTD, Chandler, Arizona 85226

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The ensuing paper summarizes an investigation on the effect of target microstructural morphology on resultant sputter deposited media magnetic performance. Significant differences in media magnetic coercivity were obtained from Co–Cr–Pt–Ta targets possessing the same chemistry, sputtered under identical conditions, but possessing different microstructural phase and crystallographic texture characteristics. This result was most likely caused by the difference in sputter yields for the Ta-containing phases in the two distinct target microstructures. Results support enhanced chromium segregation yielding a decrease in the intergranuler exchange energy field for the deposited thin films.

I. INTRODUCTION

Magnetron sputter processing has long been the dominant technique for recording media production based in terms of film quality and cost effectiveness. In pursuit of improved recording performance, scientists have sought to understand the role of process environment on typical magnetic thin film structures. While many reports have revealed important effects of vacuum level and microcontamination,[1,2] the role of sputter target microstructure has been largely ignored. Over the past several years, empirical observations by the authors have revealed that the microstructure and processing of target materials can noticeably impact the properties of resultant thin-film media. The multitude of interrelated factors involved in the physical vapor deposition (PVD) formation of media storage devices renders decoupling the target/media property and process effects rather complex. These factors include the following: (i) the dependence of atomic ejection on target material phase(s) packing density and crystallography; (ii) the relatively small mean free path of ejected atoms compared with the deposition distance at current operative pressures; (iii) the prevalence of complex shaped target erosion grooves; (iv) the relative geometries of the magnetron, target, and media system. The manifestation and magnitude of the target/media effects can vary considerably on the basis of the application, sputter process tool, and alloy set utilized.

CoCrPt(Ta,B,Nb,W,X) alloys are thermodynamically constrained to exhibit complex multiphasic microstructures depending on the specific composition. In bulk form, the Co matrix is allotropic and exhibits both FCC and HCP crystallographies. Other phases formed via the addition of elements such as Ta, B, Nb, and W are more complex with significantly reduced packing densities. Crystallite grain sizes of the various phases can vary from submicron to several hundred microns. Depending on the target material-processing route selected, a variety of crystallographic textures, different for the different phases, can be obtained. Therefore, for a given composition, distinct material processing routes can promote profound microstructural and property differences in the resultant target product. This paper describes a brief systematic study on revealing possible effects of target material microstructure and processing on subsequent media performance and properties for CoCrPtTa alloys.

II. EXPERIMENT

Media samples were produced using an Intevac MDP 250-B magnetron-sputtering tool. Simple CoCrPtTa/CrV bilayers on NiP/Al substrates with circumferential mechanical texture ($R_a \sim 2$ nm) were formed with appropriate CrV composition for lattice matching.[3] This was done in an effort to eliminate all mitigating effects on media performance other than the associated magnetics of the investigated materials. The process was optimized for bicrystal media,[4] and x-ray diffraction confirmed the crystallite texture to be (11.0)//(200). Magnetic and electrical data was collected with a vibrating-sample magnetometer (VSM) and Guzik 1701MP spinstand, respectively. Microstructural analysis was conducted with a scanning electron microscope fitted with backscattered electron imaging (SEM-BEI), and composi-

[a]Present address: Seagate RMO, Fremont, CA 94538.
[b]Present address: Hambrecht & Quist, San Francisco, CA 94107.

tional analysis was performed using a combination of Rutherford backscatter (RBS) and particle-induced x-ray emission (PIXE) techniques.

To assess and understand the effect of target microstructural morphology on media performance, two distinctly different fabrication routes were used in the manufacture of the CoCrPtTa targets. The first fabrication route employed, conventional in the data storage target industry, yielded a target microstructure consisting of an orthorhombic CoCrTa second-phase discontinuously dispersed in a CoCrPtTa matrix phase. Figure 1 shows a SEM-BEI image of the conventionally fabricated target microstructure depicting the presence of a CoCrTa phase distributed in the CoCrPtTa matrix. The matrix phase is allotropic possessing both FCC and HCP grains. The second fabrication route employed (referred to by the trade name SCP) yielded targets with a significantly refined grain size, a more dominant close packed texture, and a higher packing density Ta-containing phase compared to the conventionally fabricated target microstructure. Both sets of targets, conventional and SCP, had exactly the same bulk chemical composition and magnetic permeability to neutralize any compounding effects of target chemistry and erosion profile geometry in the present study. More details on the microstructure and properties of the SCP processed targets will be discussed in a subsequent paper.

III. RESULTS AND DISCUSSION

It is hypothesized that the processing applied to the SCP targets promotes more uniform atomic deposition of Ta atoms from the target to the substrate, resulting in an increase in chromium segregation, via tantalum enrichment in the sputter-deposited film. To support this claim, RBS data for media manufactured using both conventional and SCP CoCrPtTa targets are presented. Table I contains a summary of the compositional data and clearly demonstrates a measurable and significant increase in Pt + Ta concentration in the films manufactured using SCP target product. It is intractable to separate Pt from Ta confidently in these measurements, but the SCP process does not alter the Pt distribution in the target microstructure and would, therefore, not be expected to yield a significantly different Pt level in the film. The Ta enrichment is most likely a result of the difference in sputter yields for Ta between the two different target microstructures evaluated. Three main microstructural distinctions render more elementally sputtered Ta in the case of the SCP targets: (i) a more refined grain and phase morphology; (ii) dominance of a close packed crystallographic texture with respect to the target sputter surface; (iii) a higher concentration of Ta residing in a close-packed phase.

Remnant magnetic coercive force (Hcr) versus remnant magnetization times film thickness (Mrt) curves generated for both target types using identical sublayer processes are shown in Fig. 2. An increase of nearly 200 Oe in coercivity is demonstrated for the SCP samples relative to the conventional samples at 0.4 memu/cm^2. Furthermore, the peak Hc is also seen to shift to lower Mrt values by 0.15 to 0.20 memu/cm^2. The coercivity squareness, s^*, is observed to fall from an average of 0.80 for the conventional samples to 0.75 for the SCP samples. This is the first indication of a change in intergranuler exchange field due to the fact that as magneti-

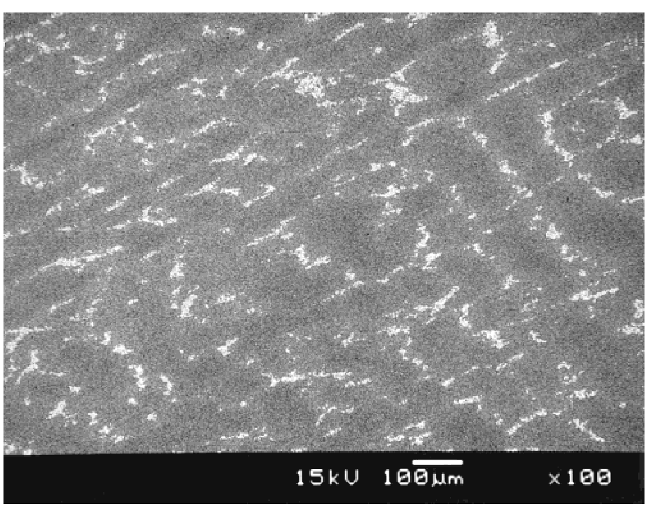

FIG. 1. Microstructure of conventionally fabricated CoCrPtTa target product.

TABLE I. RBS data on media manufactured using conventional and SCP targets.

Material process	Co	Cr (at. %)	Pt (at. %)	Ta (at. %)	Ta/Pt (at. %)	Ta + Pt (at./cm^3 × 10^{16})
Conventional	78.5	14	3.7	3.8	1.03	1.23 (±0.04)
SCP	77.7	14	3.6	4.7	1.30	1.50 (±0.05)

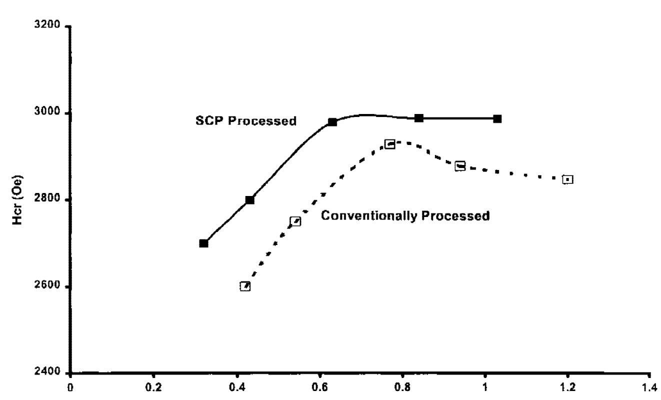

FIG. 2. Hc versus Mrt comparison for magnetic layers fabricated on 18-nm CrV sublayers.

zation reversal reverts from domain wall motion to a Stoner–Wolfarth switching mechanism,[5] the coercivity squareness approaches two-thirds (from one) for two-dimensional random thin films. The magnetization for both films is measured to be approximately 410 emu/cm^3. Mechanical dilution of Ms is expected on the basis of the Ta enrichment; however, it has been noted in the past that Ta promotes enhancement in the segregation of Cr to the grain boundaries.[6] The mechanical dilution balance would then be maintained, and the resultant increase in Cr at the grain boundaries would facilitate exchange decoupling. An alternative hypothesis to explain the magnetic data heretofore would be larger grain size. Provided the grains were sufficiently decoupled and of appropriate crystallographic texture, the coercivity would increase with the increasing domain size and the coercivity peak position would shift to lower Mrt values as fewer grains would be below the super paramagnetic limit.

The magnetic data collected above are compared to electrical performance in attempt to separate effects of grain coarsening from exchange decoupling. Figures 3 and 4 contain parametric plots for signal-to-medium-noise-ratio (SMNR) and pulse width at half-maximum (PW50), respectively, for both samples groups. Both parameters are plotted as a function of the transition parameter (estimated by Mrt/Hcr in nanometers) in order to normalize simple magnetic effects on medium noise properties. A slight enhancement in SMNR is observed for the SCP samples and is attributed to improved transition sharpness. The results (SMNR and PW50) reinforce the hypothesis of improved intergranuler exchange field decoupling and not on grain refinement. Smaller grains would indeed decrease noise, but the coercive force would be expected to go down if there were no corresponding change in the intergranuler exchange field. The SMNR relation below is a conversion of transition jitter[7] and is one of many available models in the literature:

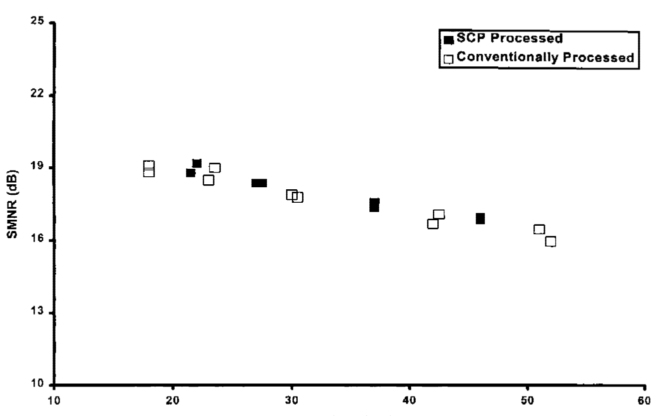

FIG. 3. Effect of material processing on sputter-deposited media SMNR.

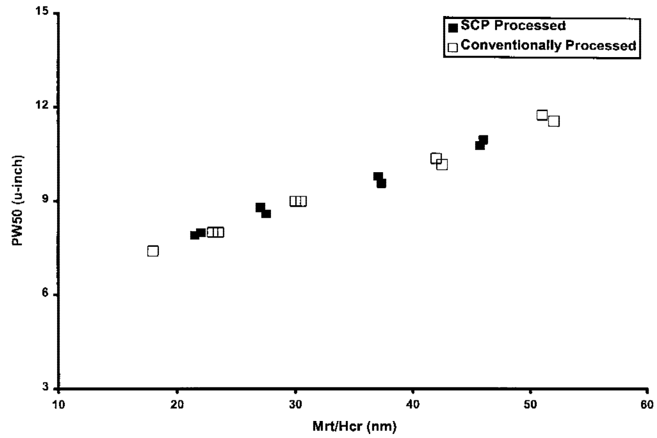

FIG. 4. Effect of material processing on sputter-deposited media PW50.

$$\mathrm{SMNR} = (\pi 5/2)(U^{1.5})(B/\sigma_x)\exp(-U\pi/4) \quad , \quad (1)$$

where $U = (\mathrm{PW50/B})$ is the channel density, B is the transition spacing, and σ_x is the down track magnetization variance. The parameter σ_x demonstrates a linear relationship with transition parameter and square-root dependence on the magnetic grain size. The magnetic grain size will approach the physical grain dimension when the intergranuler exchange field interaction has been sufficiently broken. From this simple relation, the reader may infer the relative importance of grain size and exchange interaction on media performance.

IV. CONCLUSION

In conclusion, we have demonstrated that processing of CoCrPtTa sputter targets enables improved magnetic performance and similar to slightly enhanced recording performance. Compositional data confirm a measurable increase in film tantalum composition derived when using the SCP processed targets causing greater chromium segregation to the grain boundary. This grain boundary enrichment, in turn, provides greater exchange field decoupling and magnetocrystalline anisotropy accounting for the magnetic and electrical results provided within.

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