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Microstructural Origin of the Magnetically Degraded Layer in Sendust Metal-in-Gap Recording Heads

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Abstract--Microstructural studies have been performed on Sendust films deposited on both polycrystalline and single crystal ferrites using transmission electron microscopy. We observed a strain-induced contrast in both the ferrite and Sendust and a large number of dislocations in the ferrite region near the interface. However, no intermediate layer of Al_2O_3 and SiO_2 was found at the interface. We also found that both the in-plane crystallographic texture and the microstructure of the Sendust films depend on the orientation of the underlying single crystal ferrite substrates, even though the out-of-plane crystallographic texture appears to be independent of ferrite crystal orientation. A model has been proposed to explain the microstructural origin of the magnetically degraded layer formed at the interface of the Sendust film and ferrite cores in the Metal-in-Gap heads.

I. INTRODUCTION

The Sendust alloy is an excellent soft magnetic material and Sendust films are widely used in Metal-in-Gap (MIG) magnetic recording heads. There has been much research into the origin of the magnetically degraded layer formed at the interface between the Sendust film and the ferrite core in MIG heads, primarily because it gives rise to undesired secondary outputs in playback spectra<1>. The mechanisms proposed to explain the origin of the magnetically degraded layer can generally be divided into two categories: one which attributes it to the formation of Al and Si oxides at the interface, due to oxygen diffusion caused by the high temperature manufacturing process<2,3>, and the other which attributes the degradation to an initial Sendust metal film layer with poor magnetic properties<4>. However, both mechanisms fail to explain the dependence of the secondary output on the crystallographic orientations of single crystal ferrite cores<3,5>.

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To understand the origin of the magnetically degraded layer, it is important to investigate the correlation between the microstructure and the head fabrication process. Auger-electron spectroscopy studies <3,5,6> have shown that Si and Al elements diffuse into ferrites at the interface upon annealing. Thus, it has been suggested<3,6> that the magnetically degraded layer is composed of SiO_2 and Al_2O_3. However, no direct microstructural investigation has been made apart from an experiment to determine the grain size<5>. We report results from studies of Sendust films on ferrite cores using transmission electron microscopy (TEM). A mechanism will be proposed to explain the microstructural origin of the magnetically degraded layer.

II. EXPERIMENTAL PROCEDURES

Sendust films, 1 μm thick, were deposited by rf magnetron sputtering onto polycrystalline and (332) single crystal ferrites preheated to 200 C. The Ar pressure during sputtering was 0.3 Pa and the forward power density was $4W/cm^2$. The background pressure is less than 10^{-4}Pa. These films were annealed in nitrogen at 600 C for 0.5 hr. The coercivity and permeability of both films were measured at 5 MHz and were found to be 0.5 Oe and 1000, respectively.

X-ray diffraction (Rigaku) θ–θ scans were performed using CuKα radiation to obtain overall structural information. Both plane-view and cross-sectional samples for TEM studies were prepared by first mechanically polishing to approximately 150 μm and then dimpling to a thickness of 25 μm. Finally, the dimpled samples were thinned by ion-milling until perforation. A thin carbon film was deposited on the cross-section TEM to avoid discharge in ferrite regions. Specimens were examined with a Philips EM 420T electron microscope operated at 120 KV.

III. RESULTS AND DISCUSSION

A. Sendust-ferrite Interface

Fig. 1a shows a bright field image of the cross-section of a Sendust film on the polycrystalline ferrite. The image demonstrates the typical columnar structure of the thin films. The most salient feature of the Fig. 1a is the loss of a distinct interface between the ferrite and the Sendust film. Fig. 1b shows the cross-section of the Sendust film deposited onto the ferrite core at room temperature without post-annealing. The interface is clearly observed, as is the thin buffer layer In Fig. 1a, we also see a strain-induced contrast in both the ferrite and the Sendust regions and a large number of dislocations in ferrite region near the interface. However, no intermediate layer of Al_2O_3 or SiO_2 was found at the interface.

We believe that the defect structure near the interface in the ferrite core is responsible for the magnetically degraded layer. The dislocations provide diffusion paths for both oxygen from the ferrite to the interface and for Al and Si from the Sendust film to the ferrite. Due to the loss of oxygen, more defects were generated to accommodate the elastic strain which degrades the magnetic properties of the ferrite region at the interface. On the other hand, due to the loss of Al and Si, the magnetic properties of the initial Sendust layer also deteriorate because they are sensitive to the composition of the alloy[7-8].

B. Out-of-Plane Crystallographic Texture of Sendust Films

Fig. 2 displays X-ray spectra of Sendust films on both polycrystalline and single crystal substrates ((332) orientation). The presence of strong {220} and {440} lines in x-ray patterns indicates that the films have strong crystallographic texture with a [110] direction perpendicular the film surface. Our x-ray patterns show that the out-of-plane crystallographic texture of Sendust films appears to be invariant with ferrite orientation. This is consistent with other studies of Sendust films on single crystal ferrites cut in different orientations.

(110) is the close-packed plane since the parent structure

Fig. 1: Bright field images of the cross section of the Sendust films on the ferrite s ::a) deposited at 200 C with post-annealed at 600 C for 30 minutes in N_2 and b) deposited at room temperature without post-annealing.

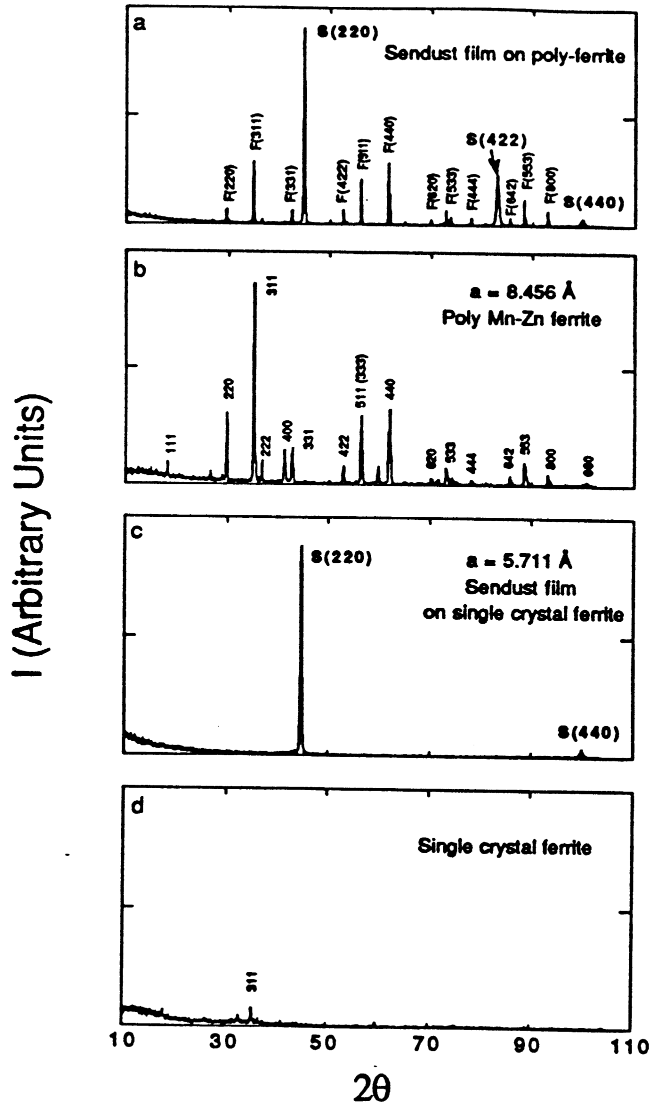

Fig. 2: X-ray spectra showing the out-of-plane {220}texture of the film.

of Sendust alloy is the bcc structure. Therefore, it is energetically favorable to have {110} crystallographic texture if the elastic energy induced by mismatched interface can be ignored. This argument suggests that the {110} out-of-plane texture might be a growth texture and therefore independent of orientation of underlying ferrite substrates.

C. In-Plane Crystallographic Texture and Microstructure of Sendust Films

If the out-of-plane direction is used as one variable to describe the crystallographic texture, another direction variable, the in-plane texture, is required to provide complete orientation information for the films on single crystal substrates. We studies his in-plane texture by electron diffraction.

Fig. 3 displays a selected area electron diffraction (SAD) pattern taken from the plane-view specimen of the Sendust film on the (332) single crystal ferrites. The SAD aperture is 2 μm in diameter; thus, the SAD pattern in Fig. 3 contains microstructural information from approximately 2000 Sendust grains. The presence of arcs rather than rings in the SAD pattern suggests that the Sendust film has a strong in-plane crystallographic texture. By careful examination of Fig. 3, it was found to be a composite of two {110} patterns with rotation of 120° (or 60°). It should be kept in mind that the single crystal substrate has an approximate <111> orientation and the absence of the third {110} pattern is due to the slight misorientation of the cutting direction with respect to the <111> direction. Therefore, the in-plane texture with two 2-fold axes 120° apart from each other reflects the orientation of the underlying substrate.

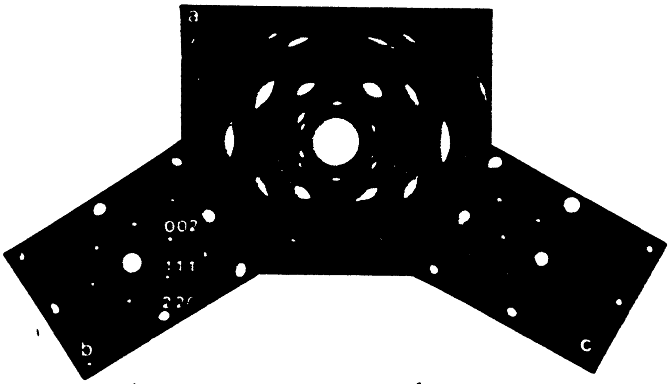

Fig. 3: SAD pattern displays a in-plane crystallographic texture related to the underlying substrate.

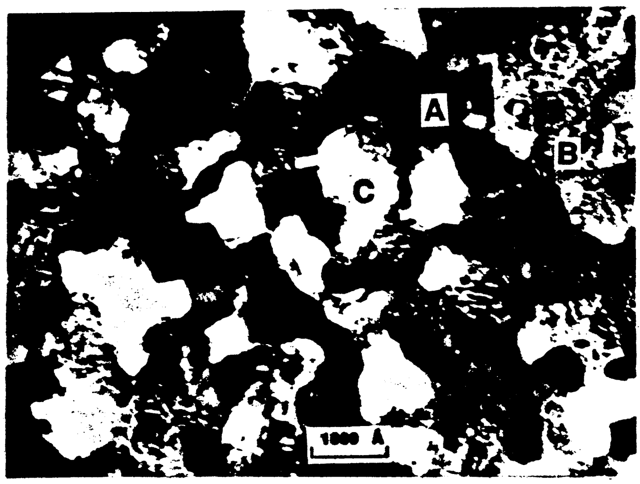

Fig. 4: A dark field image of Sendust film on (332) single crystal ferrite with a g=(220). The grains have three distinct intensity levels because of the ferrite orientation. In region B, a high density of (220)-type dislocation wsere observed.

We also observed a similar dependence of the microstructure of Sendust film on the crystallographic orientations of the underlying Sendust core. Fig. 4 displays a dark field image with a g=(2$\bar{2}$0). The grains in the image displays three distinctive intensity levels, which appear to be related to the three crystallographic variants.

IV. CONCLUSIONS

We have observed a strain-induced contrast in both the ferrite and the Sendust regions and a large number of dislocations in ferrite regions near the interface in Sendust films on ferrites. However, we did not observe an intermediate layer of Al_2O_3 or SiO_2 at the interface due to interdiffusion caused by annealing. We believe that these strained regions with defects are magnetically degraded and are responsible for the secondary output for some Sendust heads.

Even though a <110> out-of-plane texture may not be directly related to the underlying substrate, we found that the in-plane texture and the microstructure of the Sendust film are directly related to the underlying substrate. This may explain the dependence of the secondary output of Sendust heads on the orientation of the single crystal ferrite.

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