The Role of Microstructural Phenomena in Magnetic Thin Films

Year I Progress Report

Year II Continuation Proposal

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Introduction

Our program "The Role of Microstructural Phenomena in Magnetic Thin Films" started in August of 1990. We have pursued our proposed research and report herein on the progress to date. Specifically this document includes:

1. Progress Report on Work Performed August 1990 to December 1990.
2. Listing of Papers Submitted for Publication
3. Proposed Research for Year II (August 1991 - July 1992)
4. Year II Budget

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1. Progress Report

We report herein on two aspects of our research, namely the sputtering of Co-Ni-Cr films onto single crystal underlayers and the production of Co-Sm thin films with high coercivity.

A. Co-Ni-Cr Films on Single Crystal Underlayers.

During the first year of our research we have focused on the development of Co-based thin films with strong crystallographic texture. We have done this by developing Cr underlayers with strong crystallographic texture and by depositing the Co-based films on single crystal Cr substrates. Both [100] and [110] Cr single crystals have been utilized. The single crystals have the shape of a disc with the disc normal being the designated axis. X-ray diffraction spectra and the hysteresis loops along various crystallographic directions of the single crystals have been obtained. The microstructure and the magnetic domain structure of the CoNiCr/Cr foils were studied with TEM and Lorentz microscopy.

Single Crystal [100] Cr

The X-ray diffraction spectrum from the CoNiCr/[100]Cr shows the presence of a relatively strong hcp CoNiCr (11 $\bar{2}$ 0) peak and a weak fcc (200) peak along with the (200) Cr peak. The (11 $\bar{2}$ 0) peak results from the epitaxial growth of the hcp CoNiCr grains on the bcc [100]Cr single crystal. The orientation relationship (O.R.) is [11 $\bar{2}$ 0]hcp//[100]bcc, (0002)hcp//(011)bcc. This is known as the Pitsch-Schrader O.R. This O.R. causes the hcp c-axis to lie in the plane of the film. The hysteresis curve along the Cr [010] direction in the plane of the film resembles that for an easy axis and the measured coercivity is 475 Oe. The hysteresis was also obtained along the Cr [011] in the plane of the film. The loop indicates that this direction is between the hard and the easy axis of the CoNiCr film.

Single Crystal [110] Cr

In the X-ray diffraction spectrum for the [110] single crystal, two strong peaks which correspond to the (110) and (220) Cr are present. The only other diffraction peak

observed in the spectrum, as expected, is the hcp $(10\bar{1}1)$ diffraction peak. Similar to the $[100]$ single crystal, this is a result of the epitaxial growth of the CoNiCr grains on the $[110]$ Cr crystal. The O.R. is $(10\bar{1}1)\text{hcp} // (110)\text{bcc}$, $(1\bar{2}1)\text{hcp} // (1\bar{1}\bar{1})\text{bcc}$, which is commonly known as the Potter O.R. In these films the hcp c-axes are not in the plane of the film but at 28° with respect to it. The in plane hysteresis loop obtained from these crystals clearly shows the presence of both an easy axis and a hard axis in the plane of the film. The hysteresis loop indicates that the easy axis is along the $[1\bar{1}0]$ direction with a coercivity of 485 Oe. The hard axis is along the $[1\bar{1}2]$ and the coercivity is 232 Oe.

The TEM investigation results from the CoNiCr/Cr foils have revealed the microstructure of the CoNiCr grains on various low index Cr crystal surfaces including (100) , (110) and (111) . As indicated above, CoNiCr grains will grow on the (100) Cr surface according to the Pitsch-Schrader O.R. This was confirmed by TEM. In this O.R., two variants exist in the CoNiCr layer. The $[0002]$ of the hcp CoNiCr is parallel to either the $[011]$ or the $[01\bar{1}]$ in the plane, giving rise to these two variants. They are distributed evenly throughout the specimen and the boundaries between them are irregular. In addition, line defects which are believed to be stacking faults can be observed inside every grain. Lorentz microscopy studies indicate that in the demagnetized state each grain is a single domain and no long range coupling can be detected.

The CoNiCr film that was deposited on a $[110]$ broad face was found to have the Potter O.R. Once again, there are two variants in the film with the $[0002]$ almost parallel to either the $[101]$ bcc or $[011]$ bcc. The TEM bright field pictures show that the grains are elongated towards the projection of the c-axis in the plane of the film. No line defects can be observed in this case. The Lorentz images once again indicate that there is no long range magnetic coupling and each grain is most likely a single domain.

These preliminary findings will be of great value as we interpret the magnetic properties in terms of crystalline textures.

B. CoSm Thin Films

We are interested in obtaining materials with high in plane coercivity and low recording noise levels and relating these to the microstructure. A study of SmCo alloys made under a variety of processing parameters was initialized. Previous studies of these alloys had shown them to be amorphous when sputtered, and therefore they had only moderate coercivities. Furthermore, they produced considerable noise when used as recording media. However, since these alloys, when crystalline, have one of the highest known anisotropy constants they could potentially be made into thin films with very high coercivity. The amorphous nature of the film implies the potential for very small crystalline grain sizes and hence possibly low noise. A process of depositing SmCo on *unheated* sputtered Cr underlayers has produced coupon samples on glass substrates with H_c approaching 2400 Oe. We believe this to be due to very close atomic matching of the SmCo with the (110) surface of the Cr as well as due to the specific grain structure of the Cr underlayer. The hysteresis loops indicate limited intergranular exchange coupling. This is in direct contrast to our own experience and previously published results when Cr is not used. The hypothesis of the importance of SmCo/Cr interface is supported by the following facts:

- (1) Without the Cr underlayer the H_c is low and the hysteresis loops are very square.
- (2) SmCo deposited on heated Cr underlayers, which develop a (200) texture and are used for all hexagonal Co alloy media, have a low coercivity. This could be due to a poor lattice match of the (0002) SmCo and the (200) Cr.
- (3) If the vacuum is broken between the deposition of the (110) Cr underlayer and the SmCo so that a slight oxide forms, the coercivity is low.

2. **Publications:** A talk was given at MMM 1990 and a paper is to appear in the Journal of Applied Physics.

3. Proposed Research for Year II

A. CoNiCr and CoCrTa Thin Films

During the next year we plan to more fully investigate the role that crystallographic texture plays in development of high in plane coercivity of thin films. We will deposit CoNiCr and CoCrTa films on single crystal Cr substrates and control the size of the "grains" (actually they are more correctly called crystallographic variants) of the Co-based alloys. This will allow us to include grain size as a parameter to be studied.

We also plan to begin to produce some "multilayer" thin films (Co/Cr/Co/substrate). We will deposit a Co-based alloy on a Cr underlayer, followed by a thin intermediate film of Cr (100 Å). On top of this intermediate layer of Cr another Co-based thin film will be deposited. The intermediate layer of Cr is known to enhance the recording properties of Co-based media. We will be studying the effect of the intermediate Cr layer on controlling the crystallographic texture and grain size of the Co-based film and relate it to our earlier findings from the single crystal substrates.

For both cases we will be measuring the extrinsic magnetic properties of the films and interpreting them in terms of their intrinsic properties and their microstructure. The magnetic domain structure will be studied as well, as it is an important link between the microstructure of the film and the extrinsic magnetic properties.

B. CoSm Thin Films

During 1991 we will extend our investigation of the relationship between magnetic properties and microstructure of CoSm thin films. X-ray diffraction and high resolution TEM analysis will be used to investigate the structure of the films. This will enable us to explain how this is related to the texture of the underlying Cr. In addition we hope to correlate this to recording noise performance data when actual recording media are made. It is believed that media noise can be related to intergranular exchange coupling. (The recording tests are being supported by a contract with the Data Storage Systems Center.)

Finally, third elements such as Bi will be introduced into the SmCo system to investigate further the role of grain segregation by a low melting point, non-miscible, non-magnetic element.

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