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**THE ROLE OF
MICROSTRUCTURAL PHENOMENA
IN MAGNETIC THIN FILMS**

**FINAL REPORT
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Overview of Results of the Program

Over the period of the program we systematically varied microstructural features of magnetic thin films in an attempt to better identify the role which each feature plays in determining selected extrinsic magnetic properties. The following summarizes our results.

1. Single Crystal Substrates

We deposited Co-based alloys on single crystal Cr substrates to determine the role of crystallographic texture on magnetic properties. This resulted in very strong in plane magnetic anisotropy of the thin films as well as fairly straight magnetic domain walls, which were aligned along crystallographic directions. The in plane magnetization exhibited a hard direction as well as a soft direction. When the Co-alloy was deposited on [001] Cr crystals we obtained a set of two perpendicular Co-hcp variants. This morphology has been called a "bi-crystal" thin film as has been the subject of much research since the time that we originally reported it.

2. Underlayers

Since most thin films for applications in the magnetics industry are polycrystalline, we initiated investigations on the development of crystallographic texture in underlayer materials. We studied the development of both the [110] and [001] fibrous textures in Cr thin films. We included process variables such as substrate temperature, substrate bias, Ar pressure and sputtering power. The experimental findings that were new in our research included:

- (1) When deposited at elevated temperatures, the Cr films can have either the (002) texture or the (110) texture, depending on the sputtering power, Ar pressure, and/or substrate bias; the (110) texture is promoted by the bombardment energy of either deposited Cr atoms or Ar^+ ions;
- (2) The (002) texture can be initiated directly on the substrate surface, but the (110) texture does not form on the substrate surface, but as a result of film growth.

3. Interlayers

One way to control microstructural features of the magnetic thin films such as grain size and orientation is by interrupting their deposition and introducing a non-magnetic interlayer. We performed a thorough investigation of this. The hysteretic properties and remanence curves of double-layer CoCrTa thin films with various interlayers (Al, Cu, Ag, and Cr) were investigated. We found that the double-layer CoCrTa films with Cu or Ag interlayers have narrower switching field distributions but similar high coercivities, compared with the films with Cr interlayers. To understand the effects of interlayers on the magnetic properties, the crystallography of epitaxy in these multilayer thin films was also studied. The results from this work show that Ag was a strong candidate as an interlayer material in multilayer magnetic recording media. This work complemented our earlier high resolution TEM investigation of the role that interlayers play in transmitting the crystallographic texture from the first magnetic layer to the second.

4. Grain Isolation/InterDiffusion

Another aspect of our research was to investigate interdiffusion and grain isolation in Co/Cr films by studying the dependence of the magnetic properties on the substrate preheating temperature as well as on post-deposition annealing processes. Here we deposited pure Co films instead of the Co alloy films in order to distinguish between Cr segregation within the film and Cr segregation up the grain boundaries of the film from the Cr underlayer. We found that both post-deposition annealing and substrate preheating can effectively increase the magnetic isolation of the Co grains.

5. Local Atomic Arrangements

We also investigated the role of atomic segregation within the film. In order to study this we collaborated with a group from the U.S. Naval Research Laboratory. We sputter deposited Co-Cr-Ta and Co-Cr-Pt films at various temperatures to get a variety of microstructural and crystallographic textures. Results from magnetic circular dichroism measurements indicate the average net magnetic moment of the Cr atoms is opposite in direction and approximately five percent in amplitude relative to the Co moments. A comparison between the Ta and Pt edge EXAFS results shows that the temperature-dependent increase in structural disorder is greater around the Ta atoms in the CoCrTa system than is found the Pt atoms in the CoCrPt system.

6. Invention of a New Intermediate Layer for Longitudinal Magnetic Recording

The final years of the program were spent in the development of a new intermediate layer for magnetic media. Using the work of the previous research program we decided to try CrMn alloys as an intermediate layer. This was based on the fact that Mn is antiferromagnetic (like Cr). We studied diffusion characteristics of the Mn in the Co alloys as well as the resulting magnetic properties of the Co layers after Mn (and Cr) had diffused up their grain boundaries. The magnetic alloys has much greater coercivities when we used the CrMn alloys than when we used Cr alone. Based on our findings we filed for obtained a patent.

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United States Patent [19]**Lambeth et al.**[11] **Patent Number:** **5,993,956**[45] **Date of Patent:** **Nov. 30, 1999**[54] **MANGANESE CONTAINING LAYER FOR MAGNETIC RECORDING MEDIA**[75] **Inventors** David N. Lambeth, Pittsburgh, Pa.,
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E. Laughlin, Pittsburgh, Pa[73] **Assignee** Carnegie Mellon University,
Pittsburgh, Pa[21] **Appl No** 08/844,835[22] **Filed** Apr. 22, 1997[51] **Int. Cl.**⁶ G11B 5/66[52] **U.S. Cl.** 428/332, 428/336, 428/694 T,
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427/129, 427/130, 427/131[58] **Field of Search** 428/694 T, 694 TS,
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129, 130, 131[56] **References Cited****U.S. PATENT DOCUMENTS**

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Massalski et al., editors, "Binary Alloy Phase Diagrams", 2nd Ed, pp 1205, 1207-1208, 1291-1293, 2573, 2575, 2615-2617, 2620, 2622-2623 ASM International (1996)*Primary Examiner*—Leszek Kiliman*Attorney, Agent, or Firm*—Kirkpatrick & Lockhart LLP[57] **ABSTRACT**

The present invention provides for a magnetic recording media incorporating Mn-containing layers between a substrate and a magnetic layer to provide media having increased coercivity and lower noise. The Mn-containing layer can be incorporated in a rotating, translating or stationary recording media to operate in conjunction with magnetic transducing heads for recording and reading of magnetic data, as well as other applications. The magnetic recording medium of the invention preferably includes a Co or Co alloy film magnetic layer, and Mn-containing layer, preferably comprised of VMn, TiMn, MnZn, CrMnMo, CrMnW, CrMnV, and CrMnTi, and most preferably a CrMn alloy, disposed between the substrate and the magnetic layer to promote an epitaxial crystalline structure in the magnetic layer. The medium can further include seed layers, preferably polycrystalline MgO for longitudinal media, underlayers, and intermediate layers. Underlayers and intermediate layers are comprised of materials having either an A2 structure or a B2-ordered crystalline structure disposed between the seed layer and the magnetic layer. Materials having an A2 structure are preferably Cr or Cr alloys, such as CrV, CrMo, CrW and CrTi. Materials having a B2-ordered structure having a lattice constant that is substantially comparable to that of Cr, such as those preferably selected from the group consisting of NiAl, AlCo, FeAl, FeTi, CoFe, CoTi, CoHf, CoZr, NiTi, CuBe, CuZn, AlMn, AlRe, AgMg, and Al₂FeMn₂, and is most preferably FeAl or NiAl.

40 Claims, 12 Drawing Sheets