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Ellipsometric analysis of computer disk structures

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Abstract:
We have used variable angle spectroscopic ellipsometry (VASE) to analyze the materials surfaces and interfaces in multilayer sputtered media computer disks. Specifically, the system C/CoNiCr/Cr/NiP/Al has been investigated for layer thicknesses, interfacial and surface roughness, and radial and circumferential uniformity. By first characterizing the Cr/NiP/Al then CoNiCr/Cr/NiP/Al structures, we were able to fully characterize the complete disk structure. The interface width between the carbon layer and CoNiCr magnetic layer was determined to be approximately 260 Å. This is reasonable considering typical surface roughness present on magnetic disks, and that the carbon "fills" in this surface roughness. VASE is a nondestructive technique and used at atmospheric pressure, and is thus suitable for use in a production environment.

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I. INTRODUCTION

Control of the properties and thicknesses of each layer in a multilayer computer disk structure is very important for reliable disk performance. Thus, it is desirable to have an accurate knowledge of the physical properties, layer thicknesses, and homogeneity over the disk. It is well known that thin-film properties are highly dependent on microstructure, and these differ from bulk properties. Furthermore, the optical constants are especially dependent on the method and parameters of deposition, such as pressure and ion bombardment energy. Thus, optical methods can be sensitive non-invasive monitors of quality.

Variable angle spectroscopic ellipsometry (VASE) has been shown to be effective for the study of multilayer film structures.[1-7] Fixed angle ellipsometry was used by Tsai *et al.*[8] to characterize their sputtered carbon overcoats of rigid disks. Because of the nondestructive nature of ellipsometry, it has become an extremely useful tool for the study of thin multilayer systems.

II. SAMPLES AND EXPERIMENTS

All samples used in this study were magnetron sputtered and provided by Imprimis Technology (formerly MPI, a Control Data Company). The first sample was Cr/NiP/Al, where Al was the substrate. Both the NiP and Cr layers were optically thick (more than 3000 Å), so the Cr was treated as a "substrate" in the optical study. The second and third samples had the same structure: CoNiCr/Cr/NiP/Al with a nominal thickness of the CoNiCr layer of about 500 Å. The fourth and fifth samples had the structure C/CoNiCr/Cr/NiP/Al and were called sample A and sample B with the assumed structures shown in Fig. 1. All magnetic layers had 69% Co, 27% Ni, and 4% Cr.

A computer-controlled, rotating analyzer ellipsometer, with variable angle of incidence, was used to take measurements in the range from 3000 to 8000 Å.[1-3] The experimentally measured parameters are ψ and Δ, defined from the ratio of the Fresnel reflection coefficients of the medium for parallel (to the plane of incidence) and perpendicular polarizations, and are functions of the angle of incidence, and the complex index of refraction.[9] The reflection coefficients contain information about the materials under study. ψ and Δ are measured as a function of wavelength and angle of incidence. From an assumed model (Fig. 1, for example), ψ and Δ can be calculated and a regression analysis used to fit the calculated ψ and Δ to the measured ψ and Δ by modifying the model parameters.

III. RESULTS AND DISCUSSION

The variables of analysis (Fig. 1) were four layer thicknesses, two composition fractions, and the optical constants of the carbon layer. Figure 1 shows the final parameter solution of the analysis, for both samples. The procedure was as follows: first, the optical constants of a disk with Cr as the final layer were measured. Results of this work revealed small differences from the published values, likely due to

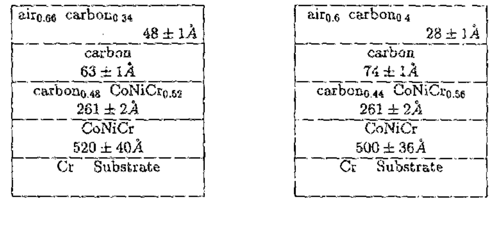

FIG. 1. Model assumed for the ellipsometric analysis of computer disks. The top and third layers down are roughness layers. The Cr is optically thick.

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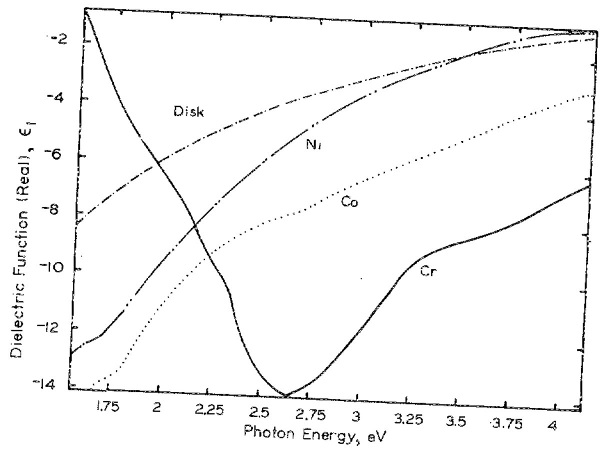

FIG. 2. Ellipsometrically measured real part of dielectric function of CoNiCr layer, and comparison with data for pure Co, Ni, and Cr.

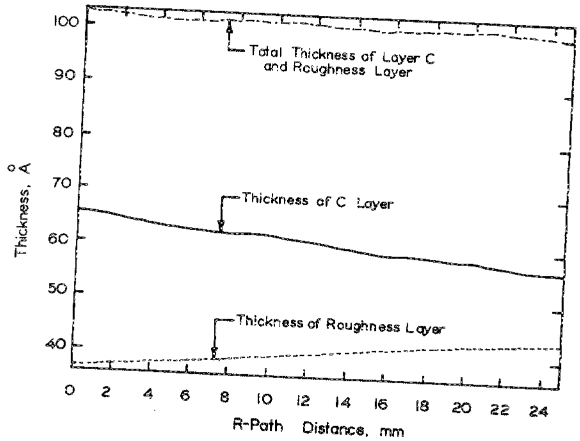

FIG. 4. Carbon and roughness thicknesses measured along the radial path on the disk.

differences of surface roughness, surface preparation, and oxidation.[10] Next, a disk with CoNiCr as the final (top) layer was studied. The resultant real part of the optical dielectric function is shown in Fig. 2, along with those of pure Ni, Co, and Cr taken from the published literature.[10] These results show that (a) the optical constants of CoNiCr are likely not due to a simple combination of Co, Ni, and Cr optical constants, and/or (b) that there were significant differences in surface conditions (oxide and/or roughness) for the three materials.

Finally, data from disks A and B with all layers present were analyzed using the model of Fig. 1, with the final layer thicknesses indicated. Notice that the top and third layers are roughness layers. These were determined using the Bruggeman effective medium approximation.[6,11] The results are entirely reasonable. 30–50 Å top roughness is reasonable and typical for other materials studied by our group.[11] The interfacial (261 Å) roughness between the carbon and CoNiCr layers is also reasonable. The combined results suggest that the carbon layer tends to smooth (fill in) in CoNiCr roughness. Notice that the carbon plus roughness layers in samples A and B are comparable (111 and 102 Å). Even though the roughness layers differ from each other in thickness by 20 Å, the thinner roughness layer in sample B has a larger carbon fraction.

The optical constants of the carbon layer (within error limits) are the same for samples A and B. The index of refraction is slightly lower than typically found for diamond-like carbon (DLC), and the extinction coefficient is typical.[12,13] Tauc plots yield an E_g of about 2.1 eV for the carbon layer in samples A and B, also characteristic of DLC.[12]

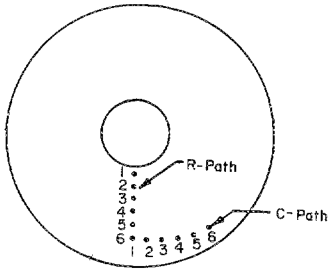

FIG. 3. Spot positions on disk used for radial and circumferential homogeneity studies.

A series of investigations on the lateral homogeneity, or uniformity, of the layers were conducted. Figure 3 shows where the measurements were made. These spots formed two paths: radial (R) and circumferential (C). The ellipsometric ψ and Δ along the paths C and R were measured. ψ and Δ along C are almost unchanged. The maximum change in thickness of the carbon layer along the C path is 3%. Therefore, the layers along circumferential paths are highly uniform.

On the other hand, ψ and Δ along the R path show systematic variations. The thicknesses of the carbon layer on sample B were calculated from the data and are shown in Fig. 4. The thickness of the carbon layer changes by about 14%, becoming thinner going from inside to outside. The thickness of the roughness layer (C + void) changes by 16% along R, yet the total thickness of the two layers is approximately constant along the R path. The results for sample A are similar to those for sample B.

IV. CONCLUSIONS

We have used variable angle spectroscopic ellipsometry (VASE) to analyze the material surfaces and interfaces in multilayer sputtered media computer disks. Specifically, the system C/CoNiCr/Cr/NiP/Al has been investigated for layer thicknesses, interfacial and surface roughness, and radial and circumferential uniformity.

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