Atomic Force Microscopy Grain Structure Characterization of Perpendicular Magnetic Recording Media

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Abstract

Magnetic recording technology plays a key role in the development of computer, audio, and video storage devices. The nanoscale grain size of current hard-disk media determines important recording properties and thus requires accurate characterization methods. In this work, we developed a new method to characterize the nanostructure of thin film magnetic recording media using a phase-imaging tapping-mode atomic force microscope (AFM). In this study, clear images obtained with the AFM were compared to those obtained with a transmission electron microscope (TEM). A statistical distribution of grain size was analyzed. This novel method is an important development because phase imaging tapping mode AFM could provide a cheaper and faster characterization alternative to TEM.

Introduction

In order to continue increases in information storage density for personal computers, advanced nanofabrication techniques are being used to produce magnetic media with grain structures in the nanometer size range. The grain size of the media determines important recording properties including aerial density, signal to noise ratio, and thermal stability [1]. In order to successfully fabricate media with nanometer grain size, advanced characterization techniques are required to accurately assess grain sizes.

Because of the nanoscale size of current PMR grains, the TEM has been the tool of choice for grain structure analysis. The TEM provides excellent resolution [2]; however, sample preparation is difficult and time consuming. The AFM can be easily used to image surface topography with little sample preparation. However, to our knowledge, there exist few other efforts using the AFM to analyze nanoscale grain sizes of magnetic thin films [3].

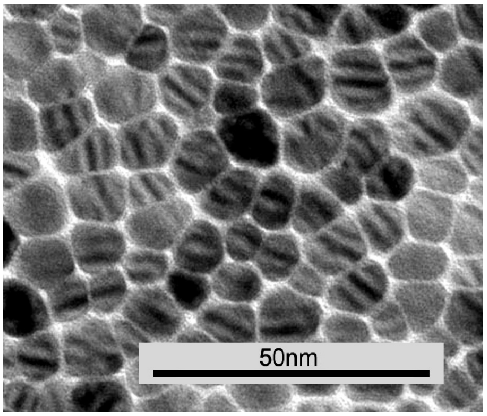

Figure 1: Bright field TEM image of PMR media with 9 nm grain size.

In tapping-mode AFM, an oscillating cantilever scans the sample surface, and tip to sample height is kept constant through the use of an electronic feedback loop. Phase-imaging is an extension of tapping-mode, which measures the contrast in the phase angle between the driving and response frequencies. This data is gathered simultaneously with topographic data. The difference in phase angle is sensitive to several material properties including composition, viscoelasticity and surface adhesion [4]. This data may be used to enhance grain boundary resolution [3]. In this study, we present grain size distributions of PMR media obtained using phase-imaging tapping-mode AFM for the first time.

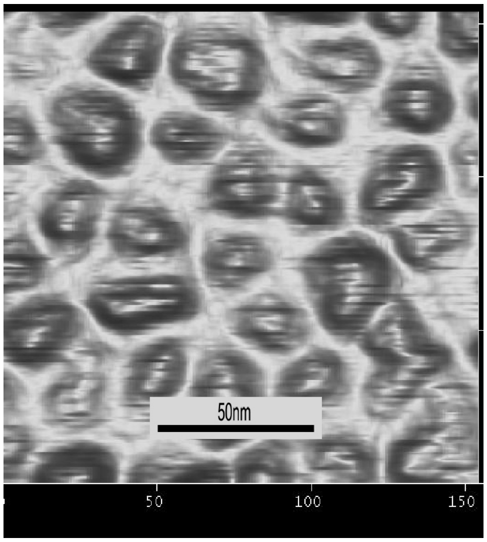

Figure 2: Phase-image tapping mode AFM scan of PMR media with 20 nm grain size.

Experimental Procedure

Two discs of CoPtCr-O PMR with different grain size were analyzed. Samples were etched for 2 minutes in an oxygen plasma to remove a 5 nm protective diamond-like carbon (DLC) layer on the surface of the media and to improve imaging response. A Digital Instruments multimode scanning probe microscope operating in tapping mode was used to characterize the samples both before and after the plasma etch process. Silicon nitride cantilevers with a resonant frequency between 285-315 kHz, and a tip radius of curvature (ROC) of 10 nm were used. TEM images of the samples were obtained before etching. Grain size was determined by taking the average of the large diameter and small diameter of a single grain, with a sample size of 30 grains used for statistical analysis.

Results and Conclusions

In Figure 1, we present a TEM image of a PMR media sample with 9 nm grain size. We compare this with Figure 2, which is an AFM phase image of a different sample of PMR media, having a measured grain size of approximately 20 nm. Note in both images, the individual grains and grains boundaries are clearly visible.

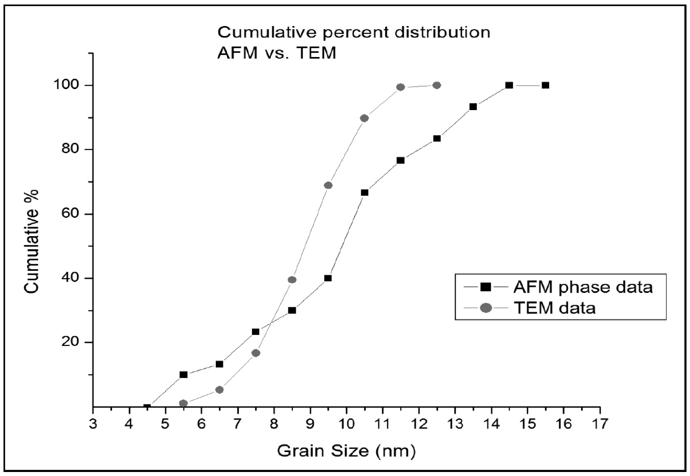

Figure 3: Cumulative percentage plot of grain sizes obtained by TEM and AFM methods.

In Figure 3, we present the measured grain size data for the sample with 9 nm average grain size in a cumulative percentage frequency plot, which has been shown to give reasonable grain size distributions even with small grain size populations [5]. The AFM method yielded slightly larger grain sizes than the TEM method. This may have been because the radius of curvature (ROC) of the AFM tip, at approximately 10 nm, approached the measured grain size and became a limiting factor in the resolution of the scans. In fact, the AFM phase image data agreed quite well with the TEM data as the calibration error of the AFM is approximately 10%.

In Figure 4, we compare the grain size distributions for the 20 nm grain size sample obtained with the AFM topography method and the phase image method. The phase image data was gathered before the sample was etched. This shows the phase difference is sensitive enough to be detected through the 5 nm amorphous DLC layer.

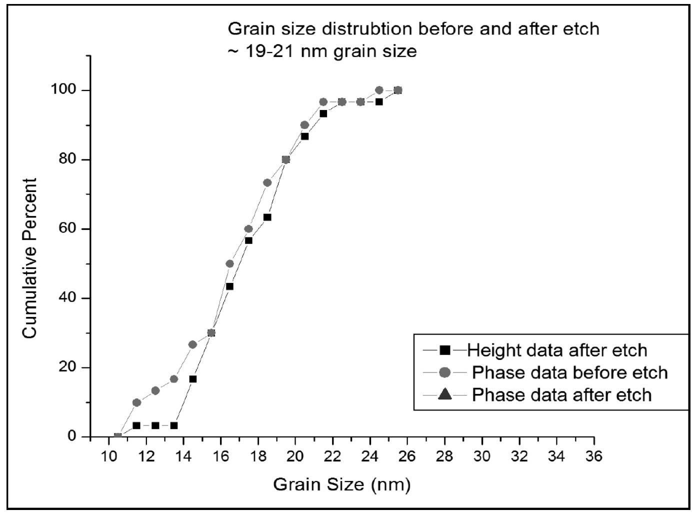

Figure 4: Cumulative percentage plot of grain sizes obtained from AFM height data, and AFM phase-image data.

In this study, we have presented the first images of PMR nanoscale grain structure captured using phase imaging tapping-mode AFM. These are found to compare to TEM nanographs. This work demonstrates that tapping mode AFM can be used for reasonably accurate grain size analysis of magnetic recording media.

Acknowledgements

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