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The NIST Magnetic Imaging Reference Sample

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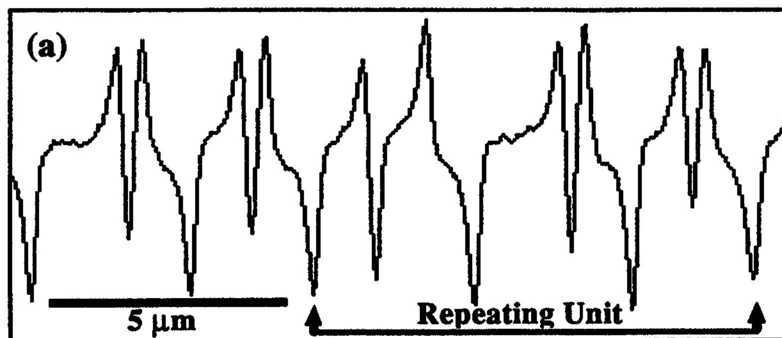
Magnetic force microscopy (MFM) is becoming widely used analytical tool in the disk drive industry. Presently, MFM images can vary greatly due to variations in tip geometry, magnetic materials used to coat the tip, and instrument configuration. Having a well characterized, widely distributed sample provides much-needed information about variations of tip magnetization and imaging technique[1]. Our magnetic imaging reference sample (MIRS) is based on a thin-film magnetic recording disk[2]. We are using a smooth, laser-textured disk, which provides less topographic influence on the MFM images. The disk was prepared in the following manner. We first wrote the magnetic data with a thin-film inductive head on a conventional spin-stand. The data pattern is shown in Fig. 1(a). We then lithographically deposited Au into an array of patterns across the whole surface of the disk. The pattern consists of the sample identification and 100 numbered 20 μm square frames. The frames within the pattern are used as landmarks for the optical microscope attached to the MFM to locate specific magnetic features. The lubrication was removed with a fluorocarbon and ethanol bath and the carbon overcoat was removed by an oxygen plasma. The disk was finally cut into 8 mm coupons.



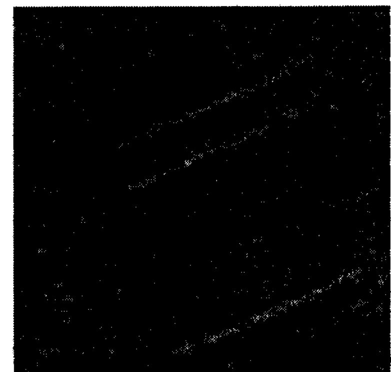


Fig. 1(a) Cross-section of MFM image of the magnetic pattern written on the disk. A tri-bit is just above the 5 in the scale bar. Fig. 1(b) The light and dark bars indicate the written transitions. A tri-bit, seen just above center is two light bars closely flanking a dark bar.

We have written a pattern which can show the polarity of the tip perpendicular to the sample surface (the Z direction). In all MFM detection schemes the tip is mounted on the end of a cantilever that is deflected or oscillated perpendicular to the plane of the sample surface. This means the tip is mostly sensitive to the Z component of the stray field gradient. In order to determine the tip's polarity we have written a repeating pattern containing two sets of three closely spaced transitions "tri-bits" separated by an isolated transition. These tri-bits are written with the same polarity. In Fig. 2 an arrow points to a depression in the MFM cross-section since the magnetization is know within the tri-bit this indicates an tip magnetization pointing down.

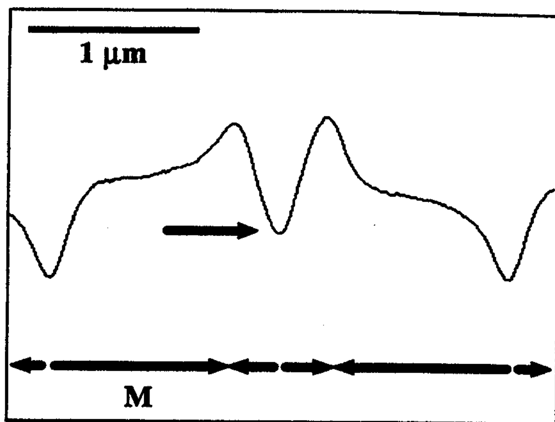


Fig. 1 MFM cross-section. The magnetization M is indicated by the arrows on the bottom. The single arrow points to where the tip is attracted. This means the tip is magnetized down.

Fig. 3. SEMPA image of the magnetic imaging reference sample. The arrow indicates the magnetization direction in the light area.

In order to determine the magnetization of the sample, and most important the magnetization within the tri-bits, we image this sample with scanning electron microscopy with polarization analysis (SEMPA)[3]. Figure 3 shows an image from the earlier sample taken with SEMPA. The arrow in the figure shows the magnetization direction in the light area.

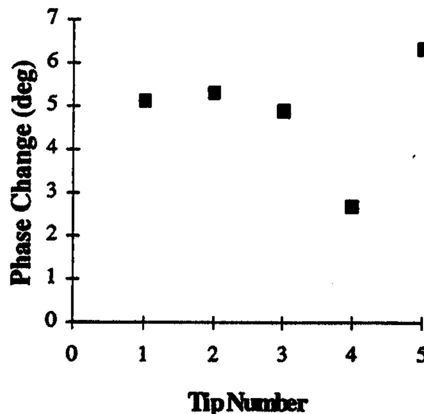


Fig. 4. Five tips were used to image the same area on one sample.

We have used one of these samples for determining the relative sensitivity of five commercially available CoCr coated tips. The tips were from the same box and used consecutively as supplied. Fig. 4 is a plot of phase change as the tip scans the sample. For this experiment the control parameters for the tips were optimized for the first tip and then all succeeding tips were operated with the same parameters. As seen in Fig. 4, the phase change for first three tips varies less than 1°. However, there was a noticeable variation in resolution of the images. The last two tips varied considerably as can be seen in the figure. Resolution varied as well. We know the disk magnetization does not vary as much as the MFM measurements, underscoring the need for a consistent, calibrated sample.

V. REFERENCES

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[3] R. J. Celotta and D. T. Pierce, "Polarized electron probes of magnetic surfaces, *Science*, vol. 234, pp. 333-340, Oct. 1986.