Keysight Technologies
Magnetic Force Microscopy Studies Using Keysight 7500 AFM

Application Note

Introduction

Magnetic force microcopy (MFM) is a mode derived from AFM for probing mechanical properties of materials. The key requirement of this technique is the separation of the response caused by long-range magnetic interactions from the response due to short-range topographic interactions. In order to achieve that, MFM is operated in a two-pass way. A first scan is taken to obtain the surface morphology, followed by positioning the magnetized tip at a certain distance above the sample. Qualitative mapping of a sample's magnetic domains is obtained in the second pass (phase image) by guiding the tip along the surface contour acquired in the first scan. Magnetic media is commonly used to store data. This application brief presents a few examples of examining material's magnetic properties of data storage devices as well as some other materials using the Keysight Technologies, Inc. 7500 atomic force microscope.

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Identifying Magnetic Domains Using MFM Imaging

The first sample selected in our MFM studies is the traditional Sony Hi8 video tape. Shown in Figure 1 are both topography and simultaneously collected MFM images that could be routinely acquired from this material. In contrast to the surface morphology that only exhibits a smooth background in conjunction with many randomly distributed nanoparticles, long-range zigzag patterning of magnetic domains are clearly resolved in the MFM data. Furthermore, it is worthy to point out that a few surface contamination locations (i.e., those protrusion islands) exist in the topography, but they have no impact at the corresponding positions in the MFM image, indicating the crosstalk between deflection signal and phase signal is negligible.

In comparison to the video tape, the presenting of those magnetic domains in computer hard discs follows a quite different way. As illustrated in Figure 2, parallel rows of nanometer-scaled bar features are frequently observed in MFM imaging. The first example (top row) shows that those magnetic domains are aligned periodically and perfectly, while the second one (bottom row) represents a case in which variations in the domain patterning (missing bars) in MFM image are captured.

Differentiating Magnetic Domains with MFM Imaging

Another benefit of hard discs is that various types of magnetic features or regions might coexist, and thus providing us some opportunities to explore or evaluate the capabilities of MFM technique. The left picture in Figure 3 is a large view MFM image (20µm × 20µm) of the computer discs, from which rich magnetic features are captured especially within the boundary band. After that, a subsequent zoom-in MFM imaging of an interesting region (marked as a black square in that picture) was contacted. The right picture of Figure 3 is the resulting image, in which two particular locations are highlighted with red or blue colors. As can be seen, the phase contrasts of the magnetic domains within both regions are dramatically different from each other.

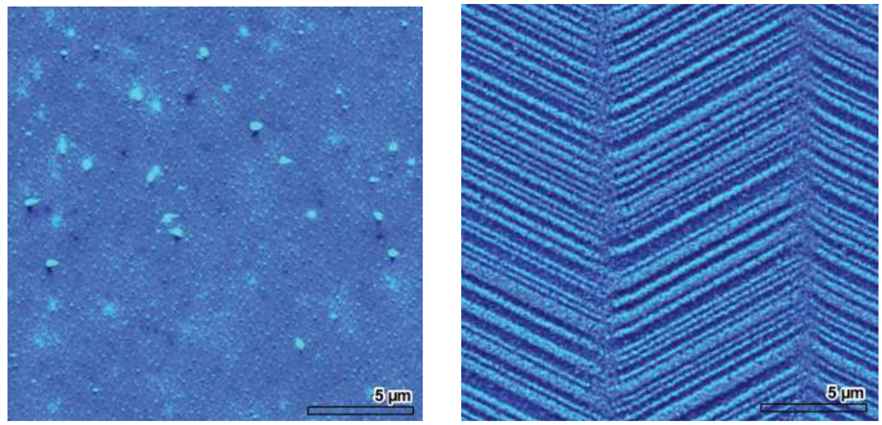

Figure 1. MFM imaging of Sony Hi8 video tapes. Both topographic image (left) and the corresponding MFM image (right) are acquired simultaneously. Scan size: 20µm × 20µm.

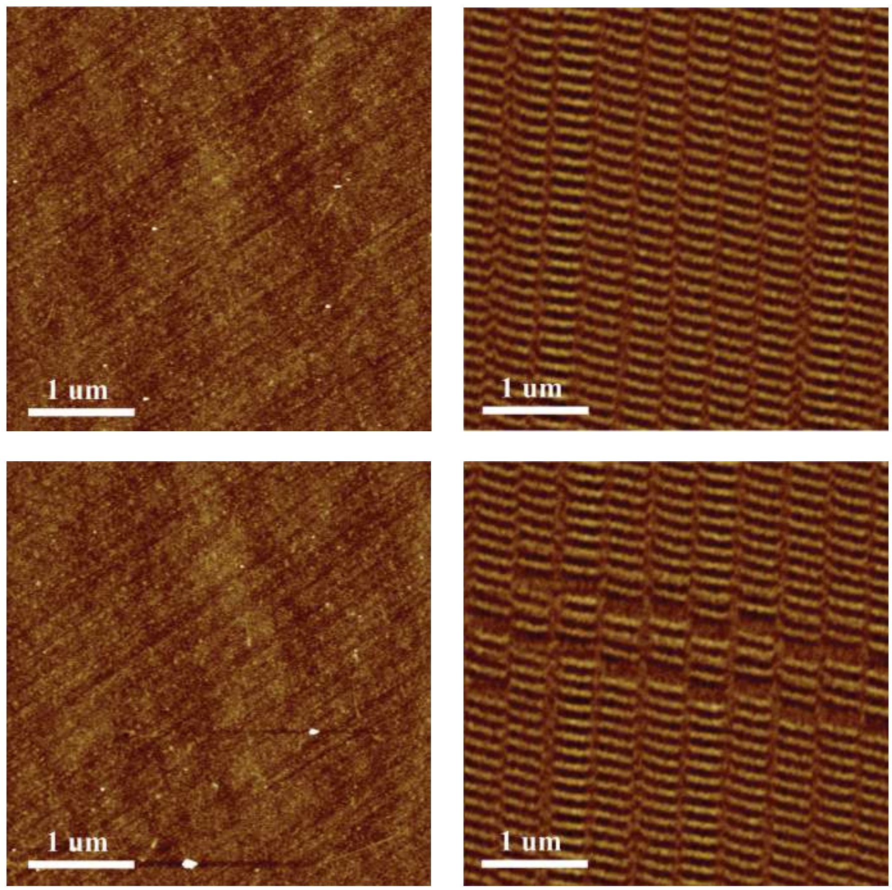

Figure 2. MFM imaging of computer hard discs. Both topographic images (left) and the corresponding MFM images (right) are acquired simultaneously. Scan size: 8µm × 8µm.

Those bars in the blue region are much brighter than the ones in the red region. In this case, the edge or boundary effects on the magnetic domains are unambiguously observed. This strongly suggested that MFM could be used to differentiate various magnetic properties.

Resolving Sub-100nm Magnetic Domains Via High-resolution MFM Imaging

One key advantage of AFM over the other microscopy techniques is its unprecedented spatial resolution. An example proving the excellent performance on MFM imaging with Keysight 7500 AFM is presented.

Taking advantage of the rich magnetic features in the hard disc, those discorded regions (some upper regions in Figure 3 large view one) were intensively studied. Instead of being as continuous bars, individual yet barely separated dots are clearly resolved at some particular regions marked by those red labels. Cursor analysis (not shown here) verified that they were with a size less than 100nm.

MFM Characterization of Duplex Stainless Steels

Duplex stainless steels (DSS) are specially designed to serve the need of those applications requiring materials with high corrosion resistance, superior formability and good weldability. Generally, they are complex systems containing the dual phase of stainless steels i.e., ferrite and austenite ones, in an approximately 1:1 ratio. Previous investigations have proven that both the composition and their spatial distribution of two components play a critical role in DSS performance. Optical microscopy and hardness measurements are the traditional ways for studying DSS, yet they are not good enough to distinguish the dual phases of stainless steels. Due to the fact that ferrite is ferromagnetic while austenite is paramagnetic, high-resolution magnetic imaging offers a solution. An illustration example is displayed in Figure 5. The left one is topographic image of a polished DSS sample. As can be seen, lots of scratches are observed and the

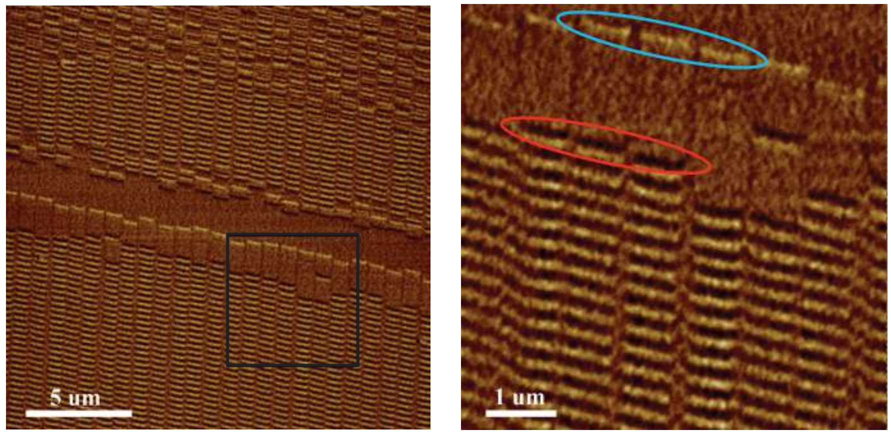

Figure 3. An example of differentiating magnetic domains in computer hard discs via MFM. Scan size: 20 µm × 20 µm (left) and 6 µm × 6 µm (right).

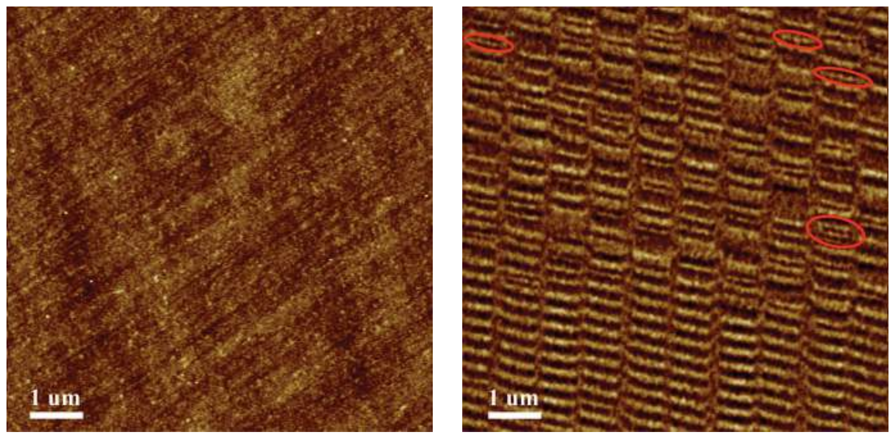

Figure 4. An example of resolving sub-100 nm magnetic features via MFM. Scan size: 8 µm × 8 µm.

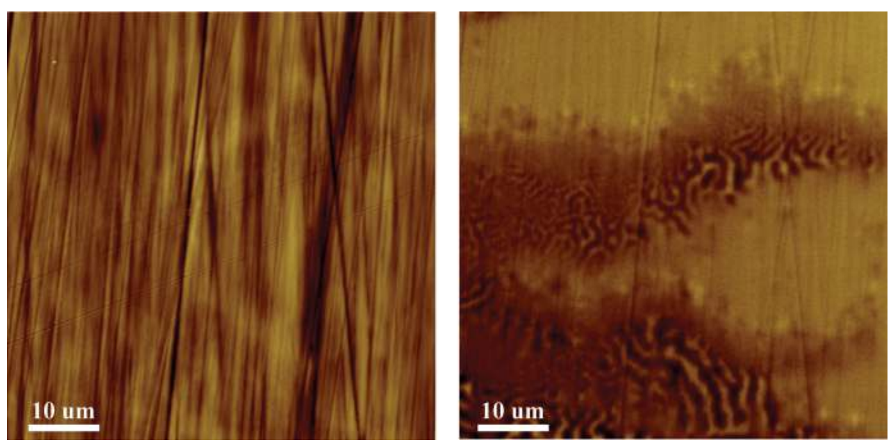

Figure 5. MFM characterization of the duplex stainless steel. Scan size: 60 µm × 60 µm.

surface morphology is quite homogenous through the entire image. However, the corresponding MFM image on the right clearly captures the micro-scale phase-segregation. Those regions exhibit a darker contrast and contain rich localized structures can be ascribed to the ferrite areas.

Summary

The utilization of atomic force microscope as a powerful tool in probing the magnetic properties of materials was demonstrated in the note. Using MFM imaging of hard discs as an example, the capability of Keysight 7500 AFM to successfully resolve sub-100nm tiny magnetic features was proven, and the possibility of differentiating various magnetic properties based on the MFM phase contrasts was demonstrated.

AFM Instrumentation from Keysight

Keysight offers high-precision, modular AFM solutions for research, industry, and education. Exceptional worldwide support is provided by experienced application scientists and technical service personnel. Keysight's leading-edge R&D laboratories are dedicated to the timely introduction and optimization of innovative and easy-to-use AFM technologies.

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