Magnetic Force Microscopy (MFM)

High Resolution and High Sensitivity Imaging of Magnetic Properties

Figure 1.
Schematic diagram of the surface property measurement by the advanced XE modes.

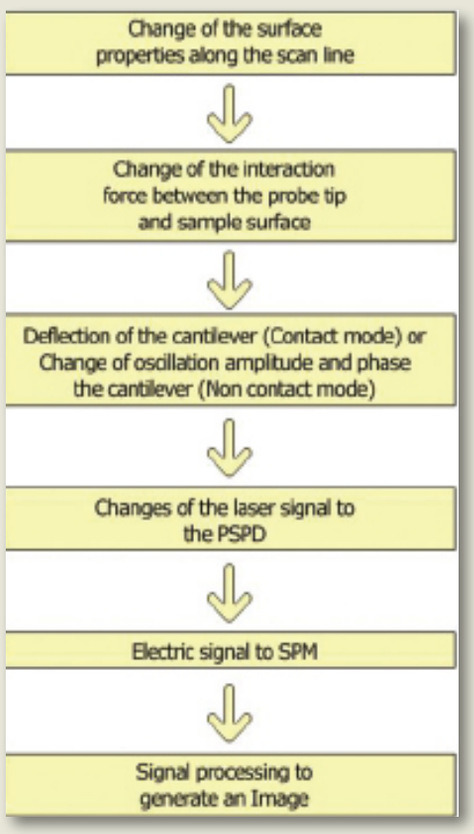
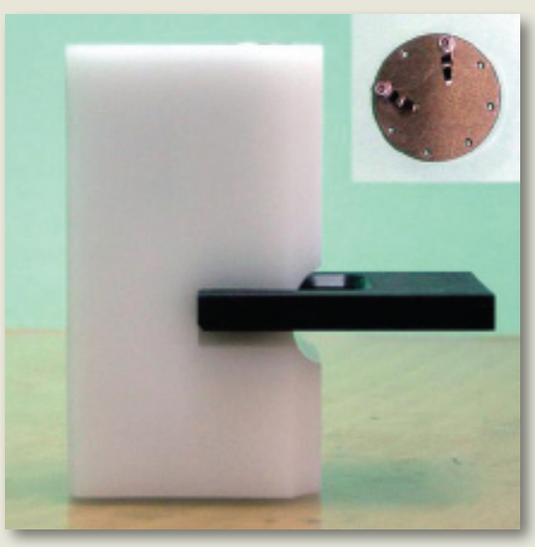


Figure 2.
Schematic diagram of the surface property measurement by the advanced XE modes.



Magentic Force Microscopy

Almost every surface property measured by AFM is acquired by the process depicted in Figure 1. MFM measurements in the XE-series AFM follow the same procedure. For MFM, the surface properties would be magnetic properties and the interaction force will be the magnetic force between the magnetized tip and magnetic sample. However, in addition to the magnetic forces, Van der Waals forces always exist between the tip and the sample. These Van der Waals forces vary according to the tip-sample distance and therefore are used to measure the surface topography.

MFM images the spatial variation of magnetic forces on a sample surface with the MFM tip coated with a ferromagnetic thin film. In the XE-series AFM, surface topography is obtained in True Non-Contact mode. At the same time, the MFM image is generated by measuring either the amplitude or the phase change of the cantilever oscillation from the magnetic force between the surface and the magnetized MFM cantilever. MFM images contain information on magnetic domain distributions on the sample surface. MFM can be used to image naturally occurring and deliberately written domain structures in magnetic materials.

During the MFM measurements, there are two forces acting on the tip; magnetic and Van der Waals forces. Hence, in MFM, the signal contains both information of surface topography (called 'Topo signal') and surface magnetic property (called 'MFM signal') generated by Van der Waals and magnetic forces, respectively. The dominating force depends on the distance between the tip and the sample surface, because the inter-atomic magnetic force persists for greater tip-to-sample separations than the van der Waals force. These van der Waals forces vary according to the tip-sample distance and therefore are used to measure the surface topography. If the tip is close to the surface, in the region where standard Non-Contact AFM is operated, the image will be predominantly topographic. As you increase the separation between the tip and the sample, magnetic effects become apparent. Collecting a series of images at different tip heights is one way to separate magnetic from topographic effects.

The key to successful MFM imaging lies in separating the magnetic signal from the entire signal. In MFM, this is done by 'Force Range' technique or 'Two Pass' technique.

Force Range Technique

Van der Waals force is a short range force while the magnetic force is a long range force. In the first scan, the tip is scanned in the region where the van der Waals force is dominant for topography image. Then, the set-point is varied to place the tip in the region where the magnetic force is dominant and scanned for MFM image, as shown in Figure 3 (a).

Figure 3.
(Left) The schematics of (a) Force Range technique and (b) two pass technique and (c) corresponding

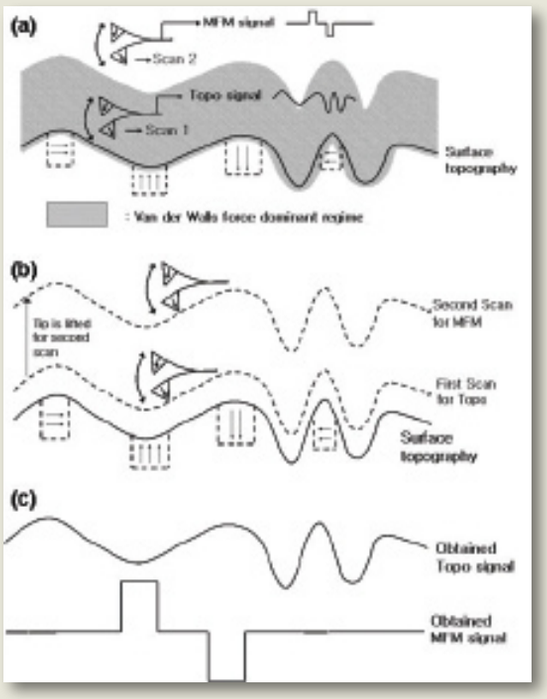


Figure 4.
Topography (a) and MFM phase (b).

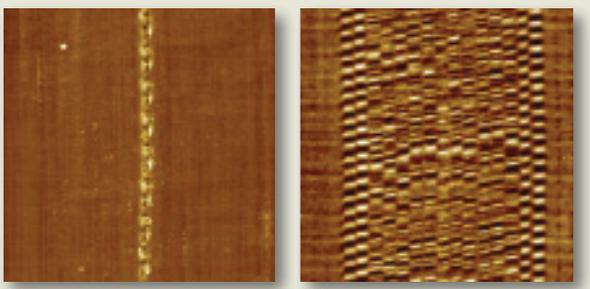
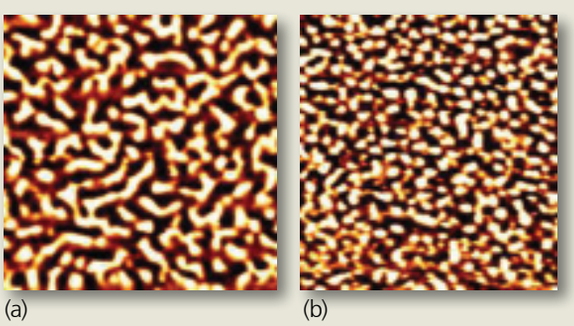


Figure 5.
MFM phase image of (Co84Cr16)100-xPtx X=13 (a) and X=28 (b).



Two Pass technique

In this MFM mode of the XE-series AFM, sample is scanned twice to separate the signal as shown in Figure 3 (b). In the first scan, the tip scans the surface as in True Non-Contact AFM to obtain the topography of the sample. In the second scan, the tip-sample distance is increased and the biased tip is scanned along the topography line obtained from the first scan as shown in Figure 2. The tip is only affected by the magnetic force and MFM image is obtained as a result.

The topographical line maintains constant tip sample distance, which equals the line of the constant van der Waals force. So, when the tip follows the topography line in the second scan of 'MFM mode', the van der Waals forces acting on the tip are kept constant. Thus, the only change in force affecting the signal is the change of the magnetic force. So, from the second scan, the MFM image, free of topography signal, can be obtained.