Procedure to Perform Magnetic Force Microscopy (MFM) with VEECO Dimension 3100 AFM

Ivan Alvarado, NRF 11/16/2006

Notice: you must be a qualified AFM user and have some proficiency in obtaining AFM images in tapping mode before you carry on with this procedure.

Probes suitable for MFM must be used. Applied Nanostructures' MAGT probes and VEECO's MESP probes are the standard. Information on either vendor is provided in the AFM main procedure. **Probes must be magnetized with a strong magnetic field prior to use**; simply place the probe close to a permanent magnet (around 0.3 Tesla) for a minute. The NRF does have a magnet that is used for different purposes, please ask the staff members if you need it.

During MFM, the Dimension 3100 performs a normal tapping mode scan first (trace and retrace) to obtain the topography of the surface, then it scans again along the same line only this time the cantilever is lifted up and the tip follows the topography so that it does not touch the surface (interleave mode). The height value of the lift must be specified when setting up the INTERLEAVE; this value can be adjusted to obtain the desired image. Changes in the magnetization of sample will be reflected on the phase image during the second scan. The topography information of the sample is then displayed on Channel 1 in the scan-dual window while the interleave information is displayed on Channel 2.

Procedure

1. Set up the probe on the carrier and align it in the head just as you do with any other probe.

2. Set the AFM in Tapping Mode and tune the cantilever.

3. Tune Cantilever drive frequency. Set the frequency range 0 to 150 kHz. Typical resonance frequency for a MAGT or MESP probes is around 60 kHz.

4. Set the scan rate to 0.5 Hz and adjust the other AFM parameters (Amplitude Set-point and Integral/Proportional Gain) as you normally do for

5. In the Scan-Dual window, under the INTERLEAVE menu set INTERLEAVE MODE to LIFT.

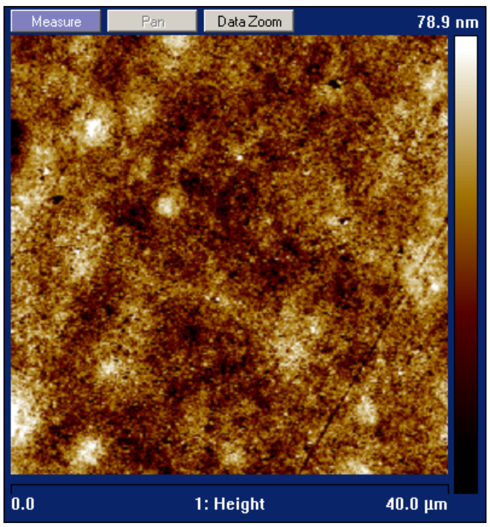
6. Set LIFT START HEIGHT to 0 and LIFT HEIGHT to 80nm. The lift height is a parameter that could dramatically change the MFM imaging, see notes below for more information.

7. In the Scan-Dual window, select the following:

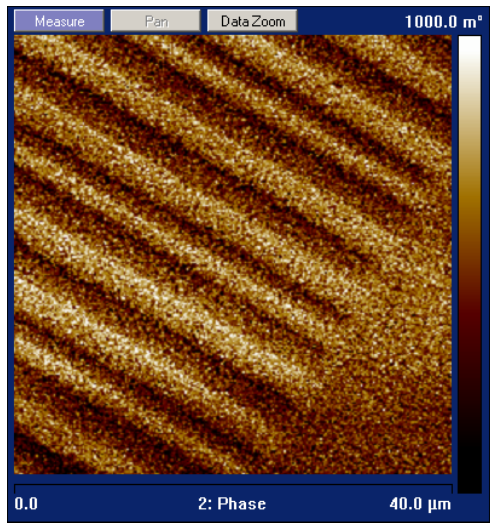
- Channel 1: Scan Line: MAIN; Data Type: HEIGHT.
- Channel 2: Scan Line: INTERLEAVE; Data Type: PHASE.
- Adjust the appropriate scale range in both channels until an acceptable image is displayed.

8. Reduce/Increase the value of LIFT HEIGHT as needed in order to obtain the desired image. See notes below for more information on the effect of the height on the MFM image.

Typical MFM image:



(a)



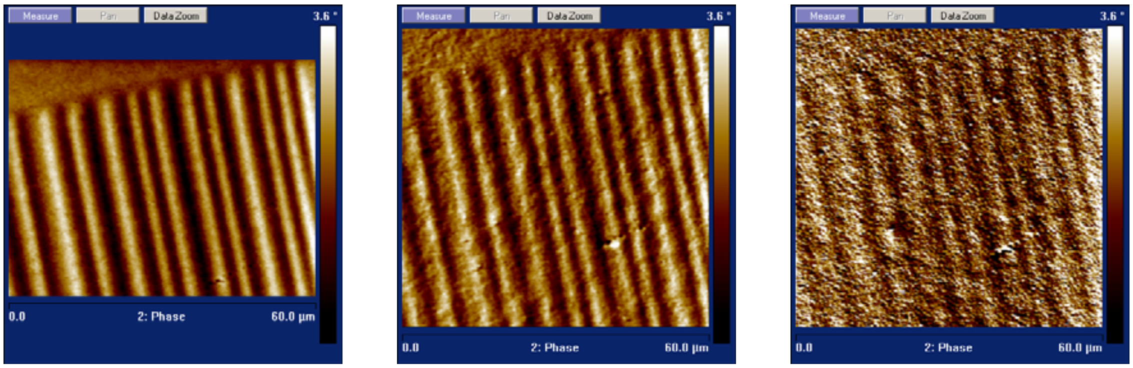
(b)

Image (a) is a normal tapping-mode image of the surface of a floppy disk. Image (b) is an MFM of the same surface in (a). The magnetic information of the floppy disk is clearly seen on the MFM image. The MFM images were taken with a VEECO's MESP probe. Always compare the normal AFM image with the MFM image; generally speaking, they should be very different.

Effect of LIFT HEIGHT on MFM

One of the most important differences between AFM and MFM is the nature of the force applied on the cantilever. In AFM, the force is merely the result of a mechanical interaction between two surfaces. In MFM, the force is the interaction with a vector force field and, as such, the net force seen by the cantilever at a particular position is the result of the superposition of many magnetic dipoles located both on the sample and on the cantilever. Thus the force on the cantilever depends strongly on the distance between the tip and the scanned surface; this distance is the LIFT HEIGHT.

Adjusting this parameter does not necessarily improve the MFM image; rather it samples the magnetic field at a different z location.



(a) Lift Height 500nm (b) Lift Height 100nm (c) Lift Height 50nm

The figures above show the MFM images of the same region of the sample taken at different Lift Heights. The sample is a piece of a floppy disk. In figure (a), the lift height is 500nm, which is well above the sample surface. The individual bits recorded on the disk are clearly marked. Figure (b) shows the image at a lift height of 100nm; the individual bits are still present, although the fine structure starts to be significant. Figure (c) shows the image produced when the Lift Height is only 50nm. At this height, the contribution of the fine structure is more important than the contribution of the superposition. At these conditions, we are measuring the local magnetic field.

At first sight, it would look like (a) is a “better” image than (c). In reality, both (a) and (c) convey different information about the sample: (a) shows the average effect of the dipoles while (c) reveals more of the fine structure and the local magnetic field present on the sample.