Scanning Tunneling Microscopy (STM) on the Veeco Multi-Mode AFM

Appropriate Samples and Sample Prep

Samples must fit on a 15mm diameter disk and cannot be more than about 5mm thick. Samples (or at least the surface) must be conductive. A conductive adhesive such as carbon tape or silver paint must be used to attach the sample to the magnetic disk. If only the surface of the sample is conductive, conductive adhesive should be used to create a conductive path between the surface of the sample and the surface of the magnetic disk. Samples must be flat since the microscope cannot measure features taller than 2µm. The maximum area that can be imaged with the microscope is 10µm by 10µm.

Stuff to Buy:

| Description	Vendor	Part no.
Magnetic disks for sample mounting	Ted Pella	16218
Carbon tape	Ted Pella	16084-3
Silver paint	Ted Pella	16062-15
Tweezers for handling probes	Ted Pella	5374-NM
STM tips	Bruker AFM Probes	PT10

Mounting the tip and sample:

1. Remove the optical head by disconnecting the two springs holding it to the scanner and also disconnecting the electrical cable (see pic below).
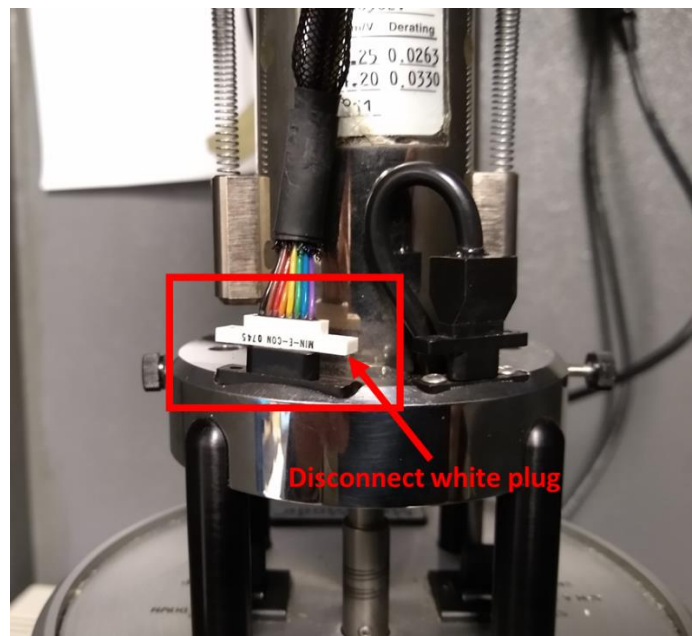
2. Place your sample on the stage. Sample must be conductive and mounted on a magnetic disk using conductive adhesive.

3. Place the STM converter head (see pic below) on the scanner while visually monitoring the gap between the tip mount and the sample surface. When the head is in place, there should be a gap of at least 5mm between the tip mount and the sample. If the gap is insufficient or the tip mount will hit the sample, hold the switch on the right side of the microscope base in the Up position to increase the gap size.

STM Converter Head
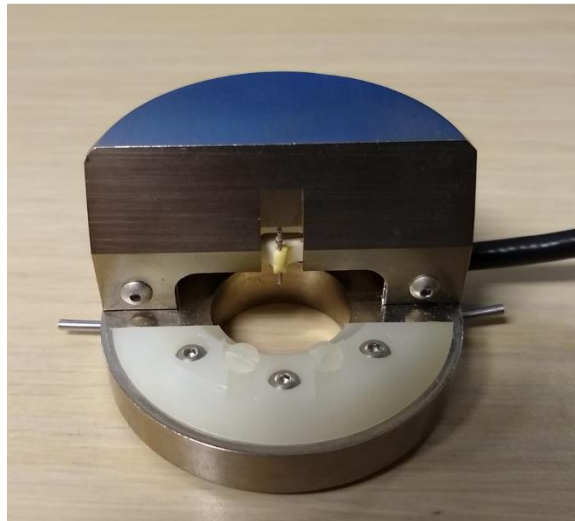
4. Remove the converter head from the scanner, and insert an STM tip into the tip mount. Make sure the tip is firmly seated into the mount. The tip should protrude from the mount approximately 2-3mm.

5. Replace the converter head on the scanner, reattach the springs and plug the electrical connector into the scanner.

Acquiring Data:

1. Set the switch on the left side of the microscope base to the *STM* position.

2. Hold the switch on the right side of the microscope base in the *Down* position to move the tip within 0.1mm of the sample surface. It may be necessary to view the tip-to-sample gap with a magnifier.

⚠ **Warning: if the tip touches the sample surface it will likely be damaged and require replacement.**

3. In the *Scan Control* window → *Other* tab, set *Microscope Mode* to *STM*

4. On the Feedback tab, set *SPM Feedback* = Log, *Current Setpoint* = 2nA, *Integral Gain* = 2, *Proportional Gain* = 2.

5. Set the *Sample bias* according to the measured or presumed conductivity of the sample surface. Bias voltages below 20mV usually provide the best quality images on samples with surface conductivities equal to or better than graphite. Resistivity across the surface can be measured with an ohmmeter. Bias values of 1-50mV typically work well for good conductors. For semiconductors and samples with high resistivity (greater than 1 MΩ/cm), bias voltages of 100mV of even higher may work best.

6. Set other desired scan parameters such as *Scan Size*, *Offsets*, *Scan Rate*, *Scan Angle*, *Samples/Line*, and *Lines*.

7. On the menu bar click *Tools* → *Offset*. Verify that the offset is within +/- 0.1 nA. If the offset is outside this range, the tip is probably touching the sample and you will need to replace the tip.

8. Click *Engage* in the *Scan Control* window or on the menu bar. If the microscope engages right away, the tip was probably touching the sample and you will need to replace the tip. If after several minutes the tip fails to engage, you probably need to lower the tip using the switch on the right side of the microscope base. If you do this, be sure to check the offset again (step 11) before attempting to engage again.

Optimizing the image in height (topography) mode

In height mode, the microscope monitors the tunneling current and uses the feedback to adjust the height of the tip in order to maintain the current at the specified setpoint. This mode is very similar to height imaging in tapping or contact mode. However, in STM factors other than tip-to-sample distance affect the tunneling current. For example, if your sample surface contains different materials with variable conductivity, the tunneling current can change dramatically despite little change in height, making the higher conductivity material appear "taller." So bear in mind that, in STM, a height image actually represents a composite of sample topography, electronic structure and properties.

Just like in tapping mode topography imaging, higher integral gain and proportional gain will help the tip track the surface better. However, STM is much more susceptible to crashing. If the gains are made too low, the tip can stop tracking the surface and crash. If the gains are made too high, the excessive noise can cause the tip to crash. The atomically sharp STM tips are also more likely to be damaged by a crash.

Two additional parameters you can tune in STM mode include sample bias and current setpoint. Current setpoints in the region of 1 - 10nA are common. Tunneling current can cause heating of the sample surface, so lower setpoints are used for very slow scans or for samples that may be damaged by the heating. Higher setpoints have the effect of increasing the gain and result in the tip moving closer to the sample surface. Higher setpoints can improve the signal-to-noise ratio of atomic scale images of some materials.

Sample bias is a voltage applied between the sample and tip in order to induce tunneling. Appropriate bias value depends on the properties of the sample. Highly conductive samples typically require 20-100mV to induce tunneling, while semiconductors and poorly conducting samples may require 1V or more. Selecting too low of a bias can cause the tip to crash into the sample before tunneling is observed. High bias voltages can cause large currents to flow (arcing) between the tip and the sample that may destroy the tip, sample, or both.

Optimizing the image in current mode

To view the current image, set the data type to current. Current data is most informative when the microscope is operated in constant height mode, in which feedback is <u>not</u> used to keep the current constant. Current mode images should only be acquired in flat areas to avoid crashes. Before imaging in current mode, it is best to acquire an image in height mode to look for features on the surface that might crash into the tip in current mode. To acquire images in current mode, slowly reduce the gains toward zero while monitoring the data for large changes in current. Proportional gain can be reduced to zero, but you may want to maintain a small value for integral gain such as 0.1.