Conductive atomic force microscopy primer

# Module setup

Always wear an anti-static wristband (plugged in…) when handling the CAFM module. If the wire of the wristband does not reach a nearby plug socket, then crocodile clips may be used to attach it to a ground point on the CAFM. Note that the stage is not at ground, it is either floating or used to apply bias. The metal guides below the stage are at ground, however, so the wristband may be attached here.

Attach the CAFM module to the scan head before loading the probe holder, while the scan head is fixed in place on the CAFM. At least partway tighten the bolts using the associated Allen key before plugging in the lead.

If the module calibration needs to be checked, it should be detached from the scan head, as the test resistor will not fit into the sockets if it is attached.

# Probe setup

## Probe choice

Diamond-coated probes are very stable and durable. When boron-doped, they have a very high conductivity, and should demonstrate Ohmic behaviour on a metallic test sample (e.g. a gold film connected to the CAFM stage). The diamond grains that cover the probe will often produce a very sharp apex, giving the probe very high spatial resolution and, particularly, spatial resolution for current mapping. However, these apices will blunt quickly, particularly under high applied forces, so the probe may become blunter.

Platinum/iridium coated silicon probes are the most generally used for CAFM measurements. They are typically sharp and demonstrate good Ohmic behaviour, but the coating can wear off quite quickly, leading to a blunt and/or non-conductive probe. This is particularly true under high contact forces or during high-current measurements. Bear in mind, though the current may be small during a measurement, the current density will be huge due to the scale of the contact.

Full-platinum probes are very useful for electrical measurements, but less effective for topographical imaging. They should always retain their conductivity, though the apex might become occluded by debris, making them very useful for addressing small contact pads

## Loading the probe holder

Always wear an anti-static wristband (plugged in…) when handling any AFM probe, and do so on an anti-static mat using the loading mount. Static discharge can easily blow up the apex of a fresh probe during handling.

Make sure it’s loaded properly

Always connect

Align -2 V

# Sample setup

Perhaps the most important part of setting up a CAFM measurement is ensuring that the sample is properly electrically connected to the stage.

Position/location relative to scan head

Always approach the sample at minimum zoom. Typically, the sample is approached after focusing on the tip at high zoom.

Probe misalignment

# Measurement setup

Data types

What’s important

Issues with ramp selection

Most generally, bias is applied from the stage, with the probe held at ground. This

# Scan management

Make sure to save your data with appropriate, future-proof, fool-proof labels. This will save a huge amount of time in the long run, particularly if you’re accumulating a large number of files. The probe type and probe number are useful but overlooked pieces of information (e.g. in case particular probes are used only on particular samples, or their history needs to be recorded). It’s good practice to make a new capture directory in your own folder for each measurement session and save data directly here, rather than later moving the data. Make sure that your chosen folder is selected before you start capturing data, so that you know where you’re saving to and don’t lose anything.

The capture controls are not entirely intuitive. Turning ‘Capture’ on will save the next frame if 1) all scan lines in one or other direction have been completed and 2) no parameters have been changed (although samples bias may be changed without affecting the capture). ‘Capture continuous’ will capture every frame that satisfies the above capture conditions, until it is switched off. ‘Capture now’ will capture however many lines of the image have been accumulated from the top or bottom since the frame has started. Capture last will save the previous frame, regardless of whether it was complete or parameters were changed.

For imaging, it is recommended to scan with a probe velocity no greater than 20 um/s. Slower is often better, to reduce both probe and sample wear. I recommend around 15 um/s for best imaging results and probe lifetime. Be careful with setting the scan rate, as this will determine the probe velocity (although the velocity itself may be set to determine the rate). In particular, if the scan size is changed, then the scan rate will stay the same, so the velocity will change. Make sure to change the rate before the scan size, to avoid implementing a rate much greater than 20 um/s.

Probe wear

# Experimental and troubleshooting methods

## Constant voltage

### 2D imaging

Stuff

### 0D time-domain measurements

Stuff

## Constant current

### 2D imaging

Stuff

### 0D time-domain measurements

Stuff

## Current-voltage sweeps

Stuff

## Force-distance spectra

Stuff

## Thermal tuning

Stuff Thermal tune – don’t cancel or abort as this can crash the software.

## Resonant frequency sweeps

Resonance sweeps

## Tomography

Tomography

## Probe cleaning

### Sticky approach

Try scanning on a surface that is stickier than the probe, such as gold, at a number of angles (e.g. 0, 90, 135). The aim is to transfer any debris from the apex to the scan area. Scan back and forth

# Data processing and analysis

## Nanoscope analysis

To download v1.4 <http://nanoscaleworld.bruker-axs.com/nanoscaleworld/forums/t/812.aspx>

v1.4 is a little bit frustrating to use, if you’re used to v1.5. Some of the functions are broken (e.g. selecting an area to measure roughness, rather than the whole image). v.1.5 is available somewhere. I have a copy, if needed.

## Matlab

Matlab scripts for data processing and analysis are available via Mathworks and github.

<https://uk.mathworks.com/matlabcentral/fileexchange/73789-surface-analysis>

<https://github.com/MarkBuckwell/surface-analysis>

## Slicer

3D Slicer may be used to assemble 2D image slices into 3D tomograms. The software is designed for bio-imaging. There might be better freeware/open source software available elsewhere.

<https://www.slicer.org/>

# Further reading

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