BioLogic

How to get clear images in Scanning Kelvin Probe (SKP)*

*Advice made throughout this tutorial can be applied to SKP measurements on the M470, and M370 instruments

Version 1.0

Aim.

This tutorial aims to provide users with the information they need to obtain clear images using Scanning Kelvin Probe (SKP). We will address a number of factors which can affect the SKP image:

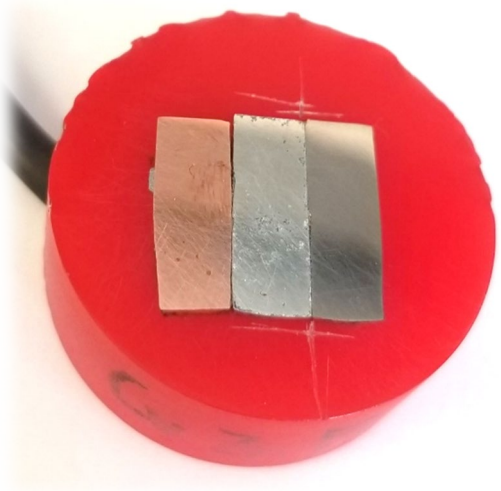
- The sample
- The probe
- Sample tilt and topography
- Configuration settings

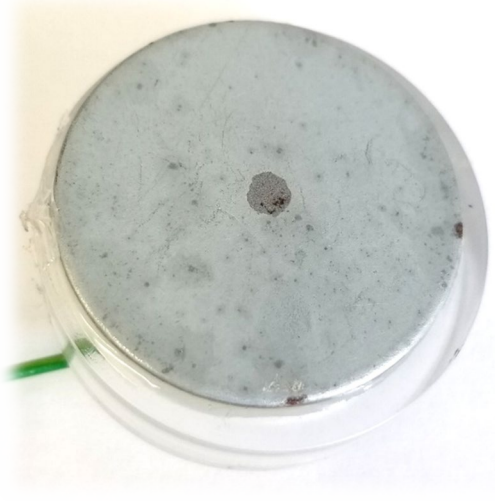
Once mastered users will be able to measure model and novel samples.

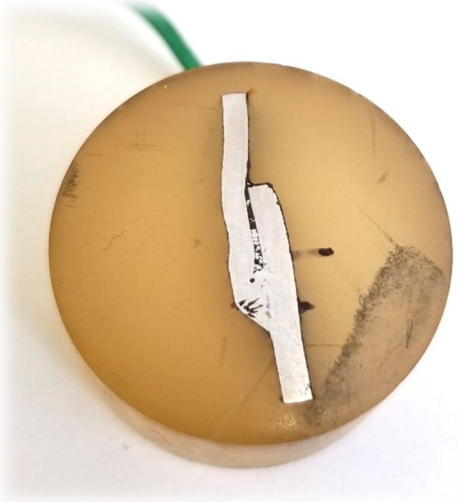
The sample.

Sample requirements.

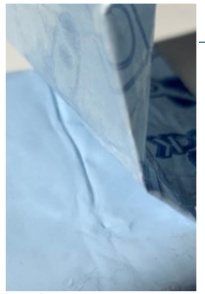
- Must be a conductor, or semi-conductor
- Suitable for coated samples, and dielectrics
- Must have an electrical connection





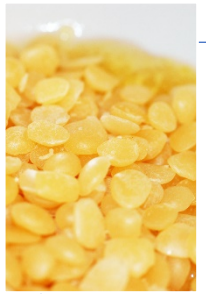


Mounting the sample.



Blu-Tac

Can be used to hold small (few cm) samples onto a blank.



Beeswax

Sample should not be porous, or adversely affected by heating.

Epoxy Resin

Should only be used for samples which are polished before measurement.

Clamping

Large, flat samples can be clamped into place on the TriCell base.

Other

PTFE tape, parafilm, double sided tape, glue, adhesive medical tapes...

Making electrical contact.

In SKP there MUST be an electrical contact to the sample.

Soldered wire

Particularly useful for epoxy mounted samples which will be used repeatedly.

Copper tape

Useful for samples not easily soldered to, or connected to with a crocodile clip. Often requires use of silver paint.

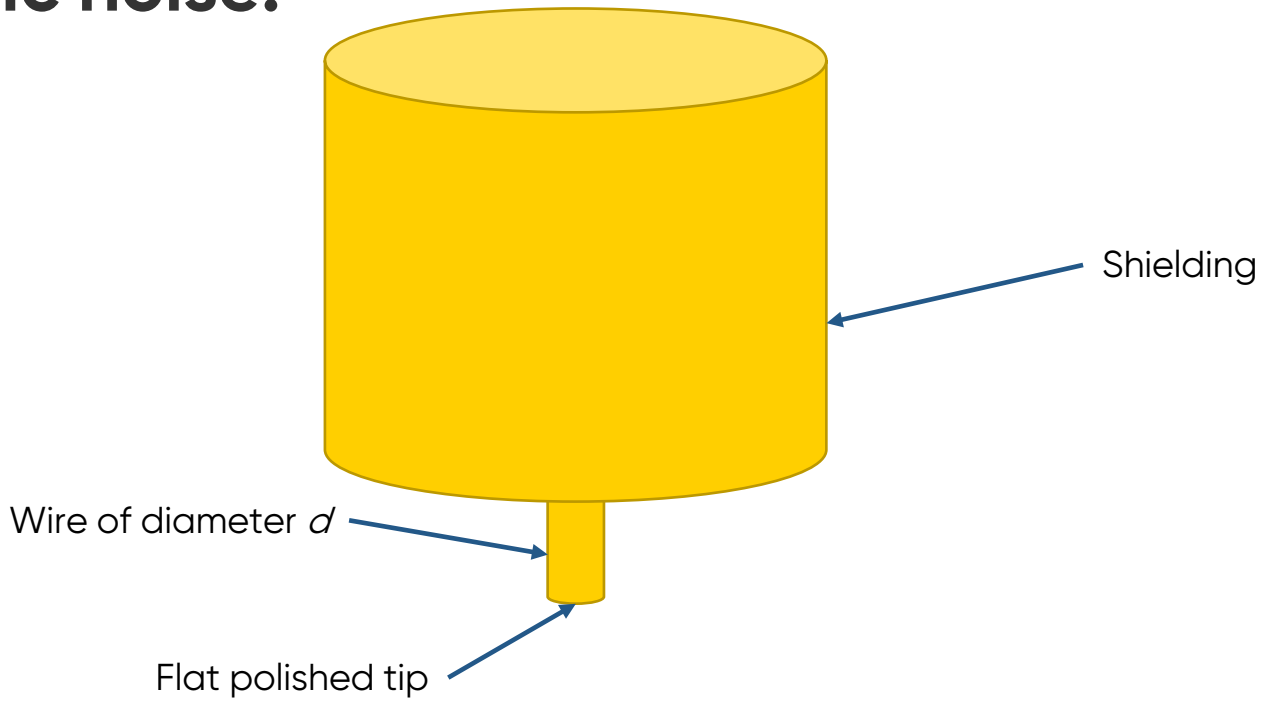
Crocodile clip

For large flat samples it may be possible to directly connect to the sample using a crocodile clip.

The SKP Probe.

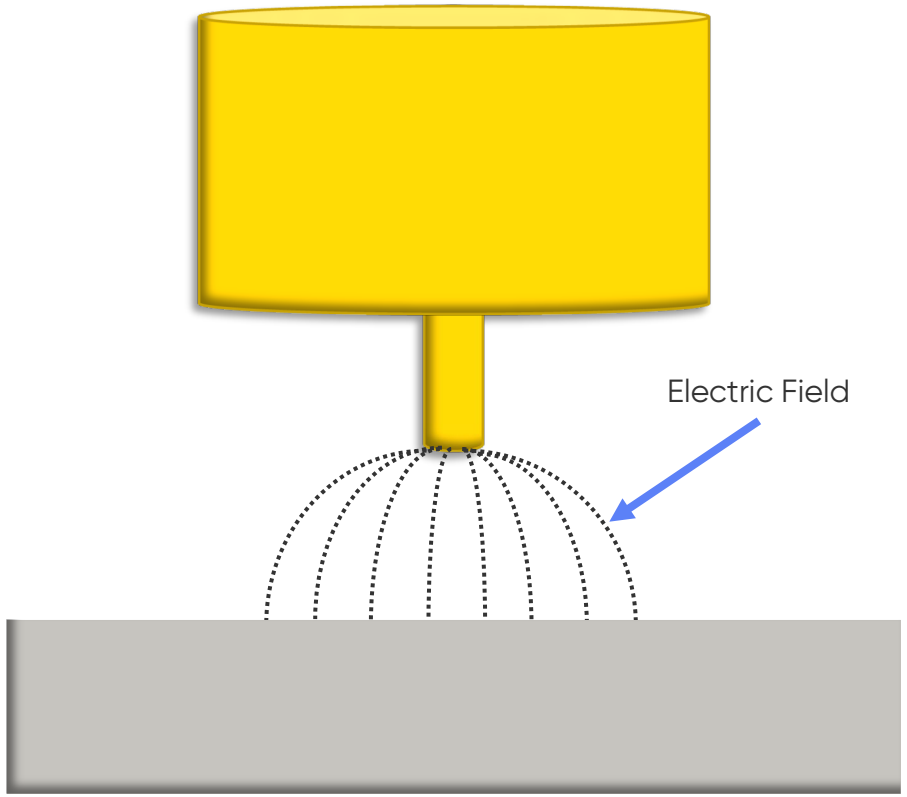
SKP probe background.

The SKP probe forms a parallel plate capacitor with the sample allowing for the highly sensitive contact potential difference measurements. Commonly the probe is a flat polished wire (W) of known diameter surrounded by a shield to reduce parasitic noise.



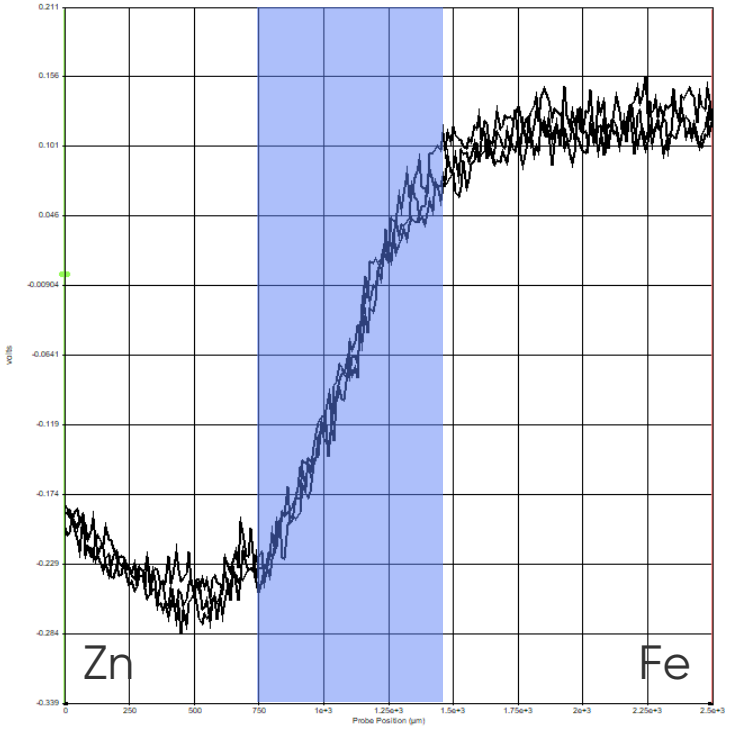
Active diameter: Fringing.

- Fringing, a trait of capacitors where the electric field extends beyond the plane of the capacitor, must be considered
- The fringing effect typically has a larger influence on smaller diameter probes
- Fringing reduces the signal quality

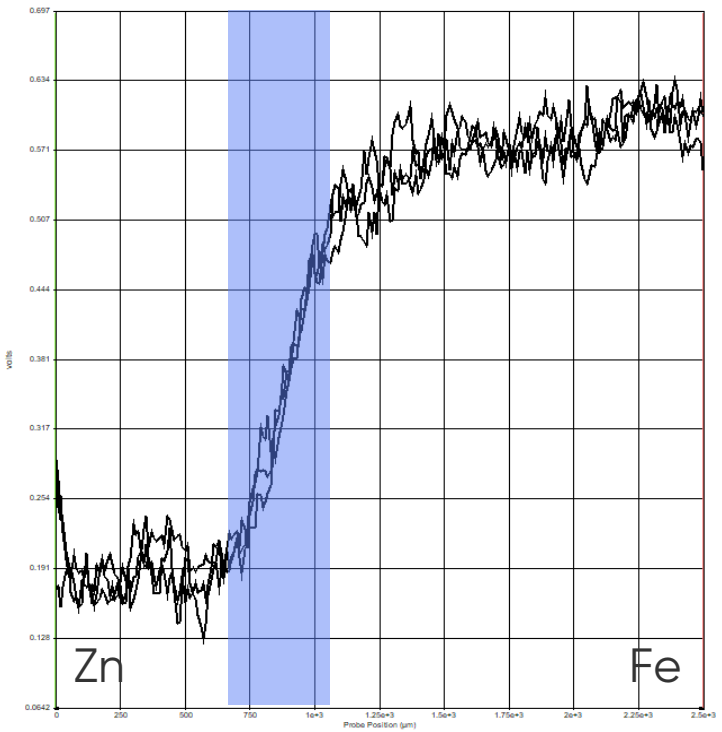


Active Diameter: Example

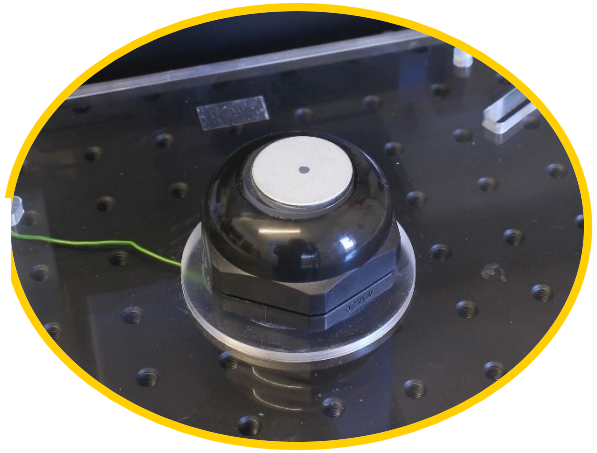
The tip diameter affects the lateral resolution



500 µm SKP probe



150 µm SKP probe



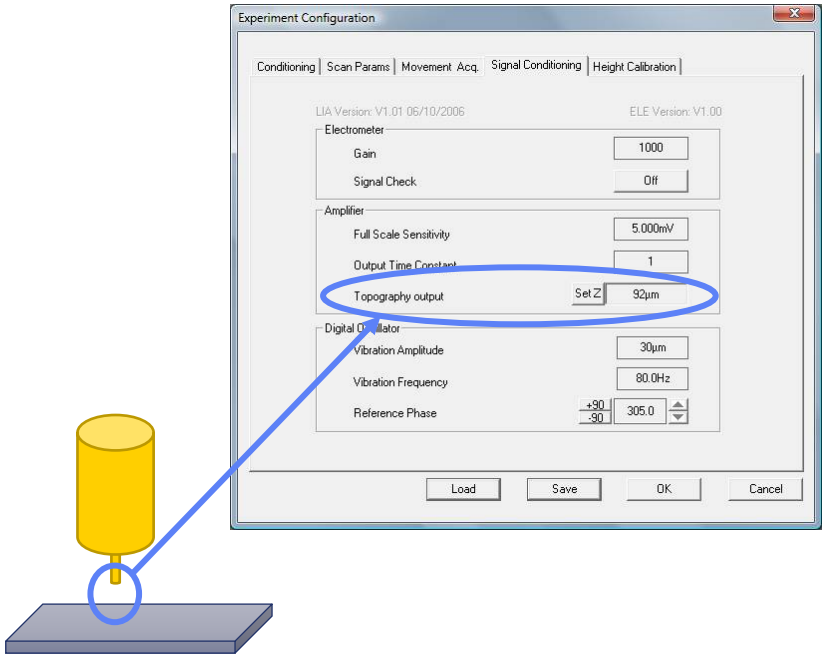
Standard Zn/Fe sample measured for comparison

The transition region is sharper for the smaller probe size

Probe height.

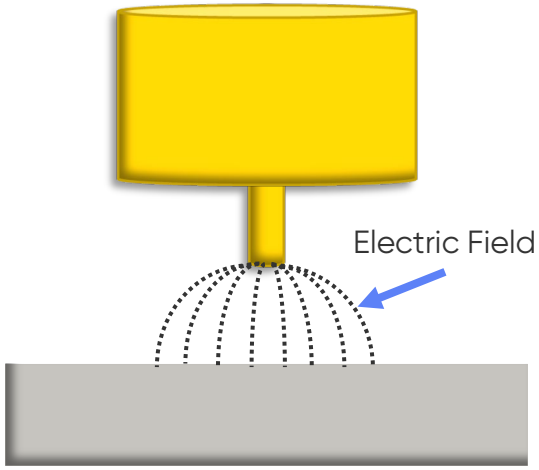
Determining probe height.

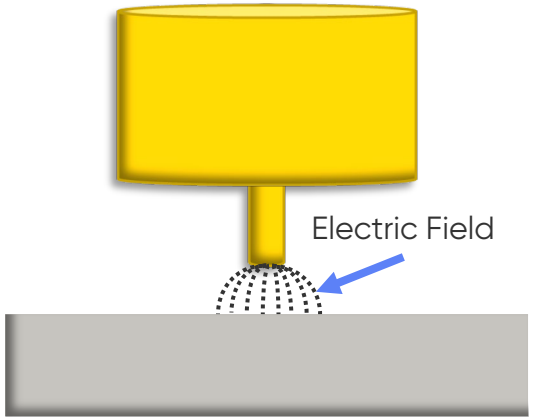
Ideally the SKP probe is positioned so it is 100 µm from the sample. The CHM or CTM experiment is used to determine the probe to sample distance. With CHM/CTM the measured capacitance is used to calibrate the probe height.



Probe to sample distance: Fringing.

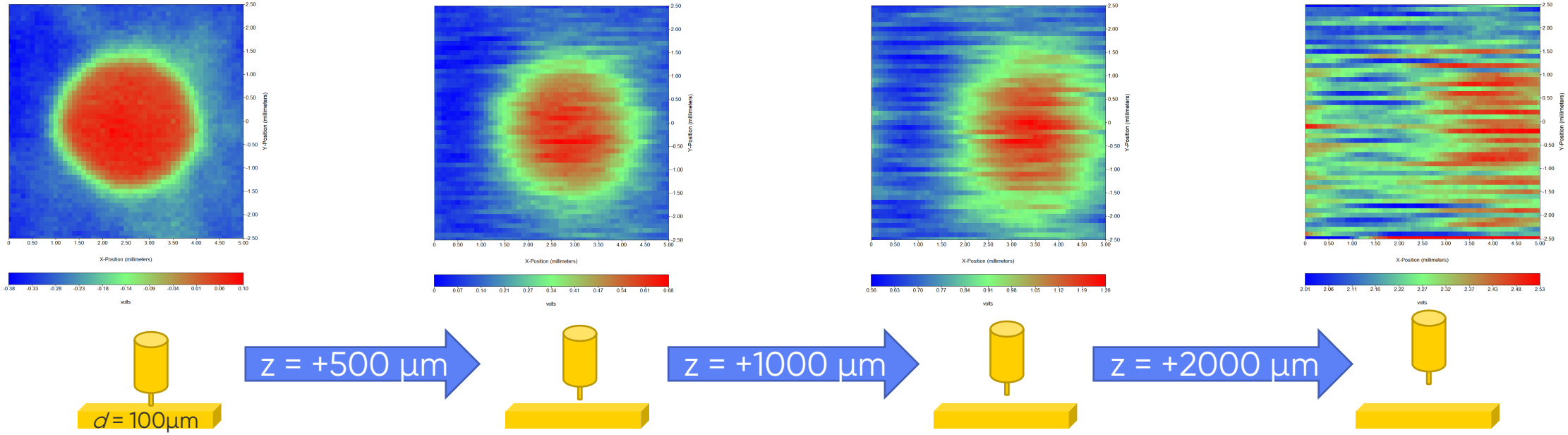
- The fringing effect typically has a larger influence when the probe is further from the sample
- Because fringing reduces the signal quality the result of increasing the probe to sample distance is a decrease in signal quality





Probe position: Example.

- To measure a high quality signal the probe should be near the surface (~100 µm)
- It should not touch the surface at any point in the scan

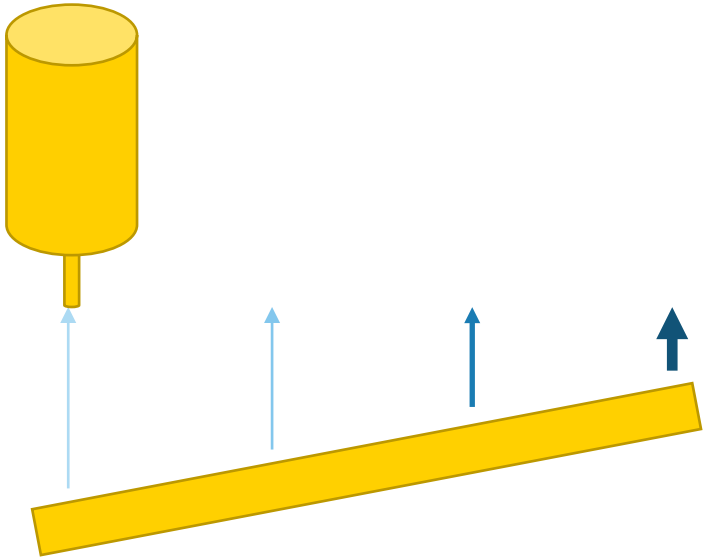


Measurements performed with 500 µm probe

Sample tilt and topography.

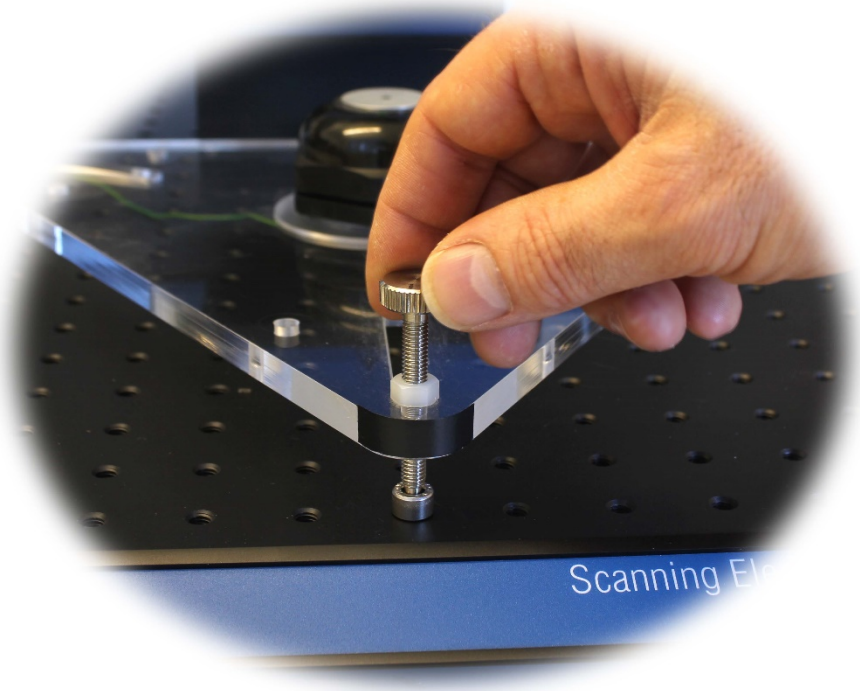
Sample tilt.

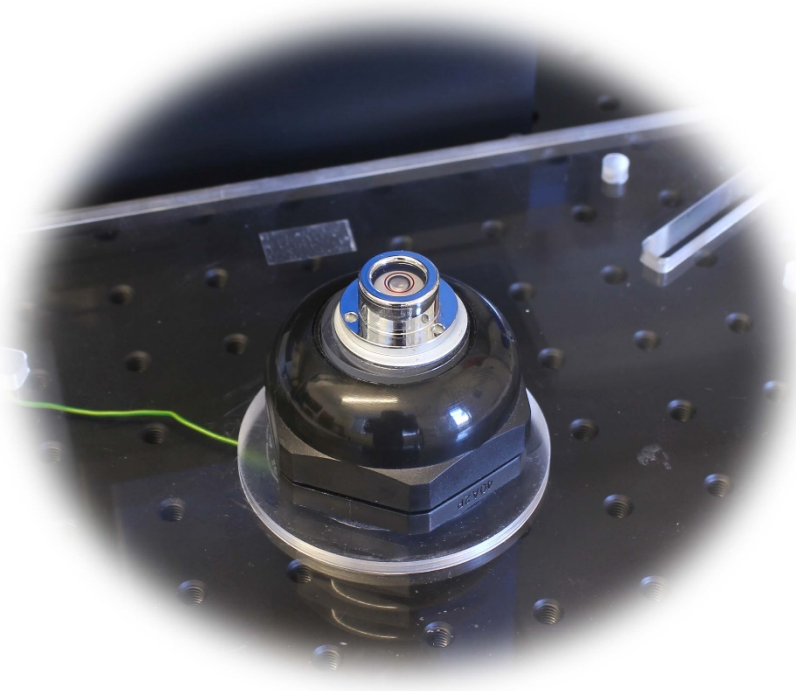
- Too much sample tilt causes partial or complete loss of SKP signal.
- Too much sample tilt can reduce the signal quality.
- Sample tilt can lead to probe crash.



Dealing with sample tilt: During setup.

A spirit level is supplied to help level the sample in the TriCell using the adjustment screws.





Dealing with sample tilt: Pre-experiment.

Bring probe near surface

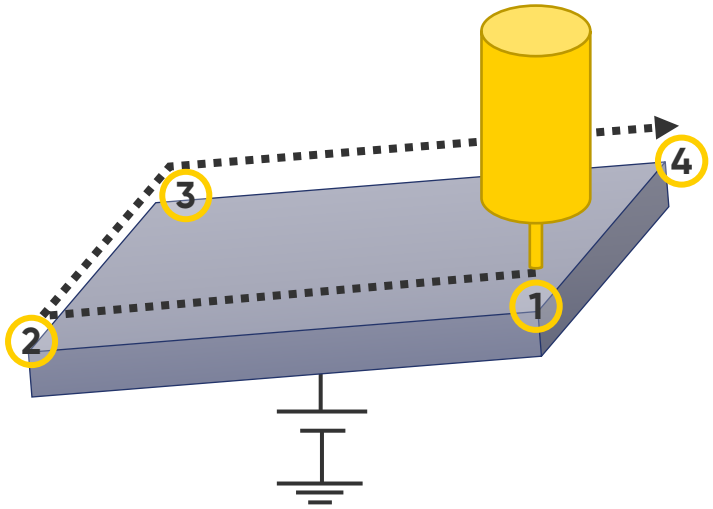
Measure "Topography output" at each corner

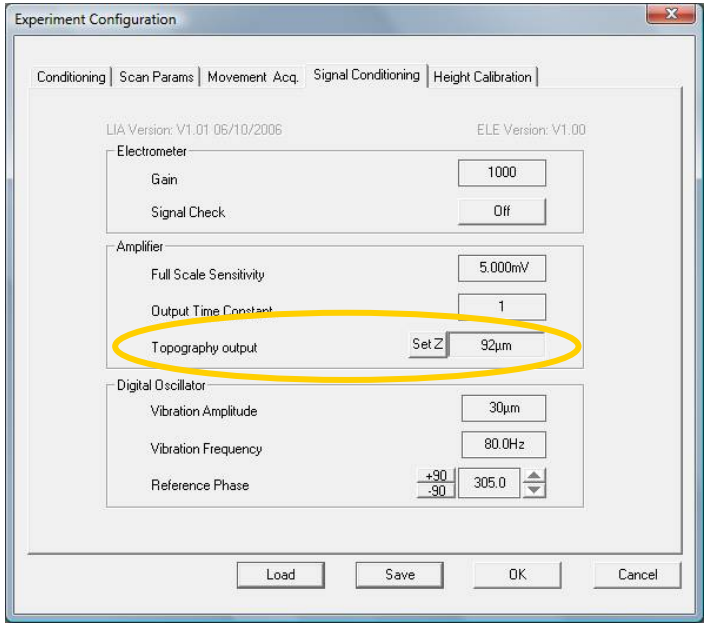
Compare:
Small "Topography output" is highest point
Large "Topography output" is lowest point

Tilt adjustment complete: Highest and lowest point are within a few 10s of µm

Retract probe from surface

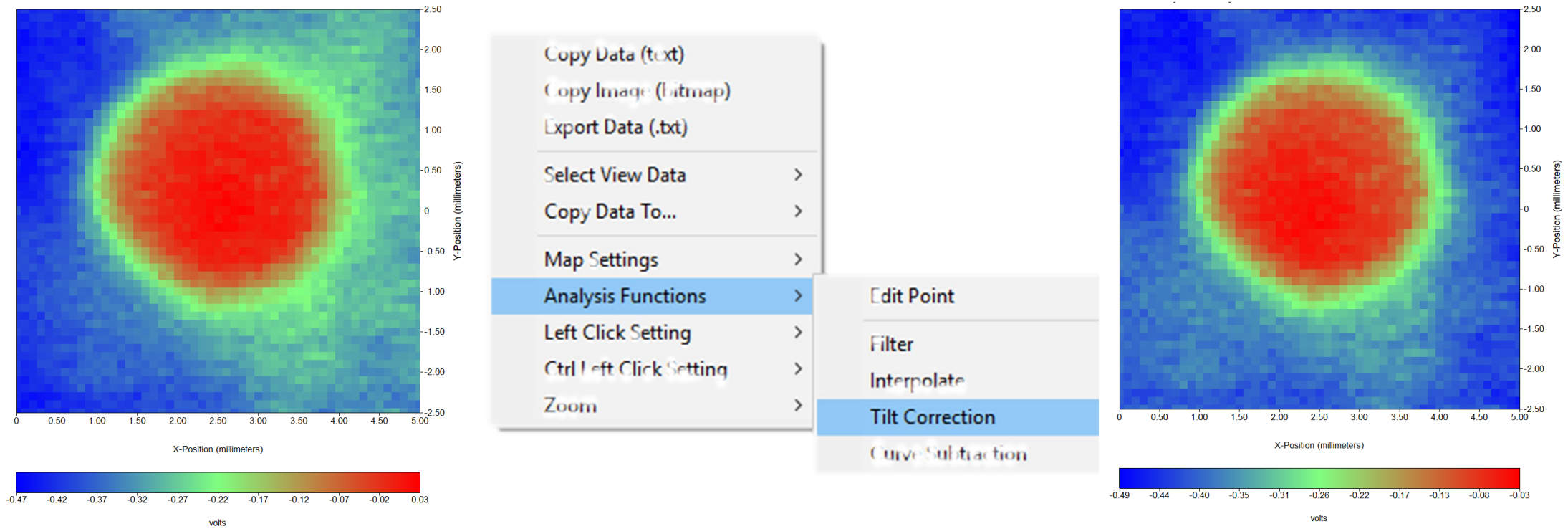
Adjust sample with screws of TriCell





Dealing with sample tilt: Post experiment.

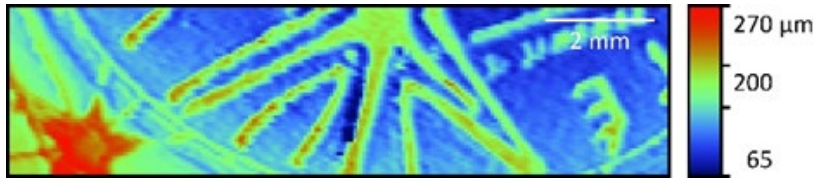
If sample tilt is apparent in an area scan it may be possible to correct for this in the M470 and M370 software.



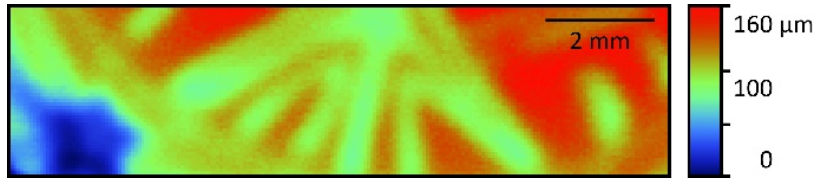
If the signal is excessively noisy, and/or the tilt cannot be adequately corrected, the sample should levelled and the experiment repeated.

Dealing with sample topography.

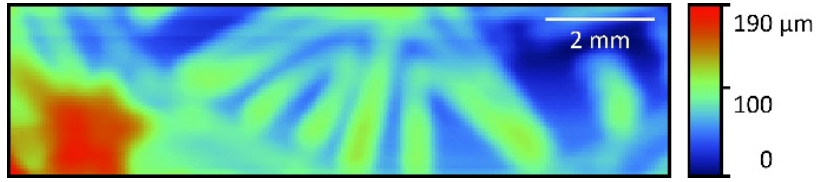
The SKP signal can depend on the sample topography. To reduce topography effects the probe can track the sample using a Height Tracking (HT) measurement with topography first measured by:



Optical Surface Profiler (OSP)



Capacitive Height Measurement (CHM)

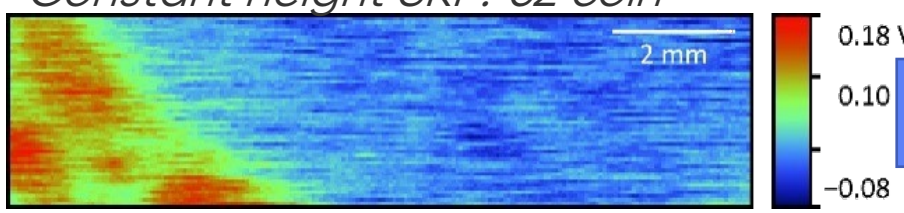


Capacitive Tracking Measurement (CTM)

To Height Track or not?

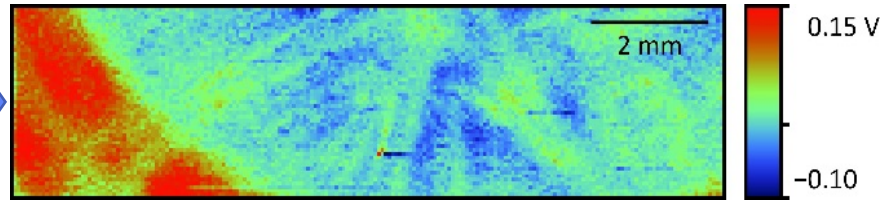
- Topography has a noticeable effect on the measured signal
- Maintaining the probe to sample distance improves the SKP signal
- Large height changes reduce SKP quality and resolution
- Consider height tracking for rough or curved surfaces

Constant height SKP: €2 coin



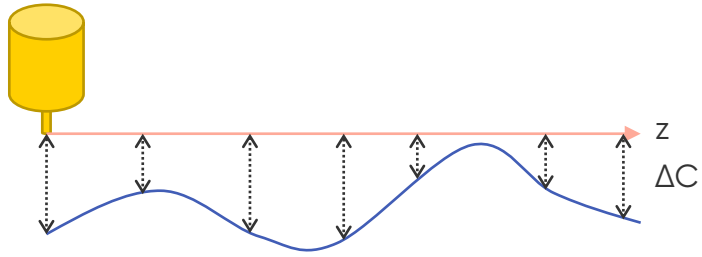
OSP topography measurement

Height tracking SKP: €2 coin

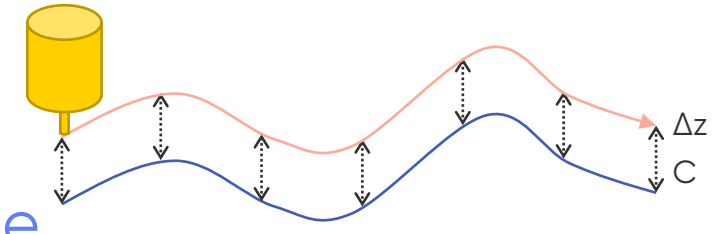


CHM or CTM topography measurement?

- **Capacitive Height Measurement (CHM)**
  - Constant height measurement
  - Used for relatively flat samples
  - Fast topography measurements



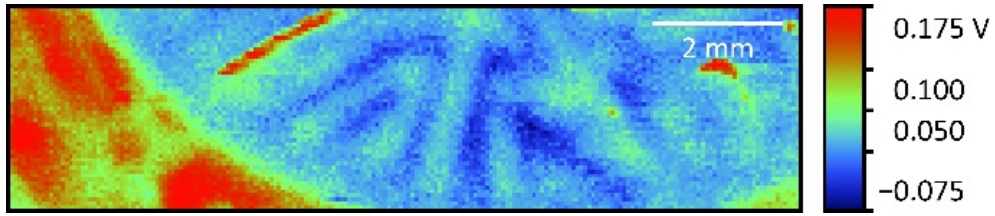
- **Capacitive Tracking Measurement (CTM)**
  - Constant distance measurement
  - Used for samples with large topography change
  - Step scan measurements *only*



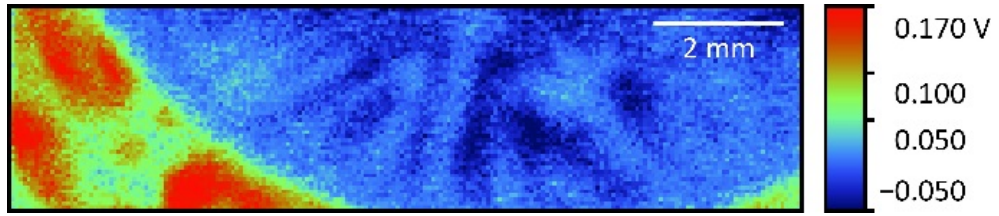
- **More information in [AN#1]**

CHM or CTM? Examples.

SKP with Height Tracking: CHM



SKP with Height Tracking: CTM

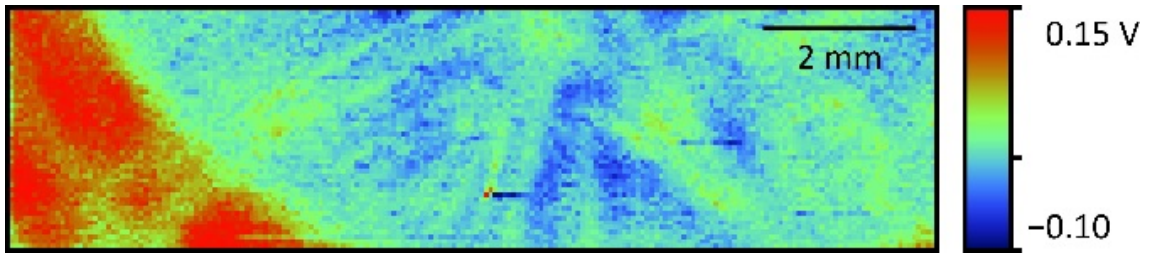


Both CHM and CTM improve the SKP signal of a sample with noticeable topography. The topography map measured in CTM can be more accurate, improving the final signal, however this has a time cost.

When there are large topography changes CTM *must* be used.

When to use OSP?

- For the fastest topography measurement
- If the capacitance of the sample is unstable
- If sample charging is an issue
- If insulating regions exist
- *NB:* The SKP probe and OSP must be aligned to avoid topography mis-match.



Tips for height tracking.

- **Use the most appropriate topography technique for the sample**
- **Confirm the measured topography matches expectations**
- **Bad topography data causes bad SKP data**
  - Spurious points should be edited
  - If the topography data is very poor re-run the experiment

- **More information can be found in TN#14**

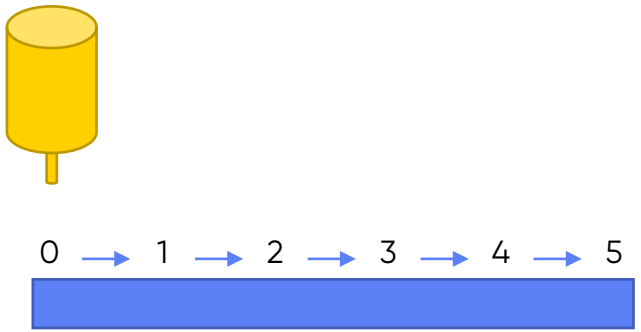
Configuration settings.

Step scan or sweep scan.

In constant height SKP both step scan and sweep scan are available

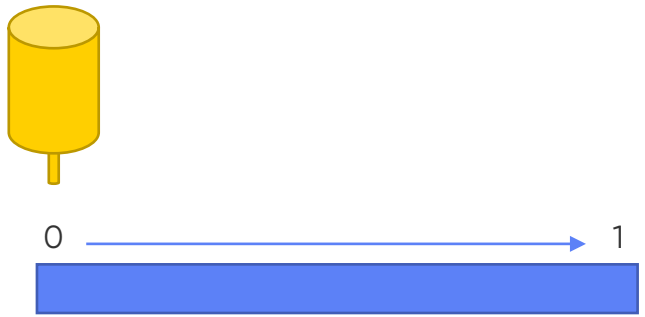
Step scan:

- Probe pauses at each point to collect data
- Lower noise measurement
- Multiple samples averaged at single point



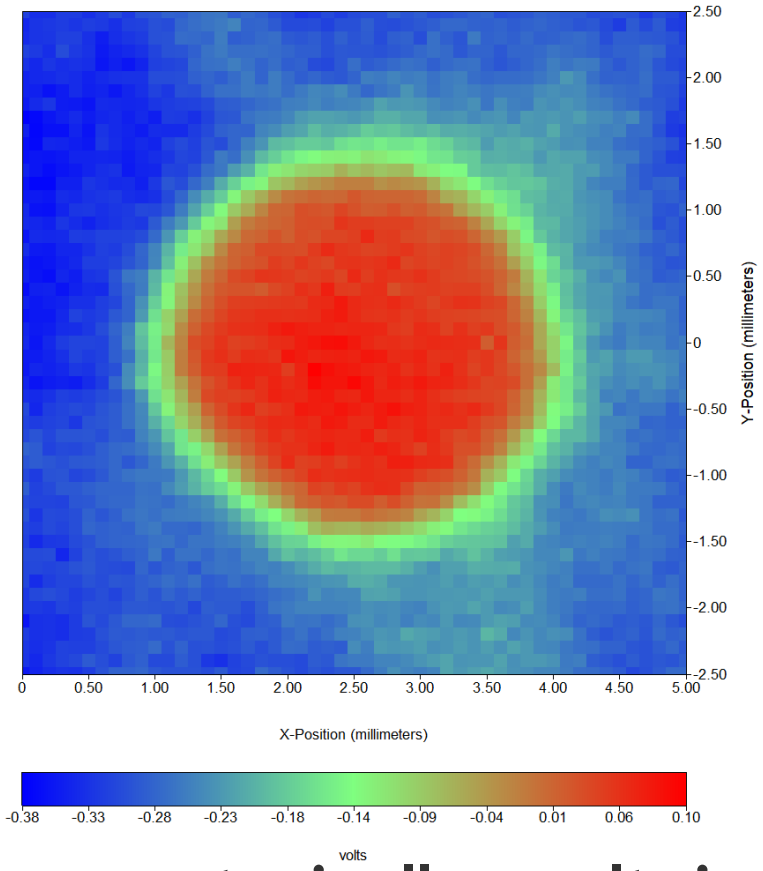
Sweep scan:

- Probe does not stop during a line, measuring at given time intervals
- Faster measurement
- Single sample measured at each point

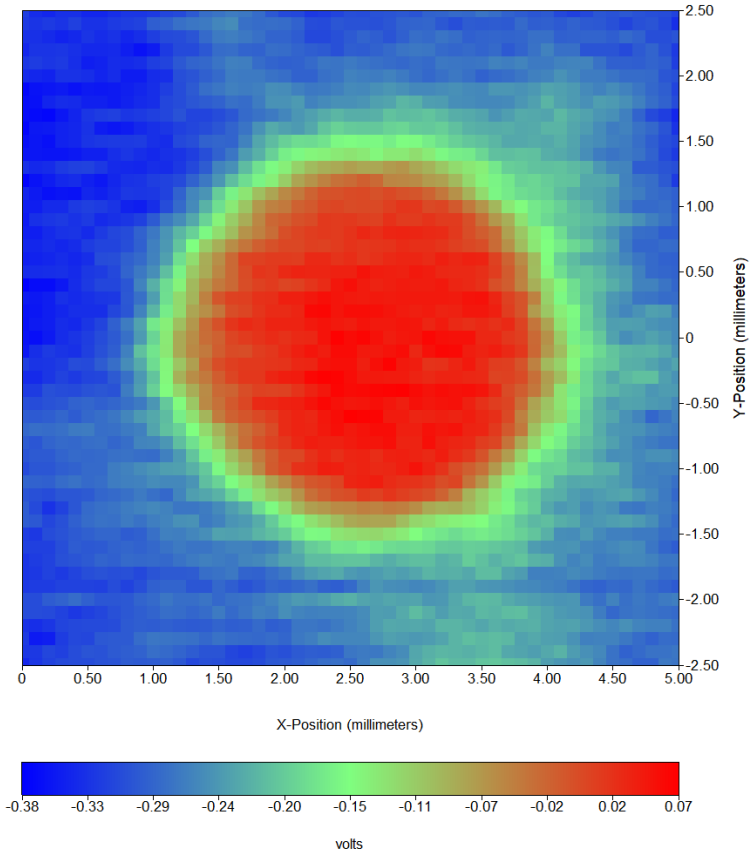


Step scan vs sweep scan example.

Step scan



Sweep scan



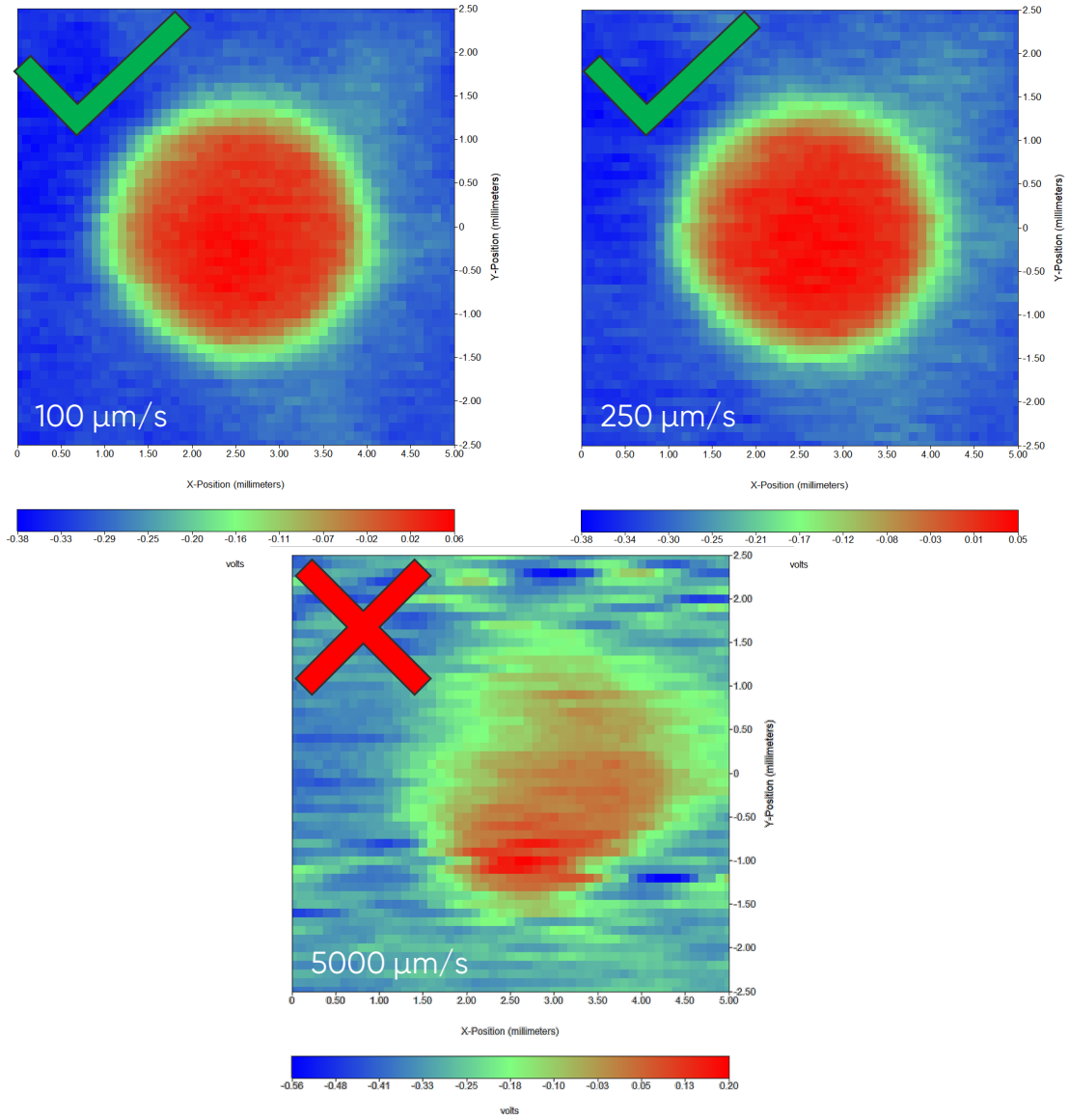
Step scan typically results in better images than sweep scan. However a step scan experiment will take longer to perform.

Selecting scan velocity.

Scan velocity selected to:

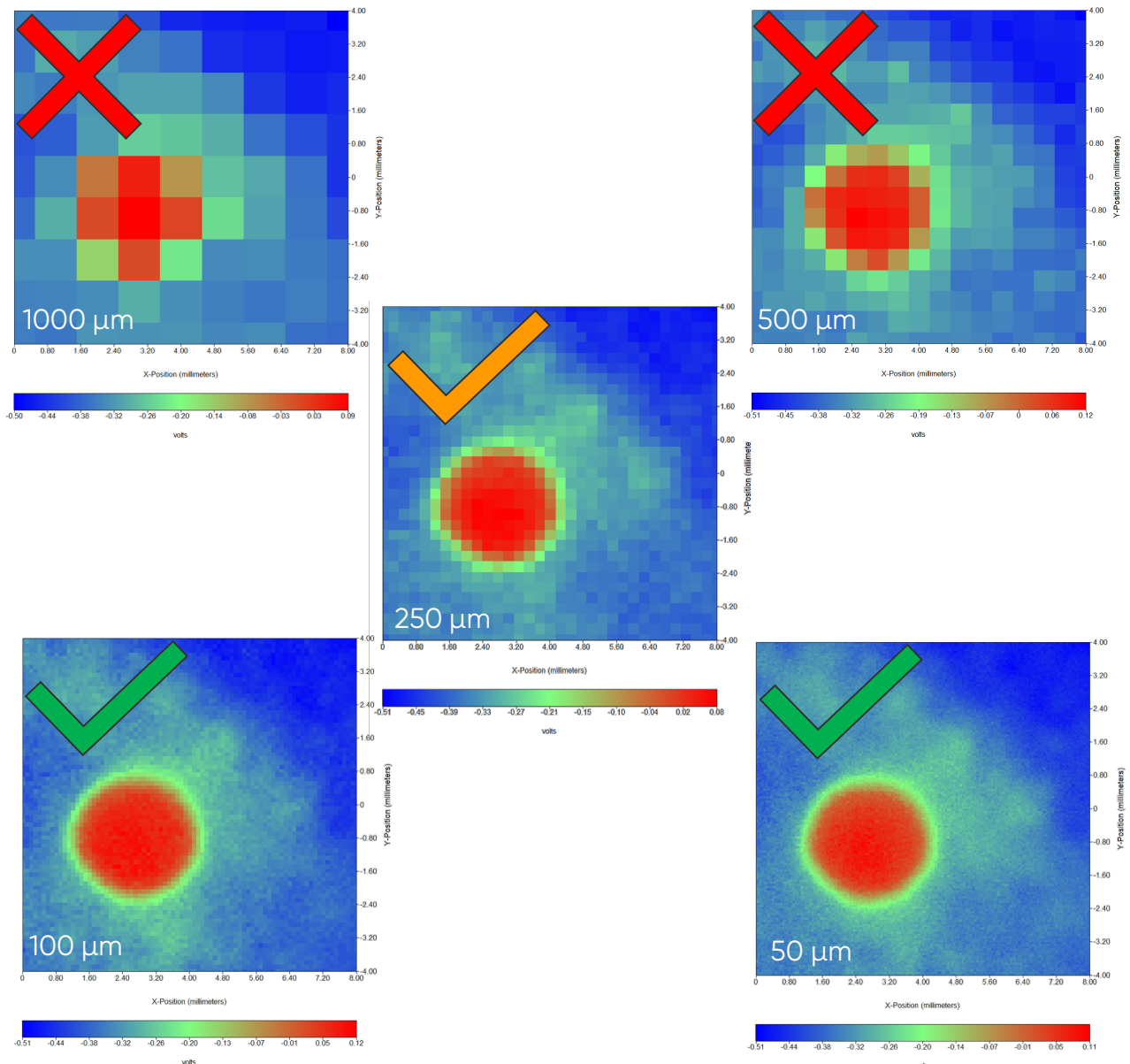
- Maintain positioning accuracy
- Avoid excess noise
- Reduce experiment time

- The PID settings may need updating when changing scan velocity, slide 32
- Increasing the step size can improve the quality of a high velocity scan



Selecting a step size.

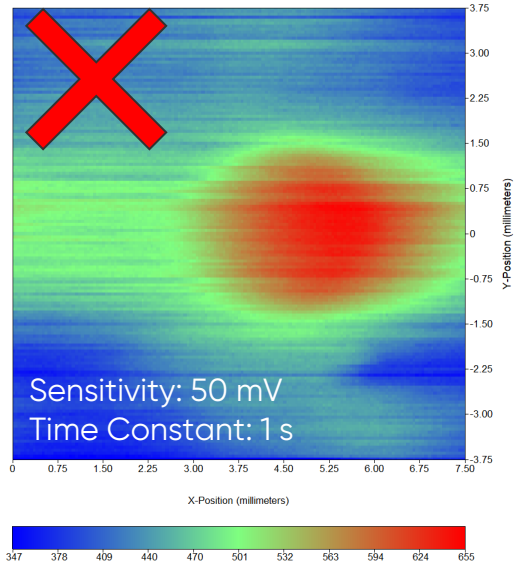
- While resolution depends on probe size, step size also matters
- Oversampling, where the step size is smaller than the probe, is common
- Smaller step sizes give clearer images but increase experiment times

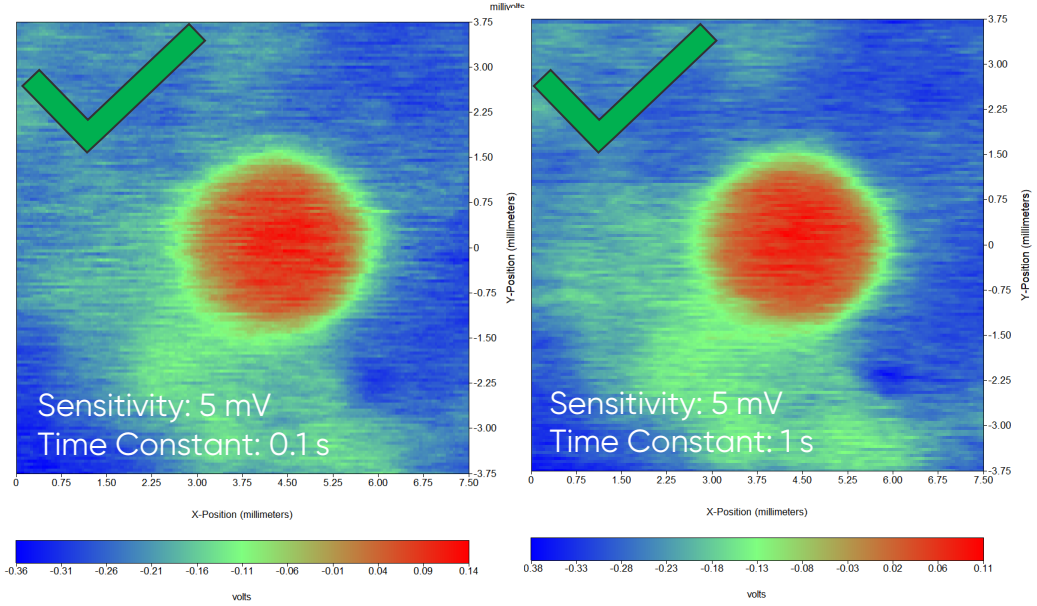


Amplifier settings.

- The full scale sensitivity must be large enough to avoid signal overload, but small enough to avoid noise.
- The output time constant is related to measurement speed. 1.0 s is used for slower scans, 0.1 s for faster scans.
- Ensure the reference phase is correctly selected.

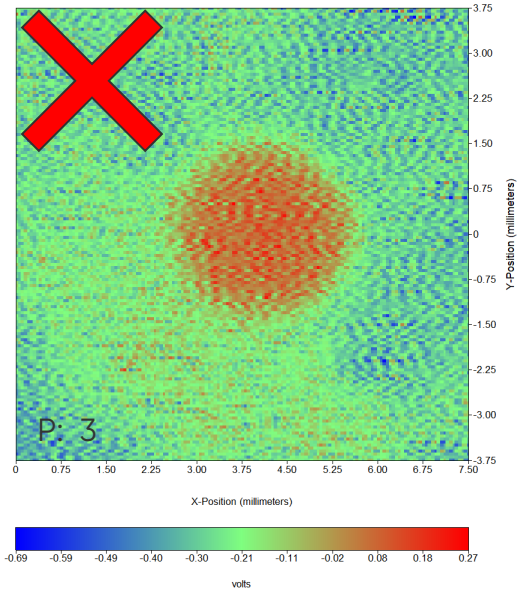
- More information in [TN#19]

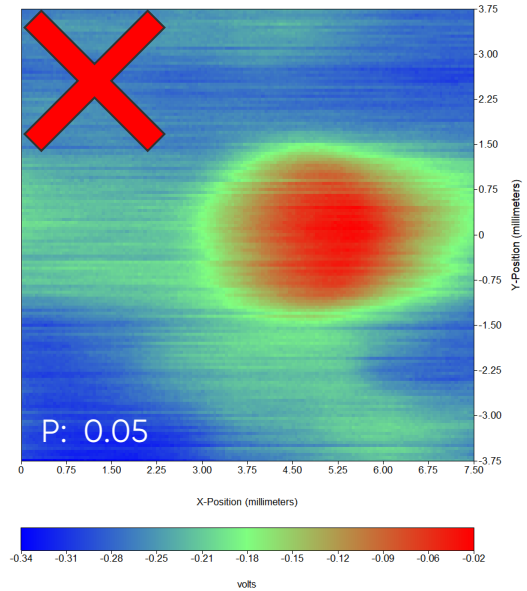


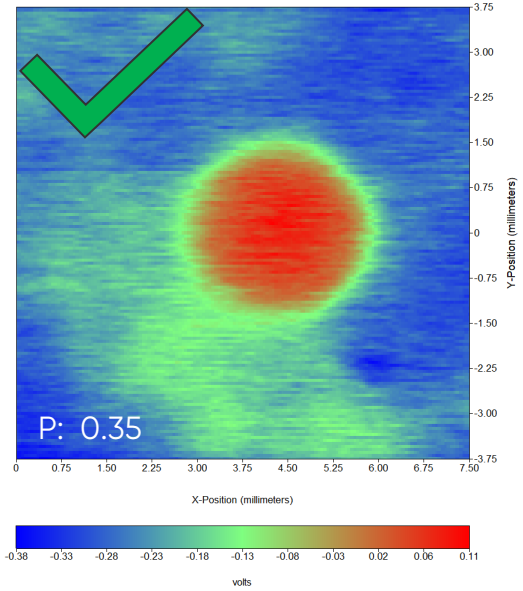


PID considerations.

- **The PID loop rate must be fast enough to respond to the measurement speed (sampling and scan rates)**
- **P is typically the most important parameter**
  - Setting P too high results in oscillations in the signal
  - Setting P too small causes the loop to respond late to change, unnaturally smoothing the data
- **More information in [TN#19]**







Conclusion.

Conclusion.

A number of considerations have been discussed with the aim of optimising the SKP measurement. These considerations relate to the probe, sample mounting, sample tilt and topography, and configuration settings. Understanding how to control each of these settings will allow users to measure standard and novel samples.

More information.

BioLogic Support: https://www.biologic.net/support/

BioLogic Contact: https://www.biologic.net/contact/

BioLogic

Thank you!

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