Prototype 3:

Topography Free SThM Calibration Sample

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A prime cause of imaging artefacts in Scanning Thermal Microscopy (SThM), is variable tip-sample contact area when a tip encounters topography. This makes characterisation of the thermal-spatial resolution a significant challenge. The topography free calibration sample described here has well defined, abrupt, and high-resolution changes in thermal conductivity with nearly zero topography and roughness. This provides a way of characterising the true thermal spatial resolution of a SThM system, and an effective method of comparing different probes and instruments.

Key Benefits

- *Quantify the actual thermal spatial resolution of an SThM system*
- *Decouple topography when characterizing a probe*
- *Provides a simple check of SThM probe quality and degradation with use.*
- *Peak to peak topography of 4 nm and roughness of 0.1 nm at active area.*

Sample Specification

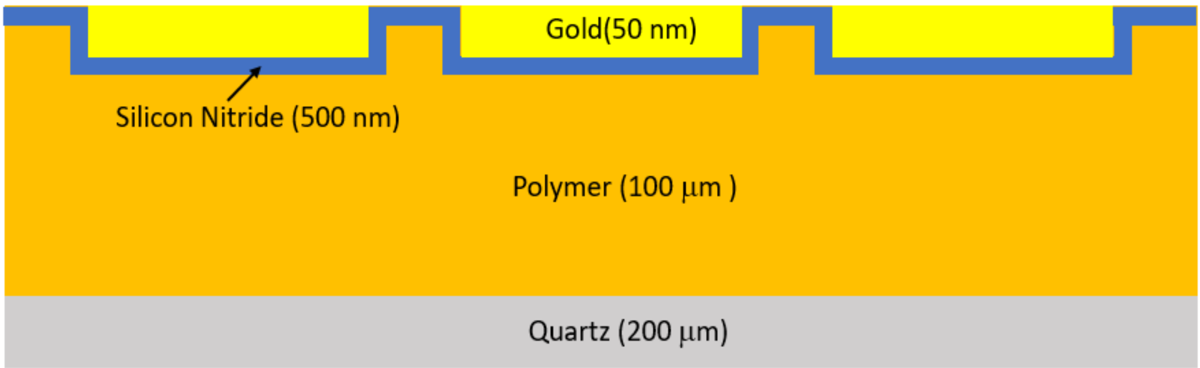


Figure 1: *Schematic showing a cross section through the sample.*

Figure 1 shows a schematic cross-section through the sample (not to scale). Each sample consists of a repeating pattern of paired gold pads, and low stress SiN embedded in a polymer resist. Figure 2 (a,b) shows the SEM image of a paired gold pad with narrow gold wires located between. Figure c and d shows the topography and thermal signal obtained with SThM. The topographic variation between the gold and surrounding silicon nitride is <5 nm, as defined from AFM measurements figure 2(e).

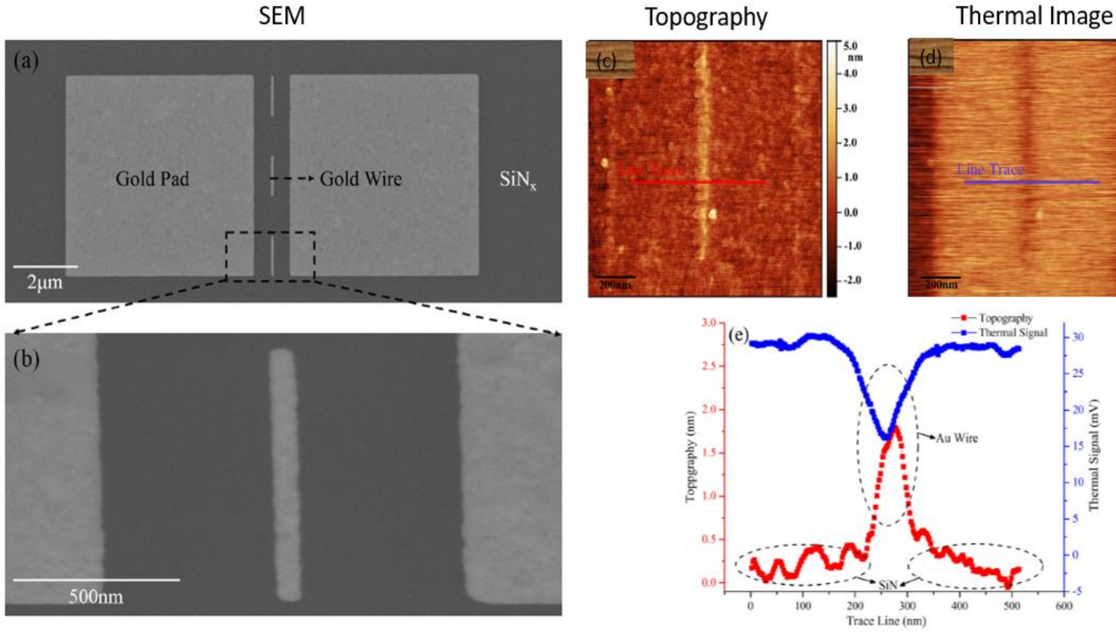


Figure 2: *SEM (a,b) AFM topographic (c) and (d) shows AFM topography and thermal images of gold wire shown in (b) (e) line profiles across gold wire from (c) and (d)*

Applications

Spatial Resolution Characterisation of SThM system

Two types of SThM probes have been characterised using the topography free sample – Commercial KNT probes and Wollaston probes.

The probe to be characterised is mounted in an AFM and the laser aligned to the cantilever in the usual manner. The probe is attached to the SThM measurement electronics and the current set high enough to produce significant self-heating. Figure 3 gives the schematic of the experimental setup used in this study.

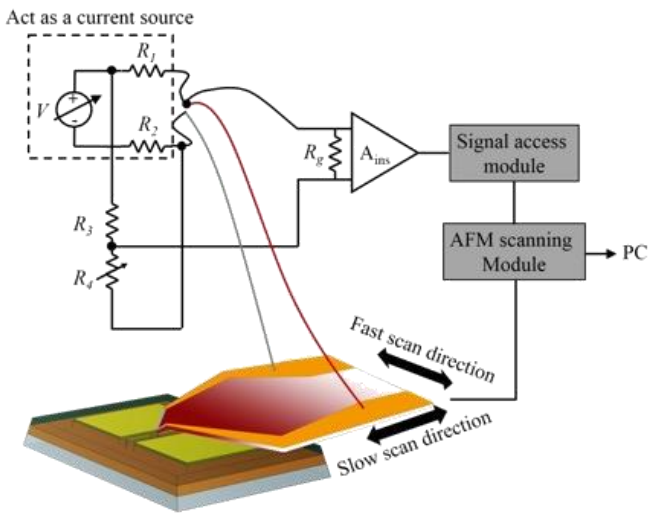
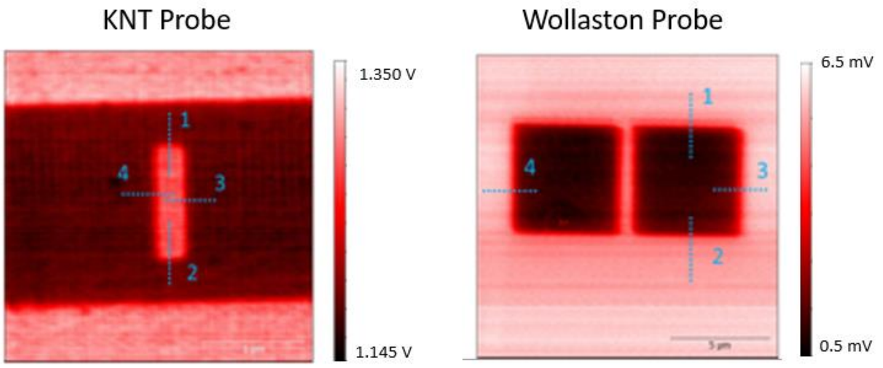


Figure 1: *Schematic representation of the active SThM measurement setup.*

The sample is approached and scanned using conventional contact-mode AFM. The temperature output of the SThM probe is acquired simultaneously with the topographic data. This provides a map of probe-sample heat transfer as the probe is scanned across the topography free features.

Line traces can be taken from the signal steps visible in the thermal data. These steps, if imaged at high enough resolution, do not exhibit an instantaneous transition between the thermal signal of the two materials. This transition can be fitted using the *deformed step* function of free open source sftwares like gwyddion, to extract an estimate of thermal-spatial resolution for the specific scan direction selected. An example of this process, along with typical results from two SThM probe types: KNT nanoprobe and Micrometric Wollaston wire probe, is given in Figure 4.



Thermo-spatial resolution for measurements under air environment

Zone	KNT (nm)	wollaston (nm)
1	104	480
2	72	380
3	72	800
4	110	760

Figure 3: *SThM thermal images for two probe types (left), an example step fit of the acquired data (top right) and example thermal-spatial resolutions extracted from the fits (bottom right). Measurements were performed under ambient conditions.*

It can be seen from the figure that both probe types exhibit anisotropic thermal-spatial resolution. This is to be expected as both probes have a tip (and hence tip-sample thermal contact) that is also anisotropic. In addition, both probes display sub-micrometre thermal-spatial resolution, with the commercial KNT probes exhibiting consistently around 100 nm spatial resolution however that of the Wollaston probe varies from a 450-750 nm due to a higher area of contact.

Another characteristic of this sample is that the lithographically defined gold features exhibit thermal resistance that is a function of both their material properties and their geometry. Therefore, different sized gold features result in different signal amplitudes during a SThM scan. By measuring this variation as a function of sample size, a robust and reproducible measure of the characteristic length scale which determines a SThM measurement of thermal conductivity may be obtained. In the present case we observe a smooth degradation of contrast for length scales down to 35 nm, such that the observed signal at 75 nm scale has a contrast level which is 70% of that measured for large area films.

Further information

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Additional information on SThM and the sample can be obtained from the QUANTIHEAT webpage.

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