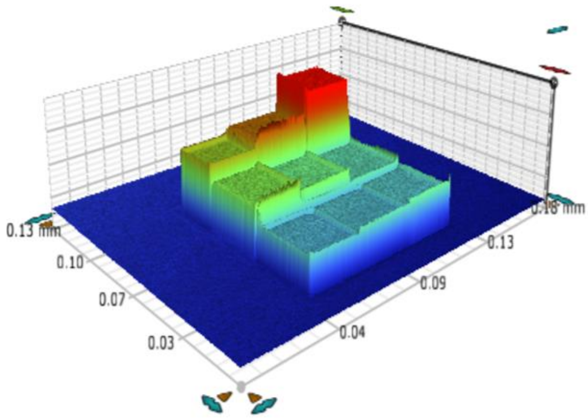
Prototype 4:

Oxide Steps Calibration Sample

Lead Partner: Kelvin Nanotechnology Ltd, UK

It is important with SThM to have a reproducibility and quantified measure of the sensitivity of the system. Facors like tip-sample contact resistance and tip-sample contact area can mask the true sensitivity. These factors change dynamically with wear and tear and one needs to quantify the degradation of the probe before and after scanning. This new oxide steps calibration sample provides a series of surfaces made of the same material, with identical roughness, but with different effective thermal conductivities. This allows the SThM sensitivity, with a given set of operating conditions, to be measured. A model is provided to extract the contact area and contact resistance from the experimental data giving additional figures of merit of a probe before and after a scan.



Key Benefits

- *Measure the sensitivity of an SThM system*
- *Compare depth spatial resolution of different probes*
- *Provides a simple check of SThM probe quality and degradation with use*
- *To compare the performance of different types of SThM probes and evaluate the thermal measurements of thin films.*

Sample Specification

Sample consists of steps of different thickness of silicon oxide defined by successive steps of photolithography and wet etching. Each pattern has 9 steps of different thickness ranging from a few nanometers to 1000 nm. Topographical images and roughness measurements were performed with a AFM used in tapping mode and step height measurements were confirmed using a surface profilometer. *Table 1* gives the values of the SiO_2 film thickness, the roughness of each step, and the steps height. Since the patterns were realized by successive HF etching the roughness of each step varies however it tends to be consistent from chip to chip. The thickness of each step varies within a ± 10 nm range and this might be due to differences in the etch rate of the HF used and variations in oxide thickness across the wafer on which chips were fabricated.

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9
Thickness (nm)	7 ± 10	12 ± 10	30 ± 10	65 ± 10	145 ± 5	237 ± 5	330 ± 15	530 ± 10	950 ± 10
Roughness (nm)	0.124	0.650	0.541	0.647	0.640	0.750	0.393	0.183	0.127
Step height (nm)	2 ± 5	20 ± 5	34 ± 5	80 ± 5	95 ± 5	95 ± 5	200 ± 5	400 ± 5	

Table1: showing the thickness and roughness of each of the steps as measured by AFM.

Applications

A commercial resistive KNT probe was used in passive mode to scan across the sample to detect the variation of thermal conductance of the sample as a function of the step thickness.

Figure 2 (a) shows the topography measurements and *2 (b)* shows the corresponding thermal data measured using a commercial resistive probe (KNT SThM -01 an). The KNT probe detects the variation of the thermal conductance of the sample as a function of the SiO_2 thickness.

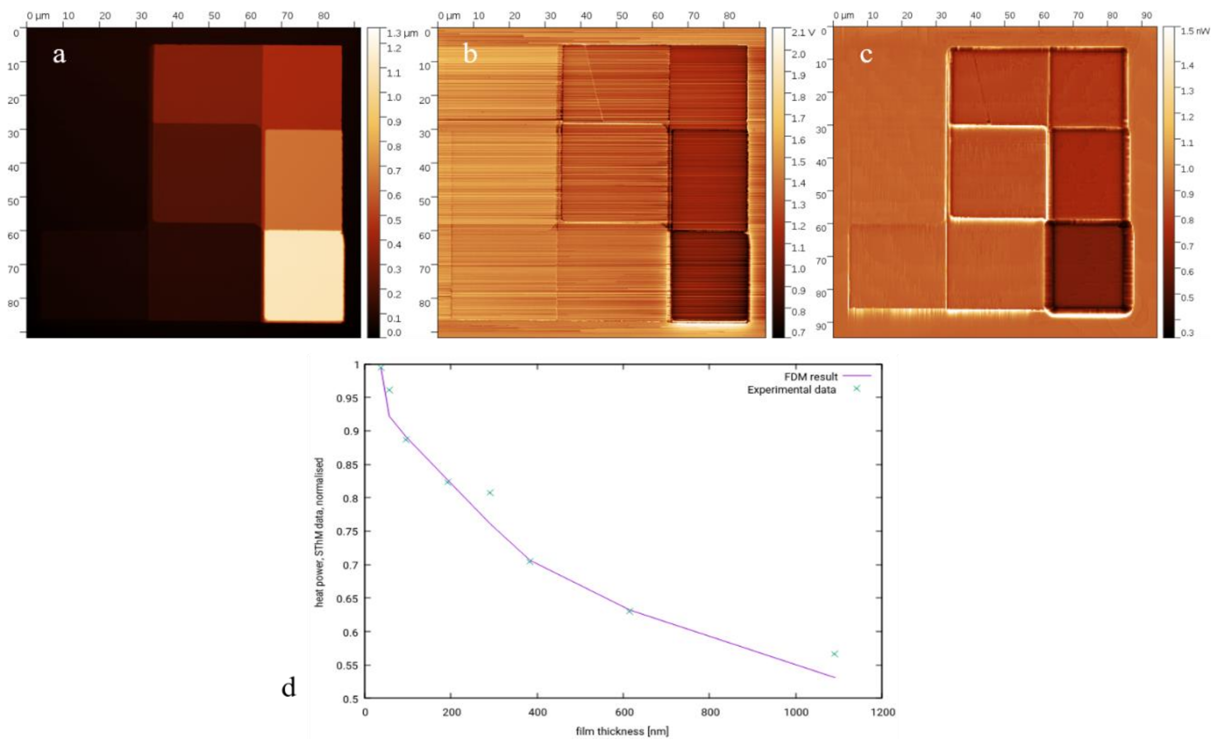


Figure 2: *(a) Topography, (b)Thermal data, (c) Modelled SThM data and (d) showing the normalised data from (b) and (c) against the step thickness*[1]

[1] Measurements and modelling done at CMI

A probe FDM model[2] was built to analyze the effect of the topography on SThM thermal contrast in imaging mode. Probe model was applied and scanned across the sample, creating a virtual SThM image, where each pixel was computed as individual solution of the Poisson equation (diffusive heat transfer mode). *Figure 2 (c)* shows the modelled SThM data obtained through this method. Topography impacts thermal contrast on a width of about 3 µm along the steps. *Figure 2 (d)* plots the normalised experimental and modelled SThM data against step height of the oxide sample. Average values from the central parts of the steps were used in the plot. Modelling data show good agreement with the experimental data. This agreement of experimental data with results from a direct modeling is promising for the determination of the sample thermal parameters of sample through the inversion of a direct modeling.

Since the contact resistance and the tip-sample interaction volume remains the same across each step height of the sample, the thermal resistance at each thickness of the oxide step can then be measured. *Figure 3* plots the thermal resistance measured at each step thickness of the oxide sample.

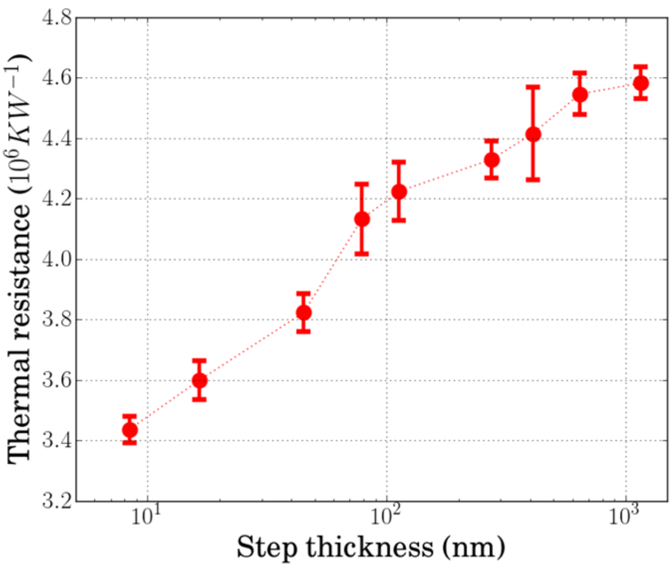


Figure 3: Thermal resistance at the probe apex measured as a function of step thickness of oxide sample (at ULANC).

The measurements were compared with the effective thermal conductance of sample as a function of oxide thickness, with the help of modelling and thermal conductance response of a range of probes with effective contact radii from 50nm-1000nm has been predicted (Figure 4). This helps in comparing the thermal response of different probes used.

[2] Prototype 13: Image Processing Tool

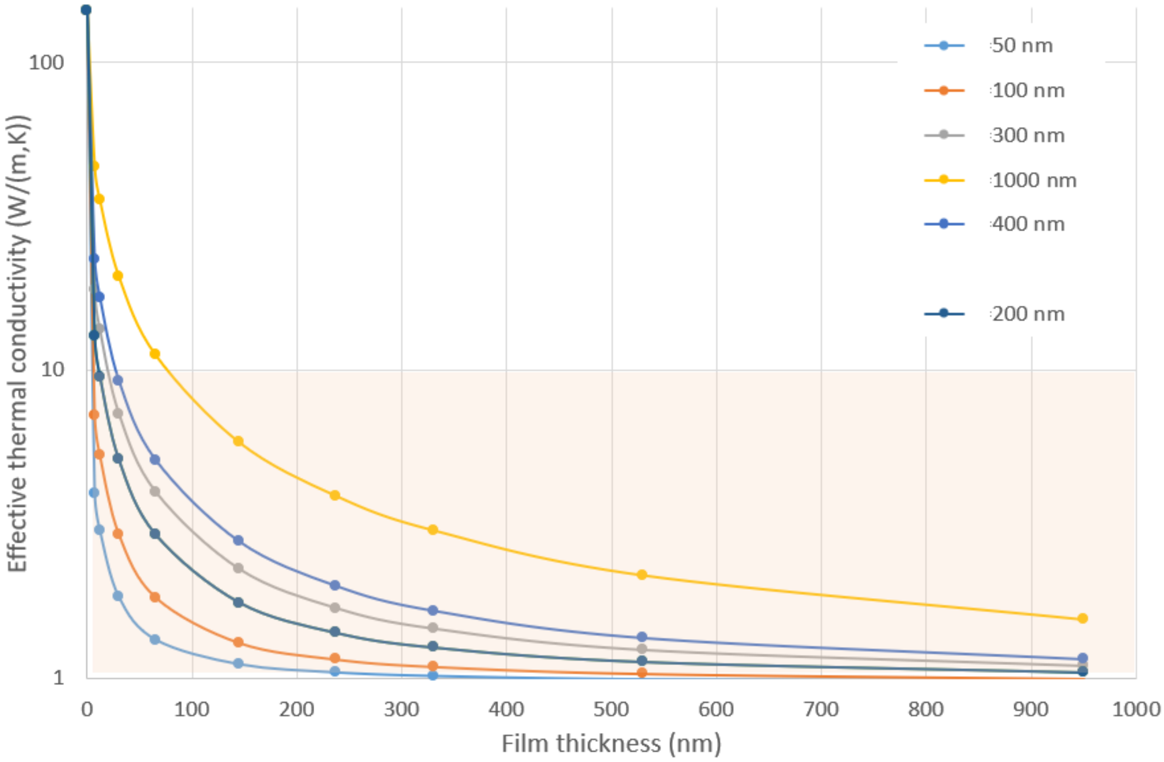


Figure 4: Modelled effective thermal conductivity of the oxide sample as a function of thickness for tips with effective contact radius 50nm – 1000nm

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