Fabrication of Topography-Free Samples for Thermal Spatial Resolution Measurement of Scanning Thermal Microscopy

Y. Ge, Y. Zhang, J. M. R. Weaver, and P. S. Dobson
School of Engineering, University of Glasgow, Rankine Building, Oakfield Avenue, Glasgow G12 8LT

Scanning Thermal Microscopy (SThM) is a well-established technique for thermal measurement at the shortest length scales (often below 100nm). It employs a micromachined AFM probe with integrated sensor that simultaneously produces topographic and thermal images[1]. The thermal contrast of the SThM image depends strongly on both topographic and thermal material variations within the sample[2,3]. However, topography also causes artefacts in thermal images. Elucidation of the mechanisms associated with the thermal interaction of tip and sample requires the measurement of samples having strong thermal contrast and negligible topographically induced artefacts[4]. This work presents a generic method for the preparation of 'topography-free' samples with spatial resolution down to the limit of conventional lithography.

The sample presented consists of multiple, lithographically defined materials with different thermal conductivities and minimal (<5nm) surface topography. Electron beam lithography was used to produce arbitrary patterns offering total flexibility in the resolution test pattern produced. Fabrication was based around a flat sacrificial substrate (GaAs) that dictates ultimate surface topography after deletion in the final step (Citric acid/H_2O_2). This process is detailed in Figure 1.

As a demonstration, 50nm to 110nm evaporated gold wires were produced as shown in Figure 2. These were imaged under ambient conditions using an SThM probe fabricated at the University of Glasgow[5]. Figure 3 shows the simultaneous topographic and thermal scans of the 50nm wires by the active mode probe. The minimal topography (~3nm) and thermal contrast can be clearly seen. The spatial offset between the topographic and thermal image, and thermal 'rise time' provide insights into the heat transfer mechanism between the probe, the sample and resolution of the SThM scan. It is worth noting that the thermal step response of the probe is seen to approximate a linear ramp having a rise time equal to the mechanical size of the SThM probe tip (100nm radius).

---

[1] A. Majumdar, Ann. Rev. Mater. Sci. **29**, 505 (1999)
[2] L. Shi, S. Plyasunov, A. Bachtold, P. McEuen, and A. Majumdar, Appl. Phys. Lett. **77**, 4295 (2000)
[3] E. Puyoo, S. Grauby, J. Rampnoux, E. Rouviere, and S. Dilhaire, THERMINIC **16**, 1 (2010)
[4] A. Soudi, R. Dawson, and Y. Gu, ACS Nano **5**, 1 (2011)
[5] Y. Zhang, P. S. Dobson, and J. M. R. Weaver, J. Vac. Sci. Technol. B **30**, 010601 (2012)

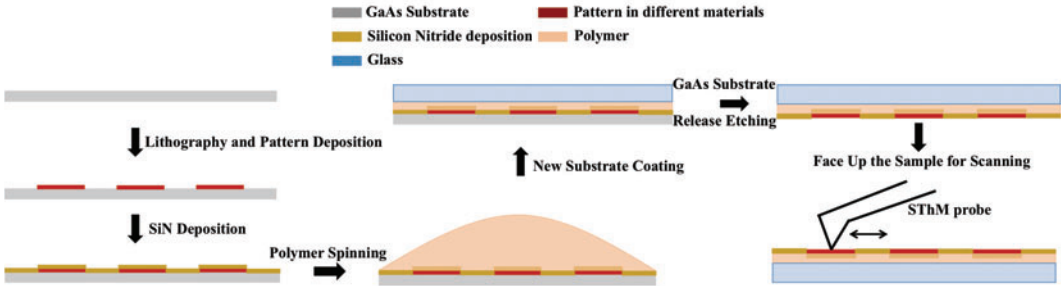

Figure 1: Fabrication process of the topography-free sample

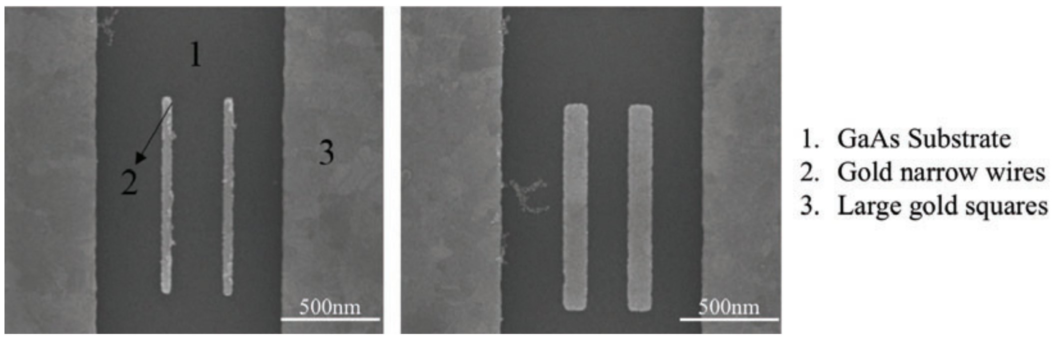

Figure 2: (a) 50nm and (b) 110nm gold wires (35nm thick) on the GaAs substrate with 35nm thick gold squares on either side for convenience of pattern location during the SThM thermal scan.

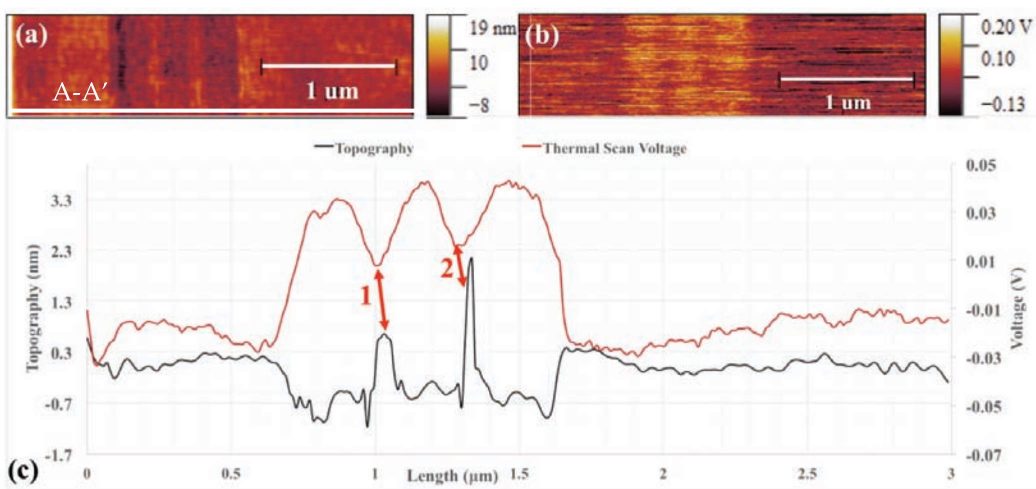

Figure 3: (a) topographic and (b) thermal image of the 50nm wide gold wires and (c) plot of topography and thermal signal at line A-A' (averaged over 128 repeat line scans to reduce noise). The topography between gold and surrounding SiNx is ~1.5nm. Thermal signal is detected by the self-heated probe with 1mA operating current. Gold wires can be detected in thermal and topographic images as shown by arrow 1 and 2 in (c). The spatial offset and differing ‘rise time’ between the topographic and thermal images may indicate the existence of a water meniscus present during scanning under ambient conditions.