[1032] Novel nanoscale method for thermal conductivity measurements

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As the downscaling of electronic devices pushes dimensions of its components towards the atomic limits, new measurement tools need to be developed to address new challenges. In particular, nanoscale heat transfer is a key mechanism which is known to limit the performance of nanoscale sized transistors in the processor chips and thus invalidate of a major component Moore's law of the processor speed increase [1]. Measurements of thermal conductivity for simple geometry such as thin films present many difficulties to traditional techniques for layer thicknesses smaller than 100 nm [2]. For example, decoupling the thermal conductivity from the interfacial resistances between the film and the substrate as well as the probe and the film is often difficult. In this report, we develop a novel approach addressing these challenges. We combine a unique cross-sectional tool and a heated probe – scanning thermal microscopy, or SThM, we were able to measure intrinsic thermal conductivity of few tens of um thin layer-on-substrate and to deduce the interfacial thermal resistance.

Beam-exit cross-sectional polishing (BEXP) uses Ar-ion beams impinging on a sample at shallow angle ($<10^{o}$) [3,4]. The cross-sectioned surface obtained has preferential geometry and sub-nm surface roughness making it easily suitable for studies via standard scanning probe microscopy methods (Fig. 1). Nanothermal microscopy techniques are gaining interest as they resolve thermal properties below the diffraction limit [5,6]. SThM uses the atomic force microscopy principles to raster a thermosensitive probe on a surface. The electrical resistance of the probe is monitored as it scans the sample and by relating this resistance with the temperature, heat transfer properties of the sample can be deduced [7]. To validate our approach, we apply this method on different commonly used materials from semiconductors to insulators such as silicon dioxide, spin-on-glass and spin-on-polymers.

The BEXP cross-sectioning process enables the measurements of the SThM response as a function of the layer thickness (Fig. 2). By analysing the SThM signal of the wedge-shaped section of the probed material, we were able to extract the thermal conductivity of the layer itself by combining analytical and finite element modelling of the sample. The thermal conductivity and the interfacial thermal resistance, which is a big unknown for all these materials, can be directly obtained by fitting the measurements of the thermal resistance as a function of the position of the probe, to our model. We confirm capabilities of this new method for standard materials using different modelling approaches. Our results demonstrate its applicability for direct measurements of otherwise hard to obtain quantities for previously unknown materials. The ease of use of our method renders it suitable for a broad range of samples and opens new paths for fundamental and applied research in wide areas from biology to spintronics.

Acknowledgements

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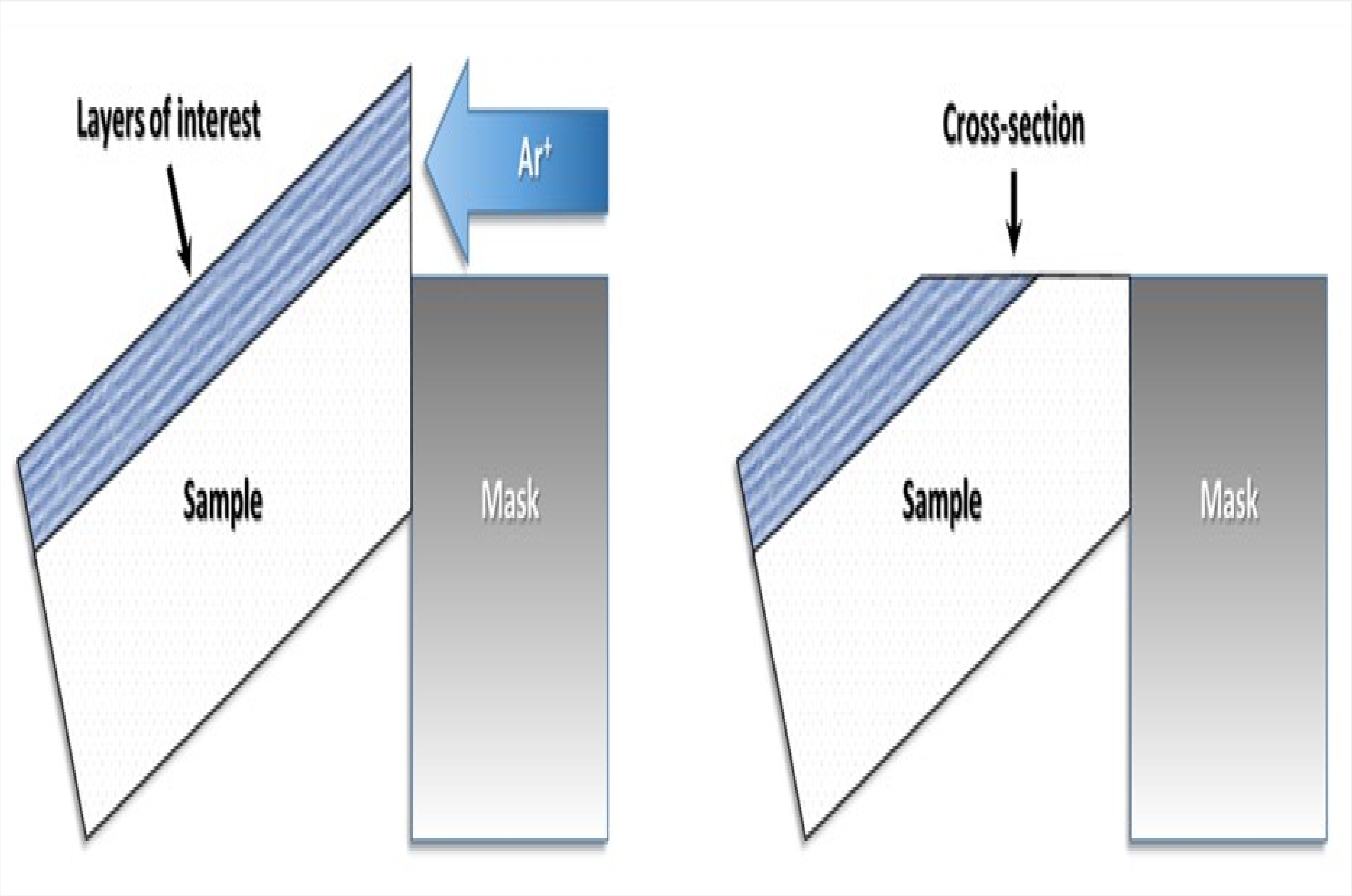

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Figure 1: Beam-exit cross-sectional polishing procedure. The cross-section layer impinged at small angle (<10°) by Ar-ion beam appears with low damage and sub-nm roughness.

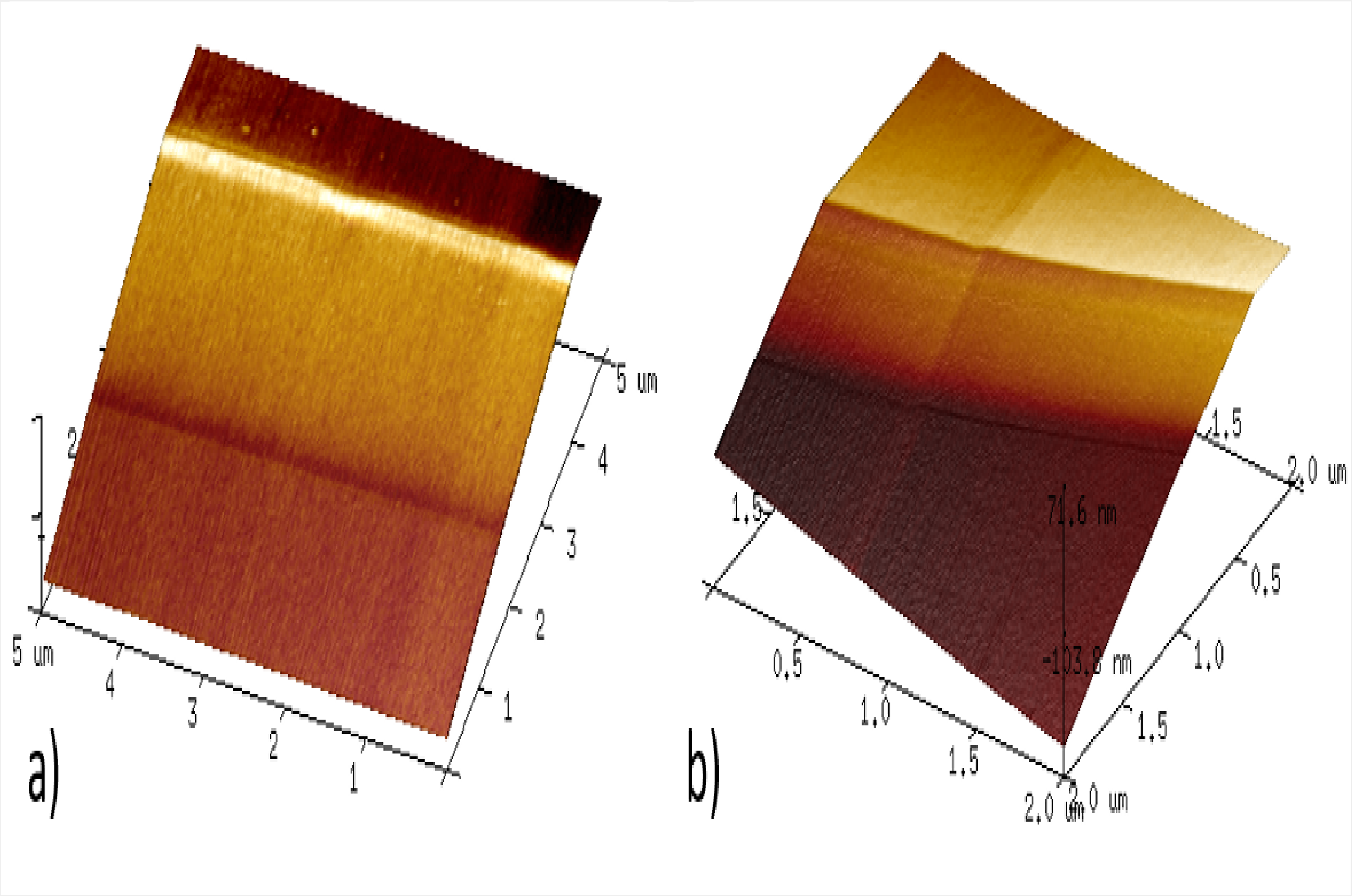

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Figure 2: 3D topography overlaid by SThM response for a) 300 nm SiO_2 b) 65 nm spin-on-carbon.