Highly sensitive NbN integrated probe for Scanning Thermal Microscopy for detecting thermal event in semiconducting technology

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Understanding local temperature distributions and heat dissipation is essential for improving the performance and reliability of microelectronic devices. As device dimensions decrease and power densities increase, thermal characterisation must resolve increasingly localised phenomena. Scanning thermal microscopy (SThM) addresses this need by combining atomic force microscopy with a temperature-sensitive probe, enabling simultaneous topographic imaging and thermal mapping at the nanoscale.

We present SThM probes incorporating a niobium nitride (NbN) resistive thermometer near the tip apex. NbN thin films can be tailored to provide high temperature sensitivity around room temperature [1,2]. Their integration onto commercial three-dimensional AFM probes relies on nanofabrication processes developed at Institut Néel, including electron-beam lithography on non-planar, suspended structures [3]. The thermometer is read using a four-wire configuration, which reduces the contribution of electrical lead and contact resistances to the resistance measurement.

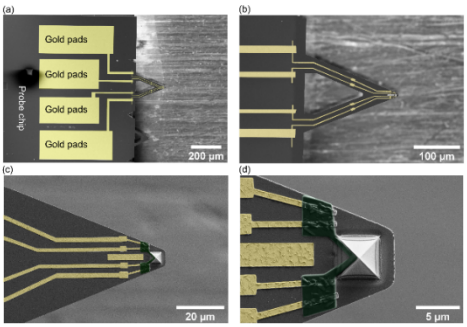


Figure 1 *SEM image of a SThM probe incorporating an NbN thermometer, highlighted in green false colour. Adapted from [3]*

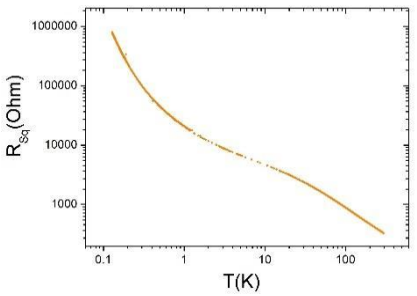


Figure 2 *Sheet resistance of NbN thin films as a function of temperature, from room temperature down to 100 mK [4]. These data illustrate the broader temperature range accessible with NbN thermometry; the present contribution focuses on room-temperature applications.*

The probes are operated with a dedicated low-noise analog measurement chain combining a current source and differential electronics [2]. These building blocks form the basis of the thermal characterisation solutions being developed by Thélyos. An AFM-compatible control unit, advanced measurement modes and automated calibration procedures are under development.

A central challenge in SThM is converting electrical signals and thermal contrasts into quantitative physical information. The measured response depends on the thermometer characteristics, heat transfer through the probe and thermal coupling between the tip and the sample. We discuss

calibration procedures and measurement approaches designed to account for these contributions and support quantitative interpretation under defined experimental conditions. Measurements on simple heating structures provide a basis for evaluating probe response, testing thermal models and assessing measurement uncertainties.

We then discuss the potential of this approach for hotspot detection and in-operando characterisation of microelectronic devices, including GaN-based power devices and heterogeneous integrated structures [5]. Local thermal measurements could help identify heat dissipation pathways, support failure analysis and provide experimental input for thermal modelling. Access to the sample surface and control of the tip–sample thermal interaction remain important conditions for interpreting these measurements.

This contribution presents the progression from NbN thermometry and probe nanofabrication to a modular measurement solution for researchers and engineers. It highlights both the capabilities of the approach and the calibration and integration work required to establish quantitative nanoscale thermal metrology for microelectronics.

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