

Calibrated Nanoscale Capacitance and Dopant Profile Measurements using a novel *Nearfield* Scanning Microwave Microscope

¹Gerald Kada, ¹Matthias A. Fenner, ²Hans-Peter Huber, ³Hassan Tanbakuchi, ¹Manuel Moertelmaier, ⁴Pavel Kabos, ⁵Juergen Smoliner, ²Peter Hinterdorfer, ¹Ferry Kienberger

¹Agilent Technologies Austria, Mooslackengasse 17, 1190 Vienna, Austria

²JKU University of Linz, Institute for Biophysics, Altenbergerstr. 69, 4040 Linz, Austria

³Agilent Technologies Inc., NanoDivision, 4330 W. Chandler Blvd., Chandler, AZ 85226, USA

⁴National Institute for Standards and Technology (NIST), Electromagnetic Division, Boulder, CO, USA

⁵Technical University of Vienna, Institute for Solid State Electronics, Floragasse 7, 1040 Vienna, Austria
Gerald_Kada@Agilent.com

Abstract

A scanning microwave microscope (SMM) for spatially resolved capacitance measurements in the attoFarad-to-femtoFarad regime is presented. The system is based on the combination of an atomic force microscope (AFM) and a performance network analyzer (PNA).

For the determination of absolute capacitance values from PNA reflection amplitudes, a calibration sample of conductive gold pads of various sizes on a SiO₂ staircase structure was used (figure 1). The thickness of the dielectric SiO₂ staircase ranged from 10 nm to 200 nm. The quantitative capacitance values determined from the PNA reflection amplitude were compared to control measurements using an external capacitance bridge [1]. Depending on the area of the gold top electrode and the SiO₂ step height, the corresponding capacitance values, as measured with the SMM, ranged from 0.1 fF to 22 fF at a noise level of ~2 aF and a relative accuracy of 20% [2].

For dopant profiling, n- and p-doped reference samples with densities between 10¹⁴ and 10¹⁹ atoms/cm³ in 1.5 micron-wide regions were imaged in dC/dV modulation mode (figure 2). A calibration curve relating signal levels and dopant densities was established [3].

Possible applications of an SMM range from quality control of integrated circuits (ICs), solar cells, and other semiconductor devices to materials science, (e.g. measurements of quantum dot dielectric constants), and to bioscience (e.g. the detection of viruses, and thickness measurements of protein layers). Examples shown will include capacitance and dielectric measurements on organic thin films (SAMs), graphene, nanotubes and nanowires as well as magnetic bacteria.

References

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Figures

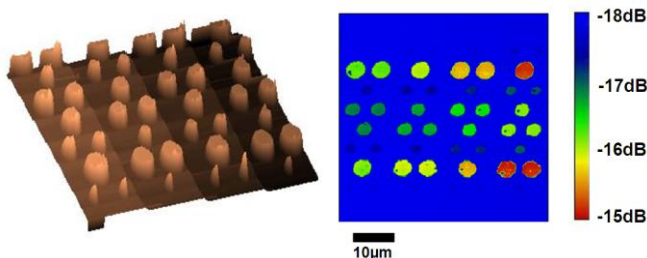


Fig 1. SiO₂ staircase in 3D-topography view (left) and corresponding PNA amplitude signal (right) used for calibrated capacitance measurements.

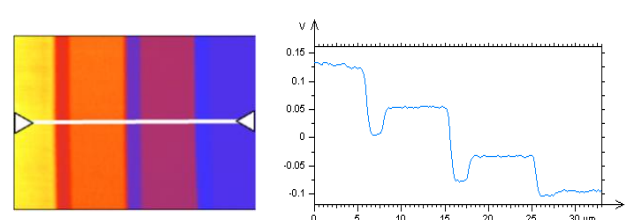


Fig 2. Dopant density calibration test sample with densities ranging from 10¹⁴ (left side, yellow) to 10¹⁹ Atoms/cm³ (right side, blue.)