Calibrated nanoscale capacitance and dopant profile measurements using a scanning microwave microscope

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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 SiO_2 staircase structure was used (figure 1). The thickness of the dielectric SiO_2 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. Depending on the area of the gold top electrode and the SiO_2 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%.

For dopant profiling, n- and p-doped reference samples with densities between 10^{14} and 10^{19} atoms/cm^3 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.

Possible applications of an SMM range from quality control of 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, graphene, nanotubes and naowires as well as magnetic bacteria.

References

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[2] J. Smoliner, H.-P. Huber, M. Hochleitner, M. Moertelmaier, F. Kienberger, J Appl Phys, **108** (2010) 064315.

Figures

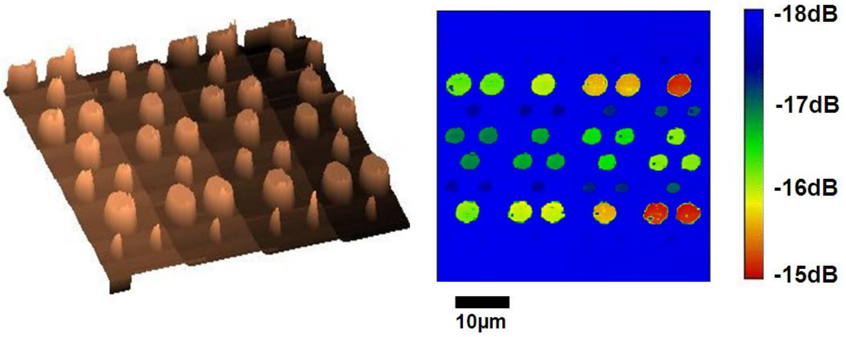

Figure 1. SiO_2 staircase in 3D-topography view (left) and corresponding PNA amplitude signal (right) used for calibrated capacitance measurements

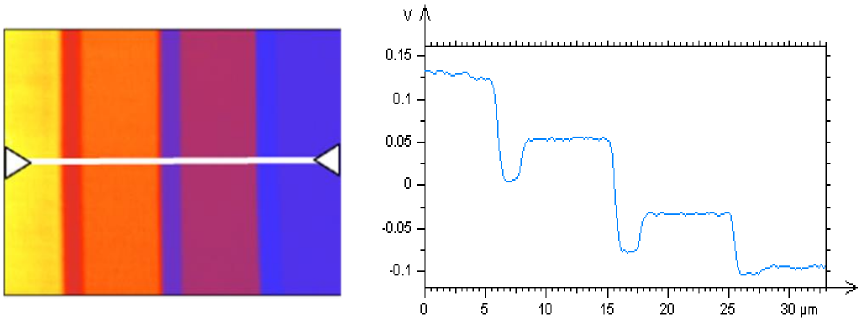

Figure 2. Dopant density calibration test sample (IMEC, Belgium) with densities ranging from 10^{14} (left) to 10^{19} atoms (right), measured in dC/dV mode.