Scanning Microwave Microscopy for Complex Material Characterization

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Scanning Microwave Microscopy (SMM) is a recent development as a nanoscale imaging technique that combines the lateral resolution of Atomic Force Microscopy (AFM) with the high measurement precision of microwave analysis at GHz frequencies. It consists of an AFM interfaced with a Vector Network Analyzer (VNA) with operating frequencies ranging from 1 to 20 GHz.
SMM allows measuring complex materials properties for nano-electronics, materials science - photovoltaics and semiconductors - and life science applications.
Here we present the basic working principles of SMM and its advanced applications. In particular, the capabilities of the SMM include: calibrated capacitance and resistance measurements with a noise level of 1 aF [1]; a 2D mapping workflow to acquire roughly 20.000 C-V curves during one image [3]; calibrated complex impedance imaging of semiconductor [2], dielectric [6, 7], and biological [9, 10] samples; point wise C-V (capacitance-voltage) spectroscopy curves allowing for oxide quality characterization, interface traps, and memory effects of novel materials.
Due to the fact that microwaves can travel and penetrate into materials, SMM has been used already for 3D tomography applications of semiconductor structures [7, 8], examples include charge redistribution monitoring or composite material quality control measurements. A new way is paved to non-destructive sub-surface imaging in material science (see figure 1).
Recently, calibrated complex impedance images of cells and bacteria have been obtained with the SMM [9, 10], proving that this method also works in liquid environments like buffer solutions.
Experimental investigations are complemented by finite element radio-frequency modelling using the 3D architecture of the probe and the sample, done with the Keysight software EMPro [4, 5].

References

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Figures

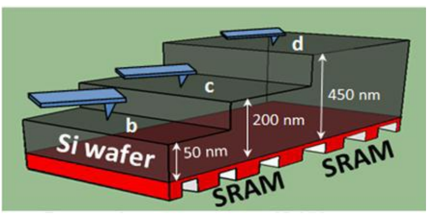

Figure 1: Sub-surface imaging of an SRAM (static random access memory) device, imaged with AFM on the backside of the p- and n-dopant lines of the SRAM structure. Microwaves originating from the scanning AFM tip in SMM mode easily permeate the oxide layers and thereby allow us to quantitatively determine dopant levels underneath the surface.