COMSOL Simulation for Scanning Microwave Microscopic Experiments

T. le Quang[1], D. Vasyukov[1], A. Buchter[1], J. Hoffmann[1], M. Zeier[1]

[1]Eidgenössisches Institut für Metrologie (METAS), Switzerland

Abstract

In the EMPIR project ADVENT the Scanning Microwave Microscopy (SMM) is investigated. The SMM is a still rather novel member of the family of scanning probe microscope. It has attracted a lot of attention recently, because this instrument can be used to characterize various electrical properties of semiconductors, like the dopant density, the sheet conductance and the dielectric properties. These characterizations can be performed thanks to the reflection of the microwave signal, which strongly depends on the impedance of the samples. As demonstrated recently, a calibration algorithm based on a one-port vector network analyzer (VNA) calibration for SMM has proven to be a good approach to extract quantitative carrier densities from n-doped GaAs samples. Even more interesting, this algorithm is robust, it yielded similar results at two different frequencies on two differently constructed SMMs. Therefore, it is interesting to check whether the same algorithm can be applied to predict the frequency dependent impedances of nano-scale circuits.

To do so, we simulated SMM measurements on various gold patterns supported by SiN membranes by using COMSOL Multiphysics® (see the attached figure). These patterns have diffferent structures: some having an isolated central pad (capacitance standards) and others having a line/spiral bridge (resistance/inductance standards) connecting this central pad with the grounded gold region outside. Then, we introduced a SMM tip being in contact with the sample similar to SMM experiments performed in reality. For each type of standard, four patterns with different sizes and different impedances were calculated. In order to check the validity of the SMM calibration algorithm, the knowledge about the impedance of the structure of interest as well as the reflection coefficient of the microwave signal measured by the VNA is required. For capacitance standards, because their capacitance does nearly not depend on frequency, we were able to calculate these values by performing simulations with the Electrostatics interface. Contrarily, the impedance of bridges existing in resistance/inductance standards depends on the frequency due to the skin effect of the metallic bridges at high frequencies and was obtained from simulations conducted using the Electromagnetic Waves interface.

For models with line bridges, the frequency-dependence of their impedance (resistance and inductive reactive) agrees well with analytical formulae for such structures. Moreover, the calibration algorithm also works well with capacitance and resistance standards and does not depend on the tip parameters as well as frequencies used in our COMSOL simulations.

Figures used in the abstract

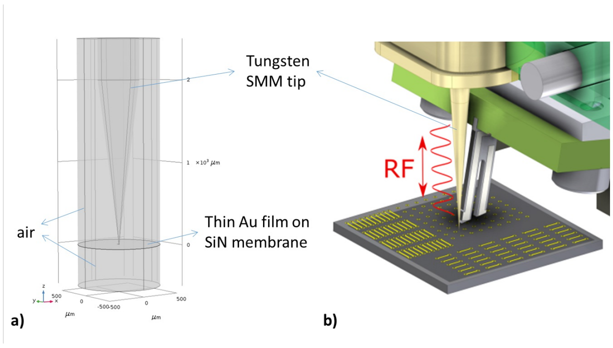

Figure 1: a) COMSOL model of the tip of the scanning microwave microscope, which is in contact with the sample. b) A schematic of a SMM tip existing at METAS, with generated and reflected RF signals travelling along it.