Modeling of Random Nanostructures Based on SEM Images and Analysis of Resulting RF-performance

K. Neumann[1], J. Moeller[1], L. Kuehnel[2], A. Rennings[1], N. Benson[2], R. Schmechel[2], D. Erni[1]

[1]General and Theoretical Electrical Engineering (ATE), University of Duisburg-Essen, and CENIDE – Center for Nanointegration Duisburg-Essen, D-47048, Duisburg, Germany
[2]Institute for Nanostructures and Technology (NST), University of Duisburg-Essen, and CENIDE – Center for Nanointegration Duisburg-Essen, D-47048, Duisburg, Germany

Abstract

In the last few years printable electronics has gained a great deal of interest since it promises mechanical flexibility and extremely low production costs. One approach to achieve printable electronic devices relies on the usage of specific inks containing e.g. dispersed semiconductor nanoparticles, where the latter are then apt to further processing steps.
In this work, doped silicon (Si) nanoparticles are printed on a metal substrate and then fuzed by subsequent laser sintering. Due to a detailed balance between melting, cohesive forces and, thermal cooling, the nanoparticles self-organize themselves to form crystalline Silicon(c-Si) cone-like nanostructures, representing a valuable structural precursor to e.g. printable high-speed Schottky diodes. However not all Si nanoparticles have enough mass to achieve cone-like structures and instead form hemispherical droplets which cannot be utilized as diodes.
The planar distribution of these droplets and the self-assembled c-Si cones that are embedded in a dielectric background medium (SU-8) can be treated like a planar random surface. Therefore, the goal of this work is to extract the random morphology and its stochastic properties in order to create an accurate numerical representation within COMSOL Multiphysics®. The model is then used to extract the parasitic capacitances of future cone-like Schottky diodes.
By analyzing the set of Scanning Electron Microscopy (SEM) images of the c-Si cones, a mathematical representation of the shapes can be retrieved. We use polynomial functions to fit the surface of each c-Si cone together with a morphing functionality that enables the representation of non-symmetric cone shapes. To model the random nature of the cone distribution and droplet distribution, hence of the planar random surface, a probability density function is defined for all parameters defining shape and position of the nanostructures. Based on these functions we can then use the LiveLink™ for MATLAB® module to generate random c-Si cone settings (i.e. realistic random surfaces) within COMSOL Multiphysics®, which are supposed to exhibit the same statistic distributions as the fabricated ones.
The influence of each stochastic parameter onto the complex admittance is analyzed by running batch simulations using the Electric Currents and Electrostatics physics within the AC/DC module. The derived capacitances (together with the cones' conductance) are essential in determining (and optimizing) the upper bound to the operation frequency (i.e.

cut-off frequency). They provide an important measure for the envisaged technology regarding its applicability to e.g. printable RFIDs and flexible lowest-cost RF electronics.

*This work was supported by the German Research Foundation DFG in the project Flexible Radio Frequency Identification Tags and System (FlexID).

Figures used in the abstract

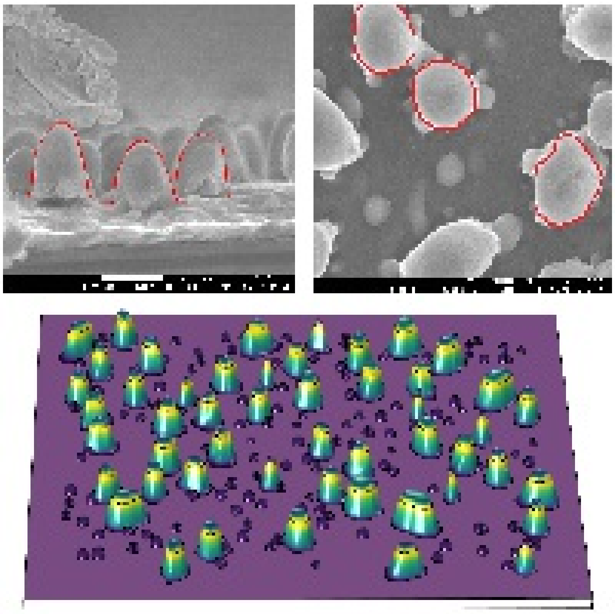

Figure 1: Scanning Electron Microscopy image of c-Si nanostructures and its stochastical representation in COMSOL Multiphysics®.