Modeling a Resonant Near-Field Scanning Microwave Microscope (RNSMM) Probe

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Abstract

The development of traceable electromagnetic (EM) materials metrology to enable the uptake of new EM and functional materials by European industries, especially electronics and ICT-related industries is of great importance in the present day. The UK's National Physical Laboratory (NPL) undertakes leading edge research in this field seeking progress on two fronts: first the development of key advanced measurement techniques and secondly the provision of a broader infrastructure for EM materials metrology in Europe.

Within this framework, NPL's aim is to go beyond the current state of the art in novel near field scanning microwave microscopes (NSMM) metrology at the micro scale, with the intention of making them capable of traceable measurements on functional materials. This intention is being supported by the introduction of a wider range of modelling techniques for this type of NSMM measurement. This talk will discuss a finite element model of the probe part of a resonant near field scanning microwave microscope (RNSMM).

This work required the use of the AC/DC Module of COMSOL Multiphysics®, specifically the electric currents capability in the frequency domain. A high frequency alternating current is applied to the probe using a terminal node, which generates an electric field around the probe. This field will be affected by the sample, and the effect can be sensed by looking at the current running through the probe. The use of a terminal node enabled the computation of the lumped parameters of the system, such as the capacitance and resistance. An analytical solution to the problem [1], for the case where the probe is a sphere and the sample is uniform and perfectly flat, was used to validate the model.

Once the model had been validated against the analytical solution, different sample configurations were investigated to understand how imperfect geometry and non-uniform materials affect the capacitance and the resistance. These other sample configurations were: geometric imperfections (such as hills and valleys), layered materials (sample of finite thickness on a metal or film on top of a substrate), and inhomogeneous samples (a flat sample consisting of two distinct sections of differing materials). Alongside, different material permittivities were considered to address the full range of properties seen in real materials.

The modelling presented in this work has proved to be a very useful tool to provide insight into the effects of likely imperfections in the real measurement technique.

Reference

[1] C. Gao and X.-D. Xiang, "Quantative microwave near-field microscopy of dielectric properties," Review of Scientific Instruments, vol. 69, no. 11, pp. 3846-3851 (1998).