Modelling of CPW Structures for the Characterisation of Thin Film Materials

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Summary

Thin film materials, also called 2D materials, play a growing role in electronics and energy applications. Examples include tunable graphene switches in THz transmission lines [1], film electrodes formed with graphene nanoplatelet solutions [2], susceptors in microwaveable food packages [3] or modern nanofabricated planar circuits where the height of metallic traces rarely exceeds 100 nm [4]. The interest in the characterisation of 2D materials is therefore substantial and two techniques have been proposed to this end in the microwave and mm-Wave frequency ranges: dielectric resonators (DR) [5] and coplanar waveguides (CPW) [4]. In both techniques, the extraction of electromagnetic (EM) parameters of thin films is based on correlations between GHz signals measured in the testing setup and those simulated for a family of models of the experimental setup, with varying material parameters in the model.

This raises two questions addressed in our work:

1. Which EM parameter(s) meaningfully describe thin film interaction with GHz waves?
2. How does one efficiently model a layer of ultra-small thickness in general purpose EM simulators?

Question #1, which concerns both modelling and characterisation, was earlier discussed with respect to susceptors responsible for controlled heating with microwaves [3][5]. It was shown that surface resistance, also called sheet resistance and expressed in Ohm per square, unambiguously determined the EM power dissipated in the susceptor. Two DR setups were proposed for measuring Rs of microwave susceptors. Herein, we extend the discussion to CPW setups after [4] and demonstrate that the same Rs parameter unambiguously determines the characteristic impedance, propagation constant, and effective permittivity of transmission lines with ultra-thin (<110 nm) signal and ground-plane layers.

Question #2 concerns the modelling aspect. In space-discrete methods, such as FDTD or FEM, being potentially most flexible for the design of material test-fixtures, the incorporation of ultra-thin films requires sub-cellular models, which are not always implemented in the available software packages. Therefore, in [6] an extensive study has been conducted for the convergence and accuracy of FDTD models of CPW-based material test-fixtures. For the thin films, a lossy dielectric surrogate preserving $R_s = (d\,\sigma)^1$ has been shown most efficient and valid up to the thickness of one FDTD cell (with cell size dictated by the CPW geometry and frequency range).

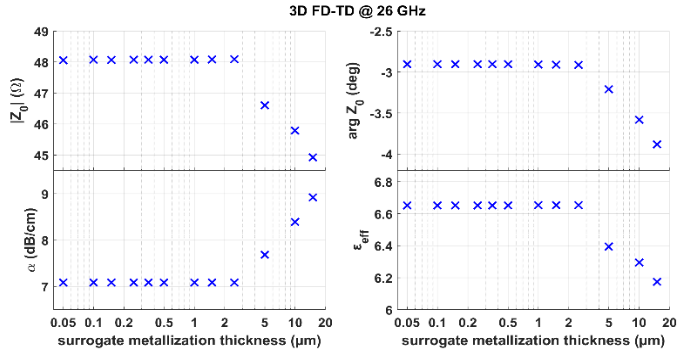

Fig. 1: Simulated parameters of CPW after [4] (case of W_2=300 μm, Rs=0.326 Ω/□, thickness 100 nm Au + 5nm Cr) at 26 GHz, with uniform FDTD meshing of 5 μm, as a function of scaled surrogate thickness – in pefect agreement with the measurements of [4] for surrogate thicknesses below 2.5 μm and ca. 2% impedance error for thickness equal to the FDTD cell size.

Our conference presentation will review the modelling results of [6] as well as ongoing model applications to the development of 10 GHz DR scanner for graphene anodes.

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