Microwave Characterization of Transparent Conducting Films

Jan Obrzut and Oleg Kirillov

National Institute of Standards and Technology, Gaithersburg, MD 20899 USA (jan.obrzut@nist.gov).

ABSTRACT

The high frequency conductivity of thin metallic and graphitic nano-films attracts interest due to many potential applications in spin electronics, electromagnetic shielding, flexible antennas, displays, and in solar cells. Surface morphology of thin conducting nano-films typically consists of an isolated clustering structure, which can evolve into a conducting percolated network [1]. The high frequency conductance of such materials is not well understood. We present measurements of microwave conductivity of thin optically transparent films in a coplanar waveguide (CPW) configuration [2]. Fig. 1 shows a signal flow graph of a two port microwave network representing a section of CPW with a conducting thin film specimen. The CPW outside the specimen section has a real characteristic impedance Z_0, while the material's properties in the specimen section are represented by the complex impedance $\boldsymbol{Z_s}$ that depends on the reflection ($\boldsymbol{\Gamma}$) and transmission ($e^{-\gamma l}$) coefficients; propagation constant ($\boldsymbol{\gamma}$) and propagation length (l). We determine the relation between the experimentally measured scattering parameters ($\boldsymbol{S}_{11}$) and ($\boldsymbol{S}_{21}$), complex impedance ($\boldsymbol{Z_s}$) and propagation constant ($\boldsymbol{\gamma}$) for the CPW test structure through a signal flow graph method. Once the signal flow is solved for $\boldsymbol{\gamma}$ and $\boldsymbol{Z_s}$, then the conductance G_s and the capacitance C_s of the specimen can be determined from conventional transmission line relations.

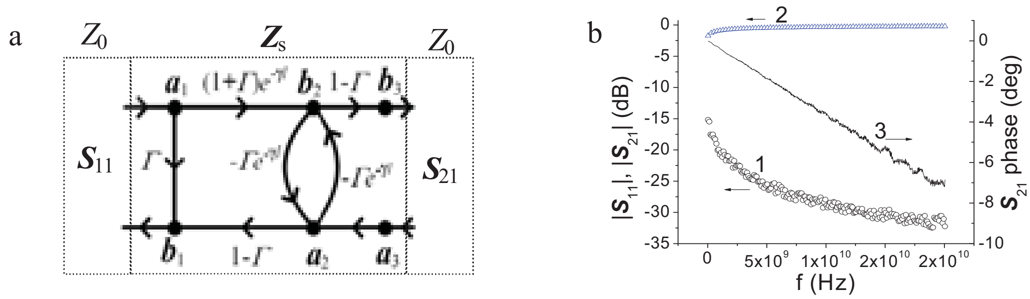

FIGURE 1. a- Signal flow graph of CPW. b- Scattering parameters for Au film. (1)-|$\boldsymbol{S}_{11}$|, (2)- |$\boldsymbol{S}_{21}$| and (3) - phase of $\boldsymbol{S}_{21}$..

Measurements are carried out on CPWs with a characteristic impedance of 50 Ω and a propagation length ranging from 450 μm to 3600 μm, which are patterned on alumina substrates by lift off lithography.

The measured phase angle of $\boldsymbol{S}_{11}$ (not shown) oscillates between ± 180° in the corresponding frequency range. In comparison, |$\boldsymbol{S}_{11}$| of the empty reference CPW was measured to be about –60 dB ($\boldsymbol{\Gamma} \approx 0$), while |$\boldsymbol{S}_{21}$| was in the range of 0 dB ($e^{-\gamma l} \approx 1$). The conductance of the film decreases considerably with increasing frequency from about 50 S/m at 1 GHz to about 10 S/m at 20 GHz. The presented results are general and applicable for characterization of electrical properties of thin nanostructured films at microwave frequencies.

REFERENCES

1. J. Obrzut, D. Pristinski and M. Yoonessi, ECS Trans. **28**, 99-106 (2010)
2. W. R. Eisenstadt and Y. Eo, IEEE Trans. Components, Hybr. Manufact. Tech., **15**, 483-490 (1992).

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