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 $Z_s$ that depends on the reflection ($\Gamma$) and transmission ($e^{\gamma l}$) coefficients; propagation constant ($\gamma$) and propagation length ($l$). We determine the relation between the experimentally measured scattering parameters ($S_{11}$) and ($S_{21}$), complex impedance ($Z_s$) and propagation constant ($\gamma$) for the CPW test structure through a signal flow graph method. Once the signal flow is solved for $\gamma$ and $Z_s$, 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)-$|S_{11}|$, (2)- $|S_{21}|$ and (3) - phase of $S_{21}$.

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

The measured phase angle of $S_{11}$ (not shown) oscillates between ±180° in the corresponding frequency range. In comparison, $|S_{11}|$ of the empty reference CPW was measured to be about −60 dB ($\Gamma \approx 0$), while $|S_{21}|$ 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


Keywords: Thin Films; Microwave Conductance; Coplanar Waveguides;