Simulation of the Electrical Properties of Conductive ITO Thin Films By Finite Element Analysis

R. A. Gerhardt[1], N. Xia[1], Y. Jin[1]

[1]Georgia Institute of Technology, Atlanta, GA, USA

Abstract

Finite element analysis (FEA) can be used to study the electrical properties of conductive ITO thin films. Previous studies have been done on insulating thin films deposited on conductive substrates [1,2]. It was found that changes of electrode size and film thicknesses can cause huge differences in the measured electrical properties and resultant error. Since ITO thin films are conductive, they are usually deposited on insulating substrates. Thus the simulation and experimental measurements presented here for films with different geometric dimensions and electrode geometry are completely different from the previous studies.
The FEA tool used in this work was COMSOL Multiphysics 5.3. We used a bi-conjugate gradient stabilized iterative solver in the ac/dc module. The goal is to solve Maxwell's Equation 1 in terms of electric potential (V) [3] which includes σ, the electrical conductivity, ε_r the relative permittivity and, ε_0 the vacuum permittivity (8.854 × 10-12 F/m). The problem then is reduced to solving the electric potential in each finite element domain. An AC voltage signal was added to the terminal electrode and the ground electrode had zero potential. The current flowing from terminal to ground electrode was extracted. The admittance (Y) can be derived using the functions in COMSOL software. Other dielectric properties such as impedance (Z) and capacitance (C) can also be deduced using Equations 2 and 3:
Z^*=1/Y^* =Z^'+jZ^'' (2)
C^*=C^'+jC^''=Y^''/ω+j Y^'/ω (3)
ITO films are treated as homogeneous layers without any defects or porosity. The procedure for modeling is as follows: (1) Choose 2D or 3D model and ac/dc electric currents interface in the COMSOL model wizard; (2) Draw the film model with or without environment; (3) Build the appropriate mesh; (4) Define the electrical parameters for each material and boundary; (4) Compute the model by the right solver in the frequency domain study; (5) Convert the COMSOL generated data into other electrical properties [4]. The insulating substrate and surrounding air environment were found to have a substantial effect on the resultant capacitance but minimal influence on the impedance of the films. Simulations for a range of film thickness, size and electrical properties were conducted. The effects of sample geometry, film conductivity and electrode geometry were discussed and compared to the experimental results, showing good agreement.
References:
[1] Kumar, S., and R. A. Gerhardt. Measurement Science and Technology 23, no. 3 (2012): 035602.
[2] Jin, Y., S. Kumar, and R. A. Gerhardt. Proc. 2015 COMSOL Conference, pp. 1-5. 2015.

[3] Kumar, S., and R. A. Gerhardt. Proc. 2009 COMSOL Multiphysics (Boston, MA, USA) pp (2009): 1-5
[4] Xia, N., PhD Thesis, Georgia Institute of Technology, Atlanta, GA, 2018.

Figures used in the abstract

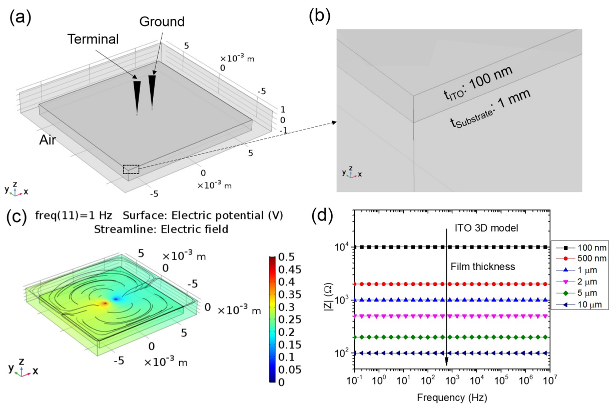

Figure 1: ITO thin films on an insulating substrate. (a, b) 3D model geometry; (c) Electric potential map and electric field lines; (d) |Z| for ITO films with different thickness [4]