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CHARACTERIZATION TECHNIQUE FOR DIELECTRIC PROPERTIES OF POLYMERS

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Novel Characterization Tool for Electro-Optic Polymers

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1. Introduction:

Nonlinear optical (NLO) polymers are currently being investigated for low voltage modulators by our research group led by Dr. Grote at the AFRL. Our goal has been to maximize the nonlinearity of the NLO core material, while minimizing the total poling voltage and the absorption loss. Thin films of deoxyribonucleic acid (DNA), that we have processed recently, show promise in providing the desired optical and electromagnetic properties, as well as the desired materials processability/compatibility. Thin films of DNA were deposited on glass and silicon substrates and the film quality, optical and electromagnetic properties and resistance to various solvents were characterized [1, 2]. The dielectric loss of the DNA films are ~ 0.1 dB/cm at 10 GHz and less than 0.5 dB/cm at 30 GHz [2].

2. Test Structure for Characterization of DNA polymers:

Our current work focuses on study of electric field poling in the DNA polymers for photonics applications. A two terminal device similar to the capacitive shunt switch[3], a recent invention of GS, will be used for characterization of the electric field poling of DNA based polymers or any other EO polymers. Effects of electric field and temperature on the dielectric properties of the DNA polymer films will be thoroughly studied using the device. The structure of the device is shown in figure 1 below. Based on the swept frequency scattering parameter measurements on the device, we can derive an electrical equivalent circuit from which we can determine the dielectric properties of the polymer film (ϵ_r and $\tan\delta$) as a function of electric field and temperature. A simple equivalent circuit for the device is shown in figure 2 [3]. The capacitance of the shunt capacitor will be determined by the dielectric constant of the DNA film which is a function of both the electric field and the temperature. The shunt resistance of the capacitor characterizes the conductance across the capacitor which is determined by the loss-tangent of the DNA film and is also a function of electric field and temperature. Other test structures such as coplanar transmission lines can be used for characterizing the in-plane poling characteristics of the DNA films. The parallel plate capacitance test structure will also be used for studies of poling on multiple polymer layer stacks. First, a single layer polymer will be studied, and then subsequently, the same device structure will be used for study of two-layer and three-layer stacks. The same device structure will be extended for studies on a Mach Zander Modulator designed using a polymer waveguide.

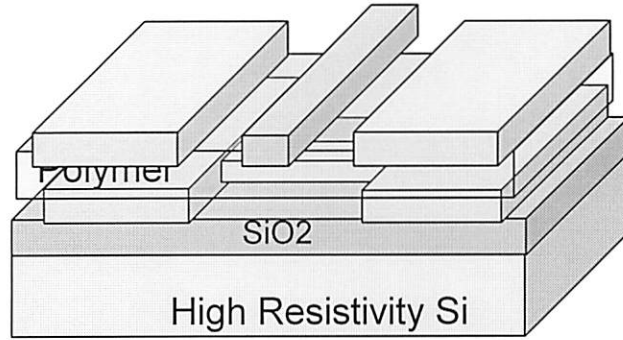


Figure 1. Parallel Plate Shunt Capacitance Test Structure implemented using coplanar transmission lines. The polymer thin-film is sandwiched between bottom (Metal1) and top (Metal2) metal layers. A single bias voltage applied to the center conductor of the CPW line on Metal2 will influence the dielectric properties of the polymer film. Ground-Signal-Ground (GSG) probes will be used for on-wafer probing of the device at the input and output. The same device structure can be used for characterization of poling for multi-layered polymer stacks.

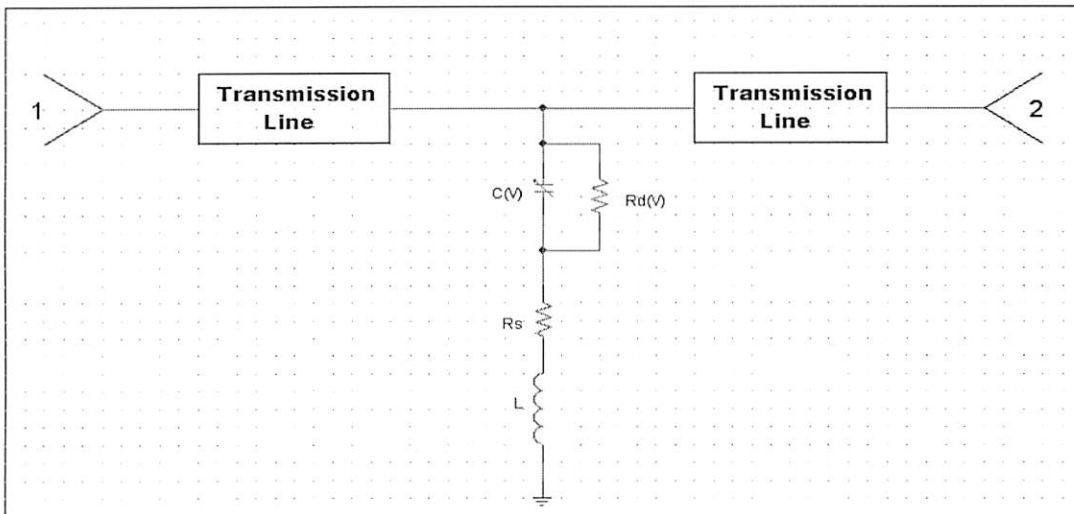


Figure 2. The equivalent circuit model for the parallel plate capacitance test structure shown in figure 1.

In figure 2, the capacitance $C(V)$ can be determined using the parallel plate capacitance formula $C(V) = \epsilon_0 \epsilon_r(V) \cdot A / t_p$; and the shunt resistance is given by $R(V) = 1 / (\omega \cdot C(V) \cdot \tan \delta)$. ϵ_0 is the dielectric permittivity of free space, ϵ_r the dielectric permittivity of the polymer being characterized, A the area of overlap of the top center conductor and the bottom electrode, t_p the thickness of the polymer, ω is the angular frequency, and the $\tan \delta$ is the loss-tangent of the polymer being characterized. By matching the experimental frequency response to the modeled frequency response, we can accurately characterize the effect of poling as a function of both electric field and the temperature.

References:

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2. G. Subramanyam et al, "Microwave Dielectric Properties of DNA Based Polymers Between 10 and 30 GHz", *IEEE Microwave & Wireless Components Letters*, to be published in April 2005.
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4. A. H. Kramer, "Array based Analog Computation", IEEE Micro, pp. 20-29, October 1996.