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High Pockel's coefficient for poled polymer in Multilayered Electro-optical device

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Abstract

We have investigated the contribution of electric proprieties and optical quality of two layers, such as TiO_2 selective layer and Sol-Gel cladding layer suitable for use as coating layers in nonlinear optic (NLO) polymer based opto-electronic devices. We will use simple technique reflection proposed by Teng and Man technique [1] for measurement of the electro-optic EO coefficients of poled thin films of EO polymer in the EO multilayer device. The poling technique has resulted in a Pockel's coefficient enhancement up to 190 pm/V with TiO2 when optimally poled with a sol-gel cladding. We provide new closed-form expressions for analysis of Teng-Man data including the dielectric constant and thickness of each interfacial film, such as cladding layer and selective layer.

1. Introduction

Polymer electro-optical materials and their hybrid systems have received considerable attention for a variety of photonic technologies. The Hybrid systems including optical and electrical components form intimate contact with EO polymer materials, such as selective barrier layers, cladding layer and multilayered slot waveguide modulators [7]. These systems are designed in order to achieve a highly efficient EO coefficient, and the role of interfaces between polymer, metal oxides and metals may be predominant [2]. Several studies have been carried with interfacial layers, like semi-conductive interfacial layer such as TiO_2 [2] and ZnO:Al [4], to improve the poling efficiency of multiple layer films. In conventional optical waveguide devices, EO active layer must be sandwiched between two layers of low refractive-index coating with a similar EO active layer thickness. Our structure is composed of the same layering of the layer in order to measure the EO Coefficient by Teng and Man technique. In the standard structure, the EO polymer film is sandwiched between two electrode and the voltage applied between the electrodes produce an electric field at the EO polymer films. As it is essential to have the higher voltage drop across the EO polymer layer, the barrier layers or cladding layer that surrounds the polymer should have a much higher conductivity than the EO polymer [5]. This configuration will be used in this paper but for a thin layer of EO polymer. In contrary, for dual-layer barrier, one of the layers will be consider as selective charge layer (SL), that will allow a higher distribution of the electric field through the polymer, and the second layer will be cladding layer (CL). The cladding layer will be sol-gel which has already been used by de Rose et al. [6]. On the other hand the barrier layer will be a TiO_2 semiconductor layer, which was always consider as a selective barrier layer with lower valence band (7.4 eV), which is known to be a very effective barrier to significantly reduce the hole injection and remove the accumulation of space charge during the poling process, leading to improve efficiency of poling of the EO polymers [2].

2. Results and discussion

The objective of our study is to evaluate the charge transport in the interfacial by electrical conductivity of each layer in the EO device structure, during the poling process for thinner thickness of EO guest-host polymer, by applying an electric field across EO device. To achieve a better optimization of the poling voltage applied across EO polymer, therefore achieving a high EO coefficient.

Our approach is to assess the reflectivity of the ITO layer to an accurate calculate of the EO coefficient and measure current density as a function of applied electric field at the poling temperature of 158°C for the device with EO polymers alone, with just selective layer such as TiO_2 and with TiO_2 and sol-gel cladding layer (see fig. 1).

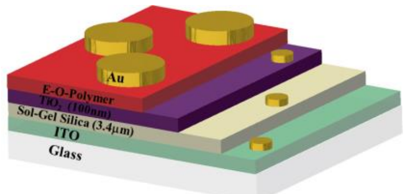

Fig. 1. Device structure with SEO100.

The J-V curve, was measured for device without CL but with a SL (TiO_2) has almost the same J-V characteristic than that without selective layer, but we observe as same as the TiO_2 layer protects slightly the EO polymer layer at low applied voltage (1.2 V). Indeed, the current density as function of poling voltage also shows that after the application of 1.5V, we observe that an increase of the efficiency of the TiO_2 layer with a distribution of the electric field is such that the current density is higher than the device without selective layer. Furthermore, TiO_2 selective layer can significantly block excessive charge injection and reduce the leakage current during high field poling. However, the device with CL gives better protection device multilayer EO, beyond 4V. Indeed, the behavior at higher poling voltage is linear and polarization of EO polymer occurs without early dielectric breakdown. This means that the CL delays it. Furthermore, we have some limit at 230V, this is due to the low thickness of the EO polymer. Thus the role of the selective layer is not negligible and remains important in the EO device multilayer, which has been shown by Enami et Al. for the multilayer slot waveguide modulators, and for which the enhanced of effective field in EO polymer layer Reduced $V\pi$ [2]. By introducing a selective barrier layer, and Sol-Gel CL the tunneling currents were significantly suppressed and the probability of dielectric breakdown was greatly reduced, and leading to 20% higher effective internal poling field strength [3] and higher degree of orientation order of poled films.

To calculate EO coefficient of poled thin films of electro-optic polymer in the EO multilayer device, we will use simple technique reflection proposed by Teng and Man technique [1]. The EO coefficient is lower for simple sample with EO Polymer sandwiched between two electrode without interfacial layer, because the electrode contact poling is limited by the applied voltage and the thinner thickness of EO polymer, which caused the dielectric breakdown early compared to the complete device with Sol-Gel CL. In the EO measurement of the multilayer EO device, we can consider that the stack Trilayer in device may simply be considered as three resistors in series and higher conductivity of CL can lead to more effective polarization field across the EO polymer, in this case a modulating voltage was applied across the ITO-Au electrodes at 1 kHz, and the incident angle θ of 1.55 micrometer laser light was set at 45°. Under this condition the half-intensity I_{dc} was determined as 4.6V. The relationship between the modulation-voltage amplitude V_m and the measured modulated-beam intensity I_m is shown in Fig.2 the I_m value is directly proportional to the V_m value. In addition, from the value of V_m/I_m from the slope of this figure, we can calculate EO coefficient more accurately in the multilayer EO device from the eq. (1), taking into account the dielectric constant and the thickness of each interface layer, such as TiO_2 and Sol-Gel CL.

$$r_{33} \equiv \frac{3.\lambda}{4.\pi} \times \frac{I_m}{I_{dc}} \times \frac{\sqrt{n^2 - \sin(\theta)^2}}{n^2 \sin(\theta)^2} \times \left[1 + \left(\frac{d_{TiO_2}}{d_{EO_{polymer}}} \right) \times \sqrt{\left(\frac{\varepsilon_{EO_{polymer}}}{\varepsilon_{TiO_2}} \right)} + \left(\frac{d_{SG}}{d_{EO_{polymer}}} \right) \times \sqrt{\left(\frac{\varepsilon_{EO_{polymer}}}{\varepsilon_{SG}} \right)} \right] \quad (1)$$

In the EO multilayer structure with a twin interfacial layer TiO_2 and Sol-Gel CL, a value of 190pm/V is achieved for a thinner thickness of EO polymer around 380nm, which reveals a better polarization of the EO layer of polymer film. However, very low values of EO coefficient about 5pm/V, were found in the standard device without interfacial layer, which demonstrates the added value of interfacial layers in an EO device. We found that we were able to pole at a much higher voltage before reaching dielectric breakdown when the sol- gel CL was present, allowing for enhancement of the maximum achievable Pockel's coefficient r_{33}.

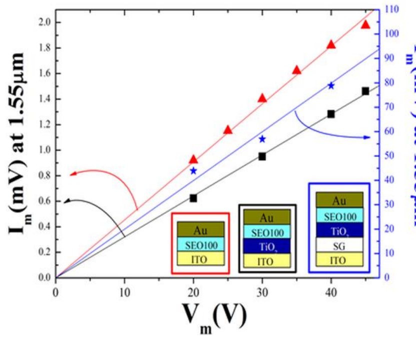

Fig. 2 Measured modulated-beam intensity Im vs modulation-Voltage amplitude Vm. For EO Polymer with and without Sol-Gel silica CL and TiO_2.

3. Conclusions

To summarize, the electro-optic coefficient of poled EO thinner polymers were enhanced by using twin layer such as TiO_2 SL and Sol-Gel CL. We have conclude that each layer, has a role to play in the structure and during polarization, Indeed, the higher conductivity of TiO_2 compared to Sol-Gel CL, can significantly block excessive charge injection and reduce the leakage current during high field poling. However, the contribution of Sol-Gel is as important, to protect a thinner thickness of EO polymer for the higher poling voltage and the early dielectric breakdown. We will use this structure to fabricate an EO modulator with thinner thickness of guest-host polymer in the near future.

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