Ridge Waveguide Electro-Optic Polymer Modulator with a New Kind of Corona Poled Crosslinkable Polyurethane*

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Abstract: A polymer electro-optic modulator has been fabricated with the functional layer acting as a kind of corona poled crosslinkable polyurethane. The three optical layers, namely waveguide, photolithography and oxygen are fabricated by spin coating. With the Reactive Ion Etching method, the ridge of the waveguide is constructed. With light at 1.31μm being fiber coupled to waveguide, the mode and the modulation properties of these devices are demonstrated in a micron control system.

Key words: modulator; polymer; ridge waveguide

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1 Introduction

The poled polymer is a new kind of nonlinear optic (NLO) material used in the modulation or sensing. Since 1990's, much research has been done on polymer electro-optic devices, which are so attractive because the polymer materials are of fast response time and low cost of and easy-to-integrate with the semiconductor devices[1,2]. The electro-optic (E-O) polymer modulator is the most promising one in the very high frequency application due to its extremely wide pass-band and very low drive voltage[2]. A device with halfwave voltage of sub-1V has been realized by the group of Dalton and Shi Yongqiang recently[2]. Hence no broadband amplifier is needed to drive the modulator. In this paper, our research on the fabrication and test of the poled polymer straight waveguide modulators is presented, as well as a kind of novel material. In laboratories, the straight waveguide modulators function is very like the M-Z intensity modulator when an analyzer is put after the device.

2 Fabrication Procedures

The waveguide structure of the electro-optic modulator with a microstrip configuration can be fabricated on Si, GaAs, quartz and glass substrate, etc, as shown in Fig. 1. Devices with this structure can acquire the biggest overlap integral of

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the optical and electrical fields. The evaporated Au of 0.2μm on the substrate was served as the ground electrode. Three light waveguide layers were spin coated on the bottom electrode. After the photoresist patterning, the core layer was etched by the oxygen RIE(Reactive Ion Etching) method to form the ridge waveguide. The evaporated transparent Au on the upper cladding layer was photoresist-patterned and electroplated to be 1.0μm in thick, which was designed as a microstrip line.

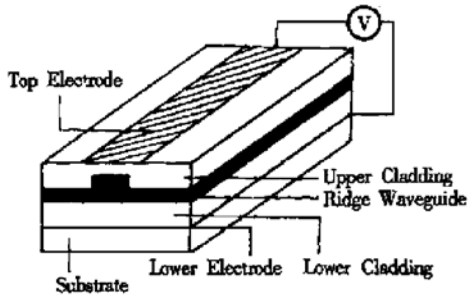

FIG.1　Ridge Straight Waveguide Modulator with Microstrip Structure

The lower cladding material was cl-1, a kind of epoxy resin. At the spin speed of 6000rps, it became 3—4μm in thick and was solidified after being heated at 100℃ in an oven for about two hours. The upper cladding was NOA61. Having been exposed to Ultra-Violet(UV) light for about several minutes, the spin-coated layer was solidified and became transparent. The active layer was the poled electro-optic polymer, sandwiched by the lower and upper claddings. The nonlinear property is obtained by the corona poling, with the setup shown in Fig. 2.

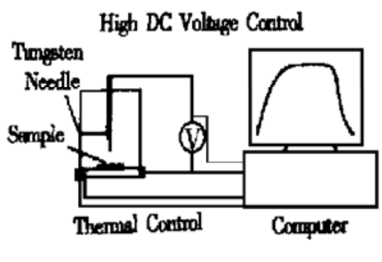

FIG.2　Corona Poling Configuration

The crosslinkable NLO polymer is formed with two parts, the crosslinking agent and the prepolymer. The former is 4, 4′-diisocyanato-3, 3′-dimethoxy-diphenyl. And the latter is formed by the reaction of Diglycidyl Ether of Bispherol A (DGEBA) with aniline and 2, 4 dinitro aniline, named BP-AN-2N. The diazo dipole in the prepolymer contributes to the noncentrosymmetric property of the material. Before our making the E-O film, the prepolymer and crosslinking agent are dissolved in the cyclohexanone to be spin-coated. In a high DC poling field, the dipole chromophores are aligned and the crosslinking reactions hardening the polymer to maintain the dipole orientation.

With the indexes of the E-O polymer, the upper and lower claddings being 1.65 , 1.56 and 1.57, respectively, the E-O core layer is made to be 0.7—0.9μm in thick, with ridge being 6—8μm in width and 0.1μm in high. The cladding layers of about 3.0μm is thick enough to confine the single mode waveguide, according to the theoretical calculation[3].

The Oxygen RIE technique is used in the fabrication of the ridge waveguide. The etching speed is about 40nm/min. The cross section taken by using Scanning Electron Microscopy (SEM) of SEM-6301F is shown in Fig. 3. The etching sidewall is not vertical because the power density is limited to 30mW/cm^2 or so to reduce the etching caused by the optical losses[4].

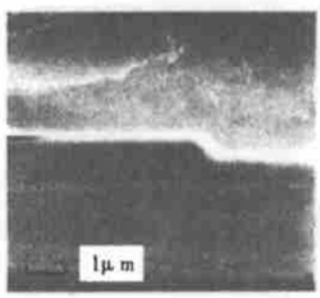

FIG.3　SEM Graph of Cross Section of Ridge Waveguide

3 Experiment Results of Waveguide and Modulation

The waveguide mode and modulation with a low frequency are tested via a micron control system, with which, the 1.3μm light is coupled by a contacted fiber at the input end and the near field pattern is taken by a CCD camera. Before CCD, the phase modulation is transfered into an intensity one by using a polarizer. Figure 4 shows that the ridge waveguide of the modulator behaves in a fine single mode, and the inset is the magnified near-field pattern. The results are accordant with the theoretical analysis[3]. For the single mode straight waveguide modulator, the obvious low frequency modulation has been detected and shown in Fig. 5. The lower part is the applied modulation voltage of 10kHz, while the upper represents the modulated light intensity.

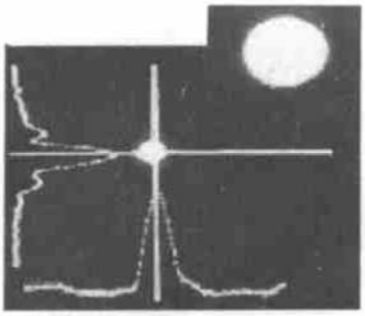

FIG. 4 Near Field Pattern of Single Mode Waveguide of 7.0μm Wide

FIG. 5 Low Frequency Modulation

4 Conclusion

A novel crosslinkable polyurethane E-O material has been first used in the modulator fabrication. The detailed device structure for the single mode straight waveguide modulator is given. The fabrication procedure and the oxygen RIE condition are explicated. The test results on waveguide and modulation show that the polymer NLO ridge waveguide modulator has been demonstrated successfully .

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用新型可交联极化聚合物材料制备的脊波导有机电光调制器*

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摘要: 制备了一种全部以聚合物为波导材料的电光调制器, 其中芯层为新型可交联极化聚胺脂电光功能材料. 旋涂制备波导薄膜、电晕极化产生非线性、光刻和氧反应离子刻蚀完成脊波导为主要的工艺步骤。1.3μm 光源光纤耦合输入脊波导调制器, 得到很好的输出端单模近场图及清晰的低频调制信号.

关键词: 调制器; 聚合物; 脊形波导

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