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A hybrid film where organic chromophores are attached to silica networks was fabricated by sol-gel process. The electro-optic coefficient r_{33} was measured to be 16pm/V and the poled film retained 95% of its initial r_{33} value after 800 hours at room temperature. A Mach-Zehnder modulator was fabricated, which supported the two lowest excited modes, TM_{00} and TM_{10}.

Keywords : poled polymer; electro-optics; sol-gel film; waveguide device; Mach-Zehnder modulator

INTRODUCTION

Poled polymers in which organic chromophores with large nonlinear optical effects are covalently bonded to the polymer backbone have been paid a great attention for photonic applications[1]. Because of great potential to obtain high electro-optic coefficients by molecular and structural engineering and their low dielectric constants, these materials have been considered strong candidates which enable to realize high speed optical modulators and switches over 100 GHz bandwidth[2]. However relaxation and scattering losses have been the

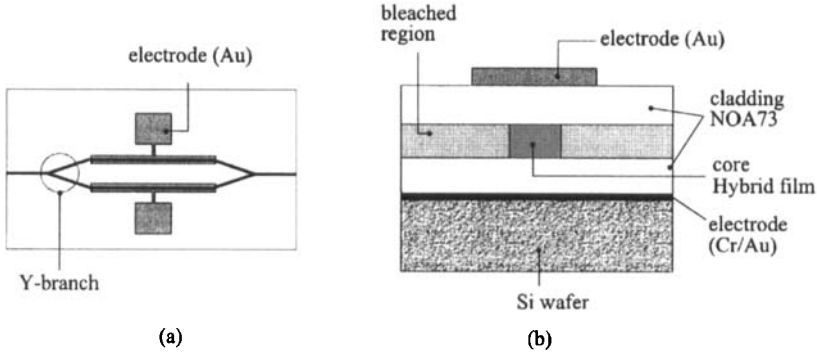

FIGURE 1 Schematic diagram of Mach-Zehnder modulator. (a) Top view and (b) side view.

major obstacles for practical device applications[3].

In an attempt to solve the problems, organic/silica hybrid materials where nonlinear optical (NLO) chromophores are chemically attached to heavily crosslinked silica networks were prepared by the sol-gel method[4]. In this paper fabrication processes of hybrid thin films and waveguiding structures are described, and mode patterns of a Mach-Zehnder modulator are analyzed.

MATERIALS AND FABRICATION OF MACH-ZEHNDER MODULATOR

NLO organic chromophore 4-[N,N-di-(2-hydroxyethyl)amino]-4'-nitrostilbene (DANS diol) was synthesized according to the method reported in Ref. 5. The dye-attached sol-gel monomer was synthesized by using the urethane reaction between DANS diol and 3-isocyanatopropyl triethoxysilane in N'N-dimethyl formamide solvent. The coating colloidal solution was prepared by sol-gel technique. Thin films were fabricated by spin casting method and the electro-optic effect was established by the DC contact poling method. The electro-optic coefficient r_{33} was measured to be 16 pm/V at λ=1.3μm and the poled film retained 95% of its initial r_{33} value after 800 hours at room temperature.

Figure 1 shows the structure of a Mach-Zehnder intensity modulator. For

the lower and upper claddings, UV-cured epoxy NOA73 (Norland Optical Adhesive) was used with a typical thickness of 5μm and the refractive index of the cladding was 1.546 at λ=1.3μm. The core layer was made of the 2.3 μm-thick hybrid film with the refractive index of 1.61 at λ=1.3μm. Photobleaching method was used to define the lateral guiding region[6]. The pattern of the waveguide was formed by evaporating gold on top of the multilayer film and a mercury lamp of 300 W was irradiated for two hours, which reduced the refractive index by 0.008. For DC contact poling a new gold electrode was deposited over the top surface and the film was poled at 125°C for two hours with the electric field strength of 80 V/μm. Then the gold layer was etched away to form a top electrode. The cross-section area of the waveguide was 2.3×6 μm^2 and the length of the active region of the modulator was 15 mm.

CHARACTERIZING THE MACH-ZEHNDER MODULATOR

The operation characteristics of the device were examined using 1.3 μm and 1.5 μm laser diodes. The mode patterns observed by a CCD camera in Figure 2(a) shows that the excited mode is not a single mode (Fig. 2(a)). However the mode pattern repeated with the period of 48V as a function of applied voltage. Using the beam propagation method, it was found that the observed mode profile was a superposition of the two lowest excited modes, TM_{00} and TM_{10}. Figure 2(c) shows that the intensity profiles obtained by computer simulation exactly coincide with the observed mode patterns.

CONCLUSION

Organic/silica hybrid material was successfully fabricated. Thin films of excellent optical quality were obtained and a Mach-Zehnder modulator was fabricated using the film, which supported the two lowest excited modes, TM_{00} and TM_{10}.

Acknowledgements

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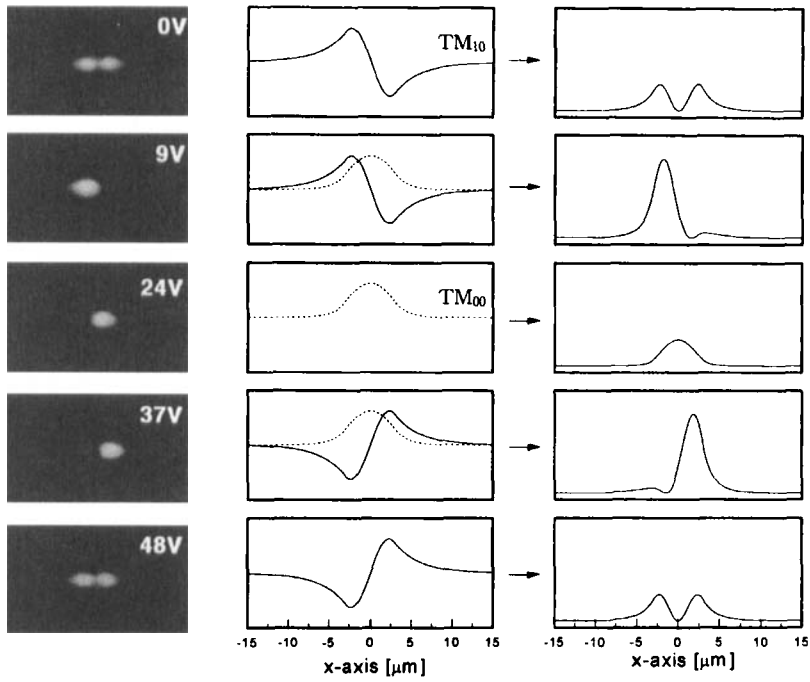

FIGURE 2 (a) Observed mode patterns as a function of applied voltage. (b) Electric field and (c) intensity profiles obtained by computer simulation.

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