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14. ABSTRACT

This program was for the demonstration and development of a new generation of ultra-high bandwidth optoelectronic switching devices based on an unique combination of ultra-low loss ion-exchanged glass integrated optical waveguide devices coated with highly efficient and ultra-high bandwidth electro-optic polyymers. This innovative approach combines the complementary strength of inorganic and organic materials and is based on a new material processing technology.

15. SUBJECT TERMS
Polymer-glass, waveguide, devices, ultra-fast photonic, ultra-high bandwidth, optoelectronic, electro-optic polymers, organic materials, inorganic materials

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Final Technical Report

Grant # F49620-97-1-0239

Active Polymer-Glass Waveguide Devices for Ultra-Fast Photonic AASERT-97

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1/1/99 - 3/31/99	$ 46,039
4/1/99 - 6/30/99	$ 52,719
7/1/99 - 9/30/99	$ 90,257
10/1/99 - 12/31/99	$ 39,429
1/1/00 - 3/31/00	$ 33,620
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10/1/00 - 12/31/00	$ ____0___

1. Abstract

This program was for the demonstration and development of a new generation of ultra-high bandwidth optoelectronic switching devices based on an unique combination of ultra-low loss ion-exchanged glass integrated optical waveguide devices coated with highly efficient and ultra-high bandwidth electro-optic polyymers. This innovative approach combines the

complementary stregth of inorganic and organic materials and is based on a new material processing technology.

2. Subject Terms

Electro-optic modulator, High bandwidth telecommunications, Optical waveguides, Fiber Optics, Electro-optic polymers, Ion-exchange waveguides

3. Technical Objective

This program is aimed at the development of a new generation of ultra-fast optoelectronic switching devices based on a unique combination of ultra-low loss ion-exchanged glass integrated optical waveguide devices coated with highly efficient and ultra-fast electro-optic polymers. The goals of this program are to demonstrate ultra-fast (>100 GHz) and ultra-low loss (<0.1dB/cm) electro-optic modulators.

4. Technical Approach

The modulator is based on an ion-exchange waveguide that is fabricated by the diffusion of Ag^+ ions into Na^+ glass. The diffused Ag^+ ions form a change in the index of refraction in the glass that is used to guide the light. A cross section of the proposed electo-optic modulator is shown in Fig. 1. The light enters the device in a buried section of the ion-exchange waveguide. The buried section serves to provide a virtually lossless transition from optical fibers and also allows the light to be directed under the metallic ground plane. Next, the light is directed upward to the heterogeneous glass composite waveguide through an adiabatic transition. Co-planar electrodes are fabricated on the surface of the modulator such that they can apply an electric field to the electro-optic film, which changes the index of refraction of the electro-optic film. The modulation of the index of refraction induces a phase change in the light that can be converted to an amplitude modulation on the light.

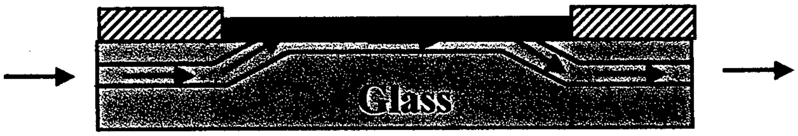

Fig. 1. Cross sectional side view of the heterogeneous electro-optic glass modulator.

5. Accomplishments/New Findings

Since the beginning of the project in April of 1997, the California Institute of Technology has successfully synthesized a chromophore with a diarylaminophenyl donor. This chromophore was then mixed into a polyimide to form a guest/host (20 wt % loading) electro-optic polyimide solution (11 ml) by Northeastern. The spin coating characteristics of the polymide on glass substrates has begun at the University of Arizona. The polymide films are characterized by surface morphology and absorption spectra. At the University of Arizona, ion-exchanged waveguides have been fabricated in glass substrates and they show single mode operation at 1.55 µm. A mask set for first generation devices has been designed and fabricated by the University of Arizona. This mask set allows for the integration of selectively buried waveguides and electro-optic polymers with high frequency electrodes.

Accomplishments/New Findings

The work on the chromophore development has been accomplished.

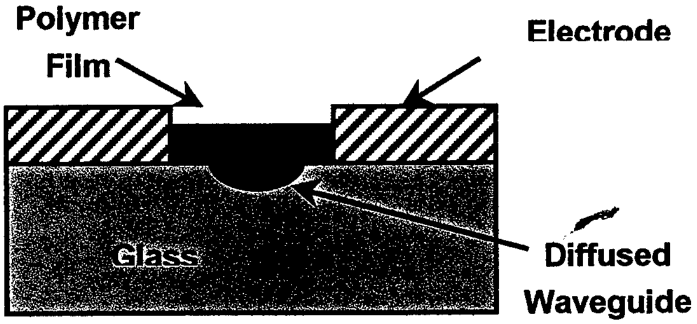

Fig. 1 Cross sectional schematic of the composite waveguide.

The initial work synthesised Chromophore **1** (Fig. 2) with a diarylaminophenyl donor and its thermal stability was compared with the corresponding dialkylamino chromophore **2**. The onset of decomposition for the diphenylamino chromophore **1** is 290 °C, while the onset for the dialkylamino chromophore **2** was 160 °C. The increase in thermal stability by about 130 °C demonstrates the utility of incorporation of the diarylamino groups.

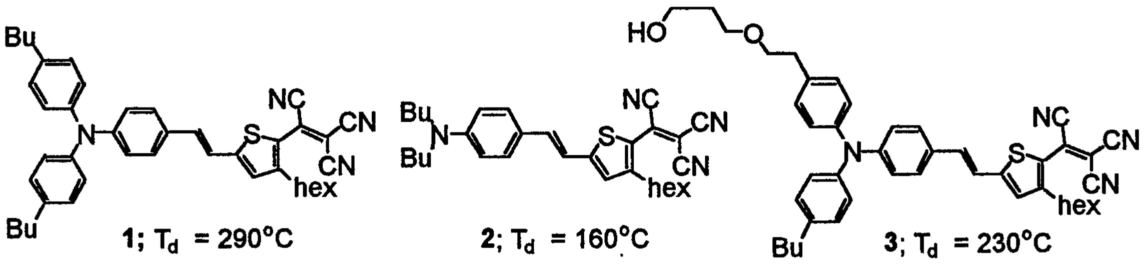

Fig. 2 Synthesized Chromophores

It is noted that the chromophore shown above is not functionalized to be incorporated covalently into a polymer. Therefore chromophore **3** functionalized with hydroxy alkyl group suitable for covalent incorporation into polymers was synthesized and the onset of decomposition of this chromophore was 230 °C. This lower decomposition onset can be ascribed to the presence of the extra ether functionality in the hydroxy alkyl chain.

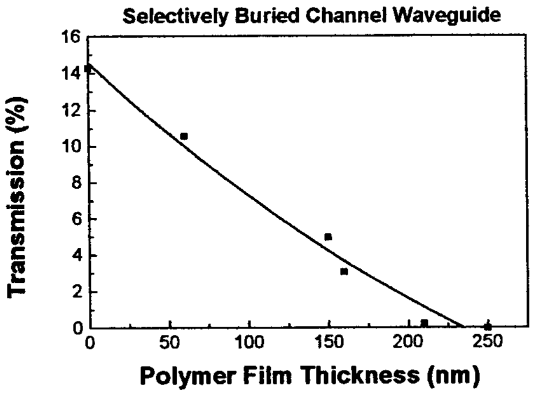

Fig3. Transmission characteristics for a polymer glass waveguide for different polymer thicknesses.

Accordingly, chromophores which do not have this extra functionality will be synthesized and thermal stability will be compared to that of chromophore **1**.

The first composite waveguides were fabricated with an ion-exchange glass waveguide and an EO polymer layer. This geometry included buried waveguide sections at the input and output of the waveguide with adbiatic transitions to direct the optical light toward the surface of the waveguide so that a composite waveguide could be formed. This robust design allowed electro-optic polymer to be spin cast on the surface of the waveguide and then optically characterized. After characterization, the polymer was removed and a new polymer thickness was spin-coated onto the surface waveguide. In this way the optical transmission characteristics could be studied as a function of EO-polymer thickness.

Progress was also made in the fabrication of high frequency electrodes. The coplanar waveguide (CPW) electrodes are fabricated by cleaning of the ion-exchange waveguides in an ultrasonic bath of solvents. A thin conductive metallic layer composed of Ti/Au is then e-beam evaporated onto the glass substrate. The metalized substrates are then coated with photoresist and patterned using standard photolithographic techniques. Next, the electrodes are electrochemically plated to thicknesses between one and two microns. After the Au plating, the photoresist is dissolved in acetone and the thin conducting layer of Ti/Au is chemically etched to form the CPW.

Measurement of the forward transmission coefficient for 1 cm long CPW has shown that plating with a DC current will result in rough and uneven surfaces on the Au. In order to overcome this effect, a pulsed plating method has been developed which uses three forward pulses of current and one reverse pulse of current. The forward pulses give the Au ions time to settle during the plating process. A simple evaluation of the plating process indicates that the electric field near the edges of the Au structures is higher and this results in an increase current flow of Au ions toward the edges of the Au structures. Applying a reverse pulse removes the loosely bound Au ions from the surface of the Au plating with an emphasis on the edges due to the higher electric field. The pulse plating results in a smoother Au surface for the electrodes, which translates to a lower transmission loss in the CPW (Fig 4). This loss is even more pronounced at higher frequencies as the skin depth becomes thinner.

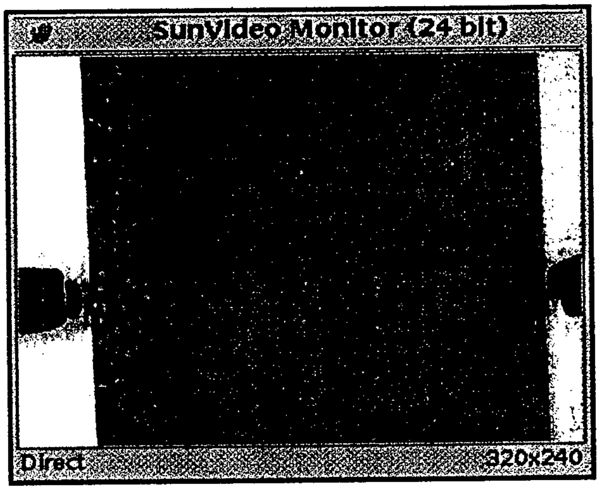

Fig. 4. Measurement of a microwave open ended stub. .

Also, new microwave structures were designed, fabricated and tested. An open ended stub component was designed and characterized. This component is used to isolate a DC component of the electric field from the load resistors of the modulator, which is important during the poling of the EO polymer film. However, the structure does allow the transmission of microwave signals so that these signals can see the matched load resistors.

6. Personnel Supported

Students working on this project Aniruddha Bashar, Yasufumi Enami, Nasuhi Yurt, and Juha-Pekka Laine.

7. Publications

None

8. Interactions/Transactions

None

9. New Discoveries, inventions, or patent disclosures

None

10. Honors/Awards

None

11. Markings

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