Integrated Optics Europium Aluminum Polymer Optical Waveguide with Graded Index Circular Core

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Abstract— **A Europium Aluminum Benzyl Methacrylate (Eu-Al/BzMA) integrated optical waveguide with 50 µm graded-index multimode circular core is fabricated by applying the Mosquito method for the potential application of optical interconnect. The parabolic index profile of the waveguide core is measured to confirm the profile exhibited by the waveguide. A preliminary experiment of the signal transmission is performed at 26 Gb/s to evaluate its capability in high dense and speed optical interconnections. According to the results, the waveguide successfully demonstrated free bit-error-rate through 5 cm waveguide transmission.**

Keywords— **Integrated optic; Optical interconnects; Polymer waveguides**

I. INTRODUCTION

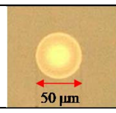
Integrated platforms of polymer optical active devices such as RE doped polymer waveguide amplifiers have attracted significant attention in many applications to reduce footprints [1]. They have the potential to be integrated with other optical components such as splitters and couplers to boost signal efficiency, and in turn compensate loss over signal transmission [2, 3]. Amplifier devices also play a crucial part in transmission systems to realize higher data rates and processing speeds in the future for high-end routers and servers, in conjunction with the rapid growth of overall computing system performance [4]. For this reason, this paper reports the preliminary results on the performance evaluation of the polymer waveguide composed of rare earth-metal (RE-M) doped polymer material (i.e. Europium Aluminum incorporated Benzyl Methacrylate (Eu-Al/BzMA)) operating in a 26 Gb/s transmission, where early research on this waveguide has concentrated on the practical use such as amplifying and lasing materials [5-11]. The graded index (GI) waveguide core is implemented, since it is superb for low propagation loss, low connection loss with GI-MMF, as well as low interchannel crosstalk properties; although the pitch size of the waveguide fabricated by the Mosquito method is relatively small [12].

It is predicted that the implementation of the Eu-Al/BzMA optical waveguide amplifier will confirm the potential of this device for the application of optical interconnect, rather than the compensation of the transmission loss by amplifying the signal.

II. WAVEGUIDE FABRICATION

In this work, the particular cladding and core material used is acrylate resin, XCL01 (photo curable modified acrylate resin (nd= 1.501)) and Eu-Al/BzMA with a larger refractive index contrast, as in [1-3]. The Mosquito method is utilized because it is straightforward and relatively efficient [4]. It has the capability to create the GI multimode circular core directly on-board, even when using high-heat resistance polymer materials [5]. The details of this method have been reported elsewhere [2-9]. Here, a 5 cm waveguide length with the core pitch of 250 µm and a diameter of 50 µm, respectively, is successfully fabricated by using the following fabrication parameters: 150 µm inner needle diameter, 325 kPa dispenser gas pressure and 61.8 mm/s dispensing speed. Accordingly, the core diameter, waveguide length and cross-section of the fabricated Eu-Al/BzMA integrated optical waveguide is shown in Table 1.

Table 1 Characteristics of fabricated Eu-Al/BzMA optical waveguide under a digital microscope

Core diameter	Waveguide length	Cross-section
50 µm	5 cm	

III. EXPERIMENTAL RESULT AND DISCUSSIONS

A. Refractive Index Profile

Determining the refractive index of the core in this work is crucial to characterize the guiding mode and the index profile of the waveguide. As more advanced technology with the demand of a higher data rate is expected, the development of the GI multimode Eu-Al/BzMA integrated optical waveguide is a prerequisite for the waveguide structure design, so that it is compatible with other complicated circuit components in the near future.

Hence, the refractive index of the waveguide is measured by utilizing a transmitted dual-beam interference microscope; the result is shown in Fig 1. According to the result, it can be deduced that a parabolic refractive index or GI profile is successfully formed in the integrated optical waveguide of Eu-Al/BzMA.

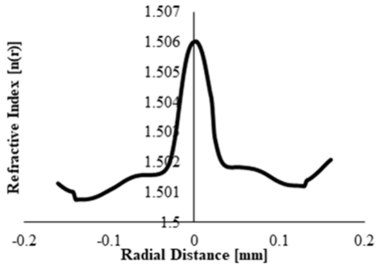


Fig. 1 Refractive index profile of the waveguide

B. *Insertion Loss*

The insertion loss of the waveguide core is measured by comparing the two measurement readings, as illustrated in [11], with some modification in the 50 µm GI multimode fiber connection. The insertion loss of the fabricated Eu-Al/BzMA integrated optical waveguide is recorded to be 4.65 dBm.

C. *Transmission Capacity for High-Speed Interconnects*

The measurement of the eye diagram is among the most important criteria used to evaluate the performance of the waveguide. Hence, it is experimentally conducted by transmitting a 26 Gb/s signal with the wavelength of 850 nm via the GI multimode circular waveguide core of the 5 cm length as shown in Fig. 2. Firstly, the pulse signal is electrically generated by the pulse pattern generator (PPG) through the RF cable. Next, the signal is converted from the electrical signal to the optical signal by using the electro-optic modulator (EOM) before combining with the signal source and passing through the waveguide via graded-index multimode fibre (GI-MMF). Then, the output optical signal from the waveguide is converted back to the electrical signal by utilizing the EOM. Finally, the output from the receiver (Rx) and transmitter (Tx) are compared and calculated by the bit error rate tester (BERT) to detect the error.

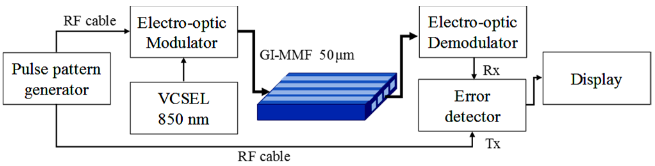
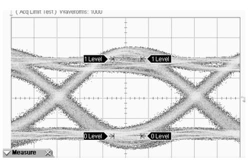
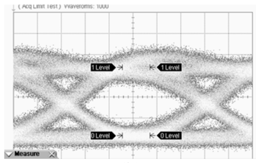


Fig. 2 Bit-error-rate performance for 26-Gb/s transmission system

Herein, two readings are taken into consideration for the evaluation of the waveguide transmission capacity. The first reading is made without the waveguide that is known as "back to back". Then, it is followed by the reading with the waveguide. The results are recorded in Fig. 3(a) and (b). Based on the results, a small degradation in the signal is observed, mainly due to the loss and attenuation that occur along the transmission. Moreover, the bit error rate (BER) power penalty is found to be 0. Thus, it is confirmed that the signal quality can be guaranteed, even if the waveguide is installed in the actual system.



(a)



(b)

Fig. 3 Eye diagram after a 26 Gb/s (a) back to back, (b) transmission through a 5 cm waveguide

IV. CONCLUSION

The integrated optical waveguide of Eu-Al/BzMA is successfully fabricated by using a micro dispenser machine via the fabrication technique of the Mosquito method. The refractive index profile of the waveguide observed indicates the GI multimode circular core of the waveguide. Furthermore, a high transmission of the waveguide has been demonstrated, with no power penalty of BER. Consequently, it is concluded that such a device is a potential component, not only as an amplifier, but also as a practical application of optical interconnect.

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