OMV3.pdf

Low Loss Heat Resistant Fluorinated Polymer Optical Waveguides for Optical Interconnects

Shotaro TAKENOBU
Asahi Glass Co., Ltd, 1150 Hazawa-cho, Yokohama 221-8755, JAPAN
**Phone:+81-45-374-7328, Fax:+81-45-374-8858, E-mail:shotaro-takenobu@agc.co.jp*

Abstract: Multimode optical waveguides using low loss heat resistant fluoropolymer were demonstrated. We fabricated 10 cm-long film optical waveguides and measured insertion loss, tolerance, and heat resistant. These results showed good performance at 1310nm.

OCIS codes: (160.5470) polymers; (230.7380) Waveguides, channeled; (200.4650) Optical interconnects

1. Introduction

Recently development of optical interconnects rapidly grow in the fields of printed circuit boards (PCBs) and mobiles all over the world. Especially optical interconnects can be good solution for protecting emission noise, providing high speed large-capacity data communication and low power consumption. So far we have been developing ultra-transparent polymer materials in infrared region and optical waveguides for years [1-2]. After these basic developments, we reported the fabrication and demonstration of 1x32 splitter, AWG, and 1.2 m-long Multimode polymer optical waveguides using dopant-free perfluoropolymer [3-5]. According to these reports , the performance of our polymer was better than that of other reported polymers. Especially it is one of the most transparent polymer among all polymers at the optical telecommunication wavelength band from 1250nm to 1650nm. However, in the case of using these dopant-free perfluoropolymer in the fields of printed circuit boards (PCBs), heat resistance and film processing are very important. Many people expect development of multi-mode polymer optical waveguides. Many reports using wavelength at 850nm have been already reported [6]. However power consumption of VCSEL at 850nm is higher than that of longer wavelength VCSEL (for example VCSEL at 1060nm). And operating speed of VCSEL at 850nm is also faster than that of longer wavelength VCSEL . In this paper, we focused on the multimode polymer optical waveguides using longer wavelength band (1060/1310/1550nm) rather than conventional wavelength 850nm. We fabricated 10 cm-long film polymer optical waveguide using crosslinkable fluorinated polymer measured insertion loss, input tolerance, and heat resistance.

2. Experiment

2.1 Material

So far we have used perfluorinated polymer (PBVE) as a core material of polymer optical waveguide. PBVE is perfluorinated poly (butenyl vinyl ether), known as Cytop®, a kind of perfluorinated amorphous polymers since 1980s.This polymer is amorphous and highly transparent in wide wavelength range. For example in case of fabricating multimode polymer optical waveguide using PBVE as a core material, propagation loss at 1310, 1550, and 1650nm are 0.047dB/cm, 0.049dB/cm, 0.070dB/cm , respectively[5].

However, Tg (Glass transition temperature) of PBVE is 108 degree. There was concern in a heat-resistant point if we used PBVE in the condition of a high temperature process such as soldering reflow and treat high temperature condition.

Therefore we developed a new class of crosslinkable fluorinated polymer which can be formulated into photosensitive compositions.

Table 1. Refractive Index and NA (Numerical Apertures) of Core and Cladding material

	@1060nm	@1310nm	@1550nm
Refractive index (core)	-	1.5329	1.5309
Refractive index (cladding)	-	1.4926	1.4914
NA (Numerical apertures)	-	0.35	0.35

OMV3.pdf

2.2 Fabrication

Fig.1 shows process comparison with dry etch polymer and photosensitive polymer. Dry etch process is complicated and it takes too much time. On the other hand, process of photosensitive polymer does not use vacuum system and it is simple and easy. The fabrication of the polymer optical waveguide was carried out using this UV cure technique as follows. Cladding and core were coated on the 6-inch Si substrate by spin-coating. They were dried up and formed by UV exposure. After developing the wafer, they was cured. Finally, overcladding was coated on the wafer by spin-coating and dried up again.
For evaluation, we cut edge of 10 cm-long film polymer optical waveguides and observed cross -sectional view of those. Fig.2 depicts photographs of waveguides a) cross–sectional view of film waveguides b) film polymer optical waveguides chip . The core size we measured was 50x 50 um square. Table 2 shows chip and core size. We didn't polish edge of polymer optical waveguides. Chip size is 100x0.2x0.08 (mm).

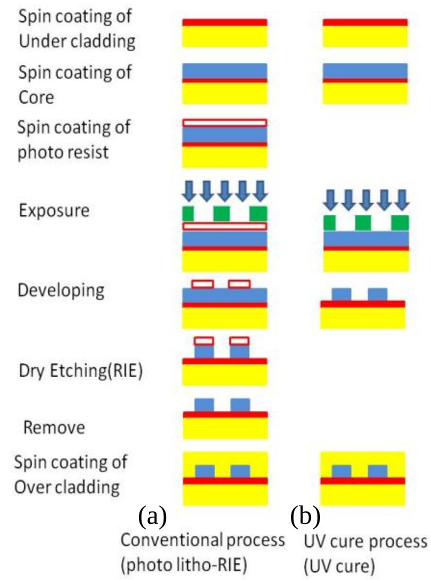
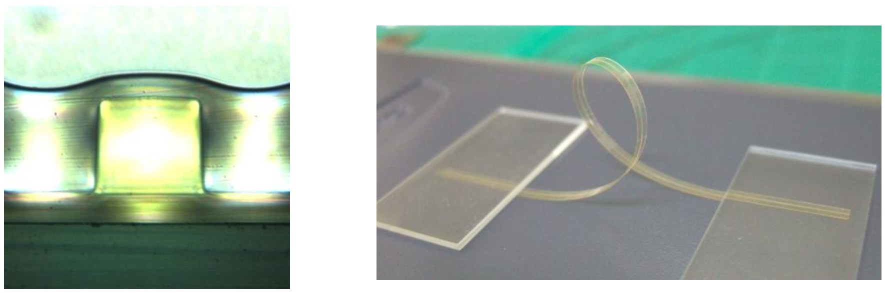


Fig.1 process comparison with a) dry etch polymer and b) photosensitive polymer

Table 2. Size of polymer optical waveguide

Edge polish	Non-polish (90deg.)
Chip size	100 x 2 x 0.08 (mm)
Core size	50 x 50 (um)



(a) (b)

Fig.2 Photographs of 10 cm-long film polymer optical waveguides a)Cross–sectional view (core size: 50x50um) b) Film polymer optical waveguides chip

2.3 Measurements

Fig.3 shows experimental setup of measurement of insertion loss in the case of connecting butt joint between input /output fiber and 10 cm-long film polymer optical waveguides. In the case of using SMF (Single Mode Fiber)/MMF (Multi Mode Fiber) for incident side, optical light of 1310nm FP-LD through GI-62.5MMF was coupled to the fabricated polymer optical waveguide. The propagated light into the waveguide was received using power meter through GI-62.5MMF. In case of LD chip for incident side, optical light of 1310nm LD chip was directly coupled to the fabricated polymer optical waveguide. The propagated light into the waveguide was received using power meter through GI-62.5MMF. We didn't use matching oil on the alignment and measurement.

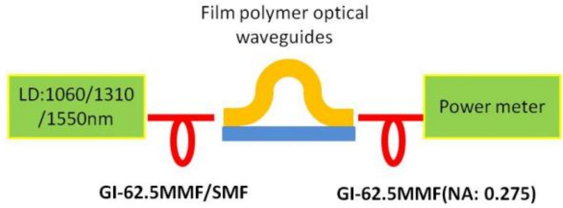


Fig.3 Experimental Setup : Insertion loss measurement in case of input fiber butt joint

3.Results

The results of the measurement shows Table 3. As shown in Table 3, the insertion losses (IL) of 10 cm-long film polymer optical waveguides were less than 3.5dB (1.33dB~3.41dB) in each wavelength. These values show good transparent characteristic. Therefore, these results are the proof of the very high transparent polymer optical waveguides in the telecommunication band.

Table 3. Summary of measurements results of insertion loss of 10-cm-long film polymer optical waveguides

IL (including coupling loss)	Wavelength (nm)		
Input (Fiber / LD)	@1060nm	@1310nm	@1550nm
SMF	-	1.66dB	3.22dB
GI-62.5MMF	1.33dB	1.81dB	3.40dB
LD chip	-	2.48dB	-

Next we measured input tolerance of the10 cm-long film polymer optical waveguides using light sources of 1310nm FP-LD through GI-62.5MMF and 1310nm LD direct incident**.** Fig.4 shows the results of tolerance. The tolerance width of the 1dB down was 26um (parallel to waveguide) and 25um (perpendicular to waveguide) in the case of FP-LD optical light of 1310nm FP-LD through GI-62.5MMF and was 31um (parallel to waveguide) and 27um (perpendicular to waveguide) in case of 1310nm LD direct incident.

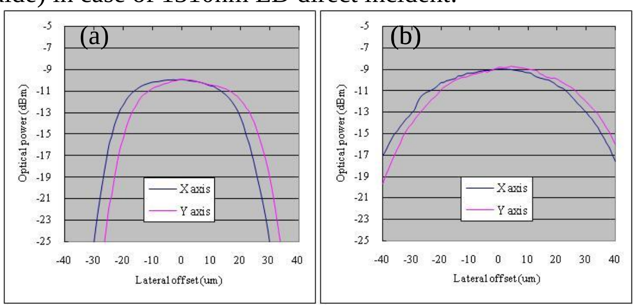


Fig.4 Input tolerance of 10-cm-long film polymer optical waveguides
(a) Input: 1310nm FP-LD through GI-62.5MMF (b) Input:1310nm LD direct incident

Finally we evaluated heat resistant test. We put 10 cm-long film polymer optical waveguides in the oven of 210 degree for 2hours in the atmosphere and measured the change of the insertion loss before and after the baking. Table 4. shows below the results. There was not the change of the insertion loss before and after the baking at 1310nm.

Table 4. Measurement results of change of insertion loss of 10-cm-long film polymer optical waveguides changed in baking (210degree for 2 hours) before and after

Input/Output: GI-62.5MMF	Wavelength (nm)	
	@1310nm	@1550nm
Change of insertion loss (delta IL)	0.08dB	0.58dB

4. Conclusion

We fabricated 10 cm-long film polymer optical waveguides using fluorinated polymer. In the case of using SMF for incident side insertion loss was 1.66(2.82) dB at 1310(1550) nm. In case of using 1310nm LD chip for incident side insertion loss was 2.48dB. Input tolerance (1dB down) of the 10-cm-long film polymer optical waveguides using light sources of 1310nm FP-LD through GI-62.5MMF and 1310nm LD direct incident were 24 and 22um. These results are very good results. We think these excellent data obtained from 10 cm-long film polymer optical waveguides proved that our polymer optical waveguide is much promising for the application to the full wavelength range optical interconnects devices. These results show a possibility of the new optical interconnects using wavelength which will be mainstream in the future.

References

[1] M. Nakamura et al, Preprints 15th Symposium on Fluorine Chemistry **1990**, 76.
[2] Y. Kuwana et al., OWF2 in the proceedings of *OFC2006*, (**2006)**
[3] S.Takenobu et al.2.5.5 2007 in the proceedings of *ECOC2007*, (**2007)**
[4] S.Takenobu et al., JWA32 in the proceedings of *OFC2008*, **(2009**)
[5] S.Takenobu et al., JThA24 in the proceedings of *OFC2009*, **(2009**)
[6] M.Shishikura et.al., P1275 *ECTC2007*, **(2007**)