Flexible Optical Waveguide with Tapered Structure Having Large Coupling Tolerance

Nobuhiko Ishizawa, Masahiro Kanda, Osamu Mikami
Tokai University
Hiratsuka, Kanagawa, 259-1292, Japan
mikami@tokai.ac.jp

Tsuyoshi Shioda
Mitsui Chemicals, Inc.
Sodegaura, Chiba, 299-0265, Japan

***Abstract*—A flexible polymeric waveguide with a tapered structure in core thickness in the vicinity of the input port was proposed. The core thickness for the uniform core region was designed to be 50μm. The tapered waveguide with a core thickness of 150μm at the input port revealed three times higher coupling tolerance performance than that for an uniform core thickness of 50μm, as designed.**

Keywords- optical interconnection; polymeric waveguide; coupling tolerance

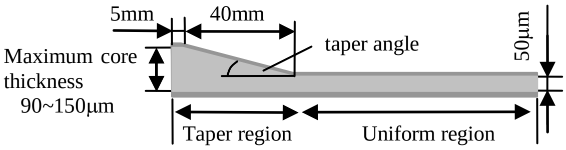
I. INTRODUCTION

Optical interconnection technology has attracted much attention to solve some problems for electronic conventional interconnection, such as signal degradation, high power consumption, electromagnetic interference (EMI), heavy weight and large footprints. The optical interconnection has several advantages such as lower power consumption and high density package [1]. However, in this approach, precise positional alignment between optical devices and the optical circuit is required, which may significantly increase the cost and time required for packaging and mounting optical devices. These days, the hinge part of mobile phones and laptops needs flexible optical waveguides. If the waveguide thickness is reduced for improvement of flexibility, the waveguide core thickness should be also reduced. As a result, it is difficult to align easily and cost effectively between an optical component and an optical circuit such as waveguide. In order to overcome these difficulties, we have proposed a flexible polymeric waveguide having a tapered region in the core thickness at the input port. On the other hand, the core thickness for the uniform core region that was large portion of waveguide was designed to be 50μm. The tapered waveguide with the core thickness of 150μm at the input port revealed three times higher coupling tolerance performance than that for a uniform core thickness of 50μm, as we expected.

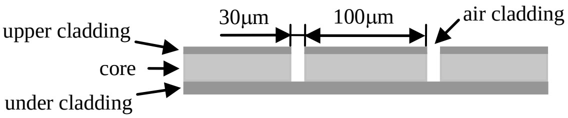
II. PROPOSED OPTICAL WAVEGUIDE

A. Structure of the Optical Waveguide

Fig. 1 shows the schematic structure of the proposed flexible polymeric waveguide. There are two regions. One is a taper region and another is an uniform one. At the uniform region, the core thickness and the length were designed to be 50μm and 80mm, respectively. At the taper region, the maximum core thickness at the edge was designed to be 90, 110, 130 and 150μm. The core thickness decreased continuously from the maximum to 50μm as shown in Fig. 1, and the length of the taper region was 45mm. The three-layered structure, such as upper cladding / core / under cladding, with a taper core was formed by our coating technique using a designated blade. The core pattern formed by two grooves was fabricated by a conventional dicing process as shown in Fig. 1 (b). The refractive indices of the core and the cladding polyimide at the wavelength of 850nm were 1.56 and 1.51, respectively. Fig. 2 shows a photograph of the cross-section of the input port of the waveguide.



(a) side view



(b) cross section

Figure 1. Schematic structure of proposed flexible waveguide.

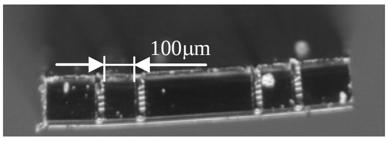


Figure 2. Photograph of cross section of the waveguide.

B. Core ThicknessProfile at the Tapaer Region

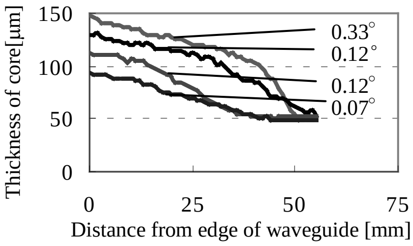


Figure 3. Core thickness profile for tapered waveguide fabricated.

Fig. 3 shows the core thickness profile by observing with an optical microscope. The core thickness decreased gradually from the maximum to 50 μm. We obtained the maximum slope of the profile as a taper angle for all samples. Table 1. shows the taper angles of design and experimental. When we designed the maximum core thickness of 150μm, we found that the taper angle for experimental was 2.4 times larger than that for design. This was due to slight flow of a poly (amic acid) solution, which was precursor of polyimide, at a core coating process.

TABLE 1. TAPER ANGLE

Core of thickness	**Taper angle**	
	Design	***Experimental***
90μm	0.06°	0.07°
110μm	0.09°	0.12°
130μm	0.11°	0.12°
150μm	0.14°	0.33°

III. TOLERANCE AND OPTICAL INSERTING LOSS

A. *Positional Tolerance Measurement*

We evaluated the positional tolerance for optical coupling between a graded index multimode fiber (GI-MMF) with a core diameter of 50μm and the input port of the waveguide. Fig. 4 shows the optical insertion loss measurement system. The near field pattern of launching light was inserted in this figure. The fiber end was butt-coupled to the input port of waveguide. The output power from the output port of waveguide was measured by a large area photo-detector and then we calculated optical insertion loss. The change in optical insertion loss by changing the taper angle corresponds to that in the optical coupling loss by assuming fixed optical propagation loss of waveguide. We evaluated the positional tolerance for the optical insertion loss higher than the minimum optical insertion loss by 1dB. We called the positional tolerance “1dB tolerance”.

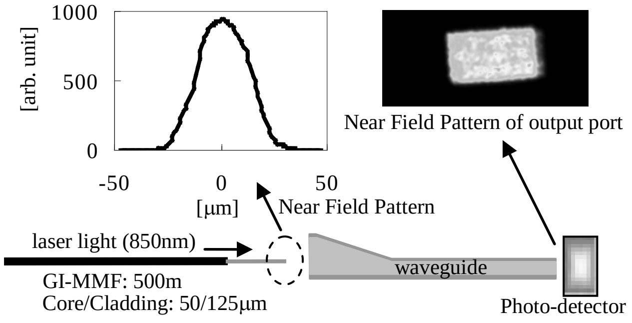


Figure 4. Optical insertion loss measurement system.

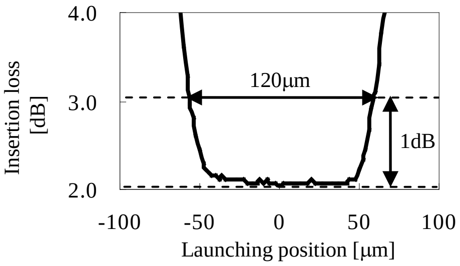


Figure 5. Example of 1dB tolerance.

Fig. 5 shows optical insertion loss change by launching position change of the fiber core center for the maximum core thickness of 130μm. We obtained the 1dB tolerance of 120μm, as shown in Fig. 5.Fig. 6 shows the maximum core thickness dependence of the 1dB tolerance. The broken line shows the relationship that the maximum core thickness is equal to the 1dB tolerance. We observed that the 1dB tolerance for all samples including the waveguide without the taper region and a core thickness of 50μm was almost similar to the maximum thickness of waveguide, as designed.

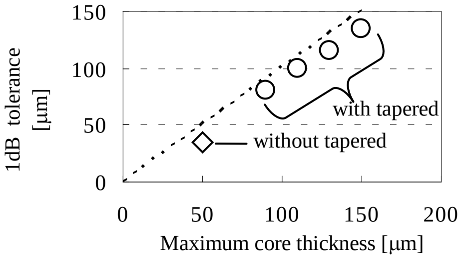


Figure 6. Maximum core thickness dependence of 1dB tolerance.

B. *Optical Inserting Loss Change*

Fig. 7 shows the taper angle dependence of the optical insertion loss. We had found that the optical insertion loss and its three times standard deviation (3σ) for 1,000 samples in the waveguide with the formed core thickness were obtained to be 2.5dB and 0.4dB, respectively, for the optical insertion loss measurement system. We observed no change in optical insertion loss with increasing the taper angle as designed. In general, optical insertion loss depends on launching condition for optical insertion loss measurement. The launching condition dependence on optical insertion loss and 1dB tolerance for the waveguide with tapered structure is ongoing.

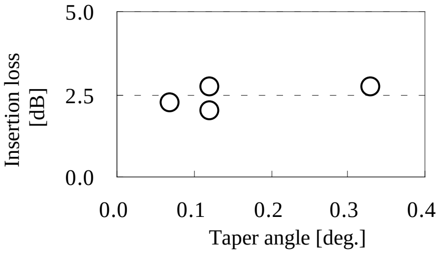


Figure 7. Taper angle dependence of optical inserting loss.

IV. CONCLUSIONS

We demonstrated a flexible polymeric waveguide with a tapered structure in core thickness in the vicinity of the input port. The core thickness for the uniform core region was designed to be 50μm. The tapered waveguide with the core thickness of 150μm at the input port revealed three times higher coupling tolerance performance than that for a uniform core thickness of 50μm, as designed. The waveguide having small portion for thick core and large portion for thin core has an advantage for easy assembly with optical components and a potential for high flexible durability.

REFERENCES

[1] M.A. Meis, “Opto-electronic backplane technology for cost effective bandwidth management,” Proc.ECTC2003, 2003, pp.1073-1076