Recent Development of Polymer Optical Waveguides Towards Next Generation FTTH Applications

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ABSTRACT

For next generation fiber to the home (FTTH) system, we are asked to use inexpensive optical devices. For that the use of soft-lithography instead of standard photolithography and dry etching technologies is attractive because cost saving optical device can be realized. Polymerization using multi-photon absorption of materials is also a good method for optical waveguide fabrication. Using these processes, we can fabricate the waveguide and connect it with optical fibers at the same time. In this presentation, several simple fabrication methods will be discussed. Optical characteristics evaluation method for polymer optical waveguides to accelerate the development of optical circuits will also be presented.

1. INTRODUCTION

Optical components and materials that play an important role for transmitting and processing optical signals in optical network system within the home or office, should be inexpensive. Figure 1 illustrate the image of home network system where plastic optical fibers (POF) and optical circuit based on optical waveguides will be used.

Low loss optical waveguides at telecommunication wavelengths can be fabricated using either glass or polymeric materials. Polymers have several features such as easy processing, refractive index controllability, flexibility and possibility to reduce their cost. Basically optical waveguides are fabricated by photolithography and dry etching technologies, though, use of soft-lithography instead of the technologies is attractive because inexpensive optical device can easily be realized. Micro-transfer molding or UV-embossing using stamps were examples of that. Polymerization using multi-photon absorption of materials is a good simple method for optical waveguide fabrication. Laser induced self-writing technology of optical waveguide is also very attractive method. Using these processes, we can fabricate and connect the waveguides with optical fibers. Because POF will be applied to the home network system, large core size waveguides become important. In this presentation, several simple fabrication methods will be introduced. New optical loss evaluation method for polymer optical waveguides will also be presented.

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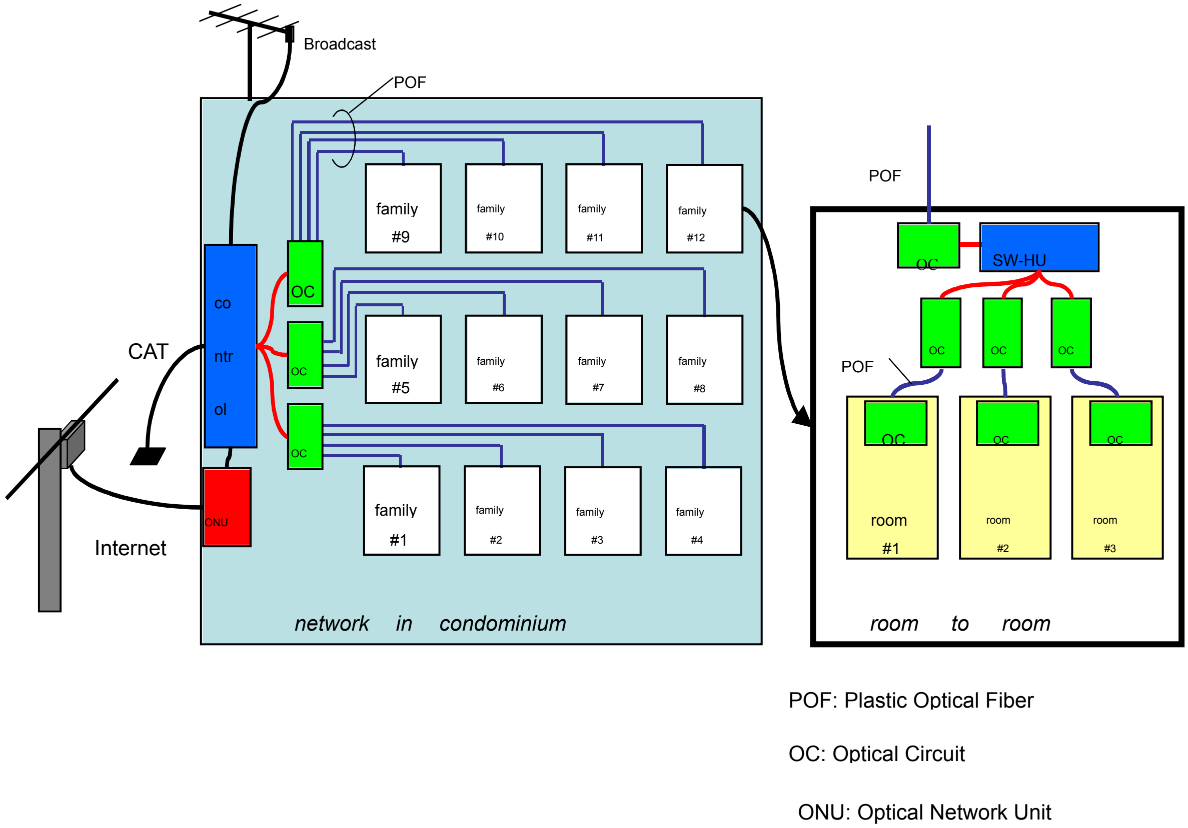

Figure 1 Image of optical home network system

2. MERITS OF POLYMERS

Figure 2 shows schematics of optical waveguide fabrication methods. Compared to photolithography and reactive ion etching technology that glass waveguides are using, fabrication methods of polymer optical waveguide (POW) are very simple. To fabricate large core size optical waveguide, ion etching needs very long time and patience. Although transparency of polymers in the telecommunication wavelength is not so good as glass counterparts, for next generation FTTH systems, VCSEL will be used as a light source. Thus transparency at data-com wavelengths will be more important for POW than telecom wavelength. Flexibility of polymers will work well for some specific applications. For that polymer substrate should be used instead of those of glass or silicon. We can select varieties of polymers for some special applications. Depending on the polymers we can select appropriate waveguide fabrication technologies. Polymers are also easy to functionalize in which high speed optical switching and signal modulation can be attained. Thus, promising approach to fabricate cost-effective optical waveguide for next generation FTTH system will be the use of polymers.

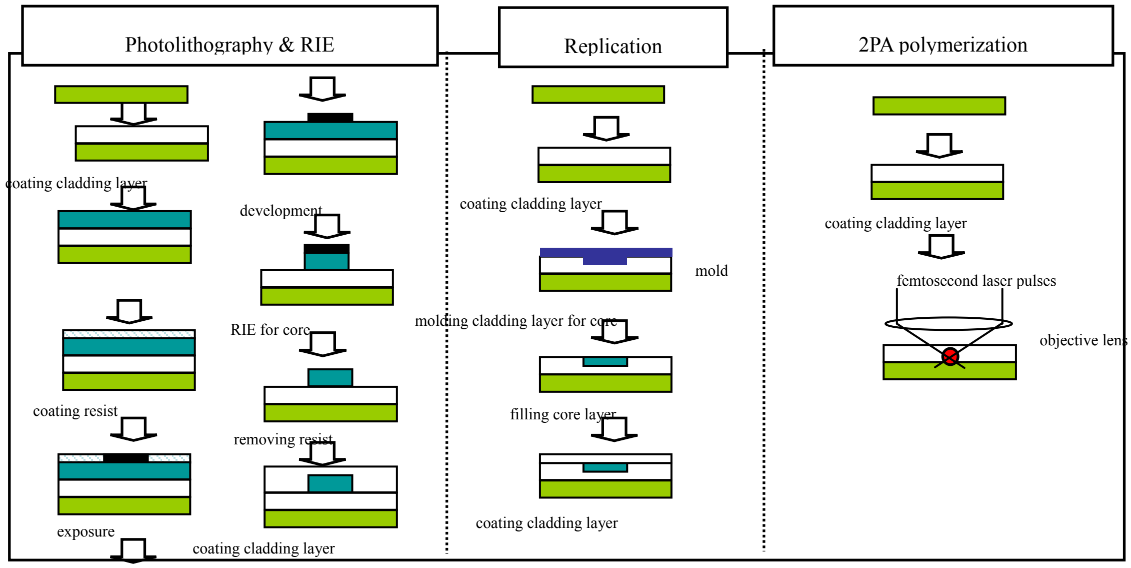

Figure 2 Optical waveguide fabrication methods

3. DEVELOPMENT OF POLYMER OPTICAL WAVEGUIDES

Two photon absorption assisted polymerization (TPAP) is applied to fabricate a variety of nano-sized patterns and is adopted to make POW because by using this technology optical waveguides could be fabricated site selectively. Figure3 shows an optical set-up of TPAP method. Using calixarene polymers, we had fabricated two dimensional POW with loss of 0.7 dB/cm at 1,300 nm. Calixarene polymer has several features such as high thermal stability and potential of inclusion complex formation with functional molecules. Three dimensional waveguide with Y-branch structure was also fabricated where two types of monomers with different polymerization reaction were used to make

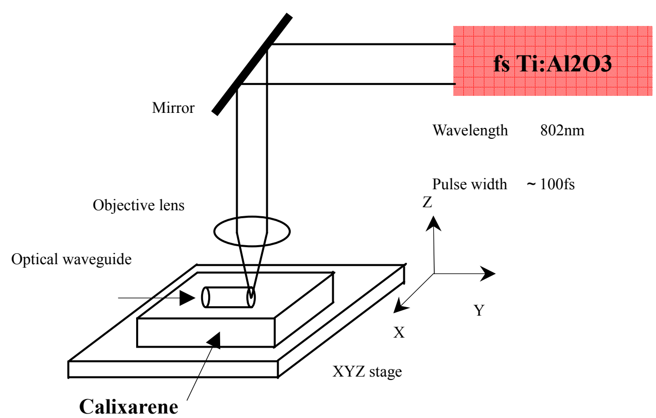

Figure 3 Experimental set-up of TPAP method

refractive index difference between core and cladding.

Hot-embossing technology by using poly-dimethyl-siloxane (PDMS) mold to make a stamp for core groove formation was also examined. This technique is also very simple to fabricate optical waveguides especially with large core size. We fabricated POWs for plastic optical fibers. Figure 4 shows photos of hot embossing processes. 1,000 µm core size waveguide with fiber guides were fabricated. Y-branch waveguide was also fabricated. Lowest loss at 650 nm where POF Transmit light well was 0.13 dB/cm.

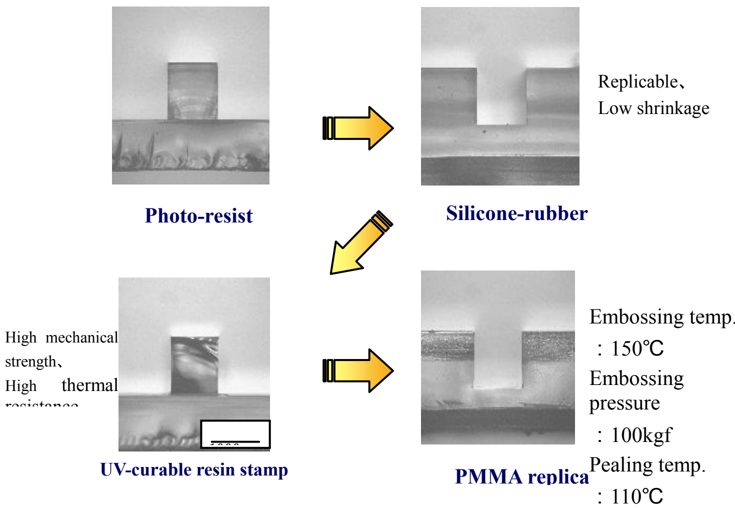

Figure 4 Photos of hot-embossing steps

4. OPTICAL WAVEGUIDE EVALUATION METHODS

Polymer optical circuits development toward next generation FTTH systems needs simple evaluation methods of optical waveguide. To clarify optimum device structure and appropriate polymer material for the device, quick and accurate evaluation of optical waveguides are inevitable. For that end, we are proposing an optical waveguide loss measurement method. In this method, optical attenuation loss was evaluated using 45 degree cut arrayed waveguides.

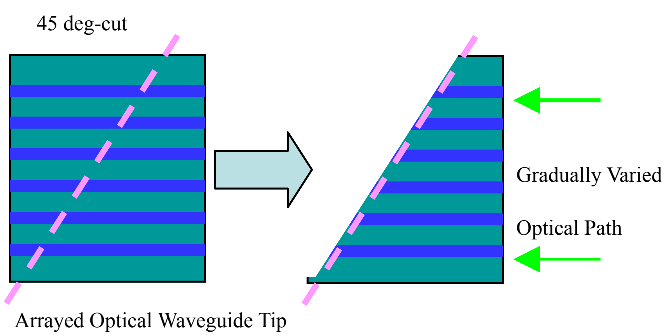

Figure 5. Fabrication of waveguide for loss measurement.

The cut waveguide could be obtained from normal waveguide array as shown in Fig. 5. As shown in Fig. 6, there was no significant difference of optical loss depending on cut angle from 0 to 60 degree. So, this type of cut waveguide worked well to change waveguide length. .

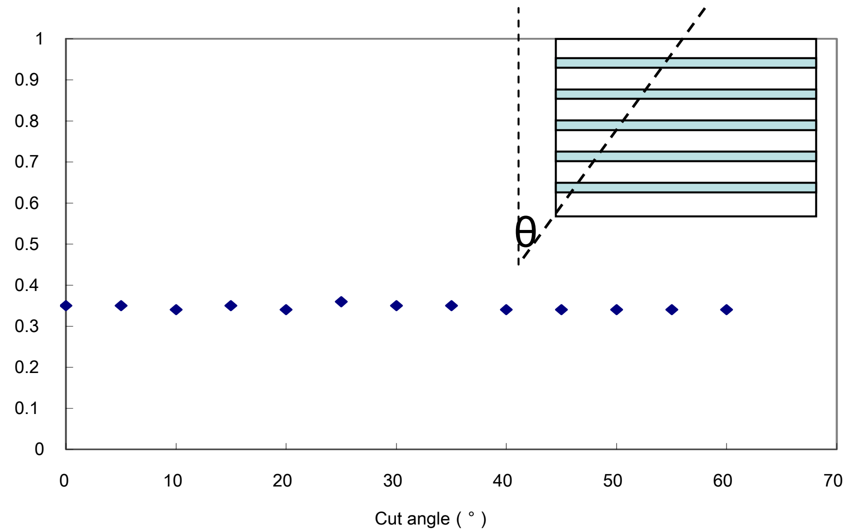

Figure 6 Cut angle dependence of insertion loss of cut waveguide.

Table 1 shows the results of loss measurement by this 45 degree cut waveguide method and standard cut-back method. The attenuation loss by this new method was almost the same as that of standard method. Evaluation time of the new method was about 1/5 of that of standard method. So this 45 degree cut method is very effective for the optical loss valuation

Table 1 Optical loss measurement results

Method	Waveguide loss (dB/cm)	Evaluation time (min.)
New simple method (45 degree cut)	0.08	29
Ordinary cut-back method	0.08	225

Including this 45 degree cut waveguides, an optical waveguide evaluation chip was proposed where Y-branch waveguides and S-shaped waveguides with several dimension were arranged. Figure 7 shows the structure of the chip.

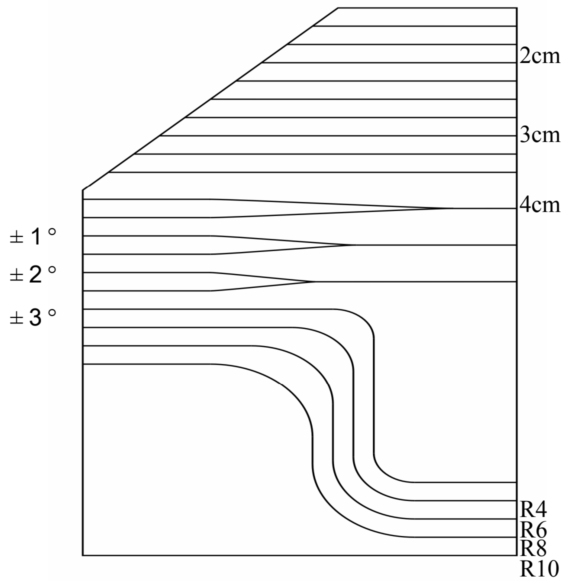

Figure 7 Optical waveguide chip

The straight, Y-branched, and S-shaped waveguides should have following standard specification.

Straight waveguides: attenuation loss<0.1 dB/cm

Y-branched waveguides :attenuation loss <3.5 dB

(for branching angle of 5 degree)

S-shaped waveguides: bending loss<1.5 dB/bent

(for r=10 mm)

Figure 8 shows the measurement setup for this optical waveguide chip. All the waveguide features can easily be evaluated by moving the input part of the chip.

5. CONCLUSION

Polymer optical waveguides are promising candidate for constructing low-cost optical system such as next generation FTTH system. They are now expected to be applied in mobile phones and semiconductor memory interfaces. Multi-mode optical waveguide evaluation is a little bit complicated compared to single-mode optical waveguide, though, evaluation method presented in this manuscript work well as a standard evaluation technology. Standardization of the waveguides will be critical issue for further advancement of them. Within a few years, polymer optical waveguides will be applied to next generation FTTH systems along with plastic optical fibers .

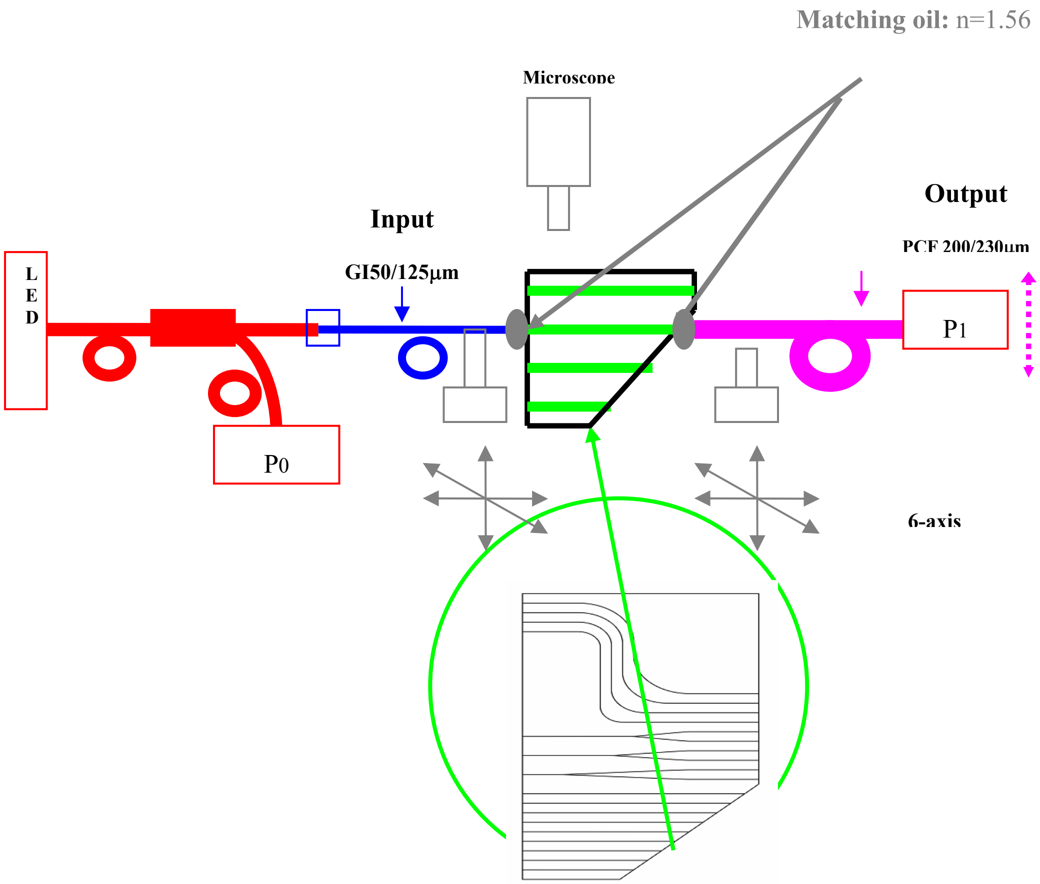

Figure 8 Measurement set-up for optical waveguide chip

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