Recent development of polymer optical circuits for the next generation fiber to the home system

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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 POF and optical circuit based on optical waveguides will be used.

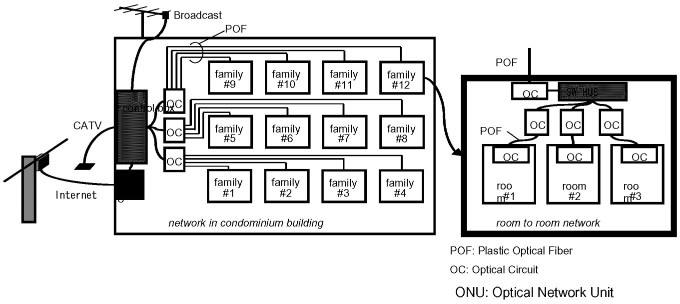

Figure 1 Image of optical home network system

These optical waveguides can be fabricated using either glass or polymeric materials. 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. Transparency of polymers in the telecommunication wavelength are no so good as glass counterparts, though, flexibility and processability of polymers will work well for some specific applications. 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 is the use of polymers.

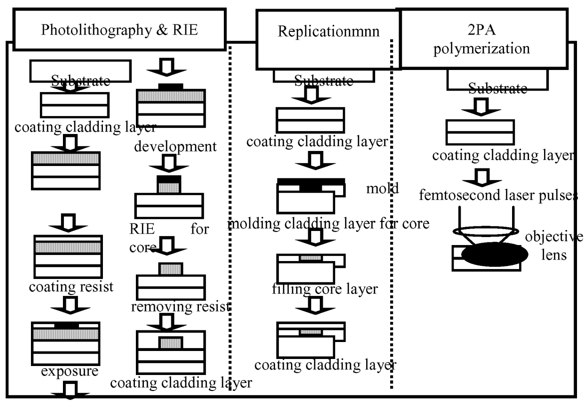

Figure 2 Optical waveguide fabrication methods

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. Figure 3 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 refractive index difference between core and cladding.

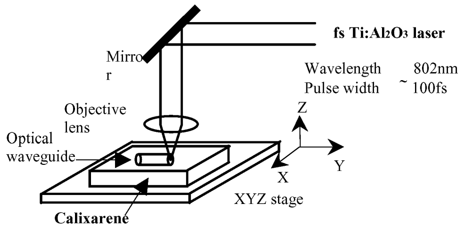

Figure 3 Experimental set-up of TPAP method

Hot-embossing technology by using polydimethyl siloxane (PDMS) mold to make 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 0.13dB/cm.

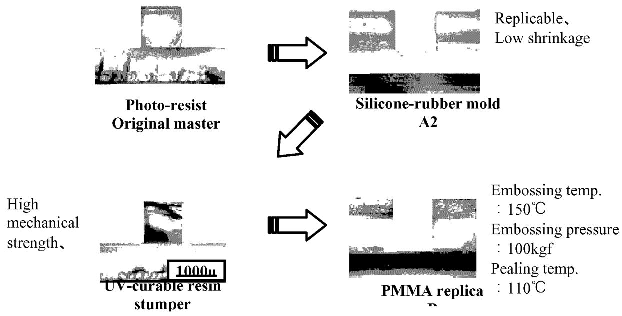

Figure 4 Photos of hot-embossing steps

Optical waveguide evaluation methods

Polymer optical circuits development toward the next generation fiber to the home systems need 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. The cut waveguide could be obtained from normal waveguide array as shown in Fig. 5

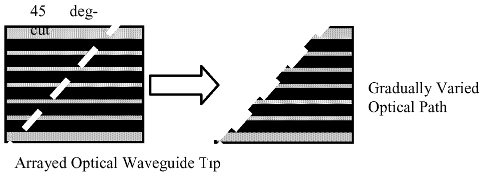

Figure 5. Fabrication of waveguide for loss measurement.

As shown in Fig. 6, there were 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. .

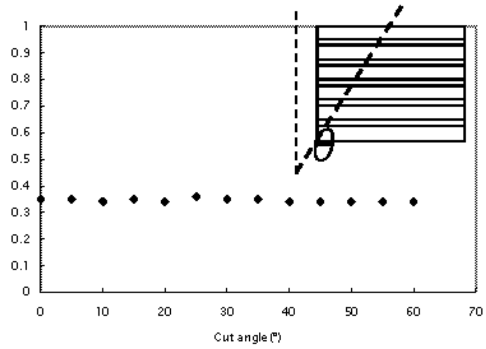

Figure 6 Cut angle dependence of insertion loss of cut waveguide.

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 rersults

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

Including this 45 degree cut waveguides, an optical waveguide evaluation chip were proposed where Y-branch waveguides and S-shaped waveguides with several dimension were arranged. Figure 7 shows the structure of the chip. The straight, Y-branched, and S-shaped waveguides should have following standard specification.

Straight waveguides: attenuation loss<0.1dB/cm
Y-branched waveguides :attenuation loss <3.5dB
(for branching angle of 5 degree)
S-shaped waveguides: bending loss<1.5dB/bent
(for r=10 mm)

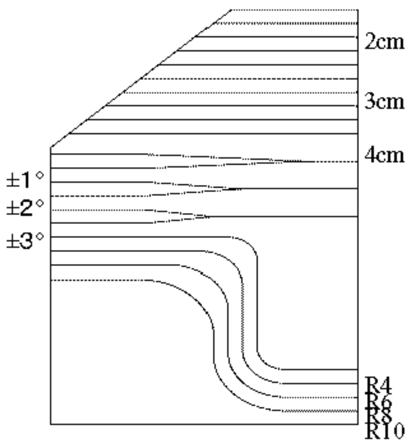

Figure 7 Optical waveguide chip

Figure 8 shows the measurement setup of this optical waveguide chip.

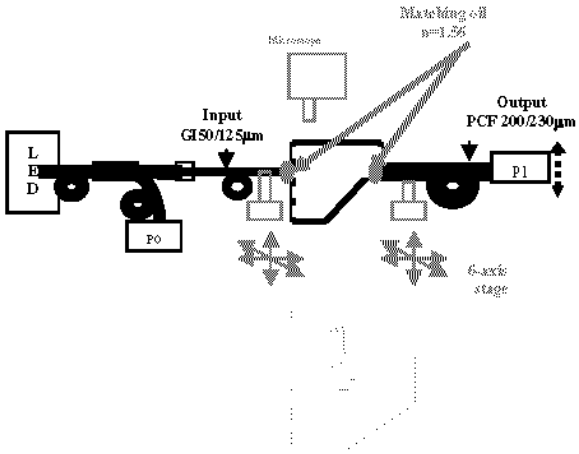

Figure 8 Measurement set-up of optical waveguide chip

Conclusion

Polymer optical circuits are promising for constructing low-cost optical system and now they are expected to be applied for mobile phones and i semiconductor memory interfaces. Standardization of the waveguides will be critical issue for further advancement of them.