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Study of optimized bandwidth depending on dopants in perfluorinated graded index polymer optical fibers

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Perfluorinated graded index polymer optical fibers, which have a graded index profile made from dopant dispersion, show high bandwidths for data communication. The dopant effect to the bandwidth optimization is reported for the first time.
Key words: Perfluorinated GI-POF, Dopant, Graded index profile, Bandwidth

1. INTRODUCTION

The perfluorinated graded index polymer optical fibers (PFGI-POF) are developed and manufactured for the high bandwidth data communication market in home and building networks. The graded refractive index profile of GI-POF makes high bandwidth theoretically and practically [1-2]. Various optimum studies of the grade index profile effect on the bandwidth have been reported [3-4]. Especially the perfluorinated polymer of PFGI-POF has a low material dispersion rather than the silica substrate of multi mode and single mode silica optical fibers in the area of near infrared wavelengths, so PFGI-POF is known to have higher bandwidth than silica optical fibers [5].

The graded refractive index profile is made from a dopant dispersion during the interfacial-gel polymerization method to make a pre-form, which is the precursor of fibers [6]. Bandwidth of optical fibers is estimated from the index exponent g value approximated by the graded refractive index profile using the WKB method [7]. This g is calculated by Eq. (1),

$$n(r) = n_1\left[1 - 2\Delta\left(\frac{r}{a}\right)^g\right]^{1/2} \qquad 0 \le r \le a \tag{1}$$

$$n(r) = n_2 \qquad r > a$$

where n_1 and n_2 are the refractive indices of the center axis and the cladding, respectively, a is the core radius, and Δ is the relative index difference which is expressed by Eq. (2) as shown in Fig.1.

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \tag{2}$$

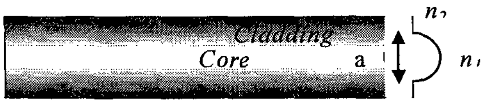

Fig.1: Structure of PFGI-POF.

In the interfacial-gel polymerization method, dopants must have a low molecule and high refractive index rather than the perfluorinated polymer utilized as a core and cladding material. In this report, the CYTOP™ polymer as shown in Fig. 2 is utilized as perfluorinated polymer and affect of some dopants on the bandwidth optimization are studied for the first time.

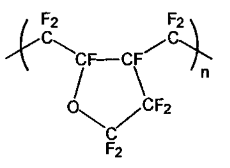

Fig.2: Chemical structure of CYTOP ™.

2. EXPERIMENTAL SECTION

2.1 Fiber preparation

Fibers were obtained by heat drawing of the graded index pre-form, which were obtained by the interfacial-gel method. 17mm diameter CYTOP polymer tube was prepared for polymer casting. This CYTOP tube was filled with a mixture of the CYTOP monomer, dopant material, polymerization initiator and chain transfer agent. After the heating for 24hr at 70℃, then for 24hr at 90℃, the graded index pre-form was obtain [3].

2,4,6-tris(pentafluorophenyl)-1,3,5-triazine (Triazine) as shown in Fig.3 was obtained by following procedure [7]. Pentafluorobenzonitrile (150g) and fluorosulfuric acid (500g) were placed in a 1000ml glass flask with stirring at room temperature for 7days. The mixture was poured into cold water with ice (3L) and the precipitated solid (132g) collected, washed with water, and dried. The solid was recrystallized from toluene twice. 2,4,6-tris(pentafluorophenyl)-1,3,5-triazine was obtained as white crystal in 46% yield. It was identified by mass spectrometry (a parent ion peak at m/z=579 with a cracking pattern consistent with the objective structure).

Chlorotrifluoroethylene oligomer (CTFE) as shown in Fig.4 was purchased from Mihama co. and distilled before experiment. Main fraction was composed of $Cl(CF_2CFCl)_7Cl$.

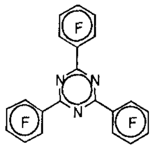

Fig.3: Chemical structure of Triazine.

$Cl-(CF_2-CCl_2)_7-Cl$

Fig.4: Chemical structure of CTFE.

2.2 Fiber measurement

The bandwidth of the PFGI-POF was investigated by determining the impulse response function of the fiber. From the input and output pulses, the transfer function was estimated by Fourier transform from the 3dB optical bandwidth [3-5].

3. RESULTS AND DISCUSSION

2,4,6-tris(pentafluorophenyl)-1,3,5-triazine (Triazine) and the chlorotrifluoroethylene oligomer (CTFE) are studied as the dopant. Considering the optimum dopant of the perfluorinated polymer, the dopant must be a fluoro material, a miscible material with the perfluorinated polymer and have a high refractive index caused by the phenyl functional group and/or halogen such as the chlorine atoms. Triazine and CTFE are used to study the material difference in order to evaluate the effect on the bandwidth.

Fibers by fabrication of a pre-form made from a different dopant under the same numerical aperture (NA) show a similar refractive index profile as shown in Fig.5.

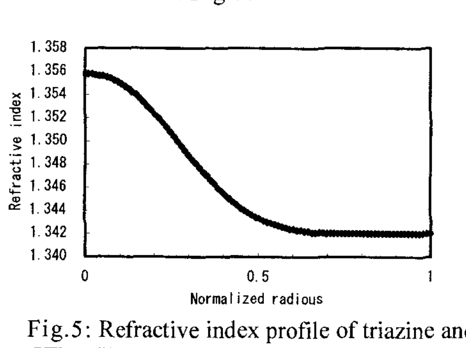

Fig.5: Refractive index profile of triazine and CTFE fiber.

The refractive index profiles of each dopant fiber are approximated by the index exponent g value using Eq. (1) and the results are shown in Table I.

Table I: Results of dopant effect on bandwidth

Dopant	Triazin	CTFE
Dopant wt%	7.0	12.7
NA	0.185	0.185
Index exponent g	2.4	2.4
Bandwidth(MHz·km)*	378	395

* 1nm spectral width of light source

These bandwidth results were plotted on the calculated bandwidth vs. the index exponent g curve using the WKB method with various launch light source width in Fig. 6.

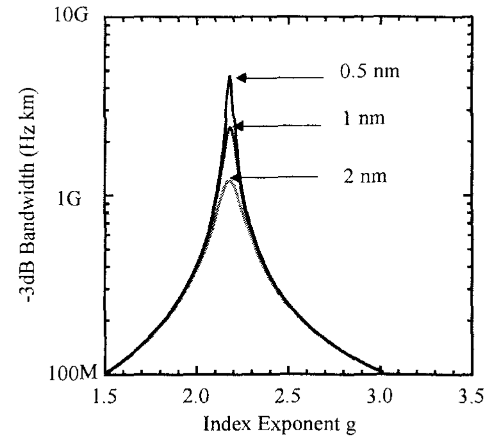

Fig.6: Dopant effect on bandwidth.

The effect of the different dopant on the bandwidth in the condition of the same fiber NA and similar g values was not apparently observed. Also the obtained bandwidth is on the calculated bandwidth vs the index exponent g curve.

However the dopant concentration was different between the Triazine fiber and CTFE fiber, so that the effect of the different dopant concentration was studied using the same dopant. The refractive index profile of the 7.2 wt.% and 3.7 wt.% Triazine dopant fibers are shown in Fig. 7 and Fig. 8 along with the calculated index exponent g.

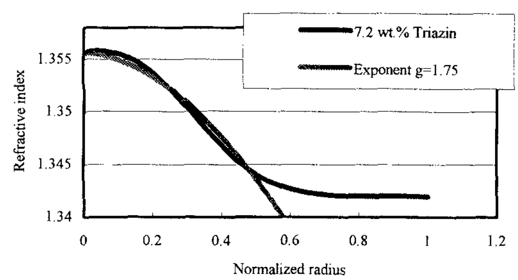

Fig.7: Refractive index profile of 7.2 wt.% Triazine fiber.

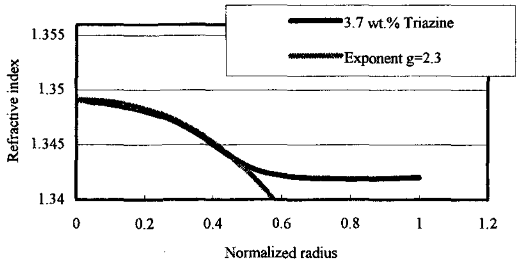

Fig.8: Refractive index profile of 3.7 wt.% triazine fiber.

Results of NA, index exponent g and bandwidth measurement of each dopant concentration are shown in Table Ⅱ.

Table Ⅱ : Bandwidth effect for each dopant concentration of triazine.

Dopant concentration	7.2 wt.%	3.7 wt.%
NA	0.192	0.138
Index exponent g	1.75	2.3
Bandwidth(MHz·km)*	131	561

* 1nm spectral width of light source

The results in Table Ⅱ show that the dopant concentration has a relation with the bandwidth. A high dopant concentration of 7.2 wt.% makes a higher refractive index profile peak, which shows a lower bandwidth. On the other hand, a gentle index profile of 3.7 wt.% shows a higher bandwidth. However this result caused by the dopant concentration is expected by the WKB method as shown in Fig.9. The difference in the bandwidth for similar g value between the Triazine and CTFE is supported by this result.

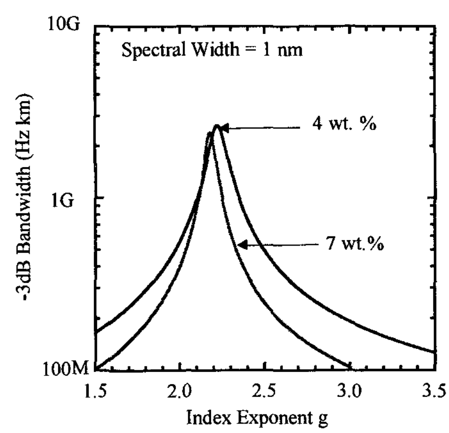

Fig.9: Effect of index exponent g value depending on the dopant concentration on the bandwidth of the Triazine fiber

4.CONCLUSION

The effect of the dopant on the bandwidth optimization was studied in the PFGI-POF. In this study, 2,4,6-tris(pentafluorophenyl)-1,3,5-triazine (Trizine) and the chlorotrifluoroethylene oligomer (CTFE) were evaluated as the dopant. These dopants have obvious and probable differences in their chemical molecule structure, the triazine is a crystal and having a phenyl functional group, while CTFE is a liquid and composed of chlorine atom. To control the bandwidth of the PFGI-POF using different dopant molecule is expected for the PFGI-POF manufacturing. No other effects of the dopant material contributed to the optimized bandwidth of PFGI-POF were observed.

5.ACKNOWLEDGEMENT

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6.REREFENCES

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