A new approach to mass fabrication technology of microstructured polymer optical fiber preform

Lili Wang (王丽莉)[1], Yani Zhang (张亚妮)[1], Liyong Ren (任立勇)[1], Xuezhong Wang (王学忠)[1], Tonghai Li (李同海)[1], Baowen Hu (胡宝文)[1], Yulin Li (李育林)[1], Wei Zhao (赵 卫)[1], and Xinghua Chen (陈兴华)[2]

[1]*Xi'an Institute of Optics and Precision Mechanics of Chinese Academy of Scinces, Xi'an 710068*

[2]*Xi'an Jiaotong University, Xi'an 710049*

We have successfully fabricated microstructured polymer optical fiber (MPOF) preforms by polymerization method of monomer and thermo-melting-extrusion of PMMA grains in home-made mould. Monomer-based fabrication of MPOF preform offers key advantages over both conventional capillaries stack-draw and drill-machining methods. By varying structure of the mould, it is easy to make different cross-section preforms of speciality fibers with holes of arbitrary shapes and sizes in any desired arrangement. We have also exploited preparation method of MPOF preforms with chemical doping or modification of the polymer itself, and successfully incorporated laser dyes, rhodamines into core of MPOF preform.

OCIS codes: 220.4000, 160.4670, 060.2280, 999.9999 (photonic crystal fiber).

The widespread uses of organic and polymeric materials in photonics, nanophotonics and biophotonics have generated renewed interest in guiding-light properties. Specifically, light transmitting and the stimulated emission process in polymeric optical fiber (POF) have received growing interest for practical applications in shorter-distance data telecommunication, solid lasers, amplifier, and various of optical sensors, image transmitters.

Microstructured POFs (MPOF), are a new category of POF, which has been recently introduced into low-loss and high bandwidth application of POF in visible region. Recently, Eijkelenborg *et al.* have reported a method of fabricating MPOF preforms that is known as drill-machining of PMMA[1-5]. MPOF preform also can be made of PMMA by using capillaries stack-and-draw process. However, these methods have problems in terms of yield, quality and cost of production. Reacting extrusion is most promising fabrication technology of MPOF preforms. However, up to now, it has not been reported that this method have made good winning.

In this presentation, we firstly report the fabrication of PMMA-based MPOF preforms with high 18 holes and 36 holes by using two method: *in-situ* polymerization of monomer in a pre-made mould and thermo-extrusion of PMMA grains by extruder.

In order to do this, we designed a mould which could be suitable to prepare very large performs and achieve very demanding levels of uniformity in holes of preform.

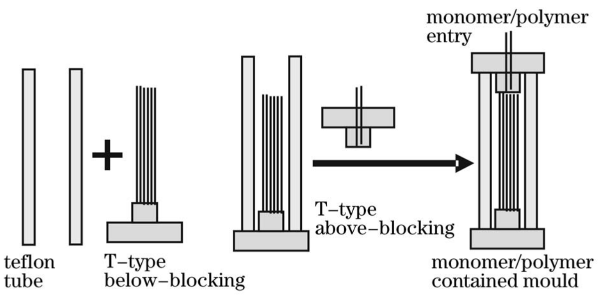

Fig. 1. Schematic of mould setting up procedure.

Figure 1 shows a schematic of main components and setting up procedure of a home-made mould. After designing the structure required in the final fiber, the hole pattern is locked in mould by metal-stick, and the size and shape of the hole can be freely changed by using different shape metal-stick: circle, ellipse, and triangular holes.

In a pre-made mould, we carried out the radical polymerization of methyl methacrylate (MMA). Benzoyl peroxide was used as an initiator. It takes about 72 hours from polymerization starting to ending at 95 °C. Figure 2 shows photos of 18-holes of primary preform of MPOF made from MMA.

We tried to use the primary preforms (length: 30–50 cm, diameter: 4 cm) to draw second MPOF preforms of

Fig. 2. Photo of primary MPOF preforms.

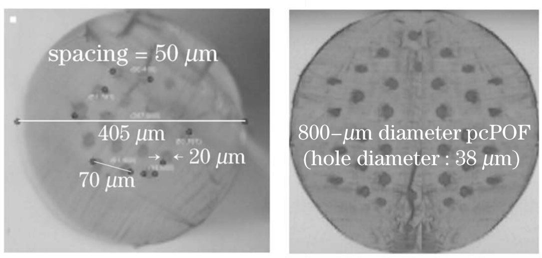

Fig. 3. Photos of MPOF secondary preform made from primary preform.

tens of meter lengths with diameters in the range about 1–3 cm. Figure 3 shows micrographs of a PMMA second preform and a rhodamine-doped PMMA second preform from *in-situ* polymerization method.

It can be seen that the air hole microstructure consists of two rings of holes in a hexagonal pattern. Some deformations are visible, such as in the hole diameters and shapes. During fiber drawing, collapse of the holes was not observed. However additional air holes in cladding was observed. This was caused from defects in preform. Compared with the preform that the second preform was drawn from, the hole structure in the second preform has a slightly reduced hole diameter to hole spacing ratio, $d/\Lambda = 0.33$, whereas in the designed primary preform $d/\Lambda = 0.4$. These initial results indicate that the one-step polymerization method of MPOF perform is promising despite the perform have some structure defects induced from volume-shrinking in polymerization.

Finally, we also studied a direct extrusion process to produce MPOF preforms. The extruded PMMA viscosity liquid was directly put in a mould pre-heated by furnace to create a 70-mm diameter, 400-mm length of preform with the photo shown.

The hole structure and integrity of the extrusion-moulding preforms are with higher quality than that prepared from *in-situ* polymerization of monomer in same mould. However transparence is a little problem than that prepared from direct polymerization method. The extruded preform was thin yellow-colored because thermo-induced chemical reaction.

According to above primary results, we believe that

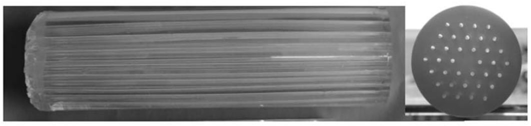

Fig. 4. Photo of a MPOF preform, diameter: 7 cm; length: 40 cm.

reacting extrusion processing is most promising and effective fabrication method for mass production of various types of MPOF preforms. The reacting extrusion preparation of 36 holes of MPOF perform is currently being done.

We have successfully fabricated MPOF preform by *in-situ* polymerization of monomer, and thermo-extrusion of polymer grains in pre-made mould. Compared to conventional methods such as capillaries stack-draw and drill-machining, our method could freely control the fiber structure by changing and tuning of mould components. Preparation of rhodamine-doped MPOF preform indicated that various of functional dyes can be doped in the MPOF preform.

We believe that these preforms are suitable to prepare MPOF with low-loss, high bandwidth on a large scale. It is expected that these MPOF preforms will be useful in fabricating local-area networks, and image guiding systems.

This work was supported by the National Natural Science Foundation of China under grant No. 60437020. L. Wang's e-mail address is wangll@opt.ac.cn.

References

1. M. A. van Eijkelenborg, M. Large, A. Argyros, J. Zagari. S. Manos, N. A. Issa, I. M. Bassett, S. C. Fleming, R. C, Mcphedran, C. M. de sterke, and N. A. P. Nicorovici, Opt. Express **9,** 319 (2001).
2. M. A. van Eijkelenborg, A. Argyros, G. Barton, I. M. Bassett, M. Fellew, G. Henry, N. A. Issa, M. C. J. Large, S. Manos, W. Padden, L. Poladian, and J. Zagari, Opt. Fiber Technol. **9,** 199 (2003).
3. G. Barton, M. A. van Eijkelenborg, G. Henry, M. C. J. Large, and J. Zagari, Opt. Fiber Technol. **10,** 325 (2004).
4. N. A. Issa, M. A. van Eijkelenborg, M. Fellew, F. Cox, G. Henry, and M. C. J. Large, Opt. Lett. **29,** 1336 (2004).
5. A. Argyros, M. A. van Eijkelenborg, S. D. Jackson, and R. P. Mildren, Opt. Lett. **29,** 1882 (2004).