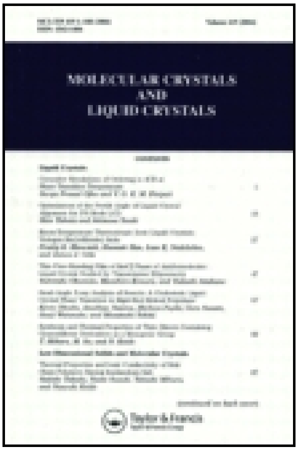

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Nature of Microelements Self Writing in Fiber Tips in UV-Curable Composites

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Nature of Microelements Self Writing in Fiber Tips in UV-Curable Composites

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It is shown the possibility to obtain different microelements self-written in the fiber end: a large cylinder, cones, and spheres. The microelement shape depends on the light absorption in the mixture of monomers and the cone angle aperture of light going away from a fiber. The superposition of these two parameters results in the formation of a microelement of the specific type.

Keywords: fiber; microelements shape; self-written microelements

INTRODUCTION

At present time, a topical problem for planar waveguide devices is the coupling of optical fibers with light sources, sensors, and planar waveguides, especially the minimization of power losses at the coupling. As usual, one uses coupling elements based on melting the optical fiber ends or photoresists with the formation of microlenses or Winston concentrators.

The well-known methods of the fabrication of coupling elements are as follows: the melting of fiber ends by an IR laser [1], formation of diffractive elements in fiber ends by the direct writing with the use of an electron beam [2], and formation of Winston concentrators in a fiber by the refractive index redistribution in it [3].

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The main defect of all these methods is the necessity of the optical positioning of these elements manually, which presents some difficulties and makes the devices too expensive.

A new and promising approach is to use physical processes resulting in the self-writing of coupling elements in a fiber top [4]. It is possible to obtain different microstructures in the fiber top depending of self-curing conditions: from a long cylinder with diameter equal to that of the waveguide core [5] up to spheres and cones [4].

The method was proposed by Cohen and Schneider [6] who produced integrated microlenses on optical fibers (MOFs) by exposing a photoresist film coating the top end of a fiber to UV light. Although this procedure was revised and improved a few years later [7], it requires difficult fabrication steps including the backing of both a photoresist and a microlens. In fact, a survey of the literature reveals that the concept of making MOFs by photolithography has not been developed widely despite the promising results presented in [6]. In this paper, we continue our previous investigations in this field [8,9,10,11]. Our aim is to summarize our experimental results and find the form of self-writing microelements with regard for all involved effects.

EXPERIMENTAL CONDITIONS

In order to perform a real-time video recording, we need to use long-focus lenses, and the object should not be small. According to this requirement, we take a quartz waveguide with a core diameter of 435 nm. Our experiments with a usual multimode waveguide with a core diameter of 50 nm and a single-mode waveguide showed that the effects of self writing do not depend on the waveguide core diameter. As a UV-curable composition, we have taken the same mixture of liquid monomers as described in [9,10]. For UV-curing at the self-writing process, we have used the emission of an N_2 laser ($\lambda = 337.5$ nm) introduced in the waveguide. At another waveguide top immersed into the mixture of monomers, a microstructure is formed. The draft of the microelement formation is shown in Figure 1.

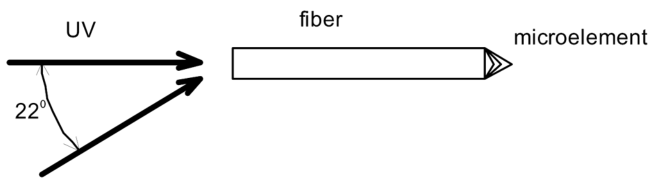

FIGURE 1 Draft of the microelement formation at the waveguide top.

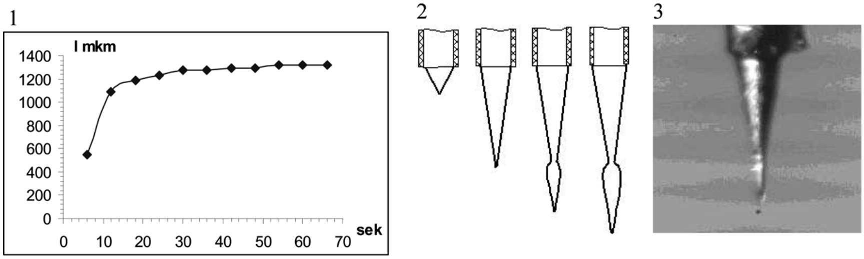

FIGURE 2 1 – Dependence of the cone length on the exposure duration, 2 – stages of microelement formation, 3 – photo of the resulting element.

Due to the presence of acid groups in the composition of monomers, we have possibility to grow a microstructure from the surface of a fiber top [9]. It is found that a high influence on the microelement grown on the waveguide top is provided by the light aperture. We have examined two cases: the introduction of light into the waveguide along its axis and at an angle of 22 degrees.

At the introduction of light in parallel to the waveguide axis, the formation of a microelement have two stages. At the first stage, a small cone appears at a small exposure at the fiber top center (Fig. 2 (2)). Then this cone grows and become more and more long, and the cone diameter becomes equal to that of the core of a fiber. The cone growth kinetics has two stages as well (Fig. 2 (1)): the first stage shows the linear dependence of the cone length on the exposure duration; then the process is slowing down and stops. The maximal average length is three times more than the core diameter.

At reaching the maximal cone length, the second stage of the process starts. At cone tip, the light go away from the cone, and, at this point, a new bulb begins to form and to grow (Fig. 2 (2, 3)). Its end is similar to that formed at the first stage of the process. This second structure forms a cone, and then its growth stops again (Fig. 2 (2)). Perhaps, if there would be no light dissipation, the third, fourth, and next cones will be formed. But, in our experiment, the process terminates after the formation of the second cone.

At the introduction of light into the waveguide at an angle of 22 degrees, a small cone is firstly formed at the core center that becomes more and more long, as in the previous case (Fig. 3 (2)). However, the cone surface is more convex, its end is not sharp, and its lengthening is not so fast as in the previous case. The maximal length of the cone is equal to three core diameters. The cone becomes more rounded, and its basis is close to a cylinder. In fact, the cone basis becomes

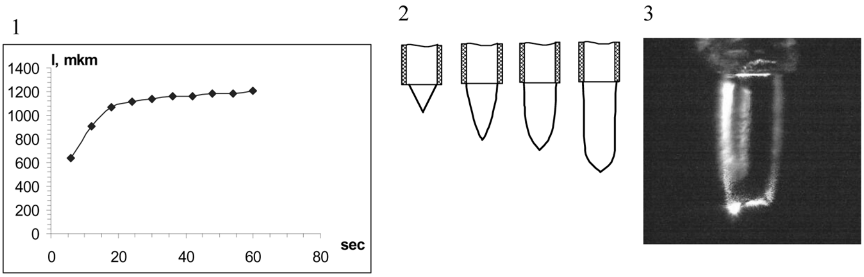

FIG 3 1 – Dependence of the cone length on the exposure duration, 2 – stages of microelement formation, 3 – photo of the resulting element.

a continuation of the core because of the self-focusing process in the UV-curable monomer mixture with positive change of the refractive index at the curing.

The kinetics of the polymeric microstructure growth (Fig. 3 (1)) has two stages in this case as well: the linear lengthening of the cone, and then the termination of this process. If there would be no light absorption in monomers, this process will not stop. Actually, at the finishing of the process, the microelement part near to the fiber end becomes close to a cylinder with a cone at its end (Fig. 3 (2, 3)). The length of the cylindrical part depends on the light absorption in a material and is about 70% of the structure length in our case.

While growing a polymeric microstructure at intermediate angles between 0 and 22 degrees, the process tends to go in one of two ways described above. At the use of a large aperture cone of light introduction and a low light absorption in the material, it is possible to obtain a self-written very long waveguide that forms a continuation of the fiber core.

In this case, the interesting process of self-writing of the connection between two optical fibers takes place, which results in the self-coupling of two waveguides ends.

CONCLUSION

At the use of the mixture of UV-curable monomers with positive change of the refractive index, it is possible to obtain different microelements self-written in the fiber end: a large cylinder, cones, and spheres. The microelement form depends on two parameters: the light absorption in the mixture of monomers and the cone angle aperture of light going away from a fiber. The superposition of these two effects will result in the formation of a microelement of the specific type.

REFERENCES

[1] Anderson, R. H. (1997). *Appl. Opt.*, *18*, 477.
[2] McCormick, F. B., Tooley, F. A., Cloonan, T. J., Sasian, J. M., Hinton, H. S., Merserau, K. O., & Feldblum, A. Y. (1991). *Opt. Quantum Electron.*, *24*, S465.
[3] Tiziani, H. J., Achi, R., & Kramer, R. N. (1996). *J. Mod. Opt.*, *43*, 155.
[4] Hocine, M., Bachelot, R., *et al.* (2002). *Synthetic Metals*, *127*, 313.
[5] Yamashita, K., Kuro, T., & Oe, K. (2004). *App. Phys. Lett.*, *85*, 3962.
[6] Cohen, L. G. & Schneider, M. V. (1974). *Appl. Opt.*, *13*, 89.
[7] Bear, P. D. (1980). *Appl. Opt.*, *19*, 2906; Lee, K. S., Barnes, F. S. (1985). *Appl. Opt.*, *24*, 3134.
[8] Fokina, M. I. (2005). *Microlenses Array Based on UV-Curable Optical Compositions with High Light Resistance for the Use at High Power Laser Sources*, //Proc. of Second Conference of Young Scientists: Saint Petersburg, Russia.
[9] Fokina, M. (2007). *Mol. Cryst. Liq. Cryst.*, *468*, 385.
[10] Fokina, M. I., Burunkova, J. E., & Denisuk, I. Y. (2007). *SPIE Proc.*, 6732-40.
[11] Fokina M. I. & Denisyuk, I. Yu. (2006). *J. Optical Techn.*, *73*, 815.