

# ACTIVE SOFT GLASS meets PASSIVE OPTICAL FIBERS

S. Todoroki

Advanced Materials Laboratory, National Institute for Material Science  
1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan

## Introduction

Optical fibers have been playing an important role in developing optical communication systems. Two representative examples are the fibers for long distance transmission and Er-doped fiber amplifiers (EDFA). Most of them are made of silica glass, whose excellent thermal stability makes their manufacturing process simple with low cost. As for the glass materials other than silica glass, although they have a potential to exhibit unique optical properties, they also have a disadvantage that fiber drawing is harder because of their poorer thermal stabilities.

As shown in Fig. 1 (upper), fiber drawing process consists of several heating and cooling operations, in which the fiber preform is annealed near the temperature range for nucleation and crystal growth. Thus, fiber-drawable composition range is limited, as shown in Fig. 2 for example, where the glass can survive not to be precipitated during the heat treatment.

In this study, a new fabrication method is proposed in order to expand the composition range of non-silica glasses applicable for optical devices. The underlying idea is a hybridization of silica fiber and non-silica glass with low softening temperature (soft glass) by one heating process to suppress precipitation (see Fig. 1 (lower)).

## Experimental

A small piece of zinc tellurite glass ( $x\text{TeO}_2-(100-x)\text{ZnO}$ ,  $x = 80, 90, 100$  in mol%) was melted on a Pt plate (10mm $\square$ ) with a heater. Two fibers were inserted into the glass melt from its side. Then, the plate is lowered to leave a small amount of the melt between the two ends. The fibers were immediately moved to an appropriate position before the melt was solidified (see Fig. 3(a)[1]). The movement of the fibers and the heater described above was controlled by a personal computer and ends within few seconds. Transmittance of the laser light through the structure (insertion loss) was measured by an optical multimeter (AQ-2140, Ando Electric Co., Ltd.,  $\lambda = 1.31\mu\text{m}$ ).

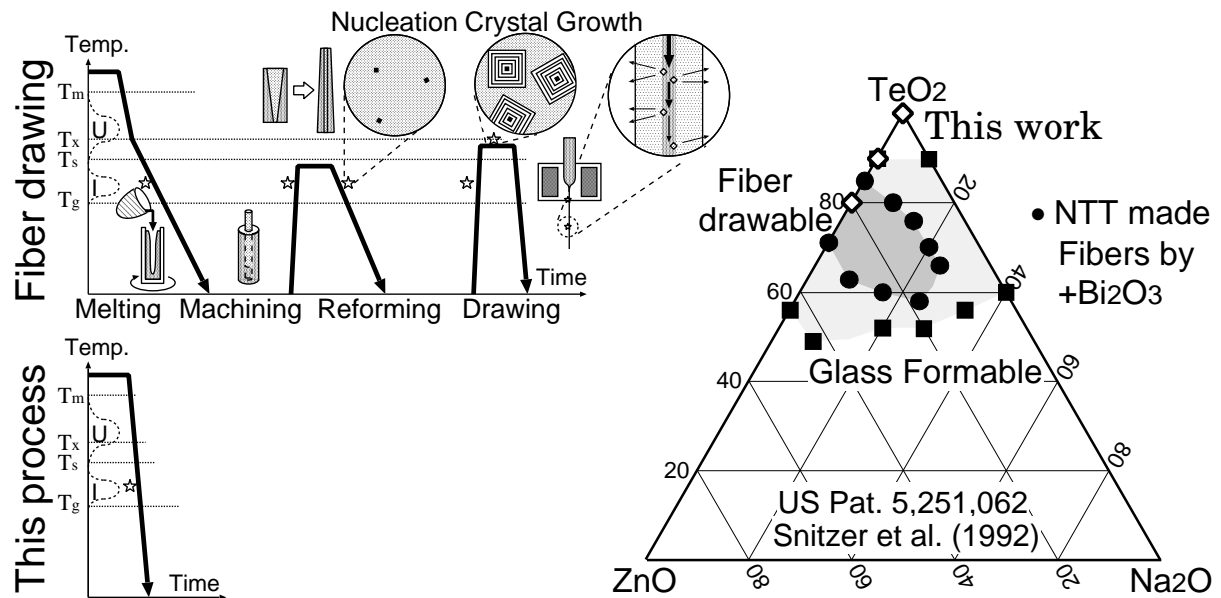


Figure 1: (left) Illustrations describing heating schedules during (upper) fiber drawing and (lower) this study. Characteristic temperatures are denoted as  $T_m$  for melting,  $T_x$  for crystallization,  $T_s$  for softening and  $T_g$  for glass transition. Temperature range for nucleation is located above  $T_g$  (denoted as 'I' in the figure) and crystal growth below  $T_m$  ('U').

Figure 2: (right) An example of composition range for tellurite glass fibers (closed marks) which are used for Er-doped fiber amplifiers. The compositions examined in this study is also plotted as open squares.

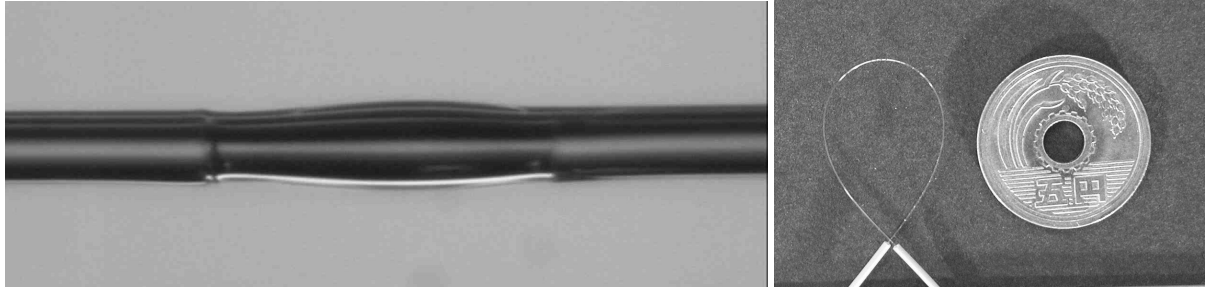


Figure 3: Photographs of an optical coupling structure. (a, left) The diameter of the fiber is 125  $\mu\text{m}$  and the distance between the two fiber end is about 0.6mm. (b, right) The fiber is bended in order to test its toughness. The diameter of the coin is 22mm.

Table 1: Properties of the glasses used in this study. Data source: O.V. Mazurin et al., Handbook of glass data.

	thermal expansion coefficient ( $\times 10^{-7}/^{\circ}\text{C}$ )	refractive index
SiO <sub>2</sub>	$\sim 6$	1.46
80TeO <sub>2</sub> -20ZnO (mol%)	170	2.08

## Results and Discussion

Joint structures were made without any apparent precipitation even for the compositions out of fiber-drawable region as shown in Fig. 2. This structure is not so fragile if properly treated that the fiber segment can be bended without fracture as shown in Fig. 3(b). Typical insertion loss value is 10dB/mm which is due to a lack of waveguide structure in the tellurite glass segment. On the basis of reflection and insertion loss measurements and a bending test[2], however, it is proved that there's no micro crystals in the quenched melt segment which cause light scattering and/or stress concentration. Thus, the quenching rate of the melt in this fabrication technique is considered to be  $10^3 \text{ K/s}$ [2].

Although the thermal expansion coefficient of tellurite glass is 2-orders bigger than that of silica glass (see Table 1), the fracture due to residual stress must be suppressed because the interface area is so small as sub-mm. The present fabrication technique has a potential to be applied to form a hybrid planar lightwave circuit and/or microcavity devices, in which lasing with ultra-low threshold is possible. Moreover, high refractive index of tellurite glass enables to capture light into microcavities efficiently. We are now planning to make such microcavities connected with optical fibers.

## Summary

Several nano liters of tellurite glass melt were inserted and quenched between two ends of silica glass optical fibers to form a new optical coupling structure, whose length was several hundred microns. No visible precipitates were found even in the quenched melt of 100% TeO<sub>2</sub>. This means that we can use considerably wider range of glass compositions to make these optical coupling structure compared with the range for making optical fibers.

## References

- [1] S. Todoroki, A. Nukui, and S. Inoue, *J. Ceram. Soc. Jpn.*, vol. 110, no. 5, pp. 476–478, 2002.
- [2] S. Todoroki, A. Nukui, and S. Inoue, in *The International Symposium On Photonic Glasses*, SPIE Proceedings, (Shanghai, China), Oct. 2002. (to be submitted).