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RECENT PROGRESS IN VAD FIBER FABRICATION PROCESS

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Since the development of the first low-loss fiber in 1970(1), rapid progresses have been made in all aspects of this technology, including glass materials and fiber fabrication processes. Especially, vapor phase deposition methods like the modified chemical vapor deposition (MCVD)(2), the outside vapor phase oxidation (OVPO)(3) and the vapor phase axial deposition (VAD)(4) methods have led us to obtain low loss and broad bandwidth graded-index fibers and low loss single-mode fibers. The VAD method has high potentiality for production cost reduction, because large sized preforms can be fabricated continuously by this method, in addition to the high deposition rate and efficiency.

The VAD method comprises two main processes; deposition of fine glass particles synthesized in the oxy-hydrogen flame and consolidation of deposited porous preform. Deposition and consolidation processes are carried out succeedingly along an axial direction, so it becomes possible to fabricate an optical fiber preform continuously. Preforms, however, contains as much OH-ions as 5-30 ppm, if consolidated without any dehydration treatment. These OH-ions originate mainly from hydrolysis reaction in the flame. Hydroxy ions and H_2O molecules contaminated in the porous preform are found to be reduced by a simple dehydration treatment with use of dehydration reagents such as $SOCl_2$ or Cl_2 gases. The dehydration treatment is made by heating the porous preform in an atmosphere containing Cl_2 gas at an elevated temperature of higher than 1000 °C, before the porous preform is consolidated at about 1500 °C into a transparent preform. This dehydration enables us to obtain lower OH content than 0.1 ppm. The OH-ion reduction of the VAD preform has opened up new ways to low loss characteristics in the longer wavelength region than 1.1 μm. Figure 1 shows a loss spectrum of the extremely lower OH content VAD fiber. The OH concentration might be less than 1 ppb level.

The biggest difference between the VAD process and the MCVD or the OVPO process is a refractive index profile formation process. Refractive index profile of the VAD preform is formed spatially and is determined by the spatial dopant distribution in the flame and mostly by the deposition properties of SiO_2-GeO_2 particles. A SiO_2-GeO_2 binary glass synthesized in the flame from $SiCl_4$-$GeCl_4$ exhibits specific deposition properties, that is, the GeO_2 content in the deposited fine glass particles on the porous preform depends on the surface temperature; GeO_2 concentration increases almost linearly with increasing temperature between 400-800 °C. It can be understood that the refractive index, i.e. GeO_2 concentration ratio, is varied by controlling temperature distribution on the porous preform surface. Temperature distribution is adjusted to a desigined profile by changing deposition condition. Figure 2 shows a bandwidth dependence on the measured wavelengths. The maximum bandwidth of the fiber is about 7 GHz-km at 1.3 μm, where a material dispersion falls to zero. Such a wide bandwidth has not been reported with MCVD fiber.

One prominient feature of the VAD method is the possibility of making a large size preform, which is equivalent to longer fiber length of more than 20 km. We have fabricated a preform corresponding to 100 km long fiber with the continuous process. The VAD process has also been applied to the fabrication of single mode fiber preforms and high numerical aperture fiber preforms. The losses of these fibers were lower than 1 dB/km in the wavelength range from 1.1 to 1.6 μm. This fact indicates that the VAD method is powerful fabrication for the wide varieties of high silica fiber preform.

References:

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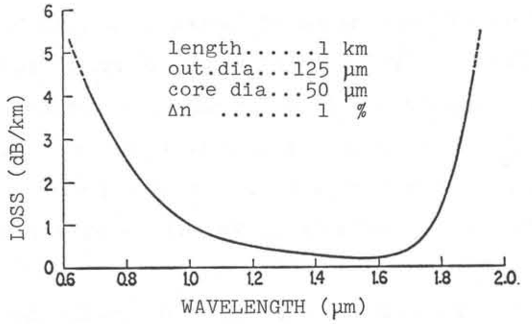

Fig.1. Loss spectrum of the extremely lower OH content VAD fiber. The residual OH concentration is estimated to be less than 1 ppb.

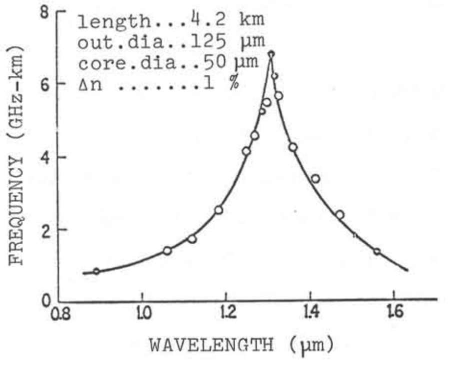

Fig.2. Wavelength dependence of the 6-dB down bandwidth. Open circles show the data points measured by laser diodes and the solid circles by the fiber Raman laser.