Hydrogenated Amorphous Germanium Optical Fiber

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Abstract: Hydrogenated amorphous germanium step index optical fibers have been fabricated by high pressure chemical vapor deposition ensuring high hydrogen content thereby passivizing dangling bonds. These fibers can be used for various infrared applications.

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1. Introduction

Germanium is widely used for various optical applications in view of its small bandgap, large transmission window (1.9 – 14 μm) and high laser damage threshold. Its large transmission window makes it useful for applications such as high-resolution infrared imaging, infrared countermeasures and more. Its high refractive index (~ 4.06 at 2.5 μm) allows for highly confined optical modes in waveguides and its high nonlinearities allow for the exploitation of numerous nonlinear optical processes including amplification and parametric oscillation. The optical fiber geometry has certain inherent advantages such as the ability to support symmetric and polarization independent modes and the potential for improved thermal management in comparison with planar semiconductor waveguides. Here we report progress towards the development of low optical loss hydrogenated amorphous germanium core optical fibers potentially useful for many applications.

2. Experiment and Results

Several different approaches have been reported for the fabrication of germanium core optical fibers. A molten core drawing approach has allowed for fibers with core sizes as small as 15μm diameter. However further reduction in core size would allow for higher power densities desirable for nonlinear applications.[1] A pressure assisted melt filling technique to infiltrate empty pores in optical fibers with crystalline Ge has also been reported.[2] High pressure chemical vapor deposition (HPCVD) was the first technique demonstrated to fabricate step index fibers.[3] Previously this technique has been applied to the fabrication of amorphous hydrogenated germanium fibers with 5.6 μm core diameters.[4] In this paper we show that the incorporation of more hydrogen leads to further passivation of the germanium dangling bonds and a decrease in the number of scattering centers in the fiber core, lowering the optical loss. Germane (GeH_4) mixed with hydrogen is used as a precursor gas and forced into a silica capillary at a pressure of 35 MPa and temperatures of 290-295°C. Germane undergoes several coupled reactions to finally form conformal films of amorphous Ge which eventually leads to centimeters long void free deposition inside the silica capillary (Figure 1).

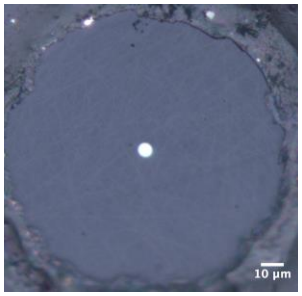

Fig. 1: Optical image of a cross section of an amorphous hydrogenated Ge core optical fiber

The temperature is kept low enough to retain hydrogen in the core to saturate the dangling bonds. A further lowering of temperature leads to much slower rate of deposition. A broad Ge peak obtained in the Raman spectrum (Figure 2) indicates the amorphous nature of the Ge core. Ge-H stretching centered at 1880 cm^{-1} indicates the presence of significant amount of hydrogen in the core.

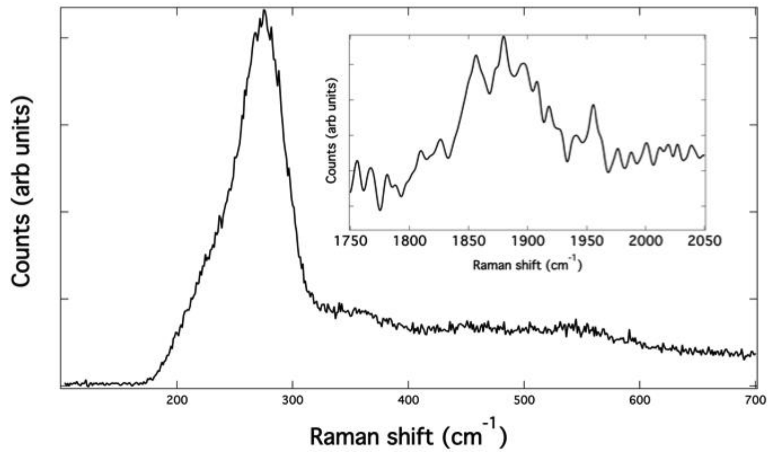

Fig. 2: Raman spectrum showing amorphous Ge core Inset: Peak showing Ge-H bond

The fiber has an optical loss of 25 dB/cm at 2 µm which is significantly lower than ~40 dB/cm loss in previously reported.[4] We attribute this large reduction in loss to the increase in hydrogen content that facilitates passivation. Figure 3 shows the wavelength dependent loss with a minimum loss of 10 dB/cm at 2.7 µm.

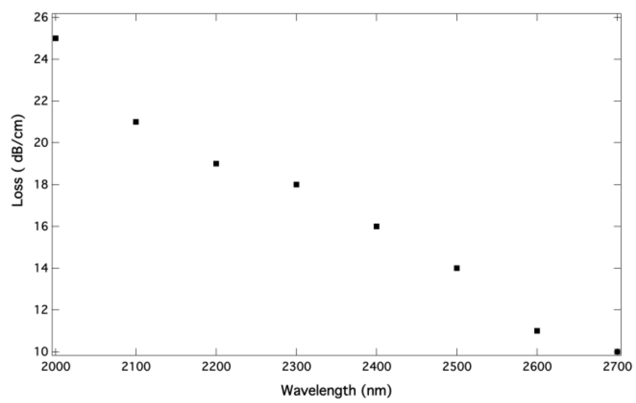

Fig. 3: Wavelength dependence of optical loss

3. Conclusion

Small core amorphous hydrogenated germanium step index optical fibers have been fabricated by high pressure chemical vapor deposition ensuring high hydrogen content thereby passivizing dangling bonds. This leads to a decrease in the number of scattering centers and ultimately the optical loss. These fibers can be used for near and mid infrared applications.

4. References

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