Radiation Resistant Optical Fiber for FBG based Sensing

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Abstract: Radiation-resistant optical fibers have been fabricated through MCVD process. The low radiation-induced-absorption in the fiber and few pico-meter shifting of Bragg-wavelength of the FBG under γ-exposure indicate its potential application for sensing in radiation environment.
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1. Introduction

Continuous strain and temperature monitoring is important for nuclear power plant and waste management sectors. By now fiber Bragg gratings (FBGs) are a widely accepted sensor type for temperature and stress measurements; especially in regions where conventional electronic sensors are too bulky or disturbed by electromagnetic interference. A variety of publications point out that FBGs written in high Germanium (Ge) doped fiber using UV exposure can be quite radiation insensitive due to the elimination of the precursors of color centers and good for use as temperature and strain sensor in the radiation environment [1] or space environments [2]. However the radiation induced loss of the connecting fiber doped with Germanium (Ge) degrades the signal to noise ratio resulting in the poor performance of the sensing system. To avoid this problem a short piece of Ge-doped fiber is used for FBGs writing and spliced with a radiation resistant optical fiber as the transmission optical fiber.

In the previous investigations for the development of radiation-resistant optical fibers, it was found that the pure-silica (SiO_2) core optical fiber has better radiation-resistance compared to GeO_2 and/or P_2O_5 doped SiO_2 core optical fibers [3]. This is due to the structure of pure-SiO_2 glass, which consists of stable bonding than that of multi-component glass. In order to obtain suitable waveguide design at operating wavelength region, a Fluorine (F) doped depressed cladding surrounding the silica core is important. Thus silica core F-down doped clad optical fiber (SCFC) is suitable for radiation resistant fiber for low loss transmission in the radiation environment. The technique commonly used in SCFC manufacture is the plasma chemical vapor deposition (PCVD) process. However the complexity of the process makes the fiber costly.

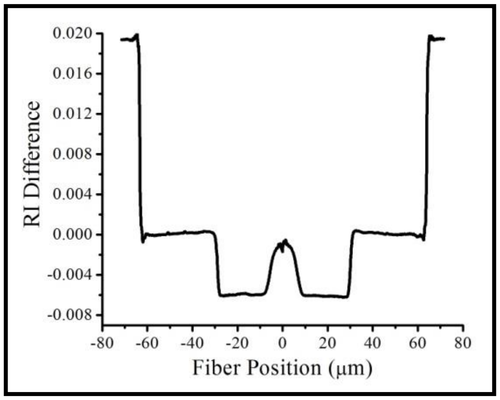
In this paper, the optimal refractive index profile of SCFC has been designed and fabricated for near-Infrared (NIR) region by using modified chemical vapor deposition (MCVD) process taking into account the limitation of the MCDV process to dope high F in silica as well as thicker F-doped inner clad. The characteristics of the fabricated optical fibers under γ irradiation have been investigated. Performance of that SCFC in combination with a Type-I FBG, written in a high Ge doped fiber, has been tested under radiation to investigate the suitability for temperature and strain sensing in the radioactive environment.

2. Experimental and Results

Silica-core F-down-doped-clad optical preforms have been fabricated by using MCVD process and drawn to fiber by using drawing tower. Different fabrication parameters have been optimized in order to achieve the desired fiber characteristics such as core diameter, F-doped-clad thickness and NA of the fiber. A typical Refractive Index (RI) profile and the absorption curve of the fabricated fiber are shown in Fig.1 and Fig.2 respectively. Absorption in the range of 1200-1400 nm is due to OH content in the fiber and can be eliminated by chlorine dehydration during preform fabrication.

The performance of the fiber under γ radiation has been tested by using a light source, a chamber with a source of radiation (60 Co) and a thermocouple, and a detector. The Radiation Induced Absorption (RIA) of the fibers has been characterized for accumulated dose of 18 MRad at the dose rate of 0.394 MRad/hr in the NIR region. In order to test the performance of the fabricated fiber as transmission medium for the fiber Bragg grating (FBG) based sensor, a FBG (Type-I) has been written on commercial high B/Ge photosensitive fiber, with Bragg wavelength at 1540 nm and spliced with the fabricated fiber, length of 12 m. The splicing loss was less than 0.5 dB. The SCFC along with sensor FBG has been γ -irradiated with a dose rate of 0.394 MRad/hr up to total 18 Mrad.

The radiation induced absorption (RIA) of the fiber under accumulated dose of 18 MRad is shown in Fig. 3 and the shifting of the Bragg wavelength due to the γ exposure is shown in Fig. 4. The result shows an overall blue shift of the Bragg peak by 46 pm under 18 MRad accumulated dose of γ and RIA of the fiber under accumulated dose of 18 Mrad is 0.02 dB/m.



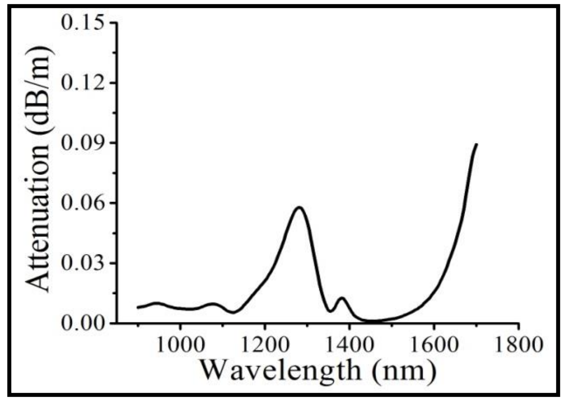
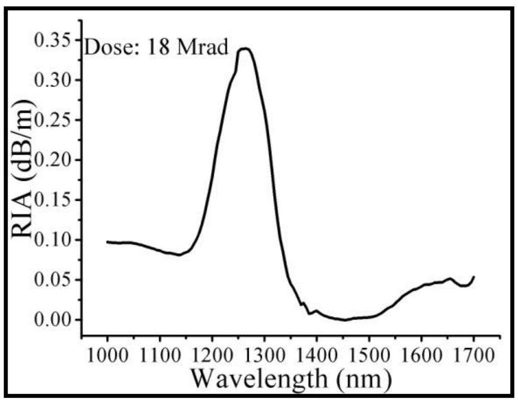


Fig.1 Refractive Index (RI) profile of the fabricated fiber

Fig. 2 Base-loss (attenuation) of the fabricated silica core-F-down doped optical fiber



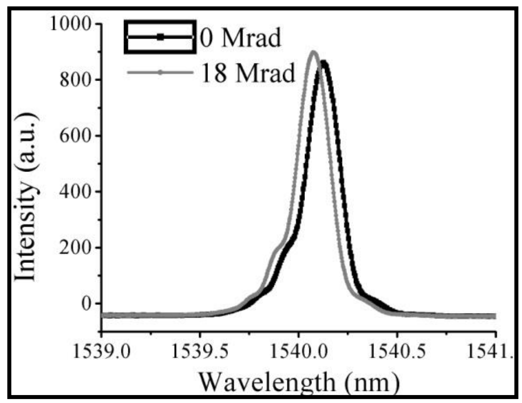


Fig. 3 FBG spectra under GAMMA radiation

Fig.4 RIA of the fiber under accumulated dose of 18 MRad

3. Conclusion

A set of radiation resistant optical fiber has been fabricated to use as a transmission medium of FBG based sensor system. The fabricated pure-silica-core fiber through MCVD process exhibits good transmission property as well as radiation resistant property in the NIR region. The 46 pm shifting of the Bragg wavelength under 18 MRad accumulated dose of γ is equivalent to variation of 4.6 °C of temperature and 38.3 μstrain of strain which can be taking into account during measurement of temperature or strain. The radiation resistant fiber can be used as a transmission medium for FBG based sensor system in radiation environment

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5. References

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