Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Ion beam induced luminescence of germano-silicate optical fiber preform

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1. Introduction

Optical fibers, as shown in Fig.1, are widely used in modern telecommunications because of electromagnetic immunity, large bandwidth, and low transmission loss.

Furthermore, the demand for data transmission under a high radiation environment is expanded in nuclear power plants, nuclear waste treatment facilities, accelerator laboratories, etc. When an optical fiber is exposed to radiation, the attenuation (RIA, Radiation Induced Attenuation) in the optical fiber (OF) is increased because of the color centers which deteriorate the transmission property and generate the absorption loss. In order to understand the radiation induced defect, Ion Beam induced luminescence (IBIL) was introduced to investigate it.

IBIL technique is to analyze IR/VIS/UV luminescence related to ion beam interaction with outer shell electrons involved in chemical bonds and structure defects of target atoms. So IBIL is sensitive to its chemical composition and has been used in analysis of material characterization, geological samples and cultural heritage objects. [1,2,3]

In silica material, four O atoms are surrounding one Si atom in tetrahedral coordination. As silica does not possess direct electronic band transitions, it is not luminescent. Luminescence comes from defects, either intrinsic or extrinsic [4]. In our samples, blue-violet luminescence is caused by Si-Si or dopant-Si homobands, called oxygen deficiency center (ODC) [5].

In this study, the influence of Copper (Cu) and Cerium (Ce) dopants to germano silica core optical fibers were investigated under proton irradiation at RBI using Ion Beam induced luminescence (IBIL) method.

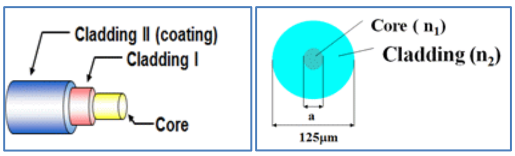

Fig. 1 Structure of Optical Fiber

2. Optical fiber fabrication

An optical fiber preform was fabricated using the MCVD (Modified Chemical Vapor Deposition) process with the solution doping method shown in Fig. 2. Cu and Ce ions were doped in the core region by soaking the silica glass tube deposited inside with the core layers in the ethanolic solution containing the ions. The glass tube was sintered and sealed to form a preform, then finally drawn into an optical fiber with 125 μm outer diameter using a high-temperature drawing process. In this experiment, OF preforms were used because of a large cross section. For a comparison, a reference single mode fiber with a core composition of SiO_2-GeO_2 was also fabricated.

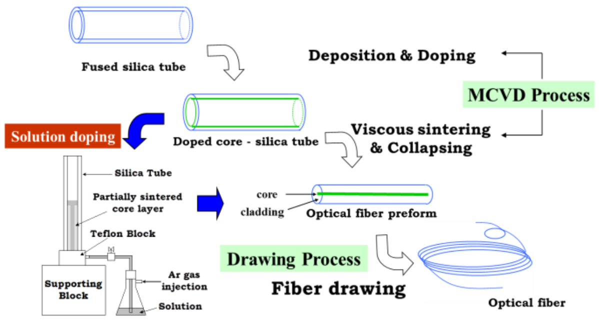

Fig. 2 Fabrication process of the optical fiber preform

3. IBIL Measurement

3.1 IBIL experimental system

The experimental setup for IBIL has been integrated on a micro-beam line at RBI in Zagreb. Beam is focused to a diameter of 5 ㎛ and scanning is performed with electrostatical deflection. Proton ions of 2 MeV energy, with beam currents ranging from 100 to 200 ㎀ were used. IBIL optical system shown in Fig. 3, consists of spectrometer, feedthrough, optical fiber and collimating lenses system. Data acquisition is controlled with SPECTOR software which simultaneously controls a spectrometer and a scanner (beam deflection), so sample mapping is also possible.

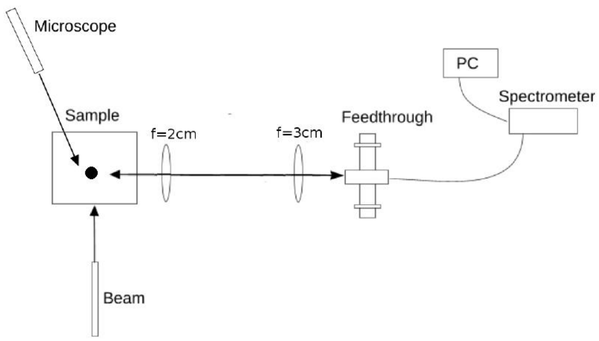

Fig. 3 Experimental setup for IBIL optical test

3.2 Results and Discussion

Two sets of measurements have been performed. In the first experiment, cores of the optical fiber preforms have been irradiated by 2 MeV proton microbeam. Sample was scanned with 1s/pixel (integration time 100 ms) and 32X32 IBIL map was obtained in Fig. 4 a). The IBIL spectra of two tested preforms (Cu doped, Ce doped) were extracted from position with the highest number of counts in map as shown in Fig. 4b. In both samples no significant differences could be observed. Two luminescence peaks have been observed in all samples, the stronger one at approximately 397 nm wavelength, and the weaker one at approximately 444 nm.

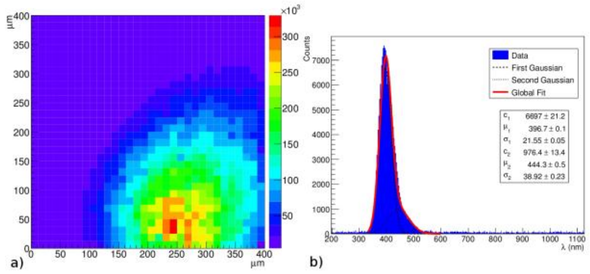

Fig. 4 IBIL map (a) and spectrum in highest detection sensitivity pixel (b) for Cu-doped fiber

Second, two particular samples have been exposed with excessive fluence of non-scanned and focused microbeam of 2 MeV protons focused to the center of the preforms. As it is seen on Fig. 5, Luminescence counts show initially the rapid rising curve and eventually reach a maximum and subsequently decays. IBIL peak of approximately 400 nm wavelength has been continuously decreasing with fluence, while the other peak of approximately 500 nm wavelength was slightly increasing.

This luminescence results cannot be explained simply in terms of either electronic or nuclear collisions alone. Assuming that the defects which produce luminescence are formed by the energy losses and the resulting defect sites are excited by the electronically deposited energy, both a nuclear damage profile and an electronic excitation profile must be considered in an interpretation of the luminescence results. [6]

Although such irradiation cannot be considered as well controlled (density of ion beam was unknown), we believe that this observation reveals the capabilities of the technique and justifies further research on the behavior of optical fibers when irradiated by protons.

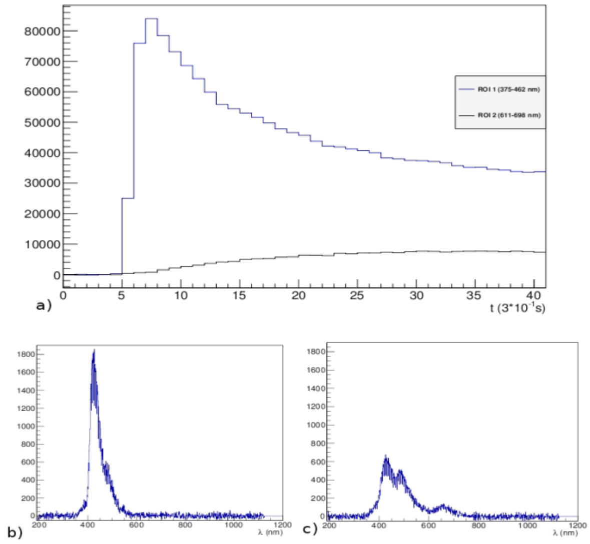

Fig. 5 a) Changes in intensity of IBIL peaks in relationship with time of proton microbeam irradiation; b) IBIL spectrum at the beginning of irradiation; c) IBIL spectrum after irradiation.

4. Conclusions

To understand the radiation induced defect of optical fibers, IBIL were tested to a germano-silica core fiber under 2 MeV proton irradiation. Although a Cu or Ce dopant was not detected by IBIL technique, the relation between the amount of radiation and luminescence can be established. This experiment showed a potential technique of studying the effects and behavior of additive elements for silica core fiber. To increase the radiation resistance of optical fibers, further investigations are needed, i.e. the proper additives and its contents and an interaction mechanism between Ge-related defects and additives.

Acknowledgements

This work was supported by the National Research Foundation (NRF) grant funded by the Minister of Education, Science and Technology of Korea (No. 2011-0031840).

REFERENCES

[1] A. Quaranta, A. Vomiero, S. Carturan, G. Maggioni, and G. Della Mea. Polymer film degradation under ion irradiation studied by ion beam induced luminescence (ibil) and optical analyses. Nuclear Instruments and Methods in Physics research Section B: Beam Interactions with Materials and Atoms, 191(1–4):680 – 684, 2002.
[2] Jamie S Laird, Jamie Wilkinson, Chris Ryan, and Andrew Bettiol. Hyper-spectral ionoluminescence system for minerals and fluid inclusions. Nuclear Instruments and Methods in Physics Research, B, 269(20):2244(7), 2011..
[3] A. Quaranta, J. Salomon, J.C. Dran, M. Tonezzer, and G. Della Mea. Ion beam induced luminescence analysis of painting pigments. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials

and Atoms, 254(2):289 – 294, 2007.
[4] Hans-Joachim Fitting. Can we make silica luminescent? Optical Materials, 31(12):1891-1893, 2009.
[5] Linards Skuja. Optically active oxygen-deficiency-related centers in amorphous silicon dioxide. Journal of Non-Crystalline Solids, 239(1–3):16 – 48, 1998.
[6]P.J. Chandler, F. Jaque, and P.D. Townsend, "Ion Beam Induced Luminescence in Fused Silica," Radiation Effects, Vol. 42, pp. 45-53, 1979