Dynamics Behaviour of UV-induced Luminescence in Hydrogen Loaded Germanosilicate Optical Fibers

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***Abstract*-- The dynamics of UV-induced luminescence in hydrogen loaded germanosilicate optical fibers gas been studied. The output beam from an argon laser was frequency doubled through BBO. The continuous UV radiation tuned at 244 nm was focused onto the core of the fiber with a lens. The fibers used in this experiment were standard telecommunication of germanosilicate optical fiber (SMF-28). For hydrogen loading, the fiber were placed in hydrogen chamber (180 atm., room temperature) for two weeks. we have used visible argon laser at 488 nm with lower power (~ 5 mW). coupling of the light into the fiber to study the luminescence. Defect responsibility between the non hydrogen loaded fiber and hydrogen loaded fiber are different. At least responsible for hydrogen loaded fiber is a modification of the defect of the non hyrogen loaded fiber. In hydrogen loaded fiber, two-step nature of the photosensitization process occurs, the first step involves formation of species that absorbs more UV light B where B is less stable than C. The formation of B is aided or catalyzed by hydrogen, whereas the formation of C appears to be independent of hydrogen.**

***Index Term*-- luminescence, hydrogen loaded fiber, two step photosensitization**

I. INTRODUCTION

Photo induced effects in germanium-doped silica optical fiber has been used to produce Bragg gratings which have numerous applications as wavelength-selective components in optical add-drop multiplexers, dispersion compensator, in line mirrors in fibre laser and fibre sensor. This effects are closely related to oxygen-deficient defects causing intense absorption band near 240 nm and a lower one at 325 nm [1]. The photosensitivity drastically increase by hydrogen-loading to this fibre which was two orders of magnitude larger than that using non-loading fibres [2].

In non-hydrogen loaded fibers, the interaction of photon and germanium oxygen deficiency centre (GODC) absorption band which is present in germanosilicate glasses near 240 nm has been reported. In all cases the GODC band is at least partially bleached with concomitant increase in short wavelength below 200 nm which have been linked to refractive index changes via the Kramers-Kronig relation. They are related to the creation of Ge(1), Ge(2) and Ge(E') centers induced by the bleaching of the 240 nm absorption band. This process is accompanied by modification of structure and densification of a glass which makes the contribution to the photorefractive effect [3].

In hydrogen-loaded, the mechanisms was change considerable. The UV irradiation to hydrogen-loaded fiber induced infrared absorption around 1,4 µm due to the OH-group [4]. Correlations of this band and induce refractive index change were believed in linear manner [5].

Absorption of 240 nm light in this fiber is accompanied by emission of broadband blue fluorescence at 400 nm and 380 nm [6]. So, it was suggested that changes in the population of these defects centre could be detected by monitoring this associated luminescence. The study of the fluorescence at 400 nm as a function of UV exposure at non hydrogen loaded fibers has been carried out by[7]. In hydrogen loaded fibers, Atkins [8] using HeCd laser at 325 nm and Argon laser at 351 nm, have reported a rapid drop in fluorescence.

In this paper, we reported that the dynamics of fluorescence of hydrogen loaded germanosilicate optical fiber at 400 nm is increased at the first period and decreased at another period after a saturated period has been achieved during irradiation by the continuous wave of 244 nm light.

II. EXPERIMENTAL PROCEDURE

The output beam from an argon laser was frequency doubled through BBO. The continuous UV radiation tuned at 244 nm was focused onto the core of the fiber with a lens. For optimisation of optical arrangement, we have used visible argon laser at 488 nm with lower power (~ 5 mW). Coupling of the light into the fiber was performed by focusing the beam with a microscope objective and positioning the fiber a few millimetres behind the focal plane. The fiber was fixed with v-groove fiber holder. Both, microscope objective and fiber holder were positioned with an XYZ micro-translation stage. By these arrangements, we can choose the propagation mode of the light in the fibre by monitoring the output light at the end of the fiber on a screen. We used a LP_{02} mode in this experiment. Light from the output end of the fiber was collimated by two lens and directed onto a 0.6 m computer controlled double monochromatic with equipped by two identical 1800 1/mm gratings in conjunction with photon counting detection. The monochromatic was adjusted at 400 nm of wavelength. The signal was registered in computer for every one second.

The fibers used in this experiment were standard telecommunication of germanosilicate optical fiber (SMF-28). For hydrogen loading, the fiber were placed in

hydrogen chamber (180 atm., room temperature) for two weeks.

III. RESULTS AND DISCUSSIONS

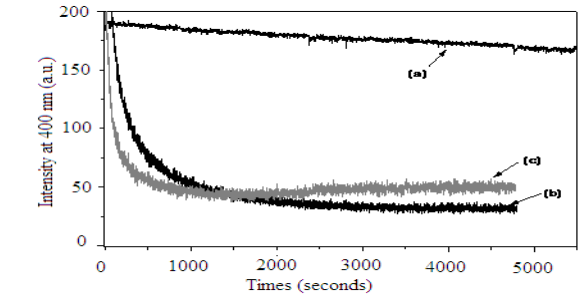
Evolution of the intensity of the luminescence during irradiation time when the use of cylindrical lens to focus the beams on the core of the non hyrogen loaded fiber and fiber hydrogenated are shown in Figure 1 (A) and Figure 1 (B) in linear and logarithmic scale respectively.

It can be noted that the intensity of non hyrogen loaded fiber (a) is stable during the irradiation time. In case of pre-hydrogenated fiber (b) and (c), the intensity has decreased dramatically in the first irradiation time, ie until about 1000 s. In these circumstances the trends are the same for the two lengths of the beams, that is to say the energy density. We found the relationship between the initial intensity N_0 and intensity over time $N(t)$:

$N(t) = N_0 t^{-0.4}$, where t is the duration of the irradiation time.

Following irradiation, the trends have changed, the intensity due to the irradiation with energy density higher, it increases higher.

Evolution of intensity, when it was replaced the cylindrical lens by spherical lens was shown in Figure 2. Its looks are different to that shown in Figure 1. In case of non hyrogen loaded fiber, the intensity dropped sharply, then it is stable after irradiation. This is different to the previously hydrogenated fiber, the intensity is increased in the first irradiation time, then decreases after irradiation.



(A)

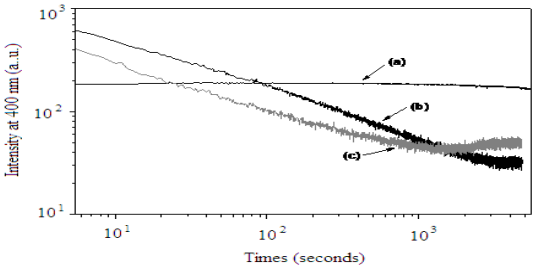


Fig. 1. Evolution of luminescence intensity at 400 nm during the irradiation time of 244 nm (P = 60 mW). The beams are focused on the core of the fiber using cylindrical lens (f = 20 cm). (a) non hydrogen loaded fiber (bundle length on the fiber is 35 mm), (b) hydrogen loaded fiber (bundle length on the fiber was 35 mm) and (c) previously hydrogenated fiber (length of the fiber bundle 5 is mm).
(A) to the linear scale and (B) on a logarithmic scale

Figure 2 shows the evolution of luminescence at 400 nm for non-hydrogen and hydrogen loaded fibers. In non-hydrogen fiber, the luminescence decreases at the first time then achieved their saturated at the following irradiation. This condition is contradiction with the hydrogen-loaded fiber, that increasing at the first time and decreasing after achieving their peak value. We can see also in the figure, the cross point between them around 500 second. This result indicate that the responsible defects of 400 luminescence band in non-hydrogen load fiber was bleached. In the presence of hydrogen, the product of bleaching then reacted with hydrogen to form another defect. These condition is true for the time before saturate. After this stage, the defect concentration decrease with following irradiation, because there is no again the defect precursor that reacted with hydrogen. For explain this phenomenon, we have irradiated another fresh fibers for 5000 seconds and taken their luminescence spectre as shown in Figure 4. The result show that there is

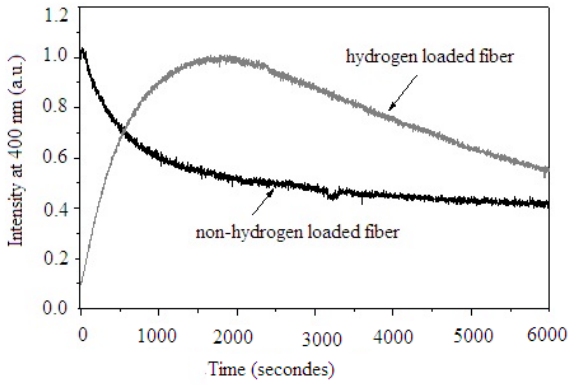


Fig. 2. Evolution of luminescence intensity at 400 nm during irradiation at 244 nm (P = 60 mW) non hydrogen loaded fiber and hydrogen loaded fiber. A laser is focused onto the core of the fiber using the spherical lens.

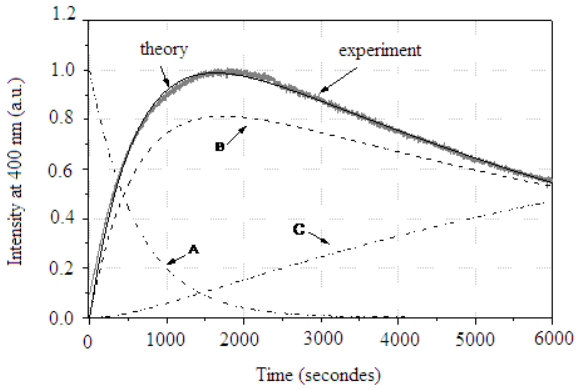


Fig. 3. Comparison of experimental results of the luminescence at 400 nmwith the model of photosensitivity in two stages. A, B and C are the species of the curve [A], [B] and [C] respectively

These last experimental results are adequate with species [B] and [C] proposed models [9]) as shown in Figure 3. We found the rate value of k1 and k2 are and respectively. We can find the curve of the dynamics for each species.

We are also interested in comparing the luminescence spectra. Because the change in intensity during irradiation between 0-1000 seconds for both fiber are remarkable as shown in Figure 4, we chose to take spectra after this condition. We used another fresh fiber. After the irradiation for 1000 second, the computer program to run to catch the luminescence spectrum with the same irradiation condition. Lasted from the time recorder spectrum is 500 second. In Figure 4 shows that the two spectra are different.

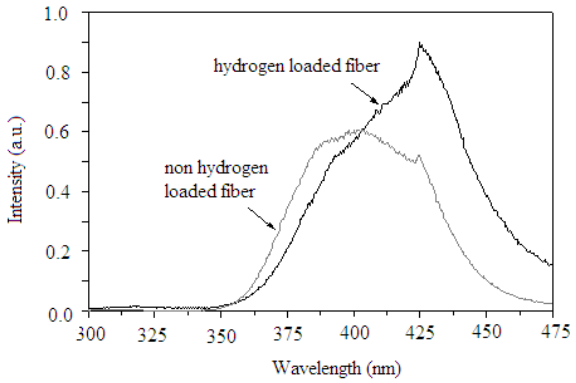


Fig. 4. Spectrum of the luminescence of the SMF 28 fiber non hyrogen and hydrogen loaded fiber. Excited at 244 nm Argon laser doubled. The spectra were recorded after 500 s of irradiation

During irradiation, one can note the evolution of the luminescence at 400 nm, when using the proposed [10], the luminescence at 400 nm due to defects GLPC, thus the possibility of the reaction is GLPC generation by the reaction

≡Si—O—Ge—O—Si≡ + H—H →
=Ge: + 2 (H—O—Si≡) (1)

Note that this reaction was proposed by [11] to explain the increase of the absorption band at 5.1 eV when they treated germanosilicate glass in hydrogen atmosphere at 400-700 ° C temperature . [12] also to use this reaction to explain the increase in photosensitivity of the fiber hydrogenated. However, the experimental results is given with the sum of the species [B] and [C] simultaneously. Indeed, it must contain the species [C]. The most of this species is GeE'. The spectrum of the luminescence in Figure 4 shows the support that the defect responsibility between the non hydrogen loade fiber and hydrogen loaded fiber are different.

At least responsible for hydrogen loaded fiber is a modification of the defect of the non hyrogen loaded fiber. Accordingly some possibility of reaction path to occur simultaneously on the other hand the reaction (1) are:

=Ge: + H—H + hν → ≡Ge•—H + H• (2)

≡Ge•—H + hν →=Ge: + H• (3)

≡Ge• + H—H →≡Ge—H + H• (4)

≡Ge—H + hν→≡Ge• + H• (5)

One can note the Raman spectrum after irradiation the concentration of O_2 molecule is increased, also the formation of H_2O was detected [12]. Differences luminescence spectra obtained as shown in Figure 4 indicates that the structure responsible for the luminescence are different.

≡Ge—O—Si≡ + H—H → =Ge—H + H—O—Si≡ (6)

≡Ge—O—Si≡ + hν → ≡Ge-···-O—Si≡ (7)

≡Ge-···-O—Si≡ + H—H →
≡Ge• + H—O—Si≡ + H• (8)

Lemaire et al. [3] showed that the enhanced of the response of hydrogen loaded in standard germanosilicate fibers to uv was caused by a reaction of H_2 at normal Ge site to produce OH groups and oxygen deficient centers through the reaction Si-O-Ge + H_2 → Si-OH + oxygen deficient Ge defect.

Awazu et al. [10] proposed that the enhanced the photosensitivity due to the GLPC transform into GeE' center under UV illumination and that the photochemical change from the GLPC to the GeE' center is related to the presence of hydrogen molecules dissolved in the glass. They found a one-to-one correlation in the concentrations of GLPC and GeE' centers generated. Araujo et al. [4] have reported that the reaction starts preferentially at Ge sites surrounded by other Ge atoms. A close relation was found between the dynamics of Ge/Si-OH formation and the induced index change. They predicted that the UV induced change is associated with formation of other Ge defects, such as Ge^{2+}, accompanied by the simultaneous generation of both Ge-OH and Si-OH groups.

Recently, Aslund and Canning [11] have proposed two-step nature of the photosensitization process, , i.e. A → B → C, the first step involves formation of species that absorbs more UV light B where B is less stable than C. The formation of B is aided or catalyzed by hydrogen, whereas the formation of C appears to be independent of hydrogen. Grubsky et al [16] have proposed that the reaction involves two stages. First, a UV photon excites a regular Ge-O bond. While it is excited the bond is attacked by a nearby H_2 molecule. The reaction produces Si-OH, a GeE' center, and atomic hydrogen.

Fu et al. [12] have used the fact that, in the Ge doped silica fiber, the Ge-O bond is weaker than the Si-O bond, they proposed the reaction that the irradiation UV will excited the molecular H_2 in two atomic hydrogen. These atomic will react to a normal Si-O-Ge site to produce GeE' centers and Si-OH.

If we used the result of [10] that the 240 nm absorption band may consist of neutral oxygen vacancy (NOV) and Ge^{2+} which were bleached and emit emission band at 400 nm when irradiated by 240 nm light. Thus, the decrease of 400 nm luminescence band in non hydrogen loaded fibre indicate that the population of Ge^{2+} was decreased, but this is in contraire with the hydrogen loaded fibre which the intensity at 400 nm was increased at the first time. This result can be

=Ge: + H—H + hν → ≡Ge•—H + H• (9)

≡Ge•—H + hν →=Ge: + H• (10)

≡Ge• + H—H →≡Ge—H + H• (11)

≡Ge—H + hν→≡Ge• + H• (12)

≡Ge—O—Si≡ + H—H →
=Ge—H + H—O—Si≡ (13)

≡Ge—O—Si≡ + hν → ≡Ge-···-O—Si≡ (14)

≡Ge-····O—Si≡ + H—H →

≡Ge• + H—O—Si≡ + H• (15)

IV. CONCLUSIONS

Defect responsibility between the non hydrogen loaded fiber and hydrogen loaded fiber are different. At least responsible for hydrogen loaded fiber is a modification of the defect of the non hyrogen loaded fiber. In hydrogen loaded fiber, two-step nature of the photosensitization process occur, the first step involves formation of species that absorbs more UV light B where B is less stable than C. The formation of B is aided or catalyzed by hydrogen, whereas the formation of C appears to be independent of hydrogen**.**

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