ENHANCED PHOTOSENSITIVITY IN 248NM KRF AND 193NM ARF EXCIMER LASER IRRADIATED GERMANOSILICATE FIBER

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Abstract- In this study, we have a demonstrated a new technique to enhance the photosensitivity of germanosilicate fiber based on KrF excimer laser irradiation prior to grating inscription process. Fibers treated with 248nm KrF excimer laser provides a two times higher refractive index change compared to the untreated optical fiber. The increment of the 193nm UV absorption band with KrF excimer laser irradiation which is associated with the germanium related oxygen deficient centers, is believed to be the reason for the enhancement of the photosensitivity with 193nm ArF excimer laser irradiated fiber Bragg gratings.

Keywords- Bragg Gratings, Photosensitivity, 248nm KrF Excimer Laser, 193nm ArF Excimer Laser

I. INTRODUCTION

Fiber Bragg gratings (FBGs) have become essential components in the implementation and growth of fiber optical communication and optical sensing industries owing to their numerous advantages which includes high sensitivity, being immune to electromagnetic interference, low fabrication cost and low weight etc. The flexibility of FBGs allow in achieving desired spectral characteristics depending on the application. Among the inscription techniques used to fabricate FBGs, the phasemask lithography technique is considered as the most commonly used technique due to its simplicity and high efficiency when employed with an excimer laser. Since the first FBG fabrication and discovery of photosensitivity in optical fibers, many interpretations on the photosensitive effect were made. Among them, a widely used elucidation to describe the photosensitive effect is that it consists of the photogeneration of carriers by bleaching the 242nm band followed by trapping of carriers at various defect sites which results in the alteration of ultra violet absorption spectrum. Furthermore, these absorption changes are related to the refractive index changes through Kramers-Kronig causality. Moreover, numerous techniques have been developed to enhance the photosensitivity of an FBG. These techniques can be classified into two categories namely, doping of optical fibers and post fabrication processes. As stronger photosensitivity plays an important role in enabling efficient gratings to be inscribed, a variety of dopants or co dopants such as B, N, P, Sn, Sb have been used to enhance the photosensitivity. When considering the post fabrication processes, low temperature hydrogen loading, writing at elevated temperatures, flame brushing, UV pre-exposure followed by hydrogen out-diffusion and thermal treatment are also frequently used techniques in photosensitivity enhancement. Furthermore, experiments have indicated different photosensitive mechanisms using ArF excimer laser light with a wavelength of 193nm which is used to induce refractive index changes in doped silica fibers and waveguides.

By far the most photosensitive optical fibers are obtained by doping with germanium where the germanium concentration in the core is responsible for producing a higher photosensitivity. Since the post fabrication processes such as hydrogen loading and flame brushing involve a reaction of hydrogen molecules with a common Ge─O─Si site, it results in the formation of OH groups and bleachable germanium oxygen-deficient centres (GODC's). Even though this results in an enhancement of the photosensitivity, when these two techniques are in cooperated to enhance the photosensitivity in germanosilicate fiber, the absorption at 1.55μm telecom window increases due to the formation of Ge─OH and Si─OH defects. Therefore, it is necessary to investigate novel methods to enhance photosensitivity in germanosilicate fibers with less time consumption, lower optical loss and photosensitive to low levels of UV fluence.

In this study, we have introduced a novel post fabrication technique to enhance the photosensitivity of H_2 free germanosilicate fiber using both KrF and ArF excimer lasers where initially the fiber is exposed to KrF excimer laser (248nm) for a known amount of pulses followed by ArF excimer laser (193nm) irradiation which results in the inscription of a fiber Bragg grating. Subsequently, the photosensitivity of these treated Bragg gratings which are exposed to a specific amount of pulses, is compared with untreated Bragg gratings.

II. EXPERIMENTAL SETUP FOR FBG INSCRIPTION

Initially, the germanosilicate optical fibers (5.5wt% Ge concentration) are exposed to KrF excimer laser (248nm) for 200 pulses with 8mJ pulse energy at a

repetition rate of 10Hz. Subsequently, 15mm long gratings are inscribed on with the employment of 193nm ArF excimer laser using the phasemask lithography technique as demonstrated in Fig. 1, with pulse energy of 8mJ at a 40Hz repetition rate. The ArF excimer laser beam is first expanded using two convex lenses and then compressed to produce a vertical beam length of 1cm using a cylindrical lens.

The optical fiber is positioned at the beam waist point where it receives the optimum laser intensity. In order to make sure that the KrF excimer laser treated region of the optical fiber is fully exposed to the UV laser beam, the fiber ends are fixed at the fiber clamps which are mounted on a three axis positioning stages. The transmission spectra are recorded and monitored using an optical spectrum analyzer (OSA) controlled by a Labview program via GPIB.

Moreover, an optical beam shutter with a close time duration of 4.08s is used to control the laser irradiation on the fiber so that stable and undisturbed transmission spectra can be recorded by the OSA throughout the experiment.

Furthermore, consecutive FBG inscription on untreated germanosilicate fibers is carried out after FBG inscription on treated fiber in order to improve the accuracy of this study.

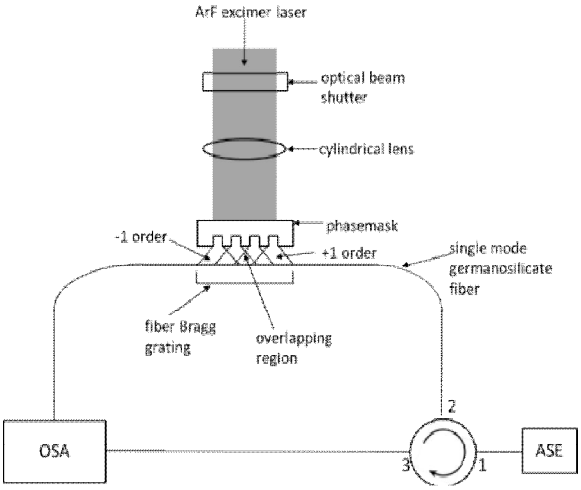


Fig. 1. Schematic diagram of the experimental setup for FBG fabrication on germanosilicate fiber using 193nm ArF excimer laser.

III. EXPERIMENTAL RESULTS AND ANALYSIS

It is noticed from Fig.2 that compared to the untreated optical fiber, the treated germanosilicate fiber provides a higher Bragg transmission loss (BTL) and a longer wavelength shift.

The BTL of the treated optical fiber takes a value which is three times higher than the untreated germanosilicate fiber.

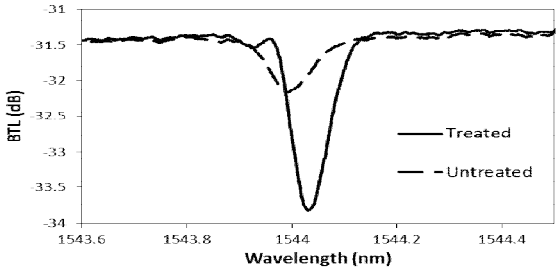


Fig. 2. Transmission spectra of the FBGs inscribed on treated and untreated germanosilicate fiber using ArF excimer laser after a time duration of 3.5min.

Fig. 3demonstrates the relationship of center wavelength and the BTL against increasing UV fluence of a treated germanosilicate fiber. Both center wavelength and BTL show similar trend of progression. The gradual increment of the two parameters, BTL and center wavelength is due to the increment of the 'ac' and 'dc' coupling of the optical fiber. In order to determine the strength of the photosensitivity of treated germanosilicate fibers, the refractive index changes between the treated and untreated optical fibers are compared.

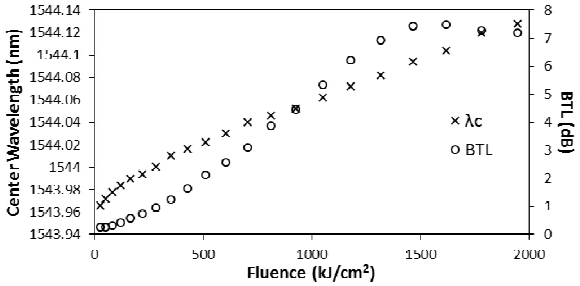


Fig. 3.Overlaid graph of center wavelength shift and variation of BTL with increasing UV fluence.

Fig. 4 illustrates the refractive index changes of treated and untreated germanosilicate optical fibers with 193nm ArF excimer laser irradiation. The treated optical fiber indicates a refractive index change of 5.5×10^{-5} which is evidently much higher than the refractive index change of the untreated fiber which amounted to 3.5×10^{-5}. It is also observed that at a moderate fluence level of 1000kJ/cm^2, the treated fiber produces a two times higher refractive index change in comparison to the untreated fiber. This phenomenon can be explained using the germanium related oxygen deficient centers (GODC) associated with germanosilicate fiber during UV irradiation.

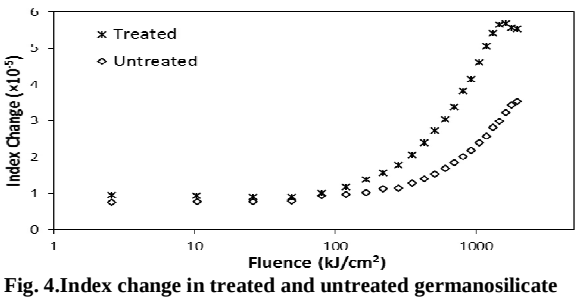


Fig. 4.Index change in treated and untreated germanosilicate optical fiber with ArF Excimer laser irradiation.

Generally, the photosensitivity of germanosilicate fiber is demonstrated using the 240nm absorption band. The origin of the 240nm absorption band is due to an oxygen deficient center related with germanium ions commonly known as germanium oxygen deficiency centers (GODC).

The GeO defect consists of a Ge atom which is coordinated with another Ge or Si atom. In the presence of UV irradiation, this bond which is responsible for the 240nm absorption band, breaks resulting in a GeE' center. It is also believed that the electron released from the GeE' center freely moves within the glass matrix where it can be eventually retrapped at the original or some other defect site.According to literature, when germanosilicate fibers are exposed to 248nm KrF excimer laser, the 240nm defect band gets bleached and introduces the growth of a short wavelength edge absorption centered at ~195nm.

Therefore, this concept justifies our experimental results. The gratings inscribed on KrF excimer laser irradiated germanosilicate fibers using 193nm ArF excimer laser results in a higher refractive index change compared to the untreated fiber due to the presence of the 195nm absorption band.

CONCLUSION

In summary, we have observed that the novel post fabrication technique where the germanosilicate fiber are initially exposed to 248nm KrF excimer laser and subsequently irradiated with 193nm ArF excimer laser to inscribe gratings provides a higher photosensitivity compared to untreated germanosilicate fiber.

The increment in the photosensitivity is due to the growth of the 193nm UV absorption band with KrF excimer laser irradiation. Further improvements in terms of UV exposure time is necessary in order to achieve optimum results.

However, we believe that the proposed technique can be in cooperated as an efficient technique with many applications where photosensitivity of the Bragg grating is considered a priority in the field of fiber optics.

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