Radiation-Induced Defects in Fluorine-doped Silica-Based Optical Fibers: Influence of the H<sub>2</sub>-Loading

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ABSTRACT

We investigated the effects of 10-keV X-ray radiation on the transmission properties of F-doped optical fibers in the 200-850 nm range of wavelengths (1.5 – 6 eV). The influence of a H<sub>2</sub>-loading of the fiber on its radiation sensitivity is also presented.

Keywords: radiation effects, fluorine, optical fibers, hydrogen, point defects

1 INTRODUCTION

Optical fibers with fluorine (F)-doped cores present interesting characteristics for transmission of signals in the ultraviolet-visible range of wavelengths. Furthermore, this kind of fibers exhibit a quite good radiation-tolerance to most of the steady state radiative environments compared to the response of other fibers doped with germanium, phosphorus or rare-earth ions [1]. Previous studies showed that the F-incorporation inside the a-SiO<sub>2</sub> glass reduces the number of precursor sites leading to the generation of absorbing point defects under irradiation like the strained Si-O-Si bonds [2]. Furthermore, it has been shown that the hydrogen (H<sub>2</sub>)-loading of optical fibers can also efficiently reduce the generation rate of some of the radiation-induced defects like non-bridging oxygen-hole centers that absorb in the visible part of the spectrum [3]. In this study, we characterized the radiation-induced attenuation (RIA) in the UV-visible range (1.5 – 6 eV) for an optical fiber with a fluorine-doped core and cladding. The influence of the sample H<sub>2</sub>-loading was also measured.

2 EXPERIMENTAL PROCEDURE

We used an ARACOR facility [4] generating 10 keV X-rays for the irradiation of our samples. The efficiency of this tool to reproduce the γ-ray an effect was previously discussed [4]. For this set of experiments, the samples were exposed to over 2 cm fiber length to a cumulated dose rate of 65 Mrad(SiO<sub>2</sub>) with a dose rate of 9 krad(SiO<sub>2</sub>)s. An adapted setup was designed for the in-situ measurements of the transmission change during and after irradiation. We injected light from a Deuterium-Halogen source inside a UV-optimized fiber pigtail connected to the tested F-doped fiber sample. The signal transmitted through this fiber link is analyzed with a HR4000 spectrometer (1.5-6 eV).

The tested multimode fiber has a core diameter of 62.5μm. Its F-doping is represented by several levels of F between 0.1 and 1.2%. Concentration of chlorine impurity is on the order of 1000 ppm in the core and cladding. The fiber cladding is also F-doped, at 1.8% level. The outer cladding is made of pure low-OH silica glass (more details in [5]). The H<sub>2</sub>-loading has been performed several months before irradiation tests at the pressure of 175 bars and temperature of 80 °C. In these conditions, the H<sub>2</sub>-concentration is within a saturation limit after 60 h. As the tested fiber has an acrylate coating, nearly all the hydrogen diffuses out the fiber before the irradiation tests. After 20 days, less than 2% of hydrogen remains in the fiber core.

3 EXPERIMENTAL RESULTS

Fig.1. illustrates the RIA growth during the irradiation of 2 cm of the F-doped fiber, with and without H<sub>2</sub>-treatment at room temperature with a dose rate of 9 krad/s.

Fig. 1: Spectral dependence of the 10 keV X-ray radiation-induced attenuation (RIA) for different total deposited doses. (A) Fluorine-doped fiber without H<sub>2</sub>-loading (B) Fluorine-doped fiber with H<sub>2</sub>-loading.
X-ray irradiation leads to the generation of several point defects that absorb in the studied range of wavelengths. Our measurements showed that the growth kinetics of the different defects during irradiation are strongly different. For H$_2$-free and H$_2$-loaded fibers, point defects absorbing below 5.9 eV (210 nm), defects in the UV range (an absorption peak is discernable at 3.6 eV) and in the visible part of the spectrum contribute to the radiation-induced attenuation. Although a H$_2$ pre-treatment does not strongly modify the fiber radiation response, our tests showed larger RIA levels for the H$_2$-loaded sample.

4 DISCUSSION

Previous studies [6] showed that the radiation-induced losses in fluoride-doped glasses are due to Si-related defects or to absorbing species related to impurities like Cl. In the final paper, the different RIA spectra during and after irradiation will be decomposed with the help of Gaussian bands corresponding to absorption bands of Si- and H-related defects previously identified in literature. Additional measurements are performed on this F-doped sample with electron spin resonance measurements (ESR) and confocal microscopy luminescence techniques will also be used to identify the defects.

We compare in Fig.2a the effect of the H$_2$-loading on the radiation response of the F-doped fiber at three different steps of doses. In Fig.2b, we present the subtraction of the induced losses in the H$_2$-free fiber to the induced losses of the H$_2$-loaded fiber to point out the negative influence of the pre-treatment in this spectral range of wavelengths.

It is obvious from our tests that in this part of the spectrum, the H$_2$-loading mainly has a negative influence on our fiber radiation response. The presence of H$_2$ does not affect the induced absorption at energies smaller than 4 eV but increases the RIA levels at greater energies. As shown in Fig.2b, this treatment induces the presence of an absorption band centered at about 4.8 eV. H$_2$-loading also increases the contribution of the UV tail of defects absorbing at > 5.5eV. The nature of the involved defects will be discussed in the final paper.

5 CONCLUSION

This abstract gives preliminary results about the radiation sensitivity of F-doped fiber to 10 keV X-rays. Several point defects are generated that induce strong absorption in the 200 - 800 nm spectral range. Nature of these point defects will be discussed in the final paper, in which additional results based on ESR and CML techniques will be presented.

REFERENCES