Influence of fluorine on the fiber performance studied through the NBOHC-related 1.9 eV microluminescence

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ABSTRACT

The distribution of Non Bridging Oxygen Hole Centers (NBOHC) in Fluorine doped optical fibers was investigated by confocal microluminescence spectroscopy monitoring the characteristic 1.9 eV luminescence band. The results show that these defects are generated by the fiber drawing and their concentration further increases after γ irradiation. The NBOHC profile along the fiber is anticorrelated to the fluorine content. This finding agrees with the role of fluorine in the fiber toughness and is discussed from the microscopic point of view on the basis of previous works.

Keywords: optical fiber, silica, F-doping, non bridging oxygen hole center, confocal microluminescence

1 INTRODUCTION

The performances of high-purity silica-based optical fibers are strongly conditioned by the generation of point defects [1]. In the visible and ultraviolet (UV) domain the fiber transmission is negatively influenced by two intrinsic silica defects, the dangling oxygen (also named NBOHC), whose structure is ≡Si-O•, and the dangling silicon (also named E' center), whose structure is ≡Si• [2-4]. The E' center is characterized by an optical absorption (OA) band at 5.8 eV, the NBOHC by several OA bands centered around 2.0 eV, 4.8 eV and 6.5 eV, each of them exciting a peculiar photoluminescence (PL) band at 1.9 eV. Their generation results from different mechanisms: drawing, UV transmission along the fiber core and irradiation in harsh environments. These processes occur in precursor sites: Si-OH bonds or strained Si-O bonds which can be distinguished on the basis of the irradiation dose dependence curves.

To improve the fiber toughness some extrinsic elements are introduced *ad hoc*. One method is the doping with halogen elements such as F that stabilize functional groups (Si-F) so as to reduce the strained bonds [5]. Moreover, since F reduces the refractive index, the fiber doping profile, both multistep- or graded-index, is designed to minimize the dispersion losses.

In this work we report the comparison among three F-doped fibers differing for their doping profile. By the confocal microluminescence technique we study in detail the NBOHC concentration along the fiber diameter detecting its 1.9 eV PL band. Our purpose is to clarify the role of F in inhibiting the NBOHC generation both by drawing and by γ irradiation.

2 EXPERIMENTAL METHOD

We investigate three types of F-doped fibers differing for the F-profile and the doping content. The *F* and *F2-D2* fibers have been provided by iXFiber S.A.S and are four and two step-index fibers, respectively, with an outer undoped high purity silica layer (external cladding) and internal cylindrical layers of highly pure synthetic silica doped with different F amounts. F doping profile grows from ~ 0.2 wt.% in the center (core) to ~ 1.6 wt.% in the outer part (internal cladding). The internal F-doped part of the fibers is made with modified chemical vapor deposition (MCVD) process. The third fiber is a graded-index fiber made up of an outer undoped high purity silica layer (external cladding) and an internal part of highly pure synthetic silica doped with an F amount growing continuously from ~ 0.2 wt.% in the center (core) to ~ 5 wt.% in the outer part (internal cladding) The F-doped part is made with plasma-activated chemical vapor deposition (PCVD) process. Hereafter, it will be named *PCVD* fiber.

Our fibers have a diameter of 125 μm and have been irradiated at room temperature by using the ^{60}Co source (1.2 MeV) at the Brigitte facility of SCK-CEN (Belgium); the accumulated dose ranges from 1.1×10^6 Gy to 10^7 Gy.

NBOHCs along the core of the fibers were detected by the confocal microscopy luminescence (CML) measurements performed with a LabRam Aramis (Jobin-Yvon) spectrometer; it is based on a He-Cd ion laser excitation line (photon energy 3.8 eV, power ~72 μW) and supplied with a CCD camera and microtranslation stages. The excitation beams penetrates of a few micrometers in the sample; the measurement geometry is the back-reflected one. We used a 40 × objective and a diaphragm diameter of 75 μm; these experimental conditions lead to a spatial resolution of ~ 5 μm. NBOHCs were detected monitoring the emission photoluminescence (PL) band around 1.9 eV; their concentration has been calculated comparing the amplitude of this PL band with that measured in a reference neutron irradiated synthetic silica sample (neutron fluence of 1.6×10^{17} n/cm^2) whose NBOHC concentration is known by the intensity of the 2.0 eV optical absorption band.

3 RESULTS AND DISCUSSION

Figure 1 shows typical PL spectra measured in the center of the as-grown and 7.8 MGy γ irradiated *F* fiber; they are characterized by a band around 1.9 eV. On the basis of the comparison with the PL spectrum of a neutron irradiated bulk sample, this emission is unambiguously related to NBOHC. This defect is already present in the fiber as the drawing effect; its concentration increases of more than one order of magnitude after γ irradiation.

Figure 2 reports the NBOHC concentration measured along the fiber diameter; data refer to the graded index fiber, *PCVD*, before and after γ irradiation at the dose of 10 MGy. The drawing induce NBOHCs, their concentration is maximum (8×10^{16} cm^{-3}) at the core center and decreases down to few 10^{15} cm^{-3} at 25 µm far from the center. Irradiation induces additional NBOHCs with a similar profile; the maximum concentration (1.2×10^{18} cm^{-3}) is in the core center. We note that the defect concentration is anticorrelated with the F content as shown in the figure.

These results are common to all typologies of investigated fibers and point out that the F improves the toughness of fibers as concerns the NBOHC generation. From a microscopic point of view, we suggest that Si-F groups reduce the concentration of strained bonds that are precursors of NBOHC defects.

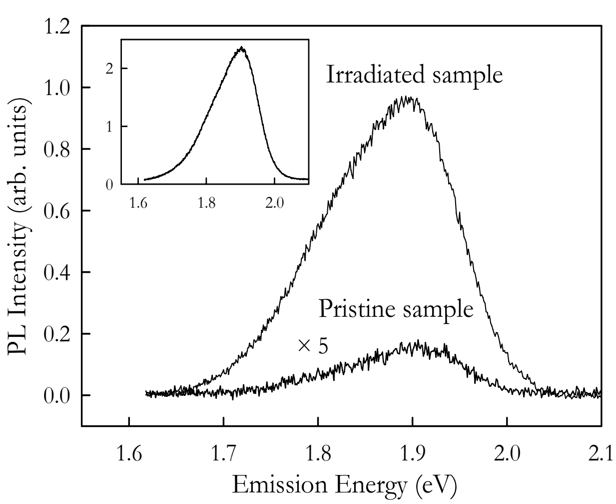

Figure 1: PL spectra measured in the fiber *F* before and after γ irradiation at the dose of 7.8 MGy. The inset shows the PL spectrum of the bulk neutron irradiated sample taken as reference.

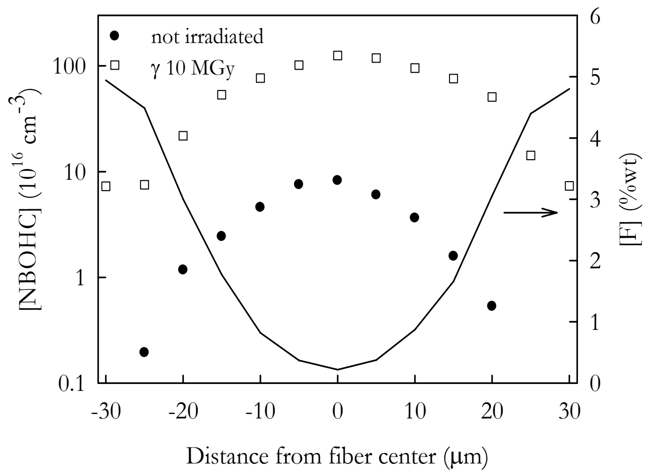

Figure 2: NBOHC concentration profiles along the diameter of the graded-index *PCVD* fiber before (full symbols) and after (empty symbols) 10 MGy γ irradiation. The F concentration is also reported in the figure in the right y scale.

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