PROCEEDINGS REPRINT

SPIE—The International Society for Optical Engineering

Reprinted from

Submolecular Glass Chemistry and Physics

3-6 September 1991
Boston, Massachusetts

Volume 1590

MECHANISMS OF UV LASER INDUCED ABSORPTION IN FUSED SILICA FIBERS

V.G.Artjushenko, V.I.Konov, N.Yu.Konstantinov*, V.P.Pashinin, A.S.Silenok
General Physics Institute, 38 Vavilov Street, SU-117942 Moscow, USSR
G.Mueller, B.Schaldach, R.Ulrich
Laser-Medizin-Zentrum GmbH,Kramerstr.6-10, D-1000 Berlin 45,
W.Neuberger
CeramOptec GmbH, Siemensstrasse 6-12, 5300 Bonn I,Germany
J.Castro
CeramOptec Inc., 188 Moody Road, Enfield, CT 06082

ABSTRACT

Alteration of absorption spectra of fused silica fibers under delivery of high power UV laser radiation (4th harmonic of Nd:YAG laser, wavelength 266 nm) was studied in comparison with their photoluminescence properties. Tested fibers were produced by various technologies based on PMCVD methods. The nature of defects responsible for UV absorption in fibers and mechanisms of their photogeneration are discussed.

1.INTRODUCTION

Fused silica fibers for high power UV radiation transport were under intensive development during few last years[1-6]. The improvement of UV transmission properties of silica fibers should supply the number of perspective industrial and medical applications of high power UV lasers (first of all of excimer lasers) with effective fiber delivery systems capable of transmitting laser radiation of high peak and average intensities during a long time. Commercially available OH-rich fibers usually used for UV radiation transport have acceptable properties when working with relatively low repetition rates but for high repetition rate regime which is character for excimer lasers fiber transmission essentially decrease[3-7]. At XeCl laser wavelength (308 nm) the fall of transmission is observable only for long pieces of fibers and transmission restores to the initial value after the stop of laser irradiation[3,5-7]. Irradiation at the shorter laser wavelengths of KrF and ArF lasers (248 and 193 nm) causes catastrophic and only partially restorable transmission decrease[5,7]. The reason of such a considerable decrease is laser-induced color centers generation. Although color centers in fused silica were studied during more than thirty years and their spectroscopic properties are principally determined very few investigations were performed to establish the mechanism of their formation in fibers[7,8]. Moreover, the development of fiber production technology results in appearance of new types of high purity silicas having nonstandard optical properties. To determine the types of defects responsible for the UV laser induced absorption in fibers produced by various technologies and to look for the most advantageous technology of manufacturing UV-transmitting fibers we have performed the comparative study of laser-induced absorption and luminescence spectra in few different types of silica fibers.

2. SAMPLES AND EXPERIMENTAL

A set of all silica step index fibers investigated in our experiments was produced using PMCVD technology of F-doped cladding deposition and rod-in tube method of making the preform by Blinov et al[9]. The fused silica rods utilized as the core material were of different OH content listed in Table 1. Fiber P18M was produced fully by PMCVD technology. Core diameter of all fibers was 400 um, NA 0.20 0.02. Table 1 also shows the absorption coefficients at excimer laser wavelengths and character absorption bands at 5.1 and 3.8 eV (from Ref.7). The character feature of fiber P18M if the existence of weak absorption band at 3.8 eV (325 nm) which is usually ascribed to the peroxy bridges[10]. So we can assume that there is an oxygen excess in this sample. The origin of 5.1 eV absorption band is not finally established. There are few models of point defects which can be responsible for this band[11,12].

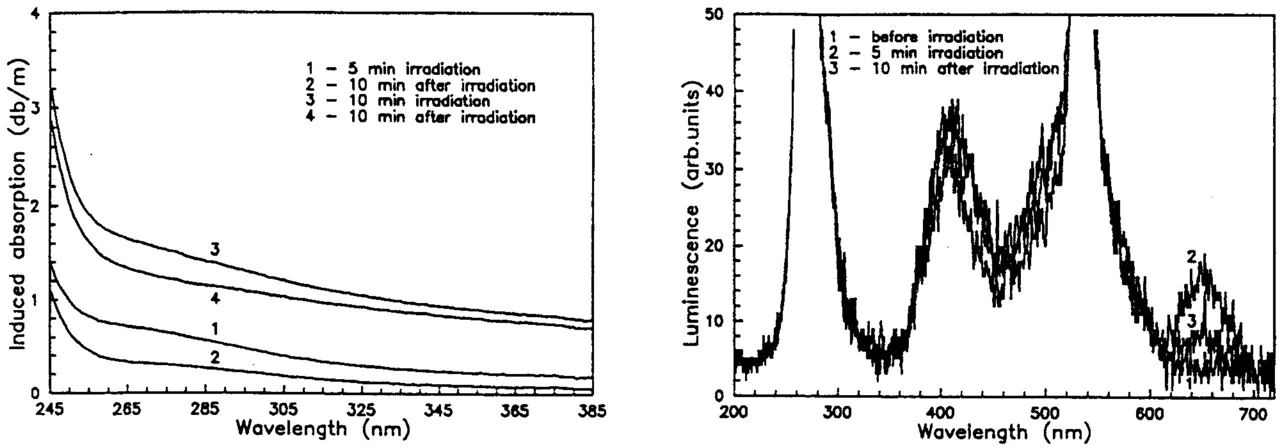

Fig.1 Laser induced absorption (left) and luminescence (right) of fiber H700.

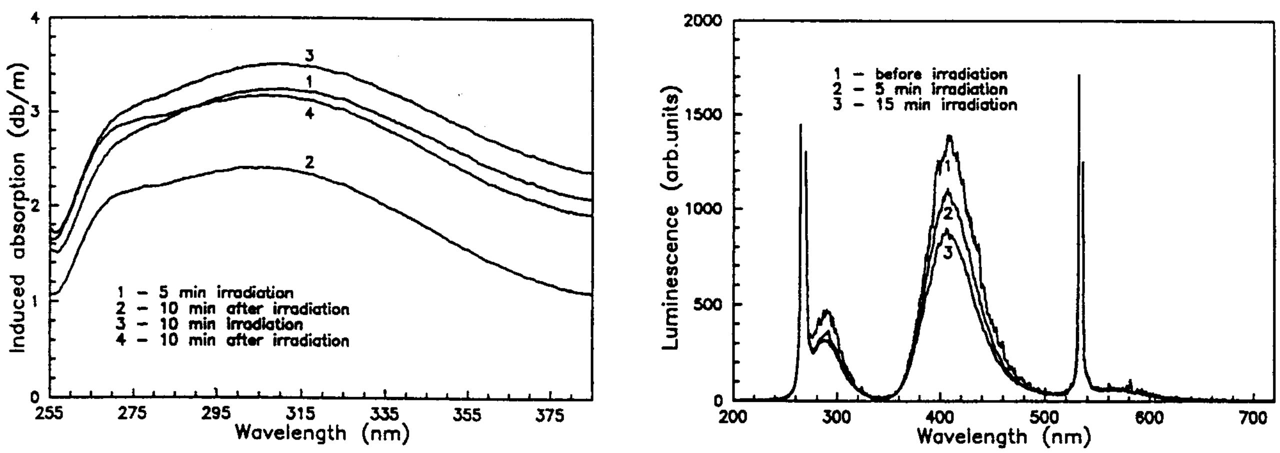

Fig.2 Laser induced absorption (left) and luminescence (right) of fiber H150.

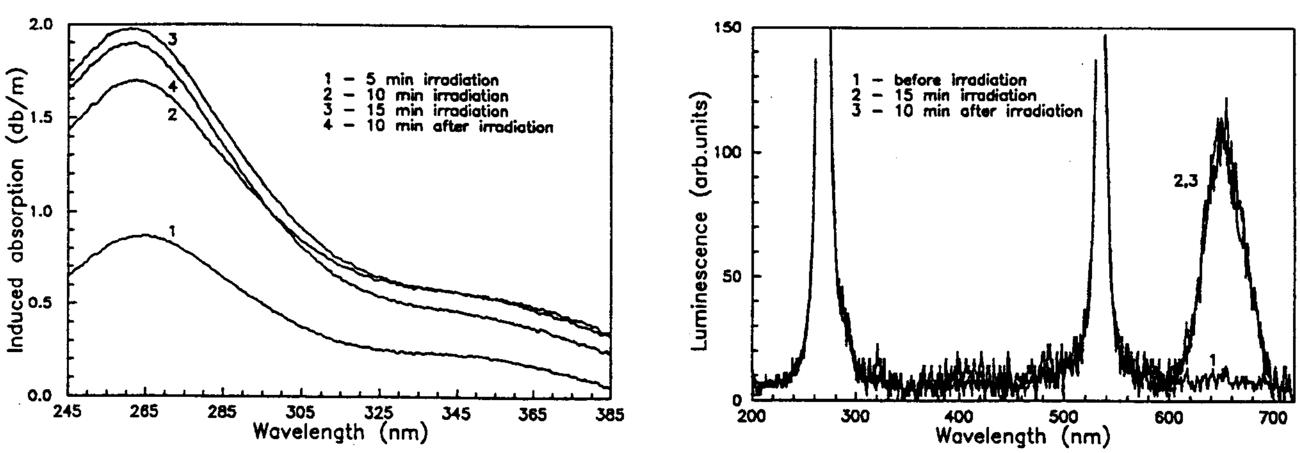

Fig.3 Laser induced absorption (left) and luminescence (right) of fiber P18M.

luminescence from induced NBOHC's is overpowered by much stronger luminescence from centers associated with 242 nm absorption.

The spectra of induced absorption of fiber H150 is rather complicated. Few absorption bands can nevertheless be distinguished. Unfortunately it was not possible to measure the absorption spectra at wavelengths shorter than 255 nm due to low initial fiber transmission in this region. We can still assume than the spectra of induced absorption are the combination of at least three bands. The fall of absorption toward 255 nm is most probably the result of distraction of defects producing absorption band at 242 nm in fresh fiber. The evidence of such a distraction is the decrease of appropriate luminescence at 290 and 410 nm. After the stop of irradiation a small increase of absorption near 255 nm occurs so we can suggest than some amount of mentioned centers recovers. The weak hump around 265 nm we ascribe to the NBOHC while the long partially restorable tail can be connected with E' centers. As a result the fiber H150 have rather small induced absorption in the region of wavelength shorter than 265 nm. If any way how to reduce the initial absorption band at 248 nm be find (for example by oxygen treatment) this fiber also can be considered as a candidate for using in this wavelength range.

4. CONCLUSION

Basing on the information about the behavior of transmission and luminescence characteristics of fibers during high power UV laser irradiation we can infer than the main defect responsible for laser-induced absorption in the wavelength range from 245 till 385 nm is nonbrigen oxygen hole center. It causes the unstable absorption band at 265 nm in OH-rich fiber H700 and more intensive stable band in low OH oxygen excess fiber P18M. For our opinion, nonbridgen oxygen is produced in fiber P18M from peroxy linkages by breaking O-O bond while in high OH fiber there can exist few mechanisms of NBOHC's generation including the dissociation of OH groups. Further search of possible methods enabling to decrease the concentration of NBOHC's precursors in all types of fibers should result in production of fibers having transmission properties acceptable for use in high power UV radiation delivery systems.

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