Mixed temperature and radiation effects on fluorine-doped optical fibers

S. Rizzolo[1,2*], S. Girard[1] , A. Boukenter[1], Y. Ouerdane[1], R. Boscaino[2], P. Paillet[3], C. Marcandella[3], J. Périsse[4], J-R. Macé[5], and M. Cannas[2]

* Serena Rizzolo
Ph. Dr
ISAE-SUPAERO
10, Avenue Edouard Belin
31400 Toulouse (France)
serena.rizzolo@isae-supaero.fr

[1]Laboratoire Hubert Curien, Université Jean Monnet, CNRS UMR 5516, 18 Rue Benoît Lauras, 42000, Saint-Etienne, France
[2]Dipartimento di Fisica e Chimica, Università di Palermo, Viale delle Scienze Parco d'Orléans II, Ed. 17, 90128 Palermo, Italy
[3] CEA, DAM, DIF, F-91297 Arpajon, France, [4]Areva NP, 10 Rue Juliette Récamier, 69006, Lyon, France; [5] Areva NP, 1, Place Jean-Millier 92084, Paris-La Défense, France

AIM

This work is centered on the paramagnetic defects induced by 10keV X-rays exposure at different irradiation temperatures (T_I) ranging from 25 °C up to 250 °C in fluorine doped fibers aiming to investigate the influence of T_I on the generation mechanisms defects.

INTRODUCTION

The radiation effects in silica have been the object of intensive studies over the last decades. One of the main investigation technique is the electron paramagnetic resonance (EPR), powerful to identify the microscopic structure of paramagnetic defects such as:

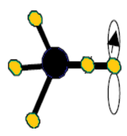
E' Center

E' center (≡Si•)
Si dangling bond

NBOHC

Non-Brinding Oxygen Hole Center, ≡*Si-O*•
O dangling bond,.

POR



PerOxy Radical: ≡Si-O-O•
Si atom linked to an oxygen molecule

The understanding of generation mechanisms and of the influence of important parameters such as the irradiation temperature is relevant to improve the radiation resistance of optical fibers.

MATERIALS AND METHODS

- Rad hard single mode optical fiber F-doped in core (0.2 wt.%) and cladding (1.5 wt.%).
- 10keV X-ray irradiations with a dose rate of 40Gy/s and a total dose of 1MGy (SiO_2). T_I varied from RT~25°C up to 250 °C.
- EPR spectra were recorded at RT to investigate E' defects and at liquid nitrogen temperature (77K) for NBOH and POR centers.

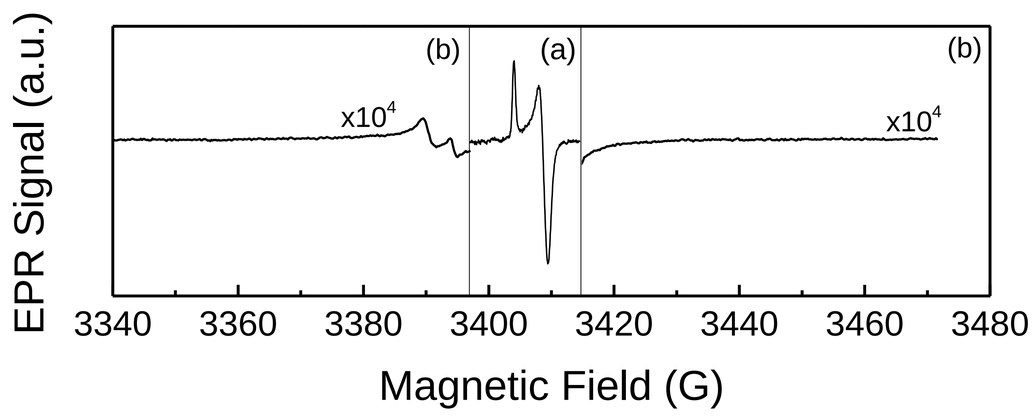


Figure 1: EPR first harmonic spectra for F-doped fiber irradiated at 250°C up to 1MGy(SiO_2). The part (a) shows the E' center line shape and in (b) is shown the EPR spectrum associated with the NBOH and the POR centers.

EXPERIMENTAL RESULTS

All defect concentrations increase with the dose, E' center evidences the largest concentration.

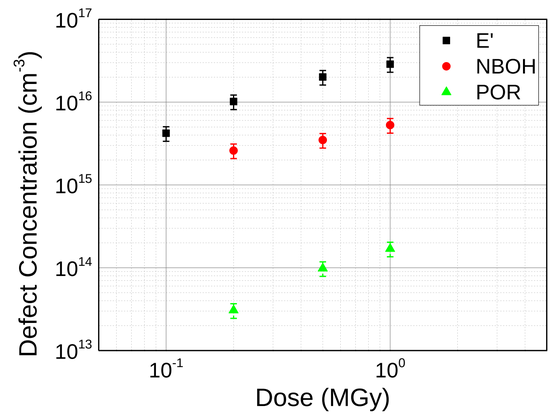
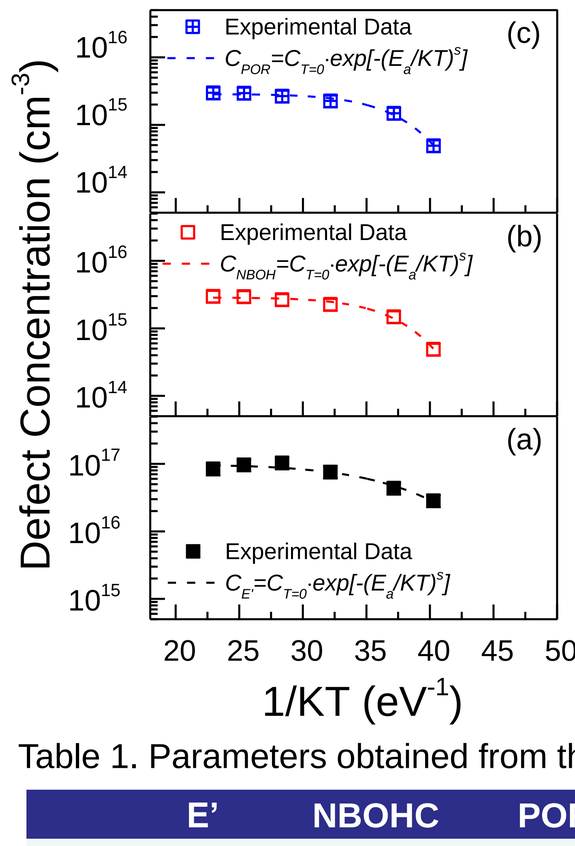


Figure 2: Concentration of E' centers, NBOHC and POR point defects as a function of the total deposited dose.

To estimate the activation energy, E_a, we fitted the experimental data with the Arrhenius law:



$$C(T_I) = C_{T=0} \cdot e^{\left(-\frac{E_a}{KT}\right)^s}$$

- ✓ $C_{T=0}$ is the defect concentration at 0K;
- ✓ s is a stretching factor.

Figure 3: Concentrations of (a) E', (b) NBOH and (c) POR centers as a function of T_I for irradiated sample at 1MGy (SiO_2). The dotted lines in each graph indicate the exponential fits.

Table 1. Parameters obtained from the fit

	E'	NBOHC	POR
$C_{T=0}$ (cm^{-3})	(10±1)·10^{16}	(2.8±0.1)·10^{15}	(2.8±0.1)·10^{15}
E_a (meV)	26±1	26±1	26±1
s	7±2	11±2	11±2

We found for the three generated defects an activation energy of **26 meV**.

CONCLUSION

Defects induced in Fluorine-doped single mode fiber by 10keV X-rays have been investigated by EPR experiments up to 1MGy (SiO_2) and for T_I from 25 °C up to 250 °C. We have identified that several paramagnetic defects related to the silica network, Si- E', NBOHC and POR are created by irradiation; their concentrations increase and saturate on increasing T_I in accordance with an activation energy of 26 meV.