Femtosecond direct laser writing of silver clusters in phosphate glasses for X-ray spatially-resolved dosimetry

Joelle Harb[1], Théo Guérineau[2], Adriana Morana[3], Arnaud Meyer[3], Guillaume Raffy[4], André Del Guerzo[4], Youcef Ouerdane[3], Aziz Boukenter[3], Sylvain Girard[3], Thierry Cardinal[2], Yannick Petit[1,2] and Lionel Canioni[1]

[1]Center of Intense Lasers and Applications (CELIA), University of Bordeaux, Talence, France

[2]Institute of Condensed Matter Chemistry of Bordeaux (ICMBC), University of Bordeaux, Pessac, France

[3]Univ Lyon, UJM, CNRS, IOGS, Laboratoire H. Curien, UMR 5516, 42000, Saint Etienne, France

[4]Univ. Bordeaux, CNRS, Institut des Sciences Moléculaires UMR 5255, 33400 Talence, France

Radio-photoluminescence (RPL) has been extensively studied in silver-doped phosphate glasses, considered nowadays as a reliable passive radiation dosimetry technique for ionizing radiations (Gamma and X-rays). After exposure to ionizing radiation, such glasses exhibit an intense luminescence while excited with ultraviolet (UV) light, which is referred to as the radio-photoluminescence phenomenon. Recently, the femtosecond direct laser writing (DLW) allows to directly inscribe three-dimensional (3D) structures inside transparent glass substrates. For silver-containing phosphate glasses, the femtosecond (fs) DLW process induces the formation of silver clusters Ag_m^{x+} (m is the number of ions and x is the formal charges) in the vicinity of the interaction voxel. Silver clusters are also responsible for a local refractive index modification allowing for various local highly-contrasted optical responses (luminescence, or refractive index) for the fabrication of photonic components and integrated devices. Unlike currently commercialized RPL dosimeters, our glasses contain two orders-of-magnitude more silver ions. To our knowledge, no research combining RPL and fs DLW has yet been conducted on such glasses. Recently in a previous work, we demonstrated the generation of silver species in highly photosensitive silver-containing sodo-gallophosphate glasses exposed to X-rays, and the subsistence under X-ray irradiation of laser-inscribed molecular species such as the fluorescent silver clusters. We reported that the phosphate glass network had a decisive influence on the X-ray photosensitivity and the formation of luminescent silver species, namely Ag^{2+} hole trap silver ions and Ag_m^{x+} silver clusters. In this framework, the targeted objective is to evaluate the performances of a spatially-resolved dosimeter exploiting the properties of the laser-induced silver clusters localized in purpose in phosphate glasses containing a high concentration of silver oxide. Thus, RPL and fs DLW have been combined to estimate the potential of those laser-inscribed structures for X-ray spatially-resolved dosimetry. Two phosphate glasses of different compositions were investigated. The spectroscopic properties of the pristine glasses were studied after X-ray irradiation at different doses to assess their dosimetry potential. The impact of X-rays on the three-dimensional inscribed silver clusters has been analyzed using several spectroscopies methods. Our analysis highlights the resilience of embedded silver clusters acting as local probes of the deposited doses. The optical and spectroscopic properties were handled to demonstrate the realization of a sensitive and reliable dosimeter. With these local probes, it is possible to define a range and a sensitivity of X-ray doses and to consider the realization of spatially-resolved dosimeters.