Scintillating sol-gel silica glasses and optical fibers for remote ionizing radiation dosimetry

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Abstract

Optically activated glasses are essential to the development of new radiation detection systems. Among these systems, optical fiber sensors attract a huge interest due to their small size, intrinsic immunity to electromagnetic interferences, flexibility and ability to be remotely interrogated. They also offer high spatial resolution of the measurement with the possibility to work in hazardous, narrow and constrained environments. In the domain of radiation dosimetry techniques, the application of optical fibers started with thermoluminescence (TL), and was followed by radiation induced attenuation (RIA), optically stimulated luminescence (OSL) and radioluminescence (RL). For RL-based techniques, the scintillation signal from the probe exposed to radiation can be recorded, allowing real-time dose-rate measurements, which makes this technique very interesting for applications in medical or severe environmental domains.
For nearly 20 years now, advances in the so-called "polymeric" sol-gel technique in our laboratories have made it possible to reproducibly provide glassy rods made of dense silica doped with luminescent elements. The synthesis of such glass rods, capable of being drawn into capillaries and then active fibers, required know-how and precise control of the hydrolysis and condensation reactions, inherent in this technique. Doping and densification also remain delicate steps in this synthesis.

Finally, the fusion-splicing and/or the assembly of luminescent sol-gel rods in a fiber structure has given rise to multiple demonstrations of their dosimetry capabilities under different radiations, using radioluminescence and optically or thermally stimulated luminescence processes. These processes, closely linked to the doping ions, such as Ce3+, Cu+, Tb3+, or Gd3+, as well as to intrinsic matrix traps, are increasingly well understood thanks to a model that can simulate optical signals under irradiation.
The aim of this paper is to present the main results of dosimetry characterizations of such sol-gel rods or fibers, combined with spectroscopic measurements as well as combined with the optical signal simulation. The involved physical processes will be discussed to better understand the behavior of these responses versus temperature and dose rate, the target being to obtain total ionizing dose (TID) measuring probes independent of these parameters.

Keywords: Sol, gel, silica glass, ion doping, luminescence, optical fibers, dosimetry

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