Eu-Doped $BaSO_4$ Nanoscintillator for X-Ray-Activated Photodynamic Therapy

João Victor Vieira Lessa[1], Mileni Mayumi Isikawa[1], Nancy Gabriela Chicango Arcos[1], Éder José Guidelli[1]

[1]*University of São Paulo - Physics Department (FFCLRP), Ribeirão Preto, São Paulo, Brazil.*
Corresponding Author Email: jvlessa@usp.br

Radioluminescent nanomaterials have attracted increasing attention in luminescence-driven biomedical applications due to their ability to convert ionizing radiation into UV–visible photons. In this work, we report the synthesis, structural characterization, radioluminescence properties, and photodynamic performance of europium-doped barium sulfate ($BaSO_4$:Eu) nanoparticles functionalized with Chlorin e6 (Ce6) through a controlled multilayer deposition strategy.

Transmission electron microscopy (TEM) reveals that the $BaSO_4$:Eu nanoparticles present well-defined morphologies with average sizes ranging from 50 to 70 nm (Figure 1a), confirming their nanoscale nature. The uniform morphology indicates a stable host lattice capable of accommodating europium ions. A crystalline structure with features suggestive of porosity is observed, which may enable the accommodation of substances of interest for drug delivery applications.

Radioluminescence (RL) spectra under X-ray excitation display a composite emission profile (Figure b). A broad UV–blue emission band is observed and may be attributed to matrix-related recombination processes or the presence of Eu^{2+} with $4f^6 5d^1 \rightarrow 4f^7$ transitions. In parallel, sharp red emission lines corresponding to the characteristic Eu^{3+} intra-4f transitions ($^5D_0 \rightarrow {}^7F_j$) are detected, confirming the coexistence of two different typer of emission. This dual behavior highlights $BaSO_4$:Eu as a versatile radioluminescent platform spanning UV to red wavelengths. Importantly, the UV–blue RL component shows strong spectral overlap with the absorption band of Chlorin e6 (Figure b), enabling efficient radiative coupling between the scintillating core and the photosensitizer shell.

The photodynamic activity was evaluated by monitoring singlet oxygen ($^1O_2$) generation using 1,3-diphenylisobenzofuran (DPBF) as a fluorescent probe. A clear dose-dependent quenching of DPBF fluorescence is observed under X-ray irradiation (Figure c), confirming effective $^1O_2$ production. Moreover, increasing the number of Ce6 deposition cycles leads to enhanced DPBF quenching efficiency, demonstrating that higher photosensitizer loading improves the photodynamic response. Overall, $BaSO_4$:Eu nanoparticles with controlled Ce6 functionalization constitute a robust mixed-valence radioluminescent system with tunable emission and efficient singlet oxygen generation, holding strong potential for luminescence-based X-ray–activated photodynamic applications.

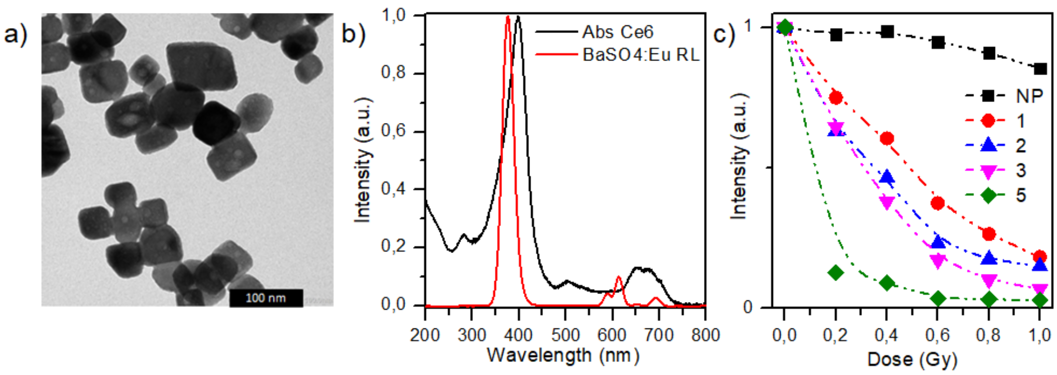

Figure 1. *(a) TEM micrograph of $BaSO_4$:Eu nanoparticles showing well-defined morphologies with sizes in the 50–70 nm range. (b) Radioluminescence spectrum of $BaSO_4$:Eu nanoparticles under X-ray excitation compared with the absorption spectrum of Chlorin e6, (c) DPBF fluorescence quenching under X-ray irradiation for bare nanoparticles and samples with increasing numbers of Ce6 deposition cycles.*

The authors gratefully acknowledge financial support from CAPES, CNPq, and FAPESP. This research occurs under FAPESP (Process no. 2025/01900-2 and 2024/21657-2)