

# Gadolinium and Terbium-covered Bismuth-loaded plastic scintillators for thermal neutron detection

Jonathan Dumazert<sup>\*1</sup>, Romain Coulon<sup>1</sup>, Guillaume H. V. Bertrand<sup>1</sup>, Stéphane Normand<sup>1</sup>, Laurence Méchin<sup>2</sup> and Matthieu Hamel<sup>1</sup>

<sup>1</sup>CEA, LIST, Laboratoire Capteurs Architectures Electroniques, 91191 Gif-sur-Yvette, France.

<sup>2</sup>CNRS, UCBN, Groupe de Recherche en Informatique, Image, Automatique et Instrumentation de Caen, 14050 Caen, France.

PERSONAL dosimetry for the monitoring of neutron exposure requires light, thermal neutron sensitive sensors with high gamma-rejection to free the measurement of the radiative background. Such devices are of primary interest for the radioprotection of workers operating on infrastructures as well as for nuclear physicians. They should additionally comply with cost-effectiveness requirements to offer a credible alternative to the exploitation of recoil protons used as a signature for an incident neutron radiation.

As the stable natural element with the highest cross section for thermal neutron capture, gadolinium appears relevant to enhance neutron sensitivity in any physical sensor. In the meantime, plastic scintillators, as low-density and low-effective atomic number media, possess a superior gamma-rejection when compared to semiconductors. Gadolinium-covered modified plastic scintillators then show a high potential for the deployment of robust and cost-effective neutron detectors. To take advantage of the low-energy photon and electron signature of thermal neutron capture by gadolinium-155 and gadolinium-157 isotopes, the contribution of background radiation to the signal and falling into the same range however has to be cancelled out. This compensation, which is critical to ensure trustable neutron detection, may be carried out in a twin-sensor scheme.

This paper presents the concept of such compensation under the form of a two-bismuth loaded plastic scintillator system: a *detection scintillator* interacts with photon and fast neutron radiation and is covered with metal gadolinium as a thermal neutron absorber, while an identical *compensation scintillator* covered with terbium solely interacts with the photon and fast neutron part of incident radiation. The authors describe the simulation-based scaling of the sensors and insulation of measurement channels, the synthesis of bismuth-loaded plastic scintillators, the experimental energy calibration of these scintillators, the nonlinear smoothing of the raw counting signals and the setting of a hypothesis test to discriminate the signal generated by the radiative signature of thermal neutron captures in gadolinium from statistical fluctuations over the compensation of both independent channels.

A laboratory prototype is tested under both photon and neutron radiations, allowing us to investigate the performance of the overall compensation system in terms of neutron sensitivity and gamma-rejection. The measurement carried out over one gadolinium-covered and one terbium-covered bismuth-loaded plastic scintillator has allowed the detection of a neutron activity in the photon radiation background of a californium-252 source at the exit of a 10 cm HDPE block (the gamma dose rate being estimated around  $1.2 \mu\text{Sv}\cdot\text{h}^{-1}$  with a standard radiameter, which matches the typical constraints of a “monitored area” in the context of radioprotection applications). Thus the concept of a neutron detection scheme, robust to “controlled area” typical photon background, was validated validating. The dual sensor-sensor prototype was also found portable, compatible with online implementation, and his cost-effectiveness advantageously compares to inorganic, silicon-based compensation schemes.