Properties of DSB: Ce^{3+}, a new inorganic scintillation material

V. Dormenev, K.-T. Brinkmann, R. W. Novotny, H.-G. Zaunick
2nd Physics Institute, Justus-Liebig-Universität, Giessen, Germany.

Self activated scintillation materials like BGO and PWO possess a unique combination of the scintillation and physical properties, including high density fast response and radiation hardness to the electromagnetic part of ionizing radiation. However, heavy materials demonstrate significant damage caused by the hadronic part of the ionizing radiation [1] excluding their consideration in future high-energy experiments at new particle colliders.

Di-Silicate of barium ($BaO\text{-}2SiO_2$) doped with cerium (DSB: Ce) is one of the new scintillation materials made from binary stoichiometric compositions and produced like a glass or glass ceramics with a multistep thermal annealing process to obtain the nano-structuring of the material. When doped with Ce^{3+}, the material becomes scintillating. The light yield amounts to approx. 100 photo electrons per MeV deposited energy. Un-doped material has a wide band gap of 4.5 eV and can be used to detect Cherenkov light. The temperature dependence of the scintillation light LY(T) is 0.05 %/°C which is 40 times lower than in $PbWO_4$, for example. Therefore, detectors based on DSB will be tolerant to temperature variation in the range of -20°C to +20°C. Thus, DSB: Ce can be considered to be a perspective material for application in calorimetry.

Several samples have been irradiated at the Radiation Centre (Giessen, Germany) using a ^{60}Co source at a dose rate of 2 Gy/min. Figure 1 presents the transmission spectra of Ce-doped (more than 1% in weight) DSB: Ce, before and after irradiation with γ-quanta.

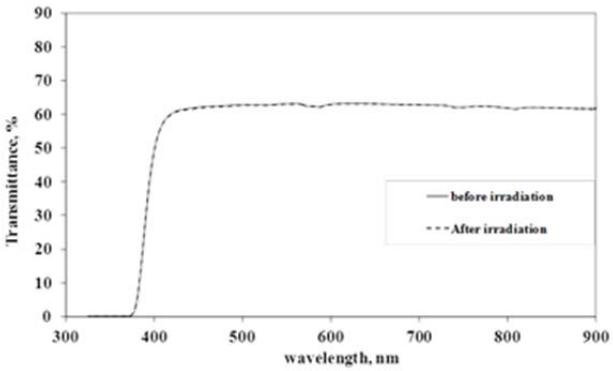

Figure 1: Comparison of optical transmission spectra of DSB: Ce samples before and after irradiation with ^{60}Co with an absorbed dose of 100 Gy measured at room temperature. The thickness of the sample was 4.5 mm.

The effect of stimulated recovery of the radiation damage was observed so far in self-activated scintillation materials, namely $PbWO_4$ [2]. Due to the presence of cerium ions with a high capture cross-section of free carriers was expected that Ce-doped scintillation materials should show a fast recombination of color centers, especially created due to shallow traps.

However, even at a high concentration of Ce^{3+} in the inorganic material our study shows that spontaneous recovery is a relatively slow process. Up to 25% of damaged transmission is recuperated in 6 hours and afterwards induced absorption remains practically stable if the samples kept in the dark. The induced absorption is decreased by a factor of two by annealing at 50°C and completely removed in a short time at 100°C, respectively. Annealing of the majority of the color centers above room temperature and their slow spontaneous recombination at room temperature show that they are due to deep traps which only weakly interact with cerium ions.

Further acceleration of the recombination of these color centers can be achieved by illumination with optical photons. Figure 2 shows the influence of the light illumination on the recovery of the induced absorption coefficient of a heavy doped DSB: Ce sample in comparison with spontaneous recovery at room temperature. This effect is achieved by photons using a LED at a photon flux of $2.9 \cdot 10^{16}$ photons/s exposing the wrapped sample.

However, the time constants for the recovery progressively increase with shifting towards the IR region. Stimulated relaxation provides simultaneous drop of the induced absorption over a wide spectral region. The illumination of the sample with blue light, which causes the ionization of the color centers, provides the fastest recuperation of the radiation induced damage.

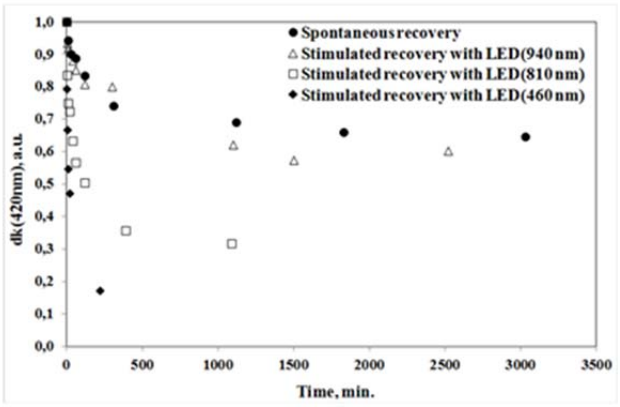

Figure 1: Stimulated recovery with optical photons of different wavelengths of the normalized radiation induced coefficient at 420 nm of a heavy-doped DSB: Ce sample after an absorbed dose of 500 Gy (^{60}Co).

References

[1] E. Auffray, M. Kojik, A. Singovski, Experimental Study of Lead Tungstate Scintillator Proton-Induced Damage and Recovery, IEEE Trans. on Nucl. Sci, 59 (2012) 2219-2223.

[2] A. Borisevich, V. Dormenev, T. Kuske, M. Korjik, S. Lugert, V. Mechinski, O. Missevitch,

DOI:10.15120/GR-2015-1-APPA-MML-MR-19

R.W. Novotny, A. Fedorov, Stimulated recovery of the optical transmission of $PbWO_4$ scintillation crystals for electromagnetic calorimeters after radiation damage, Nucl. Instr. and Meth. in Phys. Res. A 623 (2010) 1082-1085.

 DOI:10.15120/GR-2015-1-APPA-MML-MR-19