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Application of rare earth doped phosphate glasses in radiation dosimetry

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Presently ionizing radiation and radioactive isotopes are used in many fields of life, technology and medicine. Radiation and nuclear technologies are used for food and materials sterilization, radiation induced polymerization, materials modification, medical diagnostics and cancer therapies. In order to assure safe application of these technologies and to control radiation exposure to humans and natural environment radiation doses must be strictly controlled. For these reasons many techniques have been developed, which allow for radiation doses measurements. Currently many of these methods are used for particular dosimetric purposes. One of the most common in radiation dosimetry is method based on the themoluminescence properties of solid state materials. Thermoluminescence dosimetry (TLD) is based on the signal originating from electron-hole pairs recombination during heating of irradiated previously dosimeter. TL signal intensity is proportional to the dose absorbed within the material. The most often used materials in TL dosimetry are inorganic dosimeters based on the lithium fluoride (MTS-N, MCP-N).
However, preparation techniques of the presently used TLD dosimeters is difficult and their application for high doses and high dose rates measurements is problematic.
Our studies were dedicated to evaluation of rare earth elements (REE) doped phosphate glasses for application in high dose dosimeters.
A series of phosphate glass (PPG) samples doped with 0.5-1.5% of Eu2O3, Gd2O3 and CeO2 REE oxides were prepared by quench-melt technique. The initial phosphate glass matrix composition used was based on the P2O5, Na2O and Al2O3 oxides in amounts of 56, 32 and 12% (w/w) respectively. The starting materials used for synthesis were ammonium dihydrogen phosphate (NH4H2PO4), sodium carbonate (Na2CO3), aluminum oxide and respective REE oxide. Before synthesis batch components were grinded in an agate mortar and next melted in Al2O3/ZrO2 95/5 composite crucible. For decomposition of batch components, NH4H2PO4 and Na2CO3, batch was heated to and maintained in 800-900℃ for 3 hours and subsequently heated to 1200℃. After 3 hours melt were poured on a stainless steel plate preheated to 400℃. To assure homogenous distribution of all glass components, especially REE, after cooling and crushing, samples were grinded in ZrO2 planetary ball mill and subsequently melted in 1000℃ and finally poured again on the stainless steel plate. Dosimetric experiments were carried out in IARC using installed radiation sources. Glass samples in the form of small pieces (ca. 20 mg each) were irradiated with electron beam (linear electron accelerator ELU-6E, 6 MeV) or with Co-60 gamma source. Radiation doses varied from a few Gy up to 1 Mgy. TLD measurements were performed with TL RA-94 thermoluminescence reader.
As a results of our studies, it has been found, that for investigated glasses within the doses ranges of 50-100 kGy the most intense TL signal was observed for 1.5% CeO2 doped PPG glass. The best linearity of the TL signal vs. absorbed dose was found for 1.5% Gd2O3 doped glass. Pure, undoped PPG matrix was not as effective as REE PPG glasses taking into account both their sensitivity and response linerity. Proposed glasses can be considered as prospective materials for radiation dosimetry unless optimization of the glass composition and improvement of the preparation methods leading to the final dosimeters forms.

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