Phosphors for thermoluminescence radiation dosimetry

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Radiation dosimetry using luminescence techniques has made tremendous progress in the past fifty years. Several techniques have now found routine use and have received due recognition. Among the variety of luminescence process, thermoluminescence dosimetry (TLD), optically stimulated luminescence (OSL) dosimetry, radiophoto-stimulated luminescence (RPL) dosimetry and scintillation systems are of main relevance. In the field of radiation protection, especially individual monitoring of radiation workers TLD, OSL and RPL have made great impact with TLD still keeping the lead in terms of the choice of dosimeter. TLD has virtually replaced the film dosimetry in personnel monitoring. Thermoluminescence (TL) technique is now extensively used for dosimetry of ionizing radiation. Studies on radiation induced defects in insulating and semiconducting materials have been interesting over the last few decades. TL is one such process in which radiations produce defects in crystalline materials. The interaction of ionizing radiation with a material creates electron-holes pairs and allows electrons and/or holes to be trapped in localized states inside the band gap at defect sites. These electrons can be trapped at defects in the material lattice and remain trapped for either a short or a long period according to the depth energy associated to the trapping levels and to the temperature of the material at which it is kept for particular time (period). Subsequent heating of the irradiated material releases the trapped electrons and/or holes which latter on recombine themselves radiatively gives rise to emission of light. The study of the luminescence as a function of the temperature, the so called glow curve, is used to determine the trapping parameters and its integral is proportional to the radiation dose absorbed by the irradiated sample. The position, shape, and intensities of the glow peaks are related to the properties of traps responsible for the TL. Thermoluminescence study of pure and activated natural as well as synthetic material, in single crystalline and polycrystalline powder form, prepared under different physical conditions has been the subject of the research in the past few decades. Many scientists in India and abroad have investigated TL of different materials, studied their mechanisms and found number of them useful in TL applications. Among them, the most striking one is the TL dosimetry, which gives precise estimation of the radiation done and the information of its nature of radiation, which are frequently needed in radiation applications by professionals in different fields. Many materials have been found to be of use in the preparation of TLDs [1-14]. In thermoluminescence dosimetry the relationship between the signal and the absorbed dose to be measured must be determined by the appropriate calibration.

Thermoluminescence dosimeters have found increasing applications with the progress made in the development of solid thermoluminescence dosimeters and instrumentation for reading them. Many TLD based systems are now commercially available, and are widely used in routine personnel dosimetry, environmental monitoring and clinical radiation dosimetry. The extreme sensitivity of TL for detecting the presence of defects is beneficial for detecting low radiation levels, which are encountered in personnel and environmental monitoring.

Nanoscience and nanotechnology have attracted many workers in various fields from material science to biotechnology and genetics. Currently, the importance of nanomaterials in the field of luminescence, has been increased, especially, as they exhibit enhanced optical, electronic and structural properties. They have potential as efficient phosphors in display applications such as new flat panel displays with low energy excitation sources, solar energy converters, optical amplifiers and TLD phosphors. Many new physical and chemical methods of preparations have also been developed in the last two decades, nanoparticles and nanorods (powders) of several ceramic materials have been produced. More recent studies have revealed that optical, luminescence and other properties get modified by its shape and size, incorporation of impurities at different sites and also due to the presence or absence of certain defects.

Sulphates, borates, phosphates, fluorides, aluminates are known to be good thermoluminescence materials. One of the important subjects of investigation in the field of luminescence is the thermoluminescence dosimetry. A number of scientists all over the world have paid special attention to the development of TL dosimeter materials. They have suggested and standardized many materials. $CaSO_4$: Dy and Al_2O_3:C are used as phosphors in dosimetry ionizing radiations using thermoluminescence technique. High sensitivity, tissue equivalent, thermoluminescence dosimetry materials with simple glow curves and good thermal stability are important for the measurement of exposures in the field of medical physics. Only a few materials are found to possess all the above mentioned properties. At present, the commercially available, low atomic number (Z_{eff} = 7.4 for tissue) phosphors are LiF, $Li_2B_4O_7$, MgB_4O_7 and BeO. LiF activated with Mg and Ti(LiF:TLD 100) is extensively used. In view of this, the systematic TLD work on inorganic materials has been undertaken in our laboratory. Attempts have been made to investigate the possibility of the use of inorganic materials other than well-known $CaSO_4$:Dy and LiF TLD 100, in estimation of radiation dose. In recent years, several phosphors have been reported [15-24], which possess properties useful for thermoluminescence dosimetry of ionizing radiations. Some new phosphors $K_2Ca_2(SO_4)_3$:Eu; $K_3Na(SO_4)_2$:Eu; $CaSO_4$:P,Dy; LiF:Mg,Ti; MgB_4O_7:Dy; $Li_2B_4O_7$:Cu; $KMgF_3$:Eu; Li_3PO_4:Cu,Mg; $Sr_5(PO_4)_3Cl$:Eu; $Sr_2B_5O_9Cl$:Eu, $Na_{21}Mg(SO_4)_{10}Cl_3$:Dy; $Na_{21}Mg(SO_4)_{10}Cl_3$:Eu; $Sr_5(PO_4)_3Cl$:Eu; $KMgSO_4Cl$:Ce,Dy ; $KMgSO_4Cl$:Eu; $KZnSO_4Cl$:Eu; $KZnSO_4Cl$:Ce, Dy ; Na_3SO_4F:Ce,Dy ; $SrMgAl_{10}O_{17}$:Eu,Dy; $SrAl_2O_4$:Cu; $Na_5(PO_4)SO_4:Cu^+$ $NaMgSO_4F$:Ce,Cu; $Sr_6BP_5O_{20}:Ce^{3+}$; $Ca_6BP_5O_{20}:Ce^{3+}$ and Li_2SO_4:P,Dy are prepared easily with appreciable TL efficiency as compared to the conventional $CaSO_4$:Dy and LiF-TLD 100 (low Z) phosphors used in the thermoluminescence dosimetry of ionizing radiations using □-rays dose (^{60}Co). Some of the aluminate based phosphors $BaMgAl_{10}O_{17}$:Eu,Dy; $SrMgAl_{10}O_{17}$:Eu,Dy and $CaMgAl_{10}O_{19}$:Eu,Dy show prominent TL peak at higher temperature and its TL intensity is higher as compared to $CaSO_4$:Dy TLD phosphor using □-rays dose (^{137}Cs).

It is more popular for the TL dosimetry of ionizing radiations, since the TL intensity is proportional to the radiation doses. Therefore, phosphors in submicron size are applicable for low radiation dose measurements in personal dosimetry. The radiation absorption rate in the nanomaterials is very less as compared to bulk particles as well as the nanoparticle response curves with exposure are linear upto high radiation doses. Therefore, nanophosphors are applicable for high dose measurements in radiation therapy and accidental dosimetry. Thermoluminescence properties of nanocrystalline $K_2Ca_2(SO_4)_3$:Eu, $Li_2B_4O_7$:Cu, $K_3Na(SO_4)_2$:Eu, $Ba_{0.12}Sr_{0.88}SO_4$ [25-28] prepared by ball milling technique, combustion synthesis, chemical co-precipitation method have been studied and the nanophosphor's suitability as an effective gamma radiation dosimeter material has been examined. It is found that the nanophosphor is suitable for dosimetry over a very wide range of doses for gamma and other radiations. Presently, synthesis, characterization and evaluation of trapping parameters work of bulk and nanophosphors are going on in our laboratory. The important events of high sensitive phosphors obtained are presented.

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