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Name of Scholar**: DEBASHISH SEN**

Name of Supervisor**: Prof. Mohammad Zulfequar / Dr. K. Asokan**

Name of Department**: Physics**

Title of PhD: **Optically Stimulated Luminescence Dosimetry for Tissue-Equivalent Systems**

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Abstract: Ionizing radiations, very common in accelerator research and medical fields, are at the same time hazardous & beneficial for us. Controlling and monitoring the level of radiation is important. Radiation dosimeters are detectors that are meant to measure the absorbed radiation dose, i.e. the quantum of energy deposited by radiation in matter, particularly living tissue. These are very useful to get an idea about the dose the person is getting exposed to. Factors like time, distance, appropriate shielding and the basic ALARA principle of radiation safety ensure no extra exposure without any net positive benefit. The effects of radiation can be stopped or controlled in a limited way by suitable shielding materials like lead (Pb) and concrete blocks. Apart from keeping radiation exposure below safe limit, dosimetry plays a vital role in radiation therapy for cancer treatment in the medical context, i.e. in diagnosis and therapy. Accurate calculations and precise monitoring of radiation doses ensure that the therapeutic doses are effectively targeted at the cancer cells while serving minimum damage to the surrounding healthy tissues. Thermoluminescence Dosimetry (TLD) and Optically Stimulated Luminescence (OSL) Dosimetry are both widely used techniques in radiation dosimetry, especially in fields such as medical physics, radiation therapy, and radiation protection. When it comes to tissue-equivalent systems, these techniques become particularly valuable for accurately measuring radiation doses in materials that mimic human tissue. In tissue-equivalent systems, the goal is to simulate the response of human tissue to radiation as closely as possible. This is essential for various applications, including testing the efficacy and safety of radiation therapy protocols, assessing radiation exposure in occupational settings, and evaluating the impact of radiation on biological systems.

In the last decade, Inter University Accelerator Centre of New Delhi has expanded its vision and installed/planned new accelerator facilities like RBS, AMS, HCI, and FEL. For the safety of radiation workers, calculations related to the level of radiation and required shielding, etc were carried out. The major objective of this thesis work was on two aspects of radiation: (i) Theoretical calculations related to radiation shielding of selected accelerator facilities of IUAC and (ii) fabrication and characterization of some dosimetric materials, namely Dy^{3+} doped $Li_3PO_4$and Tb^{3+}doped LiF which can play very good role in tissue equivalent dosimetry.

Lithium phosphate (Li_3PO_4) doped with rare earth Dy^{3+} ions were prepared as a part of this doctoral study with varying concentrations of Dy. The characterizations were done using X-ray diffraction, Fourier Transform Infrared-Attenuated Total Reflection spectroscopy, and Scanning Electron Microscopy. Samples were also irradiated with γ rays of different doses and by UV-C rays for different exposure duration. Various promising properties of this material were identified in this study that suggests it as a TL dosimeter. Overall, it was found that the phosphor exhibits desirable properties such as human tissue equivalence ($Z_{eff} \approx 10.59$), appreciable linear TL response, dosimetric peaks at high temperatures, excellent repeatability and low fading (for UV-C radiation). These characteristics show that Li_3PO_4:Dy may be further explored for applications in medical and personal dosimetry.

Lithium Fluoride (LiF) stands out as an extensively researched material in TLD. This study specifically delves into nanocrystalline Tb-doped LiF TL dosimeters and evaluates their efficacy under He ion

and gamma ray radiation. Additionally, gamma doses displayed a highly promising response to OSL. Impressively, this material demonstrates sensitivity to both He ions and gamma radiation. Also, the material offers promising characteristics for OSL applications relevant to dosimetry and dating. The unique characteristics of the glow curves, dose-response behaviours, and OSL responses highlight the versatility and effectiveness of these nanophosphors in radiation dosimetry, making significant contributions to advancements in this field.

The thesis is presented in total six chapters including introduction, experimental techniques and the conclusion and future scope.

Chapter 1 describes the understanding of the concept of ionising radiation and its effects on materials and biological matter. An overview starting from discovery of radiation, the journey from early dosimetry to modern dosimetry, evolution of different type of dosimeters, understanding the biological effects of radiation and its accurate assessment, role of biological dosimetry in ensuring the safety and efficacy of medical procedures involving both radiation therapy and diagnosis, thereby, enabling very precise radiation treatment with minimum risks associated with radiation exposure have been discussed. Basic mechanisms of thermoluminescence dosimetry and optically stimulated dosimetry, along with the ideal characteristics for choosing a material for such radiation dosimetry have been summarized.

Chapter 2 summarizes the preparation and characterization of these dosimetric materials involving several key steps to ensure their suitability and reliability for radiation dosimetry applications. A structured approach to understand and undertake two of these preparation processes has been summarized here, namely solid-state diffusion method and chemical co-precipitation method. Some of the characterization techniques like X-Ray Diffraction (XRD), Transmission Electron Microscope (TEM), Field Emission Scanning Electron Microscopy (FE-SEM), Fourier Transform Infra-Red Attenuated Total Reflection Spectroscopy have been briefly explained.

Chapter 3 discusses the details related to dosimetry & radiation shielding calculations with specific reference to the Inter-University Accelerator Centre, New Delhi which houses many accelerators. Radiation shielding calculations were carried out for selected facilities like High Current Injector (HCI), Rutherford Backscattering Spectrometry (RBS), Accelerator Mass spectrometry (AMS), Free Electron Laser (FEL) facility and are presented in this chapter.

Li_3PO_4 doped with rare earth Dy^{3+} ions were prepared as a part of this doctoral study (presented in Chapter 4) with varying concentrations of Dy. The characterizations were done using X-ray diffraction, Fourier Transform Infrared-Attenuated Total Reflection spectroscopy, and Scanning Electron Microscopy. Samples were also irradiated with γ rays of different doses and by UV-C rays for different exposure duration. Various promising properties of this material were identified in this study that suggests it as a TL dosimeter. Overall, it was found that the phosphor exhibits desirable properties such as human tissue equivalence ($Z_{eff} \approx 10.59$), appreciable linear TL response, dosimetric peaks at high temperatures, excellent repeatability and low fading (for UV-C radiation). These characteristics show that Li_3PO_4:Dy may be further explored for applications in medical and personal dosimetry.

Lithium Fluoride (LiF) stands out as an extensively researched material in TLD as an ideal tissue equivalent. This study (presented in Chapter 5) specifically delves into nanocrystalline Tb-doped LiF TL dosimeters and evaluates their efficacy under He ion and gamma ray radiation. Additionally, gamma doses displayed a highly promising response to OSL. Impressively, this material demonstrates sensitivity to both He ions and gamma radiation. Also, the material offers promising characteristics for OSL applications relevant to dosimetry and dating. The unique characteristics of the glow curves, dose-response behaviours, and OSL responses highlight the versatility and effectiveness of these nanophosphors in tissue equivalent radiation dosimetry.

The final chapter summarizes all the findings of this research work and highlights the future scope of tissue equivalent radiation dosimetry.