SRI VENKATESWARA INTERNSHIP PROGRAM FOR RESEARCH IN ACADEMICS (SRI-VIPRA)

SRI-VIPRA

Project Report of 2024: SVP-2410

"Synthesis of Radiation Dosimeters"

IQAC
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SRIVIPRA PROJECT 2024

Title : Synthesis of Radiation Dosimeters

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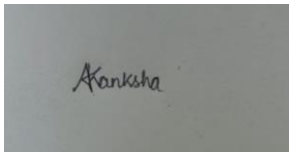
1		Akanksha	1822044	Bsc. (H) Physics	
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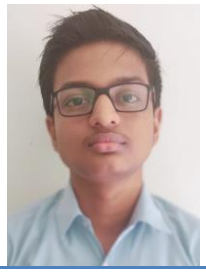
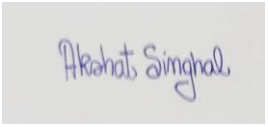
5		Akshat Singhal	1823054	Bsc. (H) Physics	
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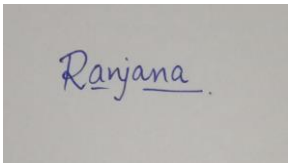
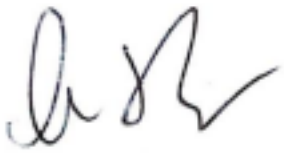
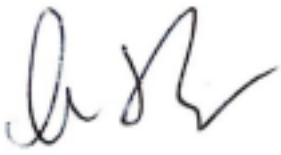
7		Ranjana	1823005	Bsc. (H) Physics	



Signature of Mentor

Certificate of Originality

This is to certify that the aforementioned students from Sri Venkateswara College have participated in the summer project SVP-2410 titled "**Synthesis of Radiation Dosimeters"**.The participants have carried out the research project work under my guidance and supervision from 1st July, 2024 to 30th September 2024. The work carried out is original and carried out in an online/offline/hybrid mode.



Signature of Mentor

Acknowledgments

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Abstract

We have reported a collection of three sub-projects under the topic of Radiation Dosimetry, to study the Thermal Luminescence properties of three different materials, namely, Lithium Tetraborate($Li_2B_4O_7$), Lithium Silicate(Li_2SiO_3) and Magnesium Tetraborate(MgB_4O_7) doped with Dysprosium[Dy(III)], Terbium[Te(III)], Europium[Eu(III)] and Dysprosium[Dy(III)] respectively in varying quantities by weight. The TL analysis was done by a Gamma Radiation source of Co-60 with a dose of 10Gy. The materials were synthesized using Solid State Reactions and Solution Combustion Synthesis method. The TL glow curve is analyzed with peaks varying for different concentration dopants. Multiple depth traps were observed. The investigations presented the materials as potential personal dosimeters for Gamma rays by studying their corresponding TL properties for different energy radiations and tissue equivalent properties. Further studies are required to establish these materials as reliable dosimeters for personal and industrial use.

KEYWORDS- radiation dosimetry, thermo-luminescence, solid-state reaction, solution combustion synthesis, lithium tetraborate, lithium silicate, magnesium tetraborate, gamma radiation, depth trap.

1 Introduction

Thermoluminescence (TL) is a phenomenon where certain materials emit light when heated after being exposed to radiation. This unique property is widely used in various applications, particularly in

Radiation Dosimetry, where TL materials serve as effective detectors of ionizing radiation. These materials can store energy from radiation and release it as light when subjected to thermal stimulation, making TL a vital area of research in material science.[1]

This research project investigates the luminescent properties of three distinct materials: Lithium Tetraborate ($Li_2B_4O_7$), Lithium Silicate(Li_2SiO_3), and Magnesium Tetraborate(MgB_4O_7). Each of the three materials presents unique luminescent characteristics and potential applications.

Thermoluminescence of Lithium Tetraborate ($Li_2B_4O_7$): Lithium Tetraborate is well-known for its effectiveness in radiation dosimetry and has been extensively studied for its TLD properties. It is used in the production of glass and ceramics and due to its Tissue-equivalent nature, it is particularly useful for TL dosimetry. $Li_2B_4O_7$ exhibits perfect linearity, which enhances its performance.

Thermoluminescence of Lithium Silicate (Li_2SiO_3): In contrast to the borates, lithium silicate exhibits a broader range of luminescent responses.Lithium Silicate in pure form and doped with Terbium(III) prepared by a solid-state reaction between Amorphous Silicon dioxide gel and Lithium Carbonate. Its ability to trap charge carriers effectively allows it to store energy, which is released as light upon heating.

Thermoluminescence of Magnesium Tetraborate (MgB_4O_7): Magnesium Tetraborate is emerging as a promising thermoluminescent material. Here, it is synthesized using the Solution Combustion Synthesis (SCS) method and is doped with Europium (III) and Dysprosium (III). It has a high sensitivity to ionizing radiation, making it suitable for measuring low radiation doses.

1.1 Radiation

Radiation is the emission or transmission of energy in the form of waves or particles through space or a medium.[2] It can occur naturally or be generated artificially and is categorized into two types: **Ionizing Radiation**, which has enough energy to remove electrons from atoms (e.g., X-rays, gamma rays), and **Non-Ionizing Radiation**, which does not have enough energy to ionize atoms (e.g., radio waves, microwaves). It can affect matter in various ways, depending on its type and energy level. It is energy that moves through space, like light from the sun or heat from a fire.[3] Some kinds of radiation are harmless, like the light we see, but others, like X-rays or radiation from radioactive materials, can be more powerful. Powerful radiation can affect our bodies, so we use special tools to check and limit

exposure to it, especially in places like hospitals and nuclear power plants. Radiation can be detected and measured using various instruments, depending on the type of radiation (ionizing or non-ionizing). It can be checked using Geiger-Müller (GM) Counters, Dosimeters, and Ionization Chambers.

1.2 Radiation Dosimetry

Radiation dosimetry, commonly known as "dosimetry," is the science of measuring the absorbed dose or dose rate that results from the interaction between ionizing radiation and matter such as x-rays and gamma rays. More broadly, dosimetry encompasses the determination—through measurement or calculation—of various radiologically significant quantities. These include absorbed dose, exposure, kerma, fluence, dose equivalent, and energy imparted, among others. Absorbed dose refers to the amount of radiation energy absorbed per unit mass of material, measured in grays (Gy) in the SI system, where 1 Gy equals 1 joule of energy deposited per kilogram of matter. The dose equivalent combines the absorbed dose with the biological effectiveness of the radiation type accounting for the greater biological damage caused by alpha and neutron radiation compared to beta and gamma radiation.[1]

A dosimeter should remain stable over time, including its shelf life and in situ period before radiation exposure. Environmental factors like temperature, oxygen, humidity, and light can affect its sensitivity or background signal. Photographic, chemical, and solid-state dosimeters are more vulnerable than ion chambers. Thermoluminescent dosimeters, like LiF, may slowly change sensitivity due to trapping center rearrangements but can be managed through annealing. Some dosimeters may experience "fading" after exposure. Environmental conditions can worsen this, and standardized techniques can help apply corrections to ensure consistent readings.

1.3 Applications of Radiation Dosimetry

Radiation dosimetry finds its application in various fields including medicine, nuclear industry, environmental monitoring, and research.

Radiation dosimetry in health physics and radiation protection involves measuring, calculating, and assessing the ionizing radiation dose absorbed by an object, typically the human body. This includes internal exposure from ingested or inhaled radioactive substances and external exposure from radiation

sources. Internal dosimetry utilizes various monitoring and imaging techniques, while external dosimetry relies on dosimeters or measurements from radiological protection instruments.[4]

Dosimetry is essential for protecting radiation workers by tracking exposure in routine and unexpected situations. It's also used in medical treatment to monitor doses and in environmental assessments like radon monitoring in buildings. Radiation workers use personal dosimeters, which have advanced from film badges to modern devices like TLDs, OSL badges, and EPDs. These devices offer real-time dose monitoring and alarms for excessive exposure.

In medical settings, dosimetry helps optimize radiation therapy, typically managed by health physicists. It uses percentage depth dose curves, dose profiles, and 3D assessments like gel dosimetry.

2 Thermoluminescence properties of $Li_2B_4O_7$:Dy

2.1 Brief Overview

Lithium Tetraborate is a white powder used in the production of glass and ceramics. With a molar mass of 169.11 g/mol and a melting point of 917°C (1,190K), it forms a colourless solid when in glass form. Its structure consists of a polymeric borate backbone with both Trigonal Planar and Tetrahedral boron centers, and Li^+ ions bound to four and five O^{2-} ligands. Lithium Tetraborate glasses have applications in ceramic coatings for electrodes, dielectric materials, rechargeable batteries, white light-emitting materials, and gamma and neutron radiation shielding.[7] Due to its tissue-equivalent nature (Z_{eff} = 7.3 compared to the biological soft tissue Z_{eff} of 7.4), it is used in Radiation Dosimetry applications.[9] Lithium Tetraborate exhibits perfect linearity, which is a beneficial Thermoluminescent (TL) property when doses greater than 10^3 Gy are applied.

Dysprosium(III) Oxide (Dy_2O_3) is a yellowish-green, hygroscopic sesquioxide compound with specialized uses in ceramics, glass, phosphors, and lasers. It has a cubic structure with a Dy^{3+} oxidation state.[8]

We have reported the production of $Li_2O{\cdot}2B_2O_3$ glass chips using the melt-quench method[6], formed by the solid-state reaction between Li_2CO_3 and H_3BO_3 in a 1:4 ratio at 950°C and annealed at 350°C. The glass chips were doped with Dy_2O_3 in varying percentages by mass (0.1%, 0.2%, 0.3%). The TL signal and dosimetry properties of both doped and undoped samples were studied.

2.2 Literature Review

Lithium Tetraborate has attracted scientific attention due to its Thermoluminescent properties. For use in TL dosimetry, Lithium Tetraborate is activated by adding various metal dopants. In previous studies, glass chips of $Li_2O.2B_2O_3$ were fabricated with dimensions of 10 mm × 10 mm × 1 mm, formed by the solid-state reaction between Li_2CO_3 and H_3BO_3 at 950°C and annealed at 350°C. The glass chips were irradiated with gamma radiation, and TL measurements were performed using a linear temperature

profile with a heating rate of 2°C/s. The results indicated a broad glow curve with a peak at 185°C. The TL intensity and integrated counts were found to be linearly correlated with gamma dose.

The glass chips demonstrated TL sensitivity at 52 counts/mGy, and the repeatability rate of dosimetric performance was found within ±10%. It was concluded that the prepared glass chips could be used as TL dosimeters for gamma doses of 100 mGy and higher. Another study measured the TL response of Lithium Tetraborate glass doped with 0.1% Cu and 0.004% Ag using the solution-assisted method. All the prepared samples displayed a stable TL response, and the product was characterized using X-ray diffraction (XRD), Scanning Electron Microscopy (SEM), and Fourier Transform Infrared Spectroscopy (FT-IR).[2]

2.3 Material and Methodology

TLD involves measuring the intensity of visible light emitted by a material when heated, following prior exposure to ionizing radiation. $Li_2B_4O_7$ possesses properties similar to human tissue[9], making it a favourable choice for medical and personal dosimetry. Its effective atomic number is close to that of soft tissue, which allows for accurate dosimetry in medical applications. Lithium Tetraborate is commonly used due to its tissue equivalence. It is effective for detecting various types of radiation, including gamma rays, X-rays, and beta particles.

2.3.1. FORMATION OF LITHIUM TETRABORATE

Lithium Carbonate (Li_2CO_3) in amounts of 1.998g, 1.996g, and 1.994g, along with Boric Acid (H_3BO_3) in amounts of 6.694 g, were mixed in solid form in a 1:4 stoichiometric ratio. Dysprosium Oxide (0.1%, 0.2%, 0.3% by weight) was added, and the mixture was ground for around 1 hour to ensure uniform mixing. A small amount of acetone was added during grinding to achieve uniformity.

2.3.2. MELTING

The mixture was transferred to a ceramic crucible and subjected to a temperature of 950°C in a furnace for 0.5 hours, leading to the melting reaction:

$$Li_2CO_3 + 4H_3BO_3 \rightarrow Li_2B_4O_7 + 6H_2O + CO_2$$

After 0.5 hours, the crucible containing the molten substance was removed, and the molten substance was poured onto a metallic plate. A second metallic plate was pressed onto it to form thin glass chips

FIG-1.MUFFLE FURNACE HEATING THE HOMOGENISED MIXTURE

2.3.3. ANNEALING

The glass chips were then annealed at 300°C for 4 hours. The developed chips were characterized for material and radiation dosimetry properties. For radiation experiments, the glass chips were exposed to Co-60 gamma radiation using gamma chambers at IUAC, New Delhi. All measurements were performed using a TLD reader.

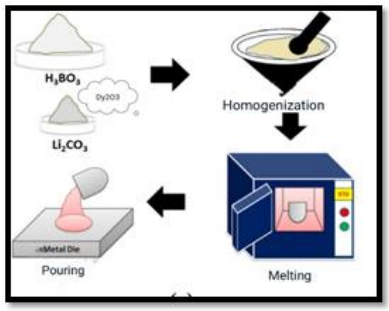

FIG-2. PROCESSES INVOLVED IN THE FABRICATION OF $Li_2O.2B_2O_3$.(Dy) GLASS CHIPS

FIG-3. FINAL GLASS

2.4 TL Analysis

Fig-4 shows the TL glow curve recorded by exposing the undoped pure glass chip to 10Gy dose and subjecting the temperature to increasing with time from 50°C to 400°C. The curve obtained upon plotting Temperature Vs TL signal intensity is a broad curve with a peak attained at 176°C with a TL signal value of 377735.

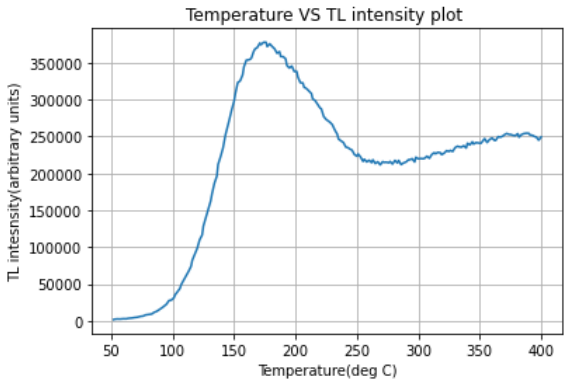

FIG-4.INTENSITY CURVE FOR UNDOPED PURE SAMPLE

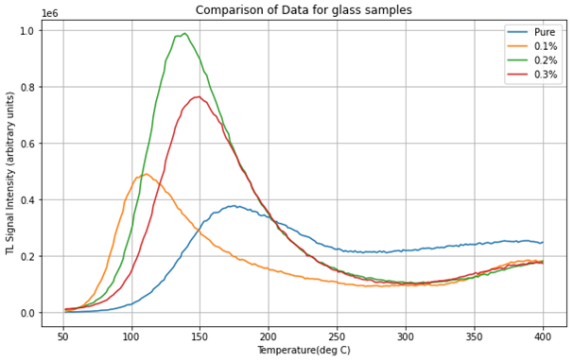

FIG-5. INTENSITY CURVES FOR GLASS OF DIFFERENT CONCENTRATIONS

Next, the doped samples were irradiated and their TL curves were studied. For the sample doped with 0.1% of Dy_2O_3, the peak is at 111°C with a TL intensity value of 490964. For the 0.2% doped sample, the peak was found to be at 139°C with a TL intensity value 988601. For the 0.3% doped sample, the peak was found to be at 150°C and the TL intensity of 763957. Their graphs are plotted in Fig-5.

Fig -6 Shows the graphs plotted for the Concentration of dopant vs. Maximum intensity.

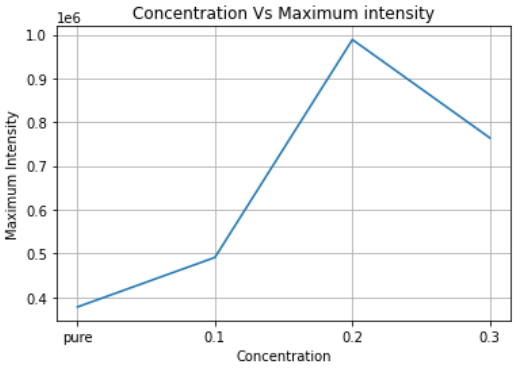

FIG-6- PLOT BETWEEN CONCENTRATION AND MAXIMUM INTENSITY

3

Thermoluminescence properties of Li_2SiO_3:Tb

3.1 Brief Overview

This research focuses on improving the efficacy of dosimeters by synthesizing various materials with enhanced thermoluminescence (TL) and optically stimulated luminescence (OSL) properties through the incorporation of suitable dopants. Specifically, we have synthesized lithium silicate (Li_2SiO_3) both in its pure form and doped with terbium ($Tb3^+$). Lithium metasilicate demonstrates excellent thermal stability, maintaining its structural integrity at elevated temperatures, making it ideal for high-temperature applications. Additionally, when doped with specific elements, it exhibits luminescent properties, which are crucial for dosimetry and radiation detection. The choice of dopants directly influences the material's luminescence, and Li_2SiO_3, when doped appropriately, is suitable for radiation exposure measurements due to its inherent luminescent properties[12]

3.2 Literature Review

Lithium silicate (Li_2SiO_3) has been identified as a promising host lattice for rare-earth-doped phosphors, owing to its chemical stability, ease of synthesis, and optical transparency. Previous research has shown that rare-earth dopants significantly enhance the luminescent properties of Li_2SiO_3. Rare-earth-doped phosphor systems are widely used in applications such as displays, LEDs, and solid-state lighting due to their high luminescence efficiency and narrowband emissions, which arise from intra-4f transitions of rare-earth ions, largely unaffected by the host matrix. Eu^{3+}, Tb^{3+}, and Ce^{3+} dopants

have been extensively studied for their ability to produce sharp emission peaks across a broad spectral range. Among them, Eu^{3+} is particularly effective for applications in radiation dosimetry and thermoluminescence. In contrast, Tb^{3+} ions are suitable for producing green luminescence and have been used in radiation detection applications. For this study, Tb^{3+} was selected for its strong light emission in photoluminescence and scintillation, which are vital for TL properties.[10]

3.3 Material and Methodology

Lithium silicates were synthesized via a solid-state reaction, combining amorphous silica (SiO_2) gel and Li_2CO_3 under isothermal conditions at 900°C for 4 hours. The pure sample was prepared using 5g Li_2CO_3 and 4.06g SiO_2.[11] Further, 2.5g doped samples were created using Li_2CO_3 in varying amounts (2.4975g, 2.495g, 2.4925g, and 2.49g) and SiO_2 (2.03g) with different concentrations of terbium nitrate (Tb^{3+}) ranging from 0.1% to 0.4%. The mixtures were ground in acetone for 30 minutes, dried to evaporate the acetone, and then calcined at 900°C to obtain the final Li_2SiO_3 product using a muffle furnace.

Reactions Involved:

$$Li_2CO_3 + SiO_2 \rightarrow Li_2SiO_3 + CO_2$$

Fig. 7.
Grinding the Li_2CO_3 and SiO_2

Fig. 8.
Fine powder of the mixed

Fig. 9.
Heating the mixture in

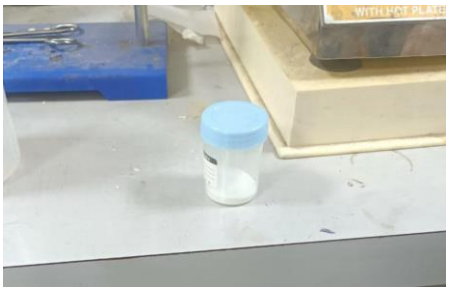

Fig. 10.
The final product after

3.4 TL Analysis

The thermoluminescence response of Li_2SiO_3 at different concentrations of Tb^{3+} is illustrated in the following graphs.

The fig.11 represents the thermoluminescence (TL) intensity as a function of temperature for different compositions doped with varying concentrations of ions.

As the concentration increases from 0.1 mol% to 0.2 mol%, there is a general increase in thermoluminescence (TL) intensity. The sample with 0.2 mol% shows the highest TL intensity among the doped samples. The sample with 0.4 mol% has the lowest TL intensity, suggesting that higher doping concentrations lead to luminescence quenching. All doped samples show two primary TL peaks around 100°C and 275°C, indicating that the trap depths or defect states responsible for the TL emission remain similar across different concentrations. The reduction in TL intensity with increasing concentration suggests a quenching effect. At higher concentrations, non-radiative recombination pathways likely dominate, reducing the luminescence efficiency. It finally signifies that the optimal

doping concentration for thermoluminescence is at 0.2 mol% , where the balance between activator and quenching effects is most favorable.

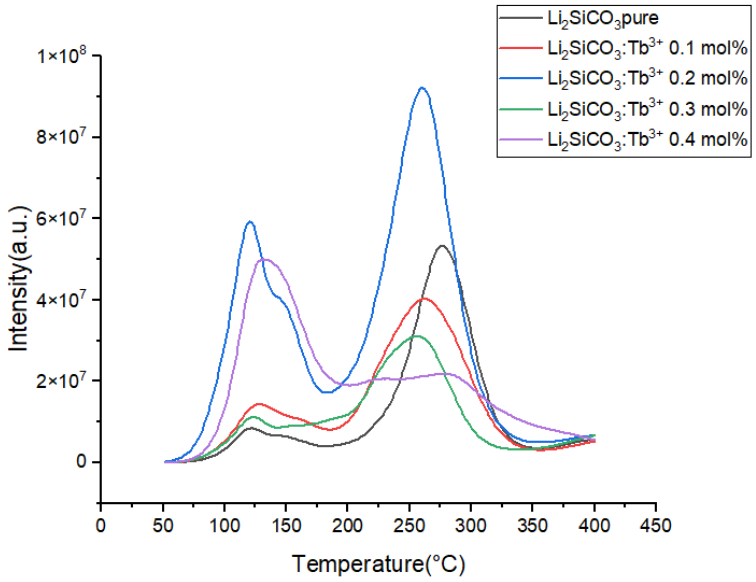

Fig. 11.
TL intensity is plotted

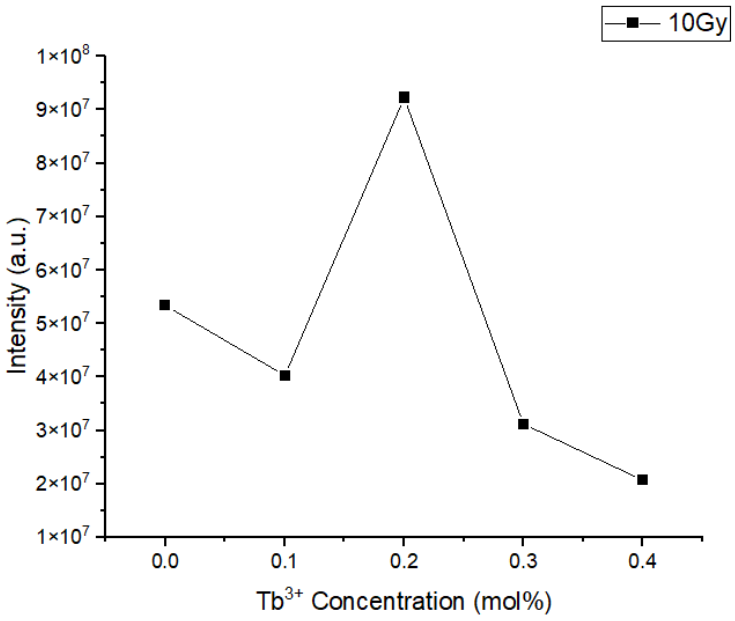

Fig. 12.
dopant concentration vs

The fig.12 presents the thermoluminescence (TL) response of Li_2SiO_3 (Lithium metasilicate) as a function of dopant concentration, with the x-axis representing dopant levels and the y-axis indicating luminescence intensity. This graph demonstrates the variation in TL response at different Tb^{3+}

concentrations . A distinct peak in the TL response is observed at a dopant concentration of 0.2%. The data demonstrate a pronounced increase in TL intensity with rising dopant concentrations from 0.0 to 0.2, culminating in a maximum response at 0.2. However, further increases in dopant concentration result in a significant decline in TL intensity, suggesting that 0.2%represents the optimal concentration for enhancing the thermoluminescent properties of Li_2SiO_3. This peak likely reflects an ideal structural or electronic state within the material at this concentration, facilitating efficient electron trapping and recombination processes that are critical for thermoluminescence. Conversely, elevated dopant concentrations appear to adversely affect the TL response, potentially due to the emergence of non-radiative recombination mechanisms or structural defects that quench luminescence.

4 Thermoluminescence properties of MgB_4O_7:Eu,Dy

4.1 Brief Overview

In this study, MgB_4O_7:Eu,Dy phosphors were synthesized using the Solution Combustion Synthesis (SCS) method. In this study the dopant concentrations of $Eu_{0.0\text{-}0.15\%wt}$ and $Dy_{0.0\text{-}0.15\%wt}$ were induced into MgB_4O_7. The synthesized material was exposed to gamma radiation from a Co-60 source. Thermoluminescence (TL) glow curve analysis, following gamma irradiation at 10 Gy, indicated that the optimal Eu^{3+} and Dy^{3+} concentration was $Eu_{0.1\%}$,$Dy_{0.1\%}$. The incorporation of these dopants was shown to enhance the TL sensitivity of the phosphor material.

The TL glow curve of MgB_4O_7:Eu,Dy showed multiple peaks at different temperature intervals, indicating various trap depths. The optimization of Eu^{3+} and Dy^{3+} concentrations was critical to maximizing the TL response, and the concentrations used in this study provided favorable dosimetric properties.

4.2 Literature Review

Borates are extensively utilized in radiation dosimetry due to their effective atomic number, linear dose-response, sensitivity, and simple production methods. These compounds exhibit a broad spectral response range, spanning from infrared (IR) to visible and ultraviolet (UV) wavelengths. Additionally, borates hold significant potential for various applications, including electronics and optoelectronics. The luminescence properties of rare-earth doped borates are particularly advantageous for exploring and investigating luminescent behavior. [14]

The compound MgB_4O_7 has attracted significant attention for thermoluminescence dosimetry due to its advantages, such as a low effective atomic number (Z_{eff}), high sensitivity when enhanced through doping, and ease of readout. Thermoluminescence dosimeters (TLDs) are passive radiation detectors that measure the dose absorbed by phosphors exposed to ionizing radiation. These devices are widely used in various fields, including environmental monitoring, space exploration, medical applications, and personnel dosimetry, with approximately 90% of personnel dosimetry worldwide relying on TLDs. MgB_4O_7, with its favorable chemical properties, wide bandgap, thermal stability, and tissue equivalency (Z_{eff} = 8.35), is particularly significant for radiation dosimetry, especially in personnel monitoring. However, its thermoluminescence (TL) sensitivity to ionizing radiation is relatively low, prompting us to explore ways to enhance TL sensitivity through ion doping. [13]

Currently, researchers are increasingly focusing on multi-ion co-doping to enhance luminous efficiency. Some research has demonstrated that luminous intensity can be modified by using different combinations of dopant and co-dopant particles.[15] Research has also shown that using equal concentrations of dopants results in lower transmittance, higher agglomeration, and improved thermoluminescence.[16]

The choice of Dy^{3+} (Dysprosium) and Eu^{3+} (Europium) as dopants is supported by their ionic radii, which are 0.911 Å and 1.807 Å, respectively. This significant difference in size allows for interesting interactions within the host lattice, potentially enhancing the properties of the material being developed. The ionic radius of 0.911 Å indicates a relatively smaller ion, which can lead to tighter packing in the crystal lattice. This can enhance stability and may influence luminescent properties positively due to reduced lattice strain. With an ionic radius of 1.807 Å, Eu^{3+} is considerably larger. This larger size can facilitate unique electronic transitions and enhance luminescence due to its ability to occupy larger sites in the crystal structure.

One of the primary benefits of the Solution Combustion Synthesis (SCS) method is its capability for in situ doping. This allows for the uniform distribution of dopants within the host material, enhancing the properties of the final product without requiring separate doping processes.[17]

4.3 Material and Methodology:

In this study, the Solution Combustion Synthesis method was employed to synthesize MgB_4O_7 phosphor doped with europium (Eu) and dysprosium (Dy). Both undoped MgB_4O_7 and doped MgB_4O_7:Eu,Dy phosphors were prepared, with Eu^{3+} and Dy^{3+} concentrations ranging between 0.05% and 0.15% by weight. The chemicals used in the synthesis included magnesium nitrate ($Mg(NO_3)_2 \cdot 6H_2O$), boric acid (H_3BO_3), urea (CH_4N_2O), europium(III) chloride ($EuCl_3$), and dysprosium(III) chloride ($DyCl_3$).

All chemicals used in this synthesis were high-purity raw materials sourced from SRL. The synthesis involved stoichiometric amounts of magnesium nitrate, urea, and dopant sources—europium(III) chloride and dysprosium(III) chloride. Additionally, a 25% excess of boric acid was introduced into the reaction zone, and the mixture was annealed at 900 °C for 2 hours to promote the formation of a solid phase with well-defined composition and structure. [13]

Initially, magnesium nitrate, urea, and boric acid were combined and dissolved in deionized water under continuous stirring for 2 hours at 300 °C on a hot plate.

$$Mg(NO_3)_2 \cdot 6H_2O + 4H_3BO_3 + CH_4N_2O \rightarrow MgB_4O_7 + CO_2 + 14H_2O + 4NO_2$$

After ensuring complete dissolution, the dopant ions (added in percentages by mass) were incorporated into the master solution, followed by a temperature increase to 500 °C for 30 minutes in the muffle furnace. Once all water was evaporated, an amorphous powder was obtained. This powder was subsequently annealed at 900 °C for 2 hours in a muffle furnace, resulting in the polycrystalline form of the phosphor.

In this process particles of MgB_4O_7:Eu,Dy{(0.05,0.05), (0.1,0.1), (0.15,0.15), at.wt.%} were synthesized. The synthesized nanoparticles were then used to study their TL properties.

Figure 1 illustrates the flowchart outlining the step-by-step procedure for the synthesis of our material MgB_4O_7 via Solution Combustion Method

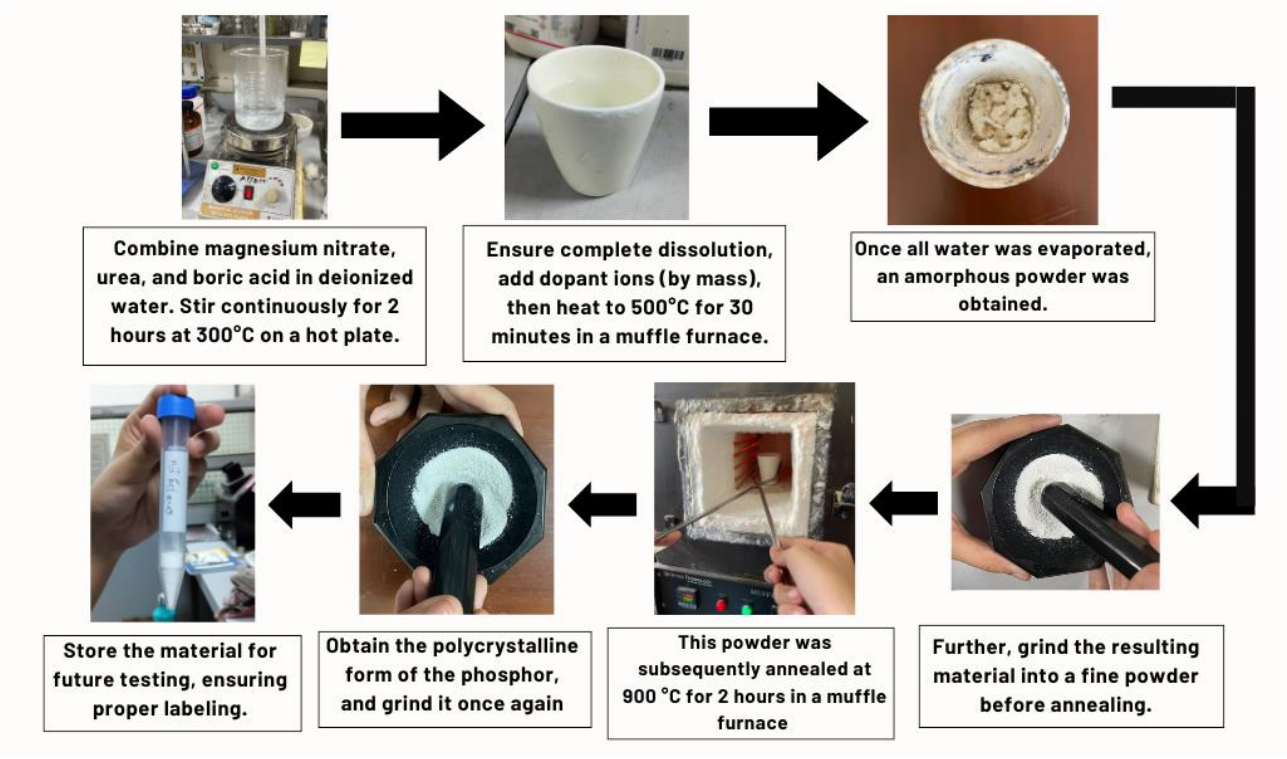

Fig. 13

4.4 TL Analysis:

TL intensity was recorded using (TLD Reader 3500) by heating the samples from 50˚C to 400˚C at a constant heating rate of 5˚C/s. The readings were taken and the data was plotted as shown in Figure (14). The TL intensity is plotted against the temperature and is called a TL glow curve. Figure (14) shows TL glow curves of the given phosphor at different dopant concentrations. It can be seen in the figure that the overall TL intensity of the given phosphor increases on increasing the dopant concentration from 0 mol% to 0.2 mol% and there is a sharp decrease in the TL intensity beyond 0.2 mol %.

Figure (15) shows a plot of dopant concentration (pure - 0.3 mol %) against the maximum TL peak intensity of MgB_4O_7:Eu,Dy samples irradiated with 10 Gy of gamma radiation. It can be observed in the figure that as the dopant concentration increases from 0.0 to 0.2 mol%, the TL intensity also increases. However, there is a drastic reduction in the TL intensity at 0.3 mol%. The reason behind this behavior shown by the phosphor lies in the fact that as there is an increase in the dopant

concentration there is a corresponding increase in the number of electron traps and recombination centers which thereby causes an increase in the TL intensity. However, beyond a typical critical value of the dopant concentration, self-absorption occurs within the phosphor, reducing its intensity. This phenomenon is called concentration quenching [18]. The TL intensity in the given phosphor is optimized at 0.2 mol %.

Figure (16) shows the TL glow curve of 0.2 mol%, with two peaks—one at 183℃ and the other approximately at 316.33℃. The first peak at 183℃ is located at a temperature that can be easily reached during readout.

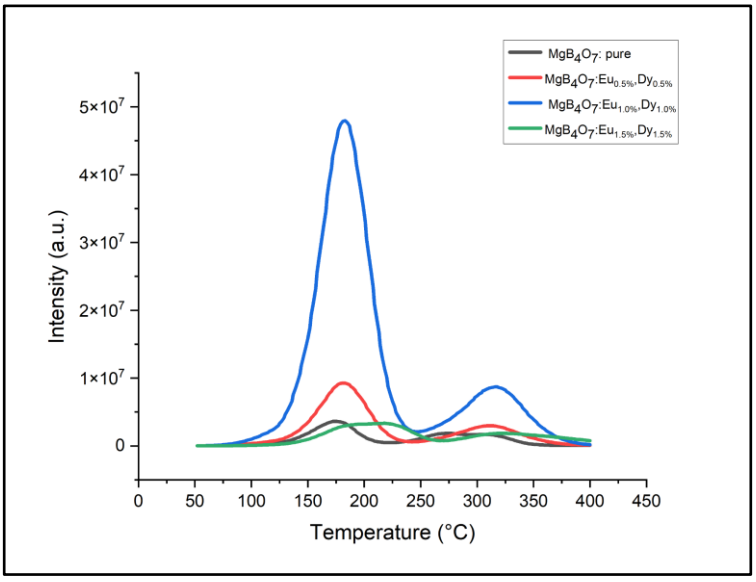

Fig. 14.
TL intensity is plotted against the

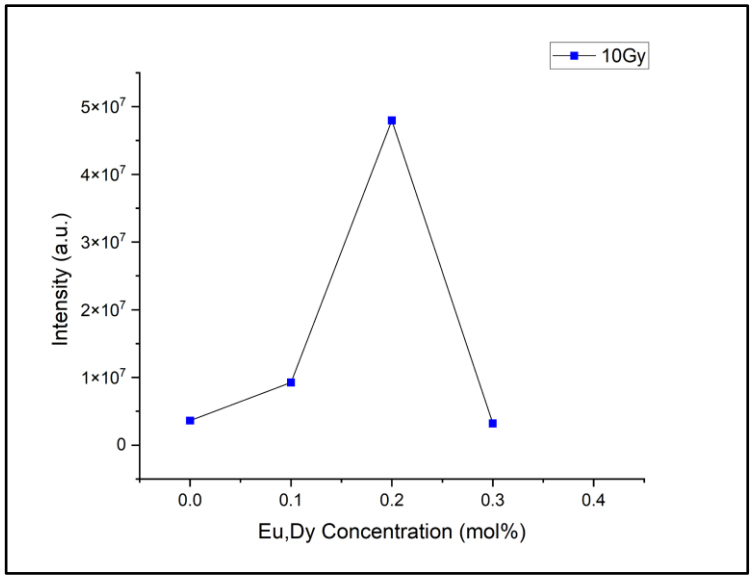

Fig. 15.
dopant concentration vs maximum TL peak

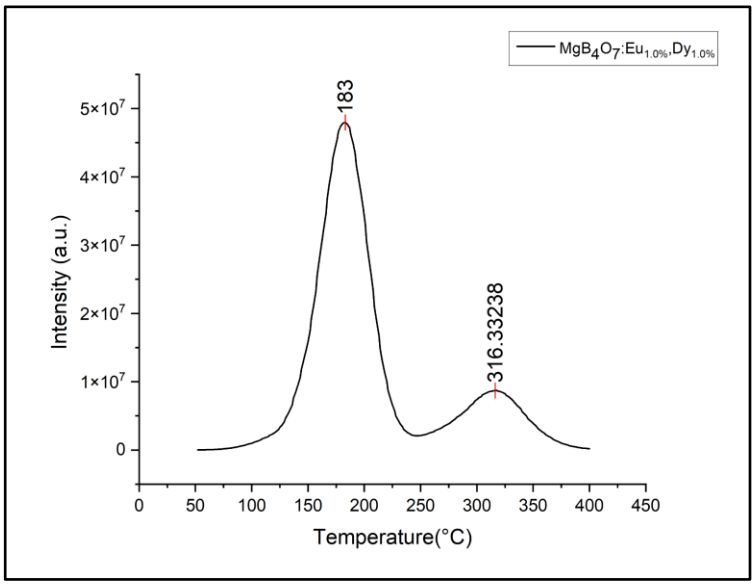

Fig. 16.
TL glow curve of 0.2 mol%, with two

5 Conclusion

The study investigated the thermoluminescence (TL) properties of various materials, including the lithium tetraborate glass chips($Li_2O.2B_2O_3$) doped with Dy(III), lithium metasilicate(Li_2SiO_3) doped with terbium ions (Tb^{3+}) and phosphor Magnesium tetraborate doped with Eu(III) and Dy(III) i.e. MgB_4O_7:Eu,Dy.

In this study, Lithium Tetraborate glass chips were evaluated for their potential as radiation dosimeters. The results demonstrate that these glass chips exhibit a reliable sensitivity to ionizing radiation, depending upon the concentration of dopant making them suitable for accurate dose measurement. The curve obtained by plotting the Temperature Vs TL signal intensity attains a peak at 176°C for the pure sample. The peak point gets to be increased as we increase the amount and concentration of dysprosium oxide. Maximum signal intensity is recorded at 139°C and 150°C for the 0.2% and 0.3% dopant sample respectively. Lithium Tetraborate glass offers a balance of sensitivity and durability, making it a promising candidate for dosimetry applications in medical and industrial settings. However, there are some limitations in terms of optimizing their sensitivity for lower radiation doses, which could be addressed through further research. In the results, the absence of multiple peaks suggests the absence of multiple depth traps. Future studies could focus on enhancing the material's performance across a wider range of radiation types and exploring its long-term stability in diverse environmental conditions. Overall, the use of lithium tetraborate glass chips presents an efficient and practical solution for radiation dosimetry, with the potential for expanded applications in the field.

The study successfully investigated the thermoluminescence (TL) properties of lithium metasilicate (Li_2SiO_3) doped with varying concentrations of terbium ions (Tb^{3+}). The results demonstrated that TL intensity is highly dependent on Tb^{3+} concentration, with the optimal performance observed at 0.2 mol%. At this concentration, a balance between activator and quenching effects was achieved, leading to enhanced luminescence. However, concentrations beyond 0.2 mol% resulted in luminescence quenching, likely due to non-radiative recombination mechanisms. This emphasizes the importance of optimizing dopant levels to improve the TL response of Li_2SiO_3, which could be beneficial for applications in radiation dosimetry. The structural and electronic environment at 0.2 mol% facilitates efficient electron trapping and recombination, essential for a strong TL response. Further research may explore alternative doping strategies or varied thermal treatments to further enhance TL properties.Additionally, all doped samples displayed two primary TL peaks around 100°C and 275°C, suggesting that the trap depths or defect states responsible for TL emission remain consistent across different Tb^{3+} concentrations. The reduction in TL intensity with increasing concentration points to a quenching effect at higher doping levels.

Lastly, the phosphor MgB_4O_7:Eu,Dy with varying dopant concentrations were successfully synthesized using the Solution Combustion Synthesis (SCS). The samples were irradiated with 10 Gy gamma radiation from a Co-60 source and their TL glow curve was plotted. The 0.2 mol% dopant concentration of Eu^{3+} and Dy^{3+} in MgB_4O_7 phosphor exhibited the best thermoluminescence (TL) response in this study. At this concentration, the material demonstrated the highest TL intensity, (which can be attributed to the optimal balance between electron traps and recombination centers). As the dopant concentration increases, the number of these traps rises, leading to enhanced TL sensitivity. However, beyond 0.2 mol%, concentration quenching occurs. The 0.2 mol% doped sample also showed two distinct glow peaks—one at 183℃, which is practical for readout, and another at 316.33℃. This makes 0.2 mol% the ideal concentration, as it maximizes sensitivity without significant quenching effects, making it suitable for practical dosimetry applications under gamma irradiation. Further studies will be carried out on this optimized dopant concentration as it shows great potential to be used as a personal dosimeter.

Overall, these findings highlight the promising applications of these materials in radiation dosimetry, with future research suggested to further enhance their performance and stability.

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