Study of Thermoluminescence of Europium Doped Barium Sulphate

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Abstract – Nanocrystalline barium sulfate doped with europium (BaSO4:Eu) was effectively ready by the synthetic co-precipitation method and its thermoluminescence (TL) dosimetry attributes were read for gamma radiation. At first the dopant (Eu) fixation was differed, beginning from 0.05 mol% to up to 1.00 mol%, and it was tracked down that the nanophosphor BaSO4:Eu with the dopant centralization of 0.2 mol% included the most noteworthy affectability inside the given parcel. The nanophosphor was additionally enhanced for its toughening temperature to get the best outcomes and was from that point tried for its reusability and blurring highlights. Further the nanophosphor was contrasted and the financially accessible standard TL dosimeter material LiF:Mg,Ti (famously alluded to as TLD-100) and it was tracked down that the nanophosphor not just had a higher TL affectability contrasted with the standard material over a wide scope of portions yet additionally had a TL reaction which was direct even past the portion of 1 kGy. Linearity in TL reaction to up to such high dosages (~1 kGy) is run of the mill of nanocrystalline TL phosphors. Every one of the examples were illuminated by Co-60 source (having 1.25 MeV normal energy) of gamma radiation. To test the energy autonomy of the nanophosphor (a significant trait of an optimal TL dosimeter) further examinations are being completed to inspect the reaction of the nanophosphor to ionizing radiations of various energies.

Keywords – Thermoluminescence, Radiation dosimetry, Nanophosphor.

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1. INTRODUCTION

A significant pattern in innovative work has been the shift of interest towards small particles. This can be summed up under the overall term "nanotechnology". In the designing and materials science local area, the expression "ultra fine particles" and "submicron particles" were utilized before "nanoparticles" appeared. These days, three primary documentations for nanoparticles are being utilized: nanoparticle, nanocrystal and nanocluster [1]. The run of the mill utilization of nanoparticles can be found in numerous fields like heterogeneous catalysis, semiconductors, microelectronics, data stockpiling, drugs, paints and earthenware production. Particles with a size between the 1 to 100nm have the extraordinary advantage that physical and synthetic properties vary from the mass material properties and are emphatically size subordinate [2]. Nano scale materials can be comprised of various ways. An expansive characterization isolates the blend strategies into one or the other base up or top down measure [3]. Base up courses are all the more regularly utilized for planning a large portion of the nano-scale materials because of the capacity to produce uniform size, shape and appropriation. Inside that base up course, substance/wet combination is broadly utilized for nano molecule age. The substance combination strategy enjoys various benefits like straightforward procedure, economical, less instrumentation, doping of unfamiliar iotas was conceivable and huge amounts of materials can be acquired [4]. This synthetic strategy could be named sol-gel [5], substance fume statement [6], receptive precipitation [7], miniature emulsion [8, 9] and low-temperature wet/compound amalgamation [10] and so on, Among these various strategies, miniature emulsion method was utilized in the current examination because of exceptionally straightforward, less instrumentation, thermodynamically steady and naturally hazard less. As of late the blend of inorganic nano particles has drawn in incredible interest because of their likely use in different fields. Barium sulfate generally alluded to as barite, is reasonable for some assorted uses on account of its high explicit gravity(4.5),opaqueness to X-beams, dormancy and whiteness [11].It is for the most part utilized as radio differentiation specialist, filler in plastics, extender in paints, added substance in drug items and printing ink. All analysts were utilized Triton X-100 and Marlipal 013/40 as a non-ionic surfactant in an artificially unadulterated grade for the readiness of BaSO4 nanoparticles. In this investigation, the use of the specialized non-ionic surfactant Tween-20 was utilized .The upsides of utilizing this surfactant as a stabilizer are connected with the shortfall of electrostatic collaboration between newly framed strong surface and surfactant particle and the impact of unfamiliar particles on the arrangement of another stage. It is likewise cheap and accessible in huge amount, simple to isolate and accordingly liked for the upscale methodology. Simultaneously here lamp fuel was utilized as an oil stage. The BaSO4 nanoparticles were blended effectively and portrayed utilizing FTIR, XRD, SEMEDS and molecule size examination.

The procedure that quantitatively gauges the ionizing radiation consumed by issue or tissue can be named as dosimetry. Blunt [1] characterizes radiation dosimetry to be a proportion of consumed portion or portion rate which essentially is a consequence of association of the ionizing radiation with issue. However, there are numerous dynamic gadgets like electronic individual dosimeters and region screens that are regularly utilized inside an office, typically inactive frameworks like thermoluminescent (TL) dosimeters and film identifications are liked with the end goal of faculty dosimetry due to their simple use and insignificant upkeep prerequisite.

As a result of its fruitful applications, themoluminescence has been perceived for a long time as a strategy for radiation dosimetry of ionizing radiation. The properties and employments of numerous TL dosimeter materials have been examined exhaustively by Mckeever et al. [2]. TL dosimeters have discovered their applications in a few fields like faculty and natural observing, clinical dosimetry, space dosimetry and archeological dating.

A few TL phosphors are currently financially accessible in various structures [3][4], a considerable lot of which have been recorded for their valuable reach and warm blurring by V.Kortov[4]. An optimal TL dosimeter enjoys significant benefits in its ease of use in light of specific properties like little actual size, radiation obstruction, versatility, high affectability, reusability, substance dormancy, a direct TL reaction range, straightforward gleam bend, low blurring, energy freedom and tissue proportionality. Till now no TL dosimeters have been found to fulfill the entirety of the above necessities. Along these lines, a hunt to set up an ideal TL phosphor is as yet going on.

BaSO4:Eu arranged in the polycrystalline structure by strong state responses has been known to show a TL force which is three to multiple times higher than that of a generally utilized Radiation dosimeter for example CaSO4:Dy (which is predominantly utilized with the end goal of staff checking in India) [12].In expansion, BaSO4 doped with Europium has likewise been accounted for in its nanocrystalline form[13]. Beforehand, nanocrystalline BaSO4:Eu has been accounted for to be an expected phosphor for the dosimetric investigation of gamma radiation just as proton radiates by S.Bahl et al. [14]. Be that as it may, in these papers [13],[14] the reliance of the TL properties on the grouping of the dopant material has not been contemplated. Accordingly, the streamlining of the nanophosphor has not been finished. This actuated us to investigate the properties of the said phosphor and to additionally improve it for the convergence of the uncommon earth pollution to set up the most ideal TL affectability for nanocrystalline BaSO4:Eu ; which is perhaps the main properties of a positive TL material. Gamma radiation has been utilized by us to advance our potential TL phosphor.

A significant advance in making a decent quality TL dosimeter is to contrast it and the generally settled guidelines. Consequently, a relative investigation of nanocrystalline BaSO4:Eu with a wellestablished dosimeter for example TLD-100 has additionally been introduced by us as a stage towards tracking down an optimal TL dosimeter.

2. EXPERIMENTAL

The nanocrystalline type of BaSO4:Eu was ready by the compound co-precipitation technique. In this strategy scientific reagent (AR) grade Barium chloride (BaCl2) was broken down in triply refined water. Europium chloride (EuCl3) of AR grade (0.2 mol %) was then added to the arrangement. The arrangement was then blended in with ammonium sulfate ((NH4)2SO4) arrangement stoichiometrically within the sight of ethanol. Ammonium sulfate was added drop savvy to the arrangement until the precipitation was finished. The hasten was sifted through and washed a few times with refined water. The nanophosphor was at long last acquired by drying the hasten at 363 K for 2 h. The nanocrystalline powder along these lines got was additionally toughened in a quartz pot at 1123 K for 1 hour in Argon climate. Microcystalline powder of BaSO4:Eu test was ready by a similar strategy embraced by Madhusoodanan et al (1999). The shape and size of the pre-arranged nanocrystalline powder materials were controlled by the examining electron magnifying instrument (SEM). SEM pictures were acquired, on JEOL, JSM-6360LV checking electron magnifying lens. To affirm the arrangement of the compound, XRD was learned at room temperature for the nanocrystalline tests by utilizing Cu-target (Cu-Kα1 line, λ = 1.5045 Å) on Philips-X'Pert Model-98 XRD machine and coordinated with the standard information accessible (JCPDS card No. 24-1035). Pellets type of BaSO4:Eu nanoparticles of around 0.6 mm thickness and 1 cm distance across were ready by taking ~ 50 mg of the nanocrystalline test, placing in a bite the dust and applying ~ 0.1 ton/cm2 pressures each time by a water driven press. These pellets were presented to 48 MeV 7 Li3+, 75 MeV C6+ and 90 MeV O7+ particle radiates at the fluence range 1×109 - 1×1013 particles/cm2 utilizing a 16 MV Tandem Van de Graaff type Electrostatic Accelerator (15 UD Pelletron) at the Inter-University Accelerator Center (IUAC), New Delhi, India. The full subtleties of this set up are given by Kanjilal et al (1993). The portion rate for 48 MeV 7 Li particles was 18.75×109 molecule/sec. The nitty gritty technique for test illumination is like that given by Salah et al (2007). For taking TL the illuminated surface of the pellet was continued confronting upwards towards the identifier (PMT) of the TLD peruser. TL shine bends were recorded utilizing a Harshow TLD peruser (Model 3500). The warming rate was 5 Ks-1. The acquired nanoparticles were likewise illuminated with various portions of 60Co gamma-beams, going from 0.1 Gy to 14.5 kGy at room temperature.

3. RESULTS AND DISCUSSION:

3.1. TL Characteristics of BaSO4: Eu

As expressed before, a decent TL dosimeter is needed to have some fundamental beneficial attributes like a basic sparkle bend structure (preferably a solitary gleam top), an extremely high affectability to ionizing radiation, a direct TL reaction bend, TL power top in a perfect world falling between the temperature scope of 1800C to 2500C and so forth [17],[18]. In this manner, it is prescribed to investigate an expected material for these properties. The ones that are read here for the current example are affectability, TL reaction and sparkle bend structure and shape. Further, the nanocrystalline test is streamlined for the grouping of the dopant to get the most extreme TL affectability and thus produce a beneficial TL dosimeter.

3.2. Optimization and TL Sensitivity

The affectability of a TL phosphor has been characterized in different manners by the researchers. Prior, as expressed by Prokic[19] in his integrative methodology, affectability is the region under the sparkle bend per unit weight of the phosphor when a unit portion of gamma radiation is given to the phosphor. While, pradhan [20] characterized affectability as the measure of light produced by a phosphor for each unit portion of radiation. This assertion is as per the "Handbook of Thermoluminescence"[18] which states affectability as TL reaction per unit portion for a unit mass of test. It is this definition that has been embraced by us in the current work to improve nanocrystalline BaSO4:Eu.

Fig 2. shows the TL shine bends for various nanocrystalline BaSO4:Eu tests, in which basically the convergence of the uncommon earth pollution is differed (from 0.05 mol % to 1 mol%) at a specific portion of 100Gy of gamma radiation. It tends to be seen from the chart that BaSO4:Eu shows a basic sparkle bend structure with a TL top at around 1870C. Additionally, the situation of the pinnacle stays fixed for a full scope of centralization of Eu(0.05 mol% - 1 mol %).

The lone variety seen is in the TL top force which at first increments with expansion in the centralization of the dopant, arrives at a greatest at a grouping of 0.2 mol % of Eu and afterward again drops down with additional increment in the dopant focus. The underlying expansion in the pinnacle power can be credited to the expanded no. of deformities/traps liable for the gleam tops; which thus implies expansion in the no. of charge transporters being caught upon illumination. On being thermally animated, these snares discharge the charge transporters to at last recombine at the recombination place and consequently lead to different sparkle tops with expanded tallness. The decrease in the pinnacle power after a specific fixation (0.2 mol%) of dopant is reached is because of focus extinguishing [21].

Affectability(TL/Gy.mg) of BaSO4:Eu as an element of grouping of the dopant for a light portion of 100 Gy of gamma radiation is displayed in Fig 3. The most elevated affectability for BaSO4:Eu has been accomplished for a grouping of 0.2 mol % of Eu. Hence, one might say that the phosphor has been effectively upgraded for its grouping of the dopant as 0.2 mol% of Eu. Considering the astounding affectability of the nanocrystalline BaSO4:Eu (0.2 mol%) when contrasted with the other changed groupings of the dopant, just BaSO4:Eu(with 0.2 mol% of Eu) has been explored and announced for its TL properties further in this paper.

3.3. TL glow curves

Fig 5. shows a trademark TL shine bend of upgraded BaSO4:Eu lighted at 4kGy of gamma radiation, while the chart in the inset shows the TL sparkle bend of a similar material at 10Gy of gamma radiation. The nanophosphor has a significant top at 1870C and a tiny protuberance at 2790C for an especially high portion of 4kGy of gamma. Concerning the little portion of 10Gy, the significant pinnacle is at 1870C with an exceptionally little protuberance at 2780C. In this way, it very well may be obviously reasoned that the given nanophosphor has a very straightforward shine bend structure which can be credited to basic conveyance of the snares. This component further permits a straightforward translation of the TL readings, with no post illumination toughening making the given phosphor exceptionally alluring as a potential TL phosphor.

3.4. TL response to gamma radiation

Perhaps the most intriguing highlights set up during the examination of nanocrystalline BaSO4:Eu phosphor is a striking linearity for a wide scope of dosages (see Fig.7), which is a trademark highlight of a fine TL dosimeter. The TL reaction stays direct for a particularly wide scope of dosages for example from 10Gy to 2kGy of gamma radiation. From there on, the phosphor gives indications of immersion with even a decline in the TL force. This sort of reaction by the nanocrystalline phosphor can be clarified as far as the track association model (TIM) [22,23].

This model wonderfully clarifies the social linearity of nanophosphors even at high portions. As indicated by TIM, both the cross-area and length of the tracks in a network are liable for the all out number of traps made because of openness to radiation. Presently in the event that we consider a nanocrystalline phosphor, the sizes of the tracks will be practically identical to the components of the molecule (for example not many nanometers), which thus will lead to less catching communities (TC) at lower portions. Presently, in nano measurements a few particles are missed during light with a high energy radiation because of little size of the particles. In this manner, more TCs are made by these unused particles on expanding the radiation portion thus we get a direct reaction even at higher dosages. Notwithstanding, if the radiation portion is additionally expanded unnecessarily, immersion or even a decline in the TL force may happen because of covering of the tracks.

Besides, the given TL reaction of the nanophosphor can be clarified as far as huge surface to volume proportion related with nano particles which brings about a higher surface obstruction energy. When this energy is defeated there are enormous quantities of traps that are made in a phosphor, which increments with expansion in the radiation portion until immersion is reached.

3.5. Comparative study with standard TLD-100

As stated earlier, it is important to compare the given phosphor to a well-established standard so as to establish a fine TL material.

3.6. Comparative TL peak intensity

Fig 4. shows relative TL top forces for improved BaSO4:Eu (0.2 mol%) with standard TLD-100 lighted by gamma radiation for the full scope of dosages. It is obvious from the diagram that the new advanced nanophosphor is profoundly delicate when contrasted with the standard TLD-100 even at a low portion of 10 Gy of gamma radiation which falls in the helpful reach for TLD-100 [4]. The phosphor is discovered to be 2.46 occasions more delicate than the standard TLD-100 even at this worth of radiation portion. Further, as the portion esteem builds, the affectability of the given nanophosphor expands suddenly and contacts a greatest worth that is 21.92 occasions more touchy than the standard TLD-100. The sudden variety in top force upsides of the upgraded BaSO4:Eu and the standard TLD-100 can be ascribed to the way that the TLD-100 neglects to hold it's anything but a fine dosimeter material because of radiation harm while the new improved nanophosphor keeps on acting like an excellent dosimetry material.

3.7. Glow curve structures

As examined before under the subheading '3.1.2. TL gleam bends', the improved nanocrystalline BaSO4:Eu phosphor shows a basic shine bend structure with a significant top at 1870C and a little mound at 2790C. Fig 6. shows gleam bend construction of standard TLD-100 illuminated at 4kGy of gamma radiation while the diagram in the inset shows the sparkle bend design of a similar material at 10Gy of gamma radiation. It very well may be obviously seen from the figures that TLD - 100 shows a straightforward gleam bend shape for a radiation openness of 10Gy of gamma with a significant top at 2170C and a little shoulder at 2810C.

In any case, as we go into higher dosages of gamma radiation (as high as 4kGy) the TLD-100 loses its straightforward gleam bend design and we get a significant top at 2150C , an optional top at 2810C and two little shoulders at 3050C and 3350C. This is essentially a direct result of the adjustment of the nature and circulation of the snares perhaps because of radiation harm at higher portions of radiation. It can plainly be seen that the standard TLD-100 loses its usefulness for higher portions of radiation while the new improved BaSO4:Eu keeps on showing an inconceivable sparkle bend structure.

3.8. TL response curves

By and by as talked about before under the subheading „3.1.3. TL reaction to gamma radiation", The new streamlined nanocrystalline BaSO4:Eu shows a wonderful direct reaction up to a portion range as high as 2kGy of gamma radiation while the TLD-100 (Fig.8) shows a supralinear reaction simply up to a portion of 500Gy past which it goes into immersion. The supralinearity of the TLD-100 can be clarified based on target collaboration model which proposes that TL is because of combinational electrons and openings made along optional charged molecule tracks. Further, the distance between these tracks lessens on expanding the radiation portion. This prompts a higher chance of the blend of the adjoining tracks, which thusly prompts the supralinearity reaction of TLD-100. The supralinearity reaction of TLD - 100 has likewise been examined exhaustively by Folkard et al. [24] and G Massillon-JL et al. [25].

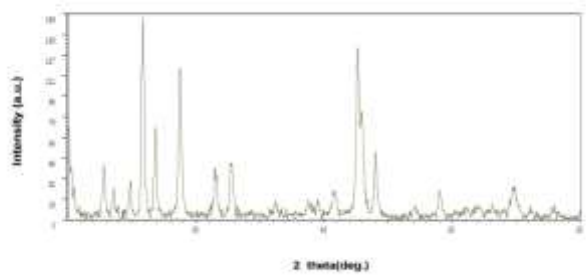

Fig 1. XRD pattern of nanocrystalline BaSO4 doped with Europium (0.2 mol%).

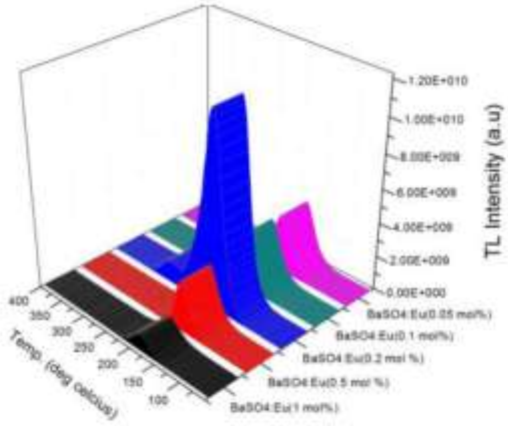

Fig 2. TL glow curves for different nanocrystalline BaSO4:Eu samples (in which the concentration of the dopant is varied) at a dose of 100Gy of gamma radiation.

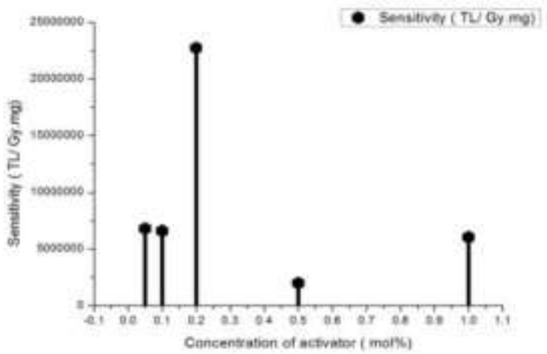

Fig 3. Sensitivity (TL Gy^{-1} mg^{-1})of BaSO4:Eu as a function of concentration of rare earth impurity (dopant) irradiated at 100 Gy of gamma radiation.

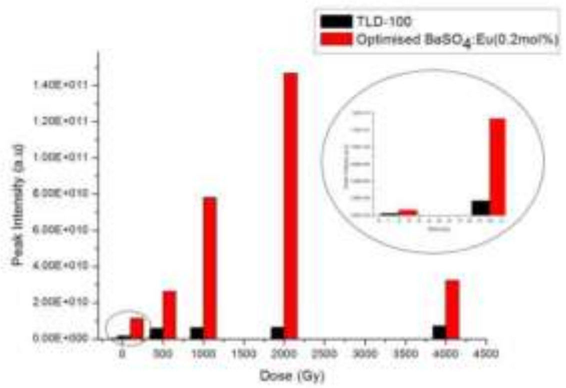

Fig 4. TL peak intensities for optimised BaSO4:Eu (0.2 mol%) and standard TLD-100 irradiated by gamma radiation at different doses i.e. 10 Gy, 100Gy,500Gy, 1kGy, 2kGy and 4 kGy.

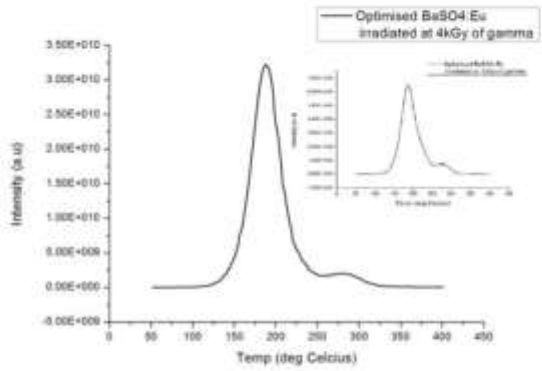

Fig 5. TL glow curve of Optimised BaSO4:Eu irradiated at 4kGy of gamma radiation. The graph in the inset shows the TL glow curve of the same material at 10Gy of gamma radiation.

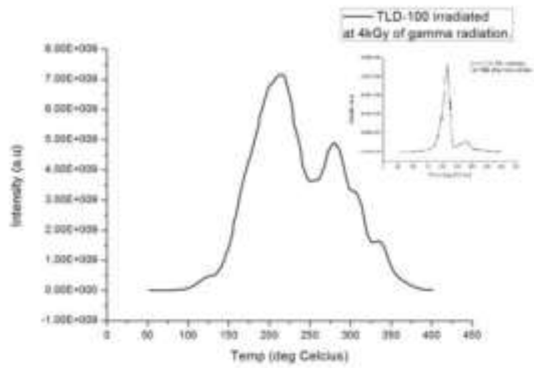

Fig 6. TL glow curve of TLD-100 irradiated at 4kGy of gamma radiation. The graph in the inset shows the TL glow curve of the same material at 10Gy of gamma radiation.

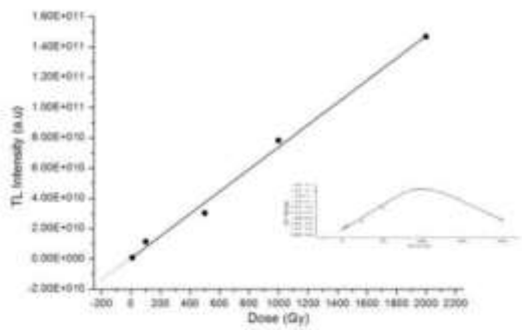

Fig 7. TL response curve of Optimised BaSO4:Eu nanocrystalline sample to gamma radiations in the dose range (10 Gy to 2000 Gy) . The graph in the inset shows the same response in the dose range 10Gy to 4kGy.

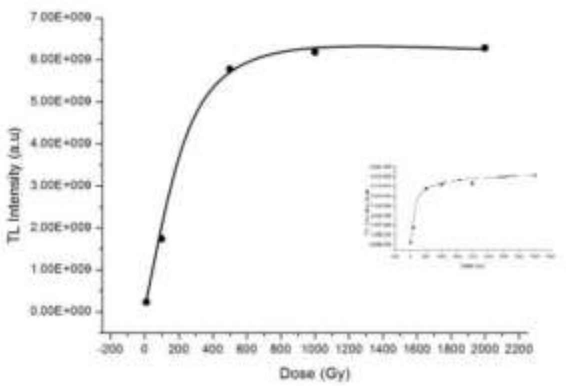

Fig 8. TL response curve of TLD-100 to gamma radiations in the dose range (10 Gy to 2000 Gy) . The graph in the inset shows the same response in the dose range 10Gy to 4kGy.

4. CONCLUSION

Nanocrystalline BaSO4:Eu arranged by the substance co-precipitation technique has been effectively enhanced for the convergence of the uncommon earth debasement to accomplish its most elevated TL affectability. The said phosphor shows the most noteworthy affectability at a convergence of 0.2 mol% of Europium. Besides, it is likewise seen that when contrasted with the standard TLD-100, the enhanced BaSO4:Eu shows shockingly high affectability over a wide scope of dosages for example 10Gy to 4kGy of gamma radiation. The XRD investigation uncovers the grain size of the enhanced BaSO4:Eu to be 40 nm. The given phosphor additionally shows many promising highlights as a potential TL dosimeter like a high TL affectability (which is a fundamental component of a phosphor utilized in close to home, clinical and ecological dosimetry), basic sparkle bend structure with the significant top at 1870C and a little protuberance at 2790C and an uncommon linearity for an expansive scope of portions with TL reaction staying straight up to a portion as high as 2kGy. Additionally, the state of the shine bend stays unaltered for the entire scope of radiation portions (for example 10Gy to 4kGy). Hence it very well may be reasoned that the new streamlined nanocrystalline BaSO4:Eu is a promising contender for radiation dosimetry having numerous helpful highlights of a fine TL dosimeter.

Moreover, the near investigation with the standard material uncovers that the current advanced example is 2.46 occasions more touchy than the standard TLD-100 in the helpful scope of TLD-100 and as we go past this valuable reach the affectability of the upgraded nanophosphor builds unexpectedly and contacts a most extreme worth that is 21.29 occasions more than of the standard TLD-100. It can likewise be noticed that the TLD-100 loses its straightforward sparkle bend shape for high dosages of radiation while the shine bend structure stays unaltered for the current enhanced nano phosphor. At long last, the new improved nanophosphor shows an amazingly better TL affectability and a wonderful straight reaction bend for a staggeringly wide scope of portions for gamma radiation (Co-60) when contrasted with the standard TLD-100 which goes into immersion for a radiation portion as low as 500Gy of gamma. This further makes the current improved BaSo4:Eu(0.2 mol%) very encouraging as an effective gamma radiation dosimeter.

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