



## Lyoluminescence study of $\gamma$ -ray irradiated Cu doped $YCa_4O(BO_3)_3$ microcrystalline phosphors for Radiation Dosimetry applications

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### ABSTRACT:

Cu doped  $YCa_4O(BO_3)_3$  crystalline materials with variable particle sizes were amalgamated by solid-state diffusion technique. XRD pattern confirmed the creation of the material and therefore the numerous components and phases there in this material. Lyoluminescence (LL) of the gamma-ray-irradiated sample was proved. A single sharp peak was found within the LL glow curve of the sample. It is established that LL exaggerated nearly linearly with gamma-ray doses up to 1.5 kGy. Photoluminescence (PL) of the sample was recorded to search out the role of rare-earth ions. The PL emission varies shows two peaks lying at 352 nm with 406 nm appointed to the  $3d^9_4s^1 \leftrightarrow 3d^{10}$  transition in  $Cu^+$  ions. Considerably, the reliance of LL of  $\gamma$ -ray-irradiated Cu doped  $YCa_4O(BO_3)_3$  phosphor on the particle size of the material has additionally been deliberated. The prepared phosphor might even be very important for sensing applications.

**Keywords:** Lyoluminescence,  $YCa_4O(BO_3)_3$ , Solid-state diffusion, dosimetry

### 1. INTRODUCTION:

The luminescence formed because of the recombination procedure throughout dissolution of irradiated materials to bound appropriate solvent is understood as lyoluminescence (LL) [1]. The quantum of light yield created is proportional to absorbed dose within the solid. The lyoluminescence occurring is supposed to its origin to transmit the energy from the radiation-induced free radicals to the solvent molecules, a section of that gets converse to visible radiation.

The LL development has been settled to seek out its applications as a system, principally for tissue comparable to measure, detection of irradiated food materials, radiation harm studies in solids, accident dosimetry and within the discovery of irradiated food materials [2-5]. Particle size of the crystal is also one among the factors on that the LL yield depends [6-

7]. Lyoluminescence of aluminum induced by lanthanides chelates in basic aqueous solution are studied [8]. The lyoluminescence (LL) strength of gamma-irradiated KCl: Sr microcrystalline powder of various particle sizes are examined [9].

They initiated that within the mesh vary of 150-355  $\mu\text{m}$ , the height LL intensity at the start will increase with increasing particle size. a replacement series of calcium-containing rare-earth borates are synthesized [10]. This family is iso-isostructural with composition of  $\text{LnCa}_4\text{O}(\text{BO}_3)_3$  ( $\text{Ln} = \text{La}^{3+}, \text{Sm}^{3+}, \text{Nd}^{3+}, \text{Gd}^{3+}, \text{Er}^{3+}$  and  $\text{Y}^{3+}$ ) and space cluster is monoclinic, non-centro-symmetry. They need smart thermal and chemical constancy and are smart hosts for light material beneath UV excitation. No organized investigations on particle size dependence of LL of  $\text{LnCa}_4\text{O}(\text{BO}_3)_3$  phosphors are represented. This paper reports particle size dependence of LL of gamma-ray-irradiated cu doped  $YCa_4O(\text{BO}_3)_3$  phosphors Photoluminescence (PL) has additionally been established to verify the amalgamation of copper ions within the host material.

## **2. EXPERIMENTAL TECHNIQUE-**

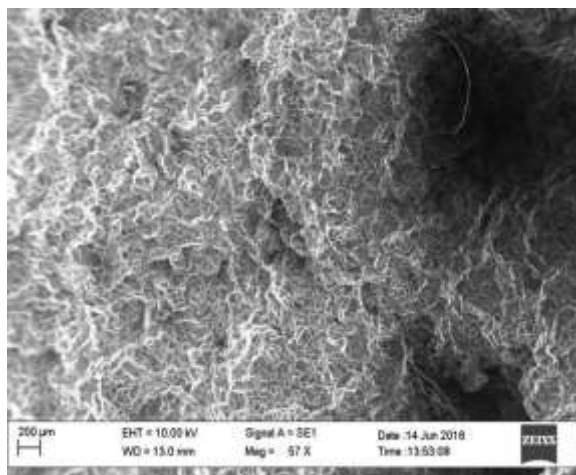
Cu doped  $YCa_4O(\text{BO}_3)_3$  phosphors were synthesised by solid-state diffusion technique. During this procedure, the fundamental quantity of carbonate, boric acid, yttrium oxide and cupric oxide was beached consistently in pastel and mortar. The mixture was then heated at 750° C for 10 hours so cooled slowly. The acquired sample was beached once more then fired at 850° C for one more 10 hours then cooled increasingly up to room temperature.

The required size of the samples was obtained by crushing and filtering them. The test sieves are accustomed sieve out the crushed powder into completely different sizes, smaller particles are sieved out initial whereas the larger particles are sieved out at the last. XRD pattern of the sample was recorded by X-ray diffractometer (PW-1710). Photoluminescence (PL) of the rare earth doped samples was recorded using a spectrofluorophotometer (Maruteck-FL-100-HS). The gamma-ray-irradiation was acknowledged using  $^{60}\text{Co}$  supply. A schedule was found out consisting of a photomultiplier tube and a nano-ammeter was accustomed to record LL.

### 3. RESULTS AND DISCUSSION:

#### 3.1. SEM CHARACTERIZATION:

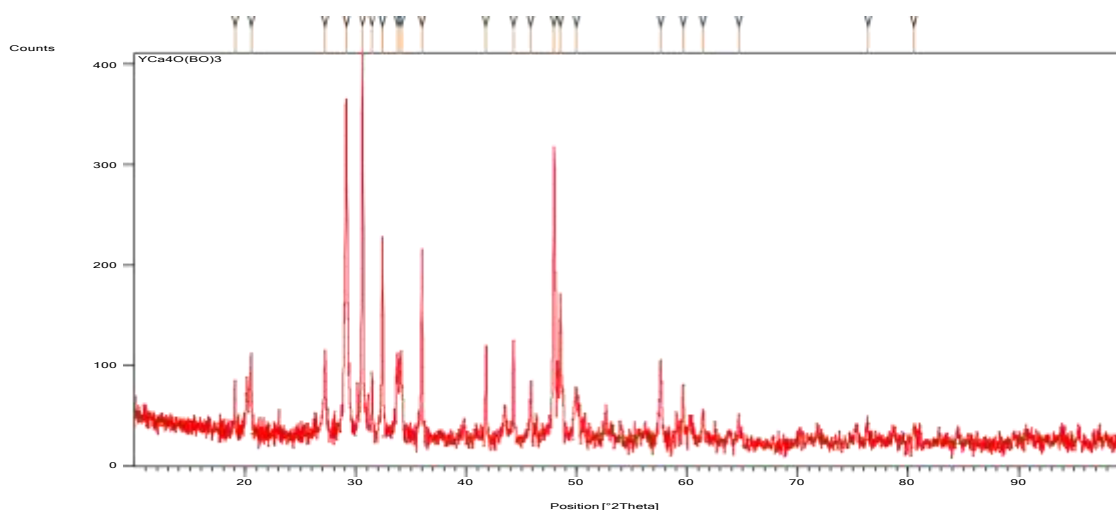
Fig 1 illustrates the SEM photograph of the sample. The surface morphology of the phosphor arises from the grain size of the small crystal grains of the order of the micrometre range. It is observed from the image that there is an unequal large particle along with a large number of small particles.



**Figure 1: SEM image of the phosphor**

#### 3.2. XRD CHARACTERIZATION:

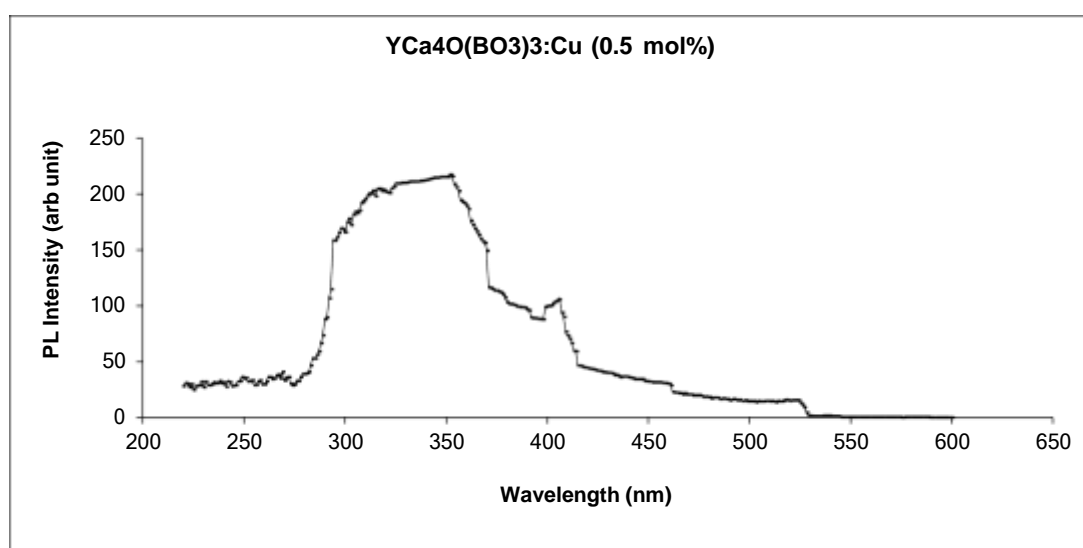
XRD examination has been distributed to differentiate the various components and stages present in the prepared phosphor. Figure 2 shows the XRD pattern of  $YCa_4O(BO_3)_3$  phosphors. XRD pattern acquired is almost similar to the JCPDS card No. 50-0403 and it should be ended that a little quantity of defilement doped within the host material doesn't involve the XRD pat



**Figure 2: XRD pattern of the  $YCa_4O(BO_3)_3:Cu$  sample.**

### 3.3 PHOTOLUMINESCENCE (PL) DESCRIPTION:

The discharge spectra of  $\text{YCa}_4\text{O}(\text{BO}_3)_3:\text{Cu}$  phosphors is shown in figure 3. 2 peaks around 352 nm and 406 nm are experiential when phosphor is excited by the electromagnetic radiation of wavelength 247 nm. Cu emits mainly due to  $3d^9 4s^1 \leftrightarrow 3d^{10}$  transition. The ascertained variation of emission could also be due to energy transfer between Cu and the imperfections of oxiborate and thus causes photoluminescence emission. So this phosphor is a favourable prospect for blue LED PL emission confirming the incorporation of Cu ions within the host materials [11].



**Figure 3: PL emission spectrum of  $\text{YCa}_4\text{O}(\text{BO}_3)_3:\text{Cu}(0.5\text{mol}\%)$  phosphors under 247 nm excitation.**

### 3.4 LYOLUMINESCENCE (LL) DESCRIPTION:

Relative LL intensity versus doping concentration (0.05,0.1,0.2,0.5,1.0,2.0mol%) for all the samples are depicted in fig.4. The LL intensity is established to have relied upon dopant application within the host  $\text{YCa}_4\text{O}(\text{BO}_3)_3$  phosphor. The concentration quenching occurs at 0.5mol % due to the aggregation of dopant ions. LL intensity at low dopant concentration within the host shows a decent property (cost-effective) for the radiation measure applications.

When the gamma-ray-irradiated Cu doped  $\text{YCa}_4\text{O}(\text{BO}_3)_3$  phosphors were liquefied in dilute hydrochloric acid having the attention of 0.42 gm/l, LL strength at first enlarged with time accomplished at the best attainable value and then decreased and finally withdrawn. Figure 5 shows the reliance of LL intensity on the particle size (determine by Sieving method) of the sample. It is found that The LL intensity initially will increase with an increased particle size of the sample associated on top of an increase particle size the LL intensity reduces with an increase in particle size. This might get on account of the greater firmness of imperfection centres in crystallites of

enormous dimensions whereas within the case of smaller dimensions there is a speedy decay of defect Centres leading to poor radiolysis merchandise.

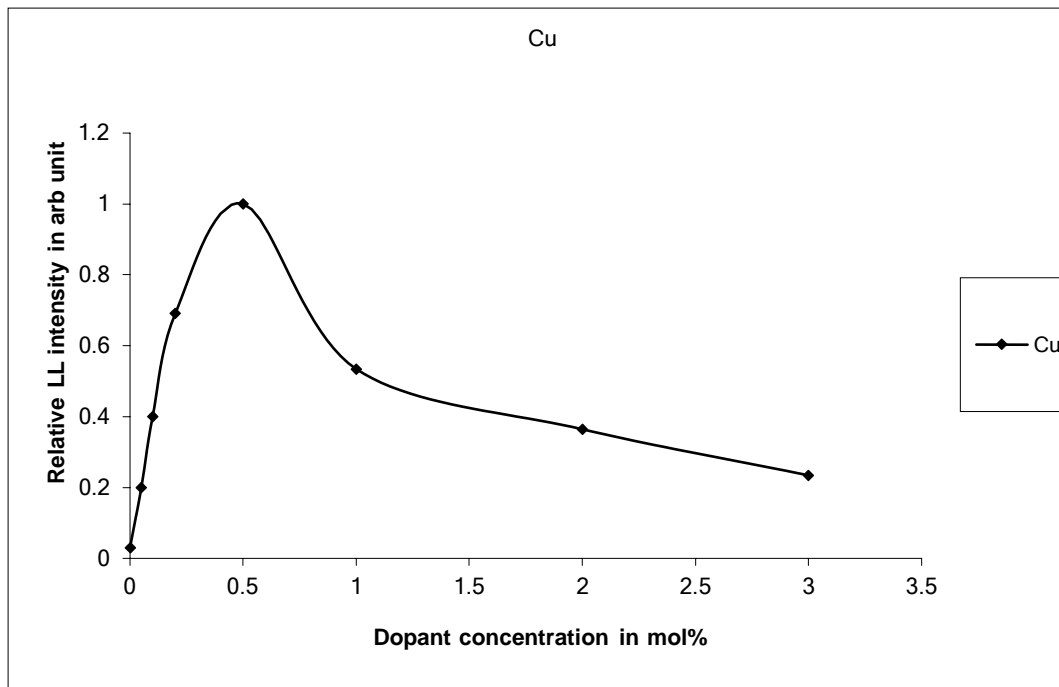


Figure 4: Relative LL intensity of  $\gamma$ -ray irradiated  $YCa_4O(BO_3)_3:Cu$  phosphors for various dopant concentration (mol %).

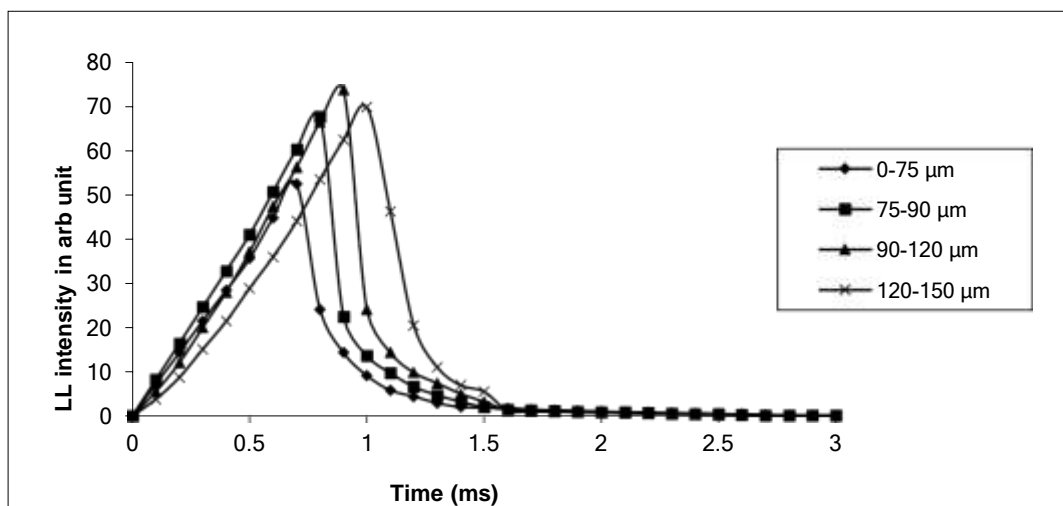


Figure 5: Time Dependence of LL intensity of  $\gamma$ -ray irradiated  $YCa_4O(BO_3)_3:Cu$  (0.5 mol%) phosphors for various particle size.

Fig.6 shows the reliance of  $t_m$  i.e. time resultant to peak LL strength on the particle size of Cu doped

$YCa_4O(BO_3)_3$  sample. It is detected from the curve that originally  $t_m$  will increase with increasing particle size of the sample. The time  $t_m$  matching to the height of the LL intensity will increase with increasing particle size. This could flow from to longer time length required for softening the samples of larger particle size. Since the dissolution rate diminishes with increasing particle size,  $t_m$  ought to increase linearly with particle size of small crystals.

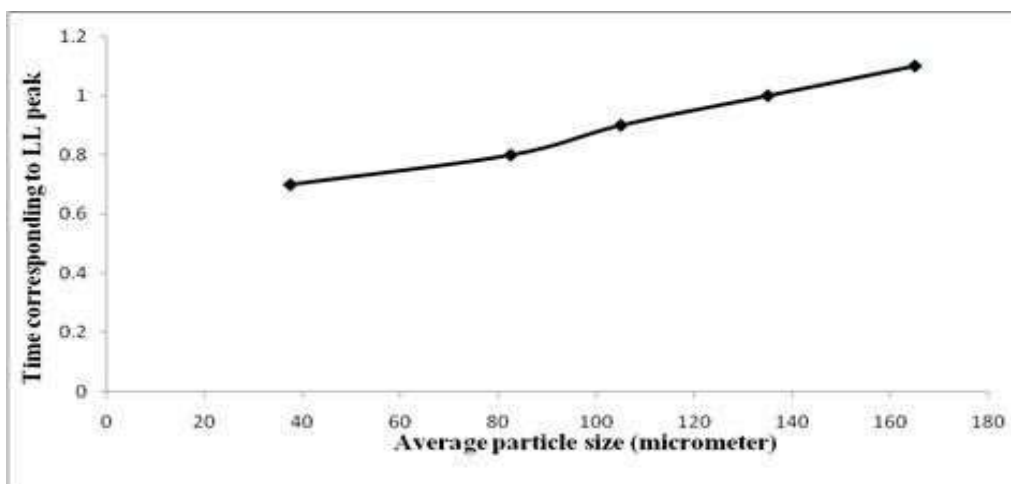


Figure 6: Discrepancy of time corresponding to LL peak intensity with particle size of  $\gamma$ -ray irradiated  $YCa_4O(BO_3)_3:Cu(0.5 \text{ mol}\%)$  phosphors.

Fig.7 shows the dependence of decay time of LL intensity on the particle size of Cu doped  $YCa_4O(BO_3)_3$  sample. It has been watched with attention from the curve that the decomposition time improved up to sure particle size of the sample and at the moment decay time decreased with increasing particle size.

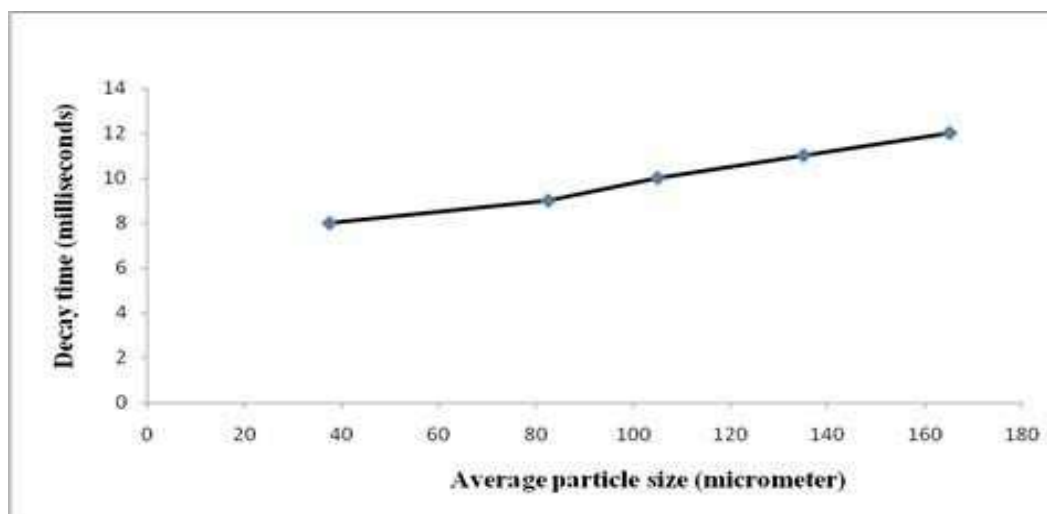


Figure 7: Variation in decay time of LL intensity of  $\gamma$ -ray irradiated  $YCa_4O(BO_3)_3: Cu(0.5 \text{ mol}\%)$

phosphors with particle size.

Figure 8 shows the impact of  $\gamma$ -ray exposure to the relative LL intensity of  $YCa_4O(BO_3)_3$  sample for Cu(0.5 mol%). The LL intensity linearly will increase up to 1.5kGy then saturate for subsequent value of  $\gamma$ -ray exposure. The enhancement in LL strength with increasing  $\gamma$ -ray dose could also be as a result of a rise within the range of active luminescent centres with  $\gamma$ -irradiation.

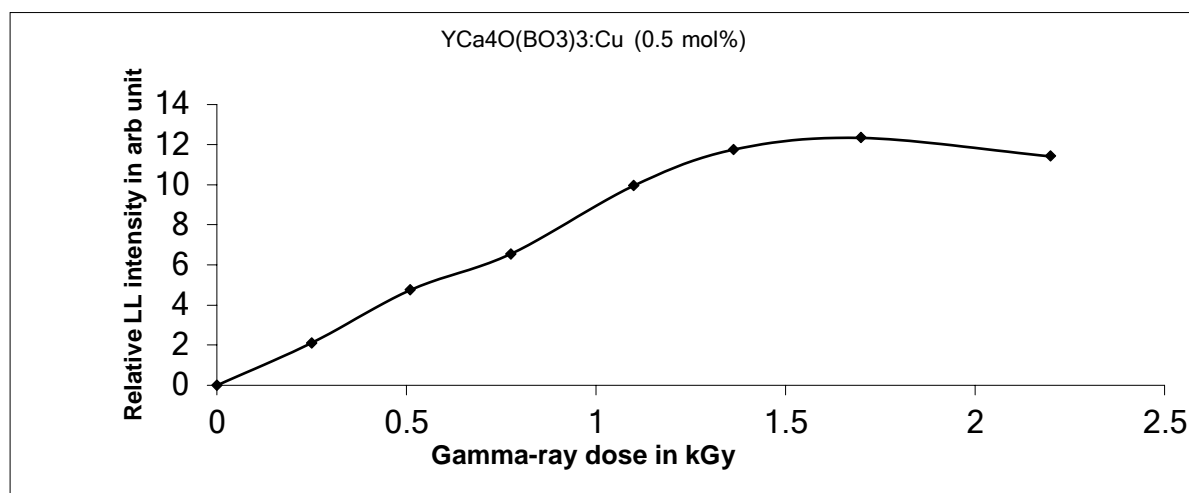


Figure 8: Dependence on LL intensity of  $\gamma$ -ray irradiated  $YCa_4O(BO_3)_3$ : Cu (0.5 mol%) phosphors on gamma-ray exposure.

Figure 9 shows the impact of storage in dark at the temperature on the height LL intensities of  $\gamma$ -ray irradiated  $YdCa_4O(BO_3)_3$  samples for Cu (0.5mol%). It is ascertained that the decay in LL intensity is unbelievably low.

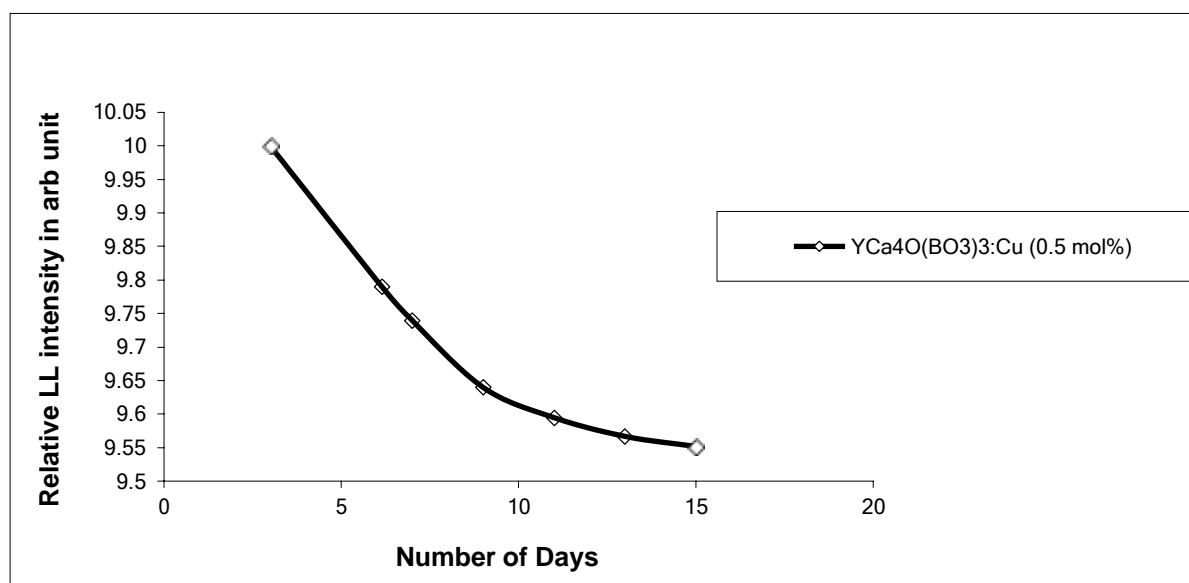


Figure 9: Dependence of relative LL intensity of  $YCa_4O(BO_3)_3$ : Cu<sub>0.5 mol%</sub> on storage time.

Borates below  $\gamma$ -rays irradiation are documented to provide varied flaw Centres like  $B^{2+}$ ,  $O^-$ ,  $(B_3O_6)^{3-}$ ,  $O^{3-}$ ,  $O^{2-}$  etc. [12-13]. On melting such borates in acceptable solvent the LL is determined due to release of dutiful energy throughout closure as per mechanism suggested by Atari [14]. Schematically, the mechanism of LL in  $YCa_4O(BO_3)_3$  is also represented by the subsequent equations.



where, X =Radicals created due to  $\gamma$ -rays irradiation.

The number of hydrated electrons will increase due to the closure of the crystallites and it will lessen due to the recombination of hydrated electrons with the holes present on the surface of the crystallites[15-21].

#### 4. COCLUSION:

Cu doped  $YCa_4O(BO_3)_3$  phosphor was incorporate via a solid-state reaction procedure Well crystallized powders with completely different particle sizes earned PL emission spectrum shows the characteristic emission of cu ions. A single peak is determined in its LL glow curve and therefore the intensity of the LL robustly depends on the particle size of the powder. The intensity of LL will increase linearly with an increase within the particle size up to an entry-level ( $\leq 90 \mu\text{m}$ ). The improvement of LL intensity is also supported to larger stability of luminescence Centres in crystallites of larger dimensions. On the opposite hand, spreading or reduction of luminescence Centres beyond the brink particle size might cause the saturation or lower LL intensity. Investigational results hints that the particle size of the phosphors may be a very important parameter and it ought to be taken into thought before recommending the phosphor for sensor and dosimetry application.

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