



SYNTHESIS AND PHOTOLUMINESCENCE PROPERTIES OF Er^{3+} – Yb^{3+} co-doped LiMgBO_3 PHOSPHOR

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Abstract

Lithium strontium borate phosphor (LiMgBO_3) doped with rare earth elements 0.02Er^{3+} and 0.08Yb^{3+} has been synthesized by solution combustion technique. For the first time Upconversion phenomenon was investigated in the samples at fixed concentration of rare earth dopants Er^{3+} and Yb^{3+} . Study shows that the synthesized materials emits in visible region after excitation in Infrared region. $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ shows the absorption in infrared region ie 820 nm to 1080 nm and at 545nm ,656nm respectively. At the excitation of 980 nm it shows the emission peakings at 590 nm and 596 nm. Upconversion mechanism was investigated in detail and attributed to the efficient resonant energy transfer from Yb^{3+} to Er^{3+} ions in this host material. Our results suggest a potential borate phosphor for Natrium Yellow and Amber upconversion phosphor.

Keywords: Borate phosphor; Upconversion; Luminescence.

1. Introduction

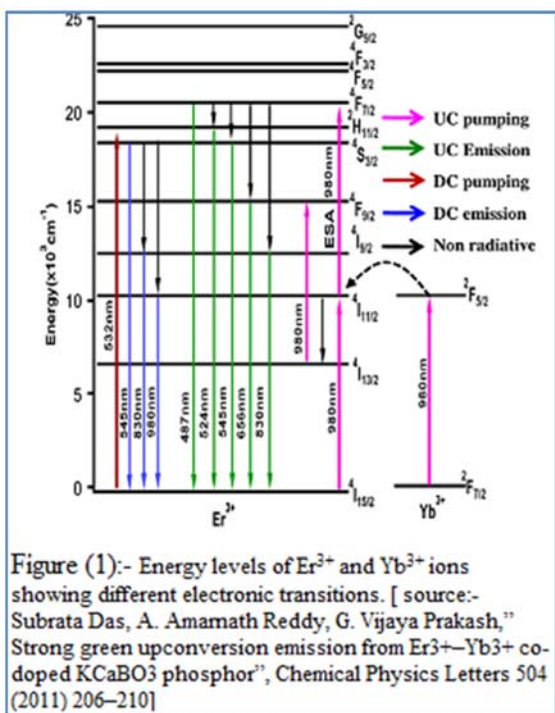
Upconversion phenomenon is now becomes an interesting topic of research due to wide range of applications ie from medical [1] to solar energy sector. Spectral mismatch losses in solar cell were reduced by upconversion materials[2]. Upconversion materials absorb near infrared light and re-emit in red, green, and blue. This three colors can combine to create a white-light source [3].

Recently, phosphors based on borates have attracted much attention due to their high stability, low synthetic temperatures, and high ultraviolet and optical damage threshold [4,5,6]. Borate crystals are intrinsically luminescent and

show thermo luminescence and other interesting optical properties [7,8]. Chr. Wyss et al used Yb^{3+} as co-dopant (sensitizer) in Er^{3+} doped (activator) laser hosts. According to them Er^{3+} has narrow absorption band from 970 to 1010 nm wavelength and Yb^{3+} has a broad absorption band from 900 nm to 1025 nm wavelength and a higher absorption cross-section.[9]. Subrata Das, et al reported strong green upconversion emission from Er^{3+} – Yb^{3+} co-doped KCaBO_3 phosphor. It gives intense green emission ($^2\text{H}_{11/2}, ^4\text{S}_{3/2}$ to $^4\text{I}_{15/2}$) through cooperative upconverted emission on 980 nm excitation [10].

The rare-earth ions Er^{3+} and Yb^{3+} are up-conversion activator and sensitizer ions, which emit green to red light effectively in different host lattices. Er^{3+} has a simple energy-level structure that consists of $^4\text{I}_{15/2}$, $^4\text{I}_{11/2}$, $^4\text{I}_{13/2}$, $^4\text{F}_{9/2}$, $^4\text{S}_{3/2}$, $^2\text{H}_{11/2}$, and $^4\text{F}_{7/2}$ states [Figure (1)]. Usually, the $^2\text{H}_{11/2}$, $^4\text{S}_{3/2}$ to $^4\text{I}_{15/2}$ and $^4\text{F}_{9/2}$ to $^4\text{I}_{15/2}$ transitions lead to green and red emissions, respectively, in Er^{3+} -activated phosphors. The luminescent properties of materials activated by Er^{3+} ions can be enhanced by the addition of Yb^{3+} ions via resonant energy transfer from Yb^{3+} to Er^{3+} through the absorption of a 980 nm photon [11].

In this work upconversion emission properties of LiMgBO_3 co-doped with Er^{3+} and Yb^{3+} ions was investigated. We report the synthesis of single monoclinic phase doped $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$. It gives Natrium Yellow and Amber emission ($^4\text{F}_{9/2}, ^4\text{S}_{3/2} \rightarrow ^4\text{I}_{15/2}$ in the Er^{3+}) through cooperative upconverted emission on 980 nm excitation.



2. Experimental

2.1. Sample preparation :- The powder sample of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ was prepared by using solution combustion synthesis[12,13]. Several borate host materials were successfully synthesized using this method [14]. The stoichiometric amounts of high purity starting materials LiNO_3 ; H_3BO_3 ; NH_2CONH_2 ; NH_4NO_3 ; $\text{Mg}(\text{NO}_3)_2$ and Er_2O_3 ; Yb_2O_3 was used for phosphors preparation. The stoichiometric amounts of the ingredients was mixed in an agate mortar with adding little amount of double distilled water. The materials then transferred into china basin. It was heated on heating menthol at about 70°C so as to obtained clear solution. The solution was then introduced into a pre-heated muffle furnace maintained at temperature 550°C for combustion. The solution boils and ignites to burn with flame which gave a voluminous, foamy powder. Following the combustion, the resulting foamy samples were crushed to obtain fine powder and then heated at temperature 750°C for 2 hr and suddenly cooled to room temperature.

2.2. Material characterizations

The phase and surface morphology of as prepared phosphors were characterized by powder X-ray diffraction pattern using Rigaku Miniflex II X-ray Diffractometer with Cu $K\alpha$ radiation ($\lambda=1.54059 \text{ \AA}$) with scan speed $2^\circ/\text{min}$

and field emission - scanning electron microscopy (FE-SEM) (Hitachi, Model-S4800 type II). The PL measurements at room temperature were performed on Hitachi F-7000 Spectrofluorometer with spectral resolution of 2.5 nm.

3. Results and discussion

3.1. X-ray Diffraction Pattern:-

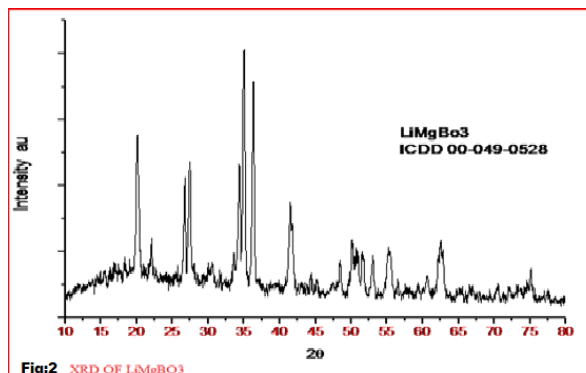
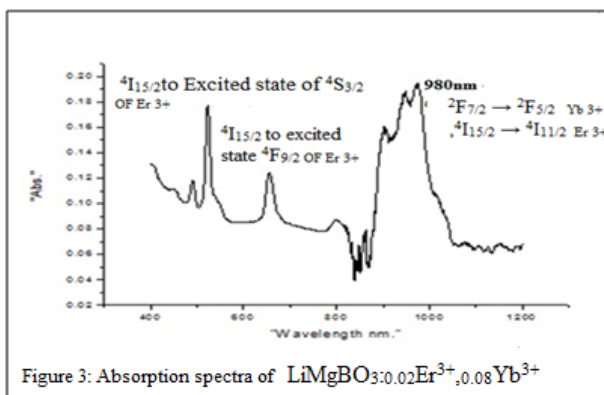


Fig.2 shows the powder X-ray diffraction (XRD) patterns of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$, and it was found to be in good agreement with the reported standard data in ICDD file no. 00-049-0528. The result clearly implies that the obtained samples are single phase and the doping of Er^{3+} and Yb^{3+} does not cause any significant change to the detection limit of the technique in the host structure.

3.2. Absorption analysis of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ phosphor

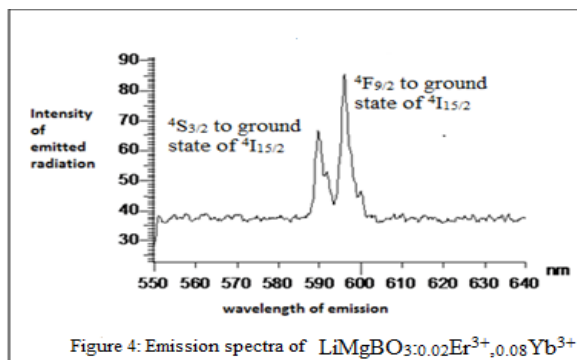


To decide excitation wavelength of sample for study of UC we did the absorption study of sample using Shimadzu UV-VIS-NIR Spectrophotometer in the range 400 nm to 1200 nm. Figure(3) shows absorption spectra of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$.

It shows the wide absorption band from 820 nm to 1080 nm and maximum intensity at 980 nm (Resonant transition from $4I_{15/2}$ to $4I_{11/2}$

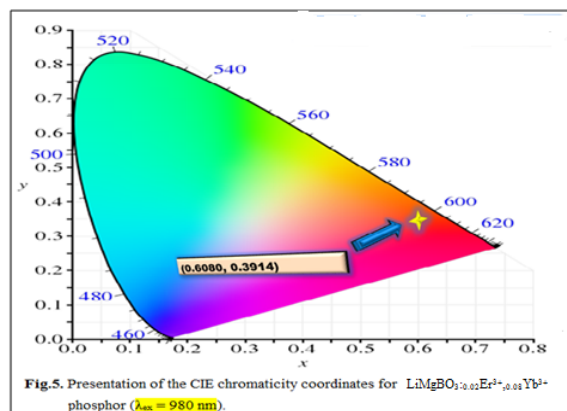
in Er^{3+} and ${}^2\text{F}_{7/2}$ to ${}^2\text{F}_{11/2}$ in Yb^{3+}). It also shows absorption peaks at 545 nm (from ${}^4\text{I}_{15/2}$ to ${}^4\text{S}_{3/2}$ transition in Er^{3+}) and 656 nm (${}^4\text{I}_{15/2}$ to ${}^4\text{F}_{9/2}$ transition in Er^{3+}). Due to both activator and sensitizer ions host material shows wide absorption from visible to IR.

3.3. Photoluminescence analysis of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ phosphor



Photoluminescence characteristics of $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ is shown in figure(4). It shows two upconversion emission peaks at 590 nm and 596 nm when excited in infrared region. It is due to mixed transitions from ${}^4\text{F}_{9/2}$ and ${}^4\text{S}_{3/2}$ to ${}^4\text{I}_{15/2}$ in the Er^{3+} .

3.4 CIE chromaticity coordinates for $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ phosphor ($\lambda_{\text{ex}} = 980$ nm)



CIE chromaticity coordinates for $\text{LiMgBO}_3:0.02\text{Er}^{3+},0.08\text{Yb}^{3+}$ phosphor at $\lambda_{\text{ex}} = 980$ nm for emission wavelength 596nm are shown in the figure (5). It shows the colour of emitted light was orange.

4. Conclusions

Single phase monoclinic $\text{LiMgBO}_3:0.02\text{Er}^{3+}$ phosphors doped with 0.08Yb^{3+} concentration has been synthesized by solution combustion technique and upconversion from near-

infrared to visible was reported for the first time. Their absorption spectra were recorded which shows the broad absorption range of material. Absorption band is broad in infrared region. Absorption intensity is maximum at 980 nm. The upconversion spectra of as synthesized phosphor showed Natrium Yellow and Amber (590nm and 596nm) emission of Er^{3+} , due to the mixed transitions from ${}^4\text{F}_{9/2}$ and ${}^4\text{S}_{3/2}$ to ${}^4\text{I}_{15/2}$ in the Er^{3+} . The intense upconversion emission from these mixed borate phosphor could be found very useful in different emerging fields.

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