Open Journals of Physical Science (OJPS)
ISSN: 2734-2123
Article Details:
openjournalsnigeria.org.ng/pub/ojps20200102.pdf
Article Ref. No.: OJPS20200102
Volume: 1; Issue: 1, Pages: 11-15 (2020)
Accepted Date: March 05, 2020

CrossMark click for updates

Open Journals Nigeria (OJN)
Open Access | Bi-annual | Peer-reviewed
www.openjournalsnigeria.org.ng
editorial@openjournalsnigeria.org.ng

RESEARCH ARTICLE **OJPS20200102**

LUMINESCENCE BEHAVIOUR OF DY^{3+} ION DOPED MAGNESIUM SULFOBORATE PHOSPHOR FOR WHITE LIGHT EMITTING DIODES

[*1]Dalhatu, A. S., [2]Hussin, R., [3]Ibrahim, B., [2]Yamusa, Y. A. and [1]Baballe, A.

*[*1]Department of Physics, Bauchi State University Nigeria, 65 Gadau, Bauchi, Nigeria*
***Phone**: +2348069364724: **Email**: sadgambaki@yahoo.com*
***Phone**: +2348139099865: **Email**: ababalle@yahoo.com*
[2]Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, 81310 Skudai, Johore Bahru, Johore, Malaysia
***Phone**: +60199898425: **Email**: roslihussin@utm.my*
***Phone**: +601136983790: **Email**: yamusaabdullahi@yahoo.com*
[3]Department of Physics, School of Sciences, Kaduna State College of Education Gidan waya, Kafanchan, Nigeria
***Phone**: 07068102222: **Email**: ibshekwolo@yahoo.com*

ABSTRACT

Several studies showed the interesting properties of trivalent lanthanide ions when doped in various types of phosphor. Magnesium sulfoborate phosphor doped with different concentrations of Dy^{3+} were synthesized using solid-state reaction method at 850 °C for 4 hours. The samples were characterized by X-ray Diffraction (XRD). The excitation and luminescence properties of $MgO\text{-}SO_4\text{-}B_2O_3{:}Dy^{3+}$ were determined. The emission spectrum of Dy^{3+} ion doped $MgO\text{-}SO_4\text{-}B_2O_3$ phosphor exhibit three bands at 480 nm, 573 nm and 660 nm with excitation of 386 nm due to $^4F_{9/2} \rightarrow {}^6H_{15/2}$, $^6H_{13/2}$ and $^6H_{11/2}$ of Dy^{3+} transitions, respectively. The excitation spectrum of Dy^{3+} ion doped $MgO\text{-}SO_4\text{-}B_2O_3$ phosphor display several bands at 347 nm, 362 nm, 386 nm, 426 nm, 449 nm and 469 nm with emission of 573 nm, which is in agreement with the ultraviolet LED (349.9–410 nm) and blue LED (450–470 nm). An intense in the emission peak at 573 nm in the yellow region was observed with the 0.5 Dy_2O_3. The luminescence properties of phosphor show that $MgO\text{-}SO_4\text{-}B_2O_3{:}Dy^{3+}$ phosphor could be potentially used as white LEDs.

Keywords: *Magnesium Sulfoborate, Phosphors, White LEDs, Luminescence properties*

INTRODUCTION

White light emitting diodes (WLEDs) in the field of solid-state lighting are promising new emitting light source due to their long life time, environmental-friendlessness and energy saving devices (Krames *et al.*, 2007; Pavani *et al.*, 2011). The previous study used three methods in order to generate white light, one by the use of primary tricolor phosphor, two by UV-LED+RGB and third by blue LED combined with yellow emitting phosphor as shown in Figure 1 (Ratnam *et al.*, 2009; Ye *et al.*, 2010). White light emission resulted from a single-phase phosphor with high luminous efficiency is required (Ratnam *et al.*, 2010). Therefore, single phase of white-emitting luminescence is UV required for -pumped white LEDs to enhance the luminescence and efficiency (Nagpure *et al.*, 2010). Phosphors doped rare earth ions have been studied by many researchers due to white light emission application. Dysprosium ions have two intense bands in the blue (484 nm) from transition of $^4F_{9/2} \rightarrow {}^6H_{15/2}$ and yellow (575 nm) from transition of $^4F_{9/2} \rightarrow {}_6H_{13/2}$ (Zhang *et al.*, 2012). There are many reports on hosts doped with trivalent dysprosium ions, such as, phosphate $NaCaPO_4$: Dy^{3+} (Ratnam *et al.*, 2010), borates $Ba_2LiB_5O_{10}$:Dy^{3+} (Liu *et al.*, 2011), silicate $CaMgSi_2O_6$:Dy^{3+} (Chen *et al.*, 2009) and some oxide Y_2O_3:Dy^{3+} (Jayasimhadri *et al.*, 2010). Among these phosphors, borate phosphors have been attracted much attention because of its a simple preparation, stable crystal structure, high thermal stability and cheap raw material (Li *et al.*, 2010). However, to the best of our knowledge, there has been no report on $MgOSO_4B_2O_3$:Dy^{3+} for application in white LEDs. Therefore, in this paper, a novel white $MgOSO_4B_2O_3$:Dy^{3+} phosphor was prepared by conventional solid-state reaction method and their photoluminescence properties, such as excitation and emission were presented.

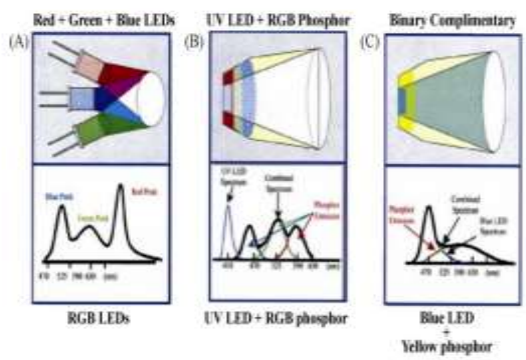

Figure 1: Diagram showing three way to generate white light from LEDs: (A) red + green + blue-LEDs, (B) UV-LED + RGB phosphors, and (C) blue-LED + yellow phosphor (Ye *et al.*, 2010)

EXPERIMENTAL PROCEDURE

A series of $MgO-SO_4-B_2O_3$:Dy^{3+} samples were synthesized using solid state reaction method. Analytical reagent MgO, H_2SO_4, B_2O_3 and Dy_2O_3 (99.99%) were used as the raw materials. The Dy^{3+} ion concentrations ranged from 0.1 mol% to 0.7 mol% in $MgO-SO_4-B_2O_3$. After raw materials were mixed and grained thoroughly in an agate mortar, the mixed powders were placed into alumina crucible and heat at 800 ^{0}C for 2 hours inside the electric furnace. The samples were cooled to room temperature, thus the $MgO-SO_4-B_2O_3$:Dy^{3+}phosphors were obtained. The phosphor samples are grained to powder form for characterization. The structure of samples of Dy^{3+} ion doped $MgO-SO_4-B_2O_3$ phosphor were characterized by powder X-ray diffraction (XRD) (Rigaku D/MAX-2500, Cu Kα, 40 kV, 150 mA). The emission as well as excitation were measured using SHIMADZU RF-540 UV spectrophotometer. The luminescence characteristics of these phosphors were measured at room temperature.

RESULTS AND DISCUSSION

XRD, EDX AND SEM ANALYSIS

$MgO\text{-}SO_4\text{-}B_2O_3$ has cubic structure with F-43c (219) space group, and its lattice parameters are a=12.0970 nm, b=12.0970 nm, c=12.0970 nm (PDF card No: 00-026-1254). The XRD pattern of the $MgO\text{-}SO_4\text{-}B_2O_3$ with concentration ranged from 0.1 to 0.7 mol% of Dy^{3+} as shown in Figure 2. We observed that all samples have the same pattern, and index to the $MgOSO_4B_2O_3$ crystalline phase. The results here also show that Dy^{3+} ions do not form any new phases in the synthesis process.

Figure 3 shows the energy dispersive X-ray (EDX) of the $MgO\text{-}SO_4\text{-}B_2O_3$: $0.5Dy^{3+}$ phosphor. In EDX the phosphor consists of Mg, S, O, B and Dy elements, thus the EDX spectrum shows all the major elements used in the prepared sample.

Figure 4 shows the scanning electron microscope (SEM) image of the sample. In SEM the shape of the phosphor particle of the 0.5% Dy_2O_3 indicates the crystalline nature of the sample, and homogeneity is observed.

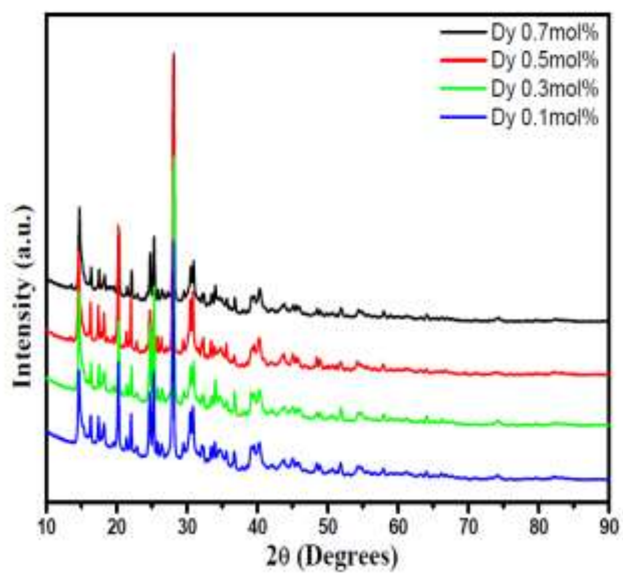

Figure 2: XRD pattern of $MgO\text{-}SO_4\text{-}B_2O_3{:}Dy^{3+}$

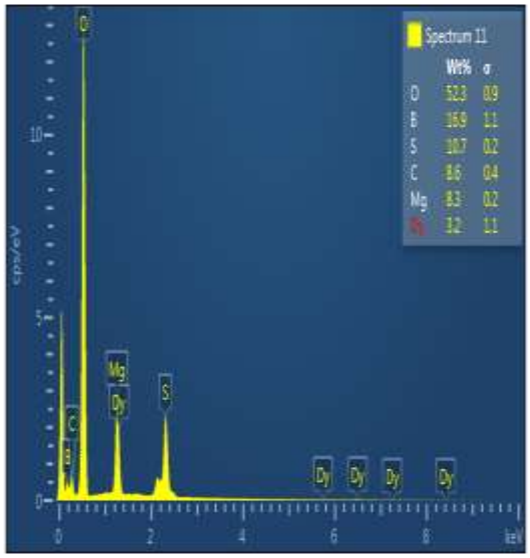

Figure 3: EDX spectra of MgO-SO_4-B_2O_3: 0.5 Dy^{3+}phosphor

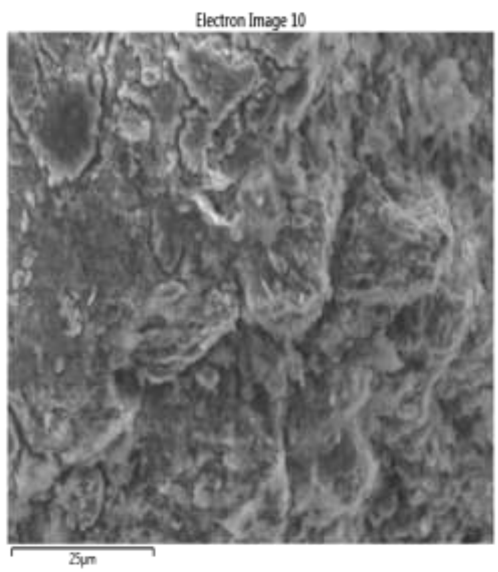

Figure 4: SEM image MgO-SO_4-B_2O_3: 0.5 Dy^{3+}phosphor

LUMINESCENCE PROPERTIES

The excitation spectra of the MgO-SO_4-B_2O_3:Dy^{3+} phosphor is shown in Figure 5. The excitation spectrum for 573 nm emission exhibit six bands at 347 nm, 362 nm, 386 nm, 426 nm, 449 nm and 469 nm (Li *et al.*, 2008). The emission spectra of MgO-SO_4-B_2O_3:Dy^{3+} phosphor shows three bands at 480 nm, 573 nm and 660 nm under excitation 386 nm, which correspond to the transitions of $^4F_{9/2} \rightarrow {^6H_{15/2}}$, $^6H_{13/2}$ and $^6H_{11/2}$ of Dy^{3+}, respectively, as shown in Figure 6. The emission intensities is increases with increasing Dy^{3+} concentration, and reach the maximum value at 0.5 mol% Dy^{3+}, then decrease because of the concentration quenching were observed (Zhang *et al.*, 2013). The excitation and emission spectra show that the white LED can be presented through combining ultraviolet chip with MgO-SO_4-B_2O_3:Dy^{3+} phosphor. Moreover, the phosphor is very suitable for a color converter of white LED that uses blue LED as the primary light source, i.e., it can be used as a white phosphor excited by UVLED chip to fabricate white light, or by blue LED chip to generate white light.

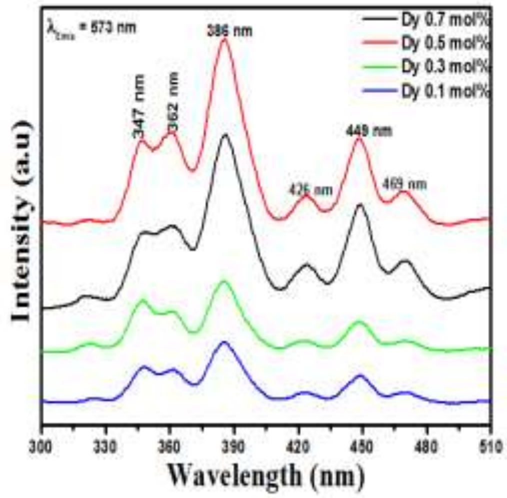

Figure 5: The excitation of MgO-SO_4-B_2O_3:Dy^{3+}

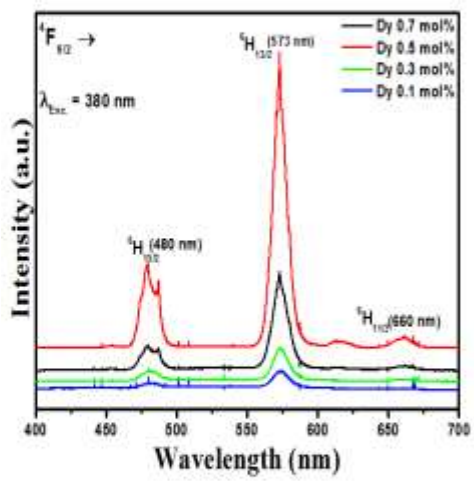

Figure 6: The emission of MgO-SO_4-B_2O_3:Dy^{3+}

CONCLUSIONS

Magnesium sulfoborate doped dysprosium ions (MgO-SO_4-B_2O_3:Dy^{3+}) has been synthesized using solid state reaction method. XRD analysis shows that the samples show two phases, such as monoclinic and triclinic phase. The emission spectrum of Dy^{3+} ion doped MgO-SO_4-B_2O_3 phosphor exhibit three bands at 480 nm, 573 nm and 660 nm with excitation 386 nm due to $^4F_{9/2} \rightarrow ^6H_{15/2}$, $^6H_{13/2}$ and $^6H_{11/2}$ transitions of Dy^{3+}, respectively. The excitation spectrum with the emission of 573 nm have several bands centred at 347 nm, 362 nm, 386 nm, 426 nm, 449 nm and 469 nm, which is in agreement with the ultraviolet LED (350–410 nm) and blue LED (450–470 nm). The optimal luminescence intensity of the MgO-SO_4-B_2O_3:Dy^{3+} phosphor is found at 0.5 concentration of Dy^{3+}. The results show that MgO-SO_4-B_2O_3:Dy^{3+} phosphor could be potentially used as white LEDs.

ACKNOWLEDGEMENT

The authors are grateful to the Bauchi State University, Gadau and Ministry of Higher Education Malaysia for providing financial assistance.

REFERENCES

Chen, Y., Cheng, X., Liu, M., Qi, Z. and Shi, C. (2009). Comparison study of the luminescent properties of the white-light long afterglow phosphors: CaxMgSi 2 O 5+ x: Dy 3+(x= 1, 2, 3). *Journal of Luminescence, 129*(5), 531-535.

Jayasimhadri, M., Ratnam, B., Jang, K., Lee, H. S., Chen, B., Yi, S. S. and Moorthy, L. R. (2010). Greenish-Yellow Emission from Dy3+-Doped Y2O3 Nanophosphors. *Journal of the American Ceramic Society, 93*(2), 494-499.

Krames, M. R., Shchekin, O. B., Mueller-Mach, R., Mueller, G. O., Zhou, L., Harbers, G. and Craford, M. G. (2007). Status and future of high-power light-emitting diodes for solid-state lighting. *Display Technology, Journal of, 3*(2), 160-175.

Li, P., Wang, Z., Yang, Z., Guo, Q. and Li, X. (2010). Luminescent characteristics of LiCaBo 3: M (M= Eu 3+, Sm 3+, Tb 3+, Ce 3+, Dy 3+) phosphor for white LED. *Journal of Luminescence, 130* (2), 222-225.

Li, P., Yang, Z., Wang, Z. and Guo, Q. (2008). White-light-emitting diodes of UV-based Sr 3 Y 2 (BO 3) 4: Dy 3+ and luminescent properties. *Materials Letters, 62*(10), 1455-1457.

Liu, Y., Yang, Z., Yu, Q., Li, X., Yang, Y. and Li, P. (2011). Luminescence properties of Ba 2 LiB 5 O 10: Dy 3+ phosphor. *Materials Letters, 65*(12), 1956-1958.

Nagpure, I., Pawade, V. and Dhoble, S. (2010). Combustion synthesis of Na2Sr (PO4) F: Dy3+ white light emitting phosphor. *Luminescence, 25*(1), 9-13.

Pavani, K., Kumar, J. S., Sasikala, T., Jamalaiah, B., Seo, H. J. and Moorthy, L. R. (2011). Luminescent characteristics of Dy 3+ doped strontium magnesium aluminate phosphor for white LEDs. *Materials Chemistry and Physics, 129*(1), 292-295.

Ratnam, B., Jayasimhadri, M., Jang, K., Sueb Lee, H., Yi, S. S. and Jeong, J. H. (2010). White Light Emission from NaCaPO4: Dy3+ Phosphor for Ultraviolet-Based White Light-Emitting Diodes. *Journal of the American Ceramic Society, 93*(11), 3857-3861.

Ratnam, B., Jayasimhadri, M., Yoon, J., Jang, K., Lee, H.-S., Yi, S.-S. and Jeong, J. H. (2009). Luminescent Properties of Tb3+-Doped NaCaPO4 Phosphor. *Journal of the Korean Physical Society, 55*(6), 2383-2387.

Ye, S., Xiao, F., Pan, Y., Ma, Y. and Zhang, Q. (2010). Phosphors in phosphor-converted white light-emitting diodes: Recent advances in materials, techniques and properties. *Materials Science and Engineering: R: Reports, 71*(1), 1-34.

Zhang, X., Lu, Z., Meng, F., Hu, L., Xu, X., Lin, J. and Tang, C. (2012). Luminescence properties of Ca 3 Si 2 O 7: Dy 3+ phosphor for white light-emitting diodes. *Materials Letters, 79*, 292-295.

Zhang, Z.-W., Sun, X.-Y., Liu, L., Peng, Y.-s., Shen, X.-h., Zhang, W.-G. nd Wang, D.-J. (2013). Synthesis and luminescence properties of novel LiSr 4 (BO 3) 3: Dy 3+ phosphors. *Ceramics International, 39*(2), 1723-1728.