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Luminescence in the system Al_2O_3-B_2O_3

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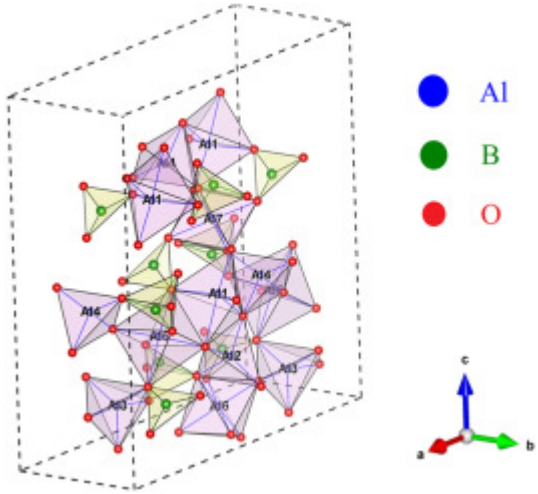
Highlights

- Combustion synthesis of phosphors in Al_2O_3-B_2O_3 system reported.
- $Al_4B_2O_9$, Al_5BO_9 and $Al_{18}B_4O_{33}$ were successfully prepared.
- Luminescence of Ce^{3+} and Cr^{3+} observed in as-combusted powders.
- Characteristic luminescence in form of narrow R lines of Cr^{3+} was observed in Al_5BO_9 and $Al_{18}B_4O_{33}$.

Abstract

Three compounds in the system Al_2O_3-B_2O_3, viz. $Al_4B_2O_9$, Al_5BO_9 and $Al_{18}B_4O_{33}$ were successfully prepared by facile combustion synthesis. Activation by 3d transition element Cr^{3+} and 4f lanthanide Ce^{3+} was attempted. Characteristic luminescence in form of narrow R lines of Cr^{3+} was observed in Al_5BO_9 and $Al_{18}B_4O_{33}$. Interaction of Cr^{3+} with the surrounding was represented by the Racah parameters. Broad band emission of Ce^{3+} arising from allowed d-f transitions in near ultraviolet (nUV) region in all 3 compounds is reported for the first time.

Graphical Abstract



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Introduction

The investigations on the system Al_2O_3-B_2O_3 have a long history. A compound was identified as back as 1887 [1]. The correct composition, however, was established much later as $Al_{18}B_4O_{33}$ [2]. Another compound, $Al_4B_2O_9$, was also discovered around the same time [3]. None of these compounds have the composition of the natural mineral jeremejevite which is $AlBO_3$. This compound could not be prepared at normal pressure. Following these early studies, a first systematic phase diagram was given by Gielisse and Foster [4]. ICDD data mention several other phases like Al_3BO_6 [5] most of which are metastable; Al_5BO_9 being notable as a stable phase at normal temperature and pressure [6]. Decterov et. al. have given a detailed history of the phase diagram of Al_2O_3-B_2O_3 system [7].

Subsequently, these compounds were found to be useful for several applications [8]. Owing to low-cost, “suitability for large scale production, high strength, and low thermal expansion and conductivity, these compounds are used as reinforcer in metal matrix composites”. It has high resistance against boron-rich glass melts and thus finds use in refractory linings [9]. Applications in catalytic converter, for thermal sealing and insulating materials in hypersonic vehicles, have also been mentioned [10]. Boron being a good neutron absorber, the aluminoborates find application in construction of reactor components.

Notwithstanding the abovementioned applications, those related to luminescence are few. Some scattered references mention luminescence in one of the phases, but systematic study is still lacking. Luminescence of Tb^{3+} [11] was investigated by Guangyan

et al. Eu^{2+} in $Al_4B_2O_9$, has been mentioned by Zheng and Chen, but emission is very weak and the excitation spectra are poorly resolved [12]. Yerpude et al., on the other hand, found Eu^{3+} [13] in this host. Luminescence of Nd^{3+}-Yb^{3+} [14] and associated upconversion [15] has been also described. Luminescence of some lanthanides in $Al_{18}B_4O_{33}$ has been mentioned, though there is huge difference in sizes of Al^{3+} and trivalent lanthanide ions Ce^{3+}[11], Eu^{3+} [16], [17], [18], Tb^{3+} [19], Er^{3+} [20]. In recent years only, some luminescence studies have also been reported for Al_5BO_9, particularly, trivalent Eu^{3+} [21] and Sm^{3+} [22]have been investigated.

Considering this lack of information on luminescence, we have undertaken the work on luminescence in system Al_2O_3-B_2O_3. Luminescence of Ce^{3+} and Cr^{3+} is reported here. Ce^{3+} usually gives strong photoluminescence due to allowed nature of the f-d transitions. Cr^{3+} can suitably occupy Al^{3+} substitutional site and give line emission in oxidic hosts. Hence, these two activators were chosen. Three phases, $Al_{18}B_4O_{33}$, $Al_4B_2O_9$ and Al_5BO_9, could be prepared using combustion method by just changing the Al:B ratio in the starting mixture.

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Experimental

Known stable phases, $Al_{18}B_4O_{33}$, $Al_4B_2O_9$ and Al_5BO_9, were prepared by combustion synthesis. A detailed description is presented in our earlier work [23]. Salient points are as follows. “Aluminium nitrate has exothermic reaction with urea. Reagent grade (Indian Rare Earths, Ltd.) Cerium oxalate/Chromium oxides were converted to the corresponding nitrates by dissolving in minimum amount of nitric acid. The nitrates were dried by prolonged, gentle warming. Stoichiometric amounts of hydrated…

$Al_4B_2O_9$

The formation of $Al_4B_2O_9$ was ascertained with the help of XRD. In Fig. 1 comparison of the measured pattern with the ICDD data file 79–1477 is made. The measured pattern is noisy due to small particle size typical of combustion synthesis. Notwithstanding the noisy pattern, sharp lines are observed superposed at the positions matching with the

ICDD file. Thus, simple combustion synthesis has produced $Al_4B_2O_9$. Methods described in literature are much more cumbersome. Four different methods for…

Conclusions

Three phases in the system Al_2O_3-B_2O_3 viz. $Al_4B_2O_9$, Al_5BO_9 and $Al_{18}B_4O_{33}$ could be prepared by the one step combustion synthesis just by changing Al:B ratio in the starting mixture. These could be activated by Ce^{3+} and Cr^{3+}. Owing to large difference in ionic sizes of the host Al^{3+} and Ce^{3+}, only 0.2% Ce^{3+} could be incorporated. New results on luminescence of Cr^{3+} in these compounds are presented. Line emission originating from $^2E \rightarrow {}^4A_{2\,g}$ transition around 700 nm is observed for Al_5BO_9 and $Al_{18}B_4$…

CRediT authorship contribution statement

S.G.Revankar – Synthesis, Manuscript writing, K.A.Gedekar- Synthesis and Editing, S.P.Puppulwar-Editing of manuscript, S.P.Wankhede- Synthesis and Editing, P.D. Belsare – Characterization, S. V. Moharil – Basic concept and Editing.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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Recommended articles

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>
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Luminescence in synthetic boromullite prepared by combustion synthesis ↗

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