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Activation of bismuth aluminate for obtaining near infrared emission

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Highlights

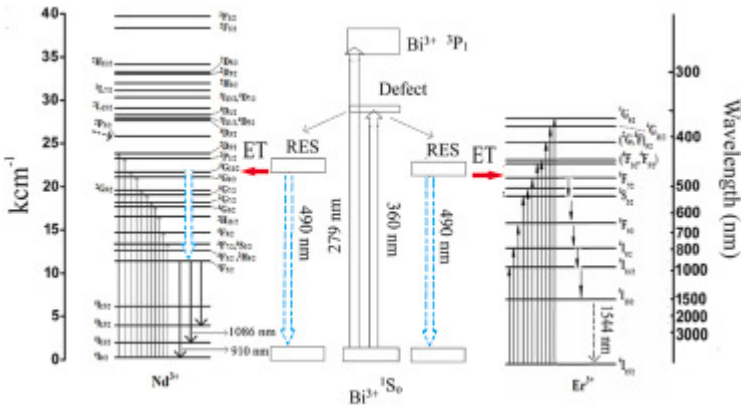
- Combustion assisted synthesis of $Bi_2Al_4O_9$ phosphors activated with Cr^{3+}, Er^{3+}or Nd^{3+} reported.
- Host sensitized NIR emission observed.
- Characteristic luminescence in form of narrow lines observed for all the activators.
- These phosphors can be useful for making low cost NIR sources.

Abstract

New results on NIR emission in $Bi_2Al_4O_9$ phosphors activated with Cr^{3+}, Er^{3+}or Nd^{3+} are presented. These phosphors were prepared by a simple two step method consisting of combustion followed by annealing at 800C. Annealing step was necessary to obtain powders with good crystallinity; as-combusted powders being amorphous. Host sensitization was observed in all the phosphors. An excitation band around 279nm

corresponds to ~~bandgap excitation of the host~~ $^1S_0 \rightarrow {}^3P_1$ transition of the Bi^{3+} ion, while that at 360nm to the defect absorption. Apart from the excitation in these host related bands, characteristic excitations also produced intense emission lines. It is suggested that these phosphors can be useful for making low cost NIR sources needed in various applications.

Graphical abstract



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Introduction

Tutov et al. [1] and Echerlin and Liebertz [2] explored the possibility of obtaining orthorhombic bismuth aluminate. They arrived at the synthesis conditions, and determined the melting point of this compound. Levin and Roth [3] assigned a formula for this compound as $Bi_20_3{\cdot}2Al_20_3$. Niizeki in 1968 solved the structure of $Bi_2O_3{\cdot}2Al_2O_3$ [4]. Abrahams et al. [5] refined the structure and investigated ionic conductivity. DFT calculations predicted a semiconductor character of this solid. The band gap was estimated as 2.71eV, and of direct type [6]. Being a semiconductor, it is a candidate for studying photocatalytic activity and dye degradation [7]. $Bi_2Al_4O_9$ can be heated in hydrogen atmosphere without phase change until 1080C, which makes it attractive for application in fuel cells [8]. Doping with divalent Sr^{2+} and Ca^{2+} yields promising electrolyte materials [9]. $Bi_2Al_4O_9$ is one of few Bismuth compounds which show Bi^{3+} luminescence even at room temperature [10]. Interesting scintillation properties were found in this compound [11]. Luminescence of Cr^{3+} enables application as a ratiometric thermometer [12]. Blasse and Ho [13] also studied luminescence of Tb^{3+} and Eu^{3+} in $Bi_2Al_4O_9$ but found no host sensitization and thus concluded that there is no energy migration over Bi sublattice.

There are no reports on IR emission in this host. NIR emissions are of considerable interest in various applications [14] such as bioimaging [15,16], telecommunications, fluorescent cooling [17], solar photovoltaics [18], Photodynamic therapy [19], photostimulated localized hyperthermia [20], eye-safe lasers [21,22], “infrared machine vision system for automatically detecting the quality of fruits” [23,24], etc. In bioimaging, UV light could be damaging to tissues also it has very limited penetration depth. These shortcomings can be overcome by use of NIR light. “First biological window (NIR I: 700–950nm) and second biological window (NIR II: 1000–1500nm) were found to be favored for bio-imaging [25]. Telecommunication windows of 1.3 and 1.55 μm are of particular interest, as they correspond to the desirable wavelengths in nanophotonic applications” [26]. Solar cells of practical importance such as c-Si and CIGS have maximum sensitivity in NIR region. Their response is poor for wavelengths below 500nm and especially in nUV region. NIR emitting phosphors which can convert light in the region 350–500nm serve as spectrum modifier to boost the photovoltaic conversion efficiency of such cells [[27], [28], [29]].

In this work, we report NIR emission in $Bi_2Al_4O_9$ host using Cr^{3+}, Er^{3+} and Nd^{3+} activators.

Though $Bi_2Al_4O_9$ can be prepared at moderate temperatures using solid state reaction [30], various novel techniques such as sol-gel [31], Glycine combustion technique [32], Glycerin Method [33], Combined Mechanochemical/Thermal Synthesis [34] have been used by various researchers for the synthesis. We used combustion synthesis followed by thermal annealing for the phosphor synthesis.

Section snippets

Experimental

$Bi_2Al_4O_9$ phosphors were prepared by combustion synthesis. A detailed description is presented in our earlier work [35]. Salient points are as follows. “Aluminium nitrate has exothermic reaction with urea. Reagent grade (Indian Rare Earths, Ltd.) Lanthanide/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 nitrates of bismuth and aluminium were…

Results and discussion

As combusted powders were amorphous in nature when urea was used as fuel, as could be inferred from the XRD pattern. (Fig. 1). Also, there was no customary foaming during

combustion. Next, we tried mixture of glycine+urea as a fuel. Urea was chosen as a fuel for aluminum nitrate and glycine for bismuth nitrate. With these modifications, conventional combustion with foam formation was observed (Fig. 2). However, XRD patterns for the as combusted powders again revealed amorphous nature. When…

Conclusions

$Bi_2Al_4O_9$ activated with some lanthanides and Cr^{3+}, could be prepared by two step combustion process. As combusted powders were amorphous in nature. Annealed powders exhibited sharp diffraction line which matched very well with ICDD data. NIR emission was observed in all these phosphors. Apart from the activator excitation lines, bands around 279 and 360 nm are observed in the excitation spectra of all three phosphors. Host ê Cr^{3+}, Host ê Nd^{3+} and Host ê Er^{3+} energy transfers have been observed…

Author aggrement

These results have not been published earlier, nor under consideration by any other Journal for publication. In the event, the article is accepted for publications, authors agree to abide by the rules and policy of the Journal.…

CRediT authorship contribution statement

S.G. Revankar: Synthesis, Characterization, Manuscript writing. **S.P. Puppulwar:** Editing of manuscript. **K.A. Gedekar:** Synthesis and Editing. **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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