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物質・材料

A novel Cr^{4+}-activated $Ca_5Ga_6O_{16}$ broadband NIR phosphor: synthesis, crystal structure and luminescence properties

TECHNOLOGY SHOWCASE

SATテクノロジー・ショーケース2025

■ はじめに

Near-infrared (NIR) spectroscopy has significant potential for several applications, including non-destructive food analysis, plant growth, environmental monitoring, and biomedical imaging. This approach enables the rapid and effective characterization of chemicals and materials. Generally, phosphor-converted light-emitting diodes (NIR pc-LEDs) provide significant benefits over others near-infrared (NIR) radiation sources due to their superior output power, efficiency, durability, and compactness. Thus, the development of NIR phosphors is essential for the effective of NIR pc-LEDs. Presently, Cr4+ doped NIR phosphors demonstrating broadband emission have attracted considerable attention as a potential activator for NIR long-wave light sources. Generally, Cr ions tend to form as Cr3+ in hosts with octahedral sites, which is not preferable for the Cr4+-doped NIR-II phosphors. Consequently, it is essential to discover a host that can effectively serve as a single activation center for Cr4+ in phosphors. In this research study, the new phosphor $Ca_5Ga_6O_{14}$:Cr would provide additional opportunities as a host matrix for Cr^{4+}-doped NIR-II phosphor materials.

■ 活動内容

1. The synthesis of Ca5Ga6O16

A new candidate for the broad-band NIR phosphors $Ca_5Ga_6O_{14}$ substituted with Cr as an activator was successfully synthesized. The influence of Cr concentration on the photoluminescence were investigated with the variation from 0.01 to 4 mol%. the $Ca_5Ga_6O_{14}$ single phase can successfully be synthesized with the Cr doping below 2 mol%. The simulated structure of Ca5Ga6O14 crystals is shown in Figure 1. This chemical has an orthorhombic crystal structure with a space group of Cmc21. The structural framework consisted of a layered arrangement of Ca2+ and Ga3+ ions, which filled octahedral and tetrahedral sites, respectively. Both are separately bound in a planar configuration, produced by sequentially sharing an oxygen stacking along the c axis.

2. Valence state and optical properties

Figure 2 indicates the diffuse reflectance absorption spectra of the synthesized phosphors. The Ca5Ga6O14 phosphor exhibited a consistent absorption pattern with chromium substitutions varying from 0.05 to 2 mol%. The confirmation of absorption bands corresponding to Cr4+, Cr5+, and Cr6+ was conducted. Furthermore, with an optimum doping concentration of Cr at x=0.0005, the intensity of the Cr6+ band was observed to be at its lowest which is benefit for the luminescence properties of the synthesized phosphor.

3. Photoluminescence properties

Under excitation at 650 nm, the Ca5Ga6O14:xCr phosphor exhibits broadband NIR II light emission within the range of 1150-1600 nm centered at 1330 nm, which is attributed to the characteristic transition allowed by the $^3T_2 \rightarrow {}^3A_2$ spin of Cr^{4+}. The results suggest that the luminescence center of this phosphor is associated with the Cr4+ ion. The optimal composition showing the best photoluminescence property is Ca5Ga6O14 with 0.05 mol% of chromium substitution as shown in Figure 3.

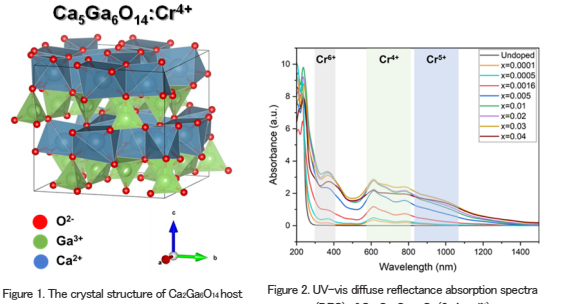

Figure 1. The crystal structure of $Ca_5Ga_6O_{14}$ host

Figure 2. UV-vis diffuse reflectance absorption spectra (DRS) of $Ca_5Ga_6O_{14}$: xCr (0-4 mol%)

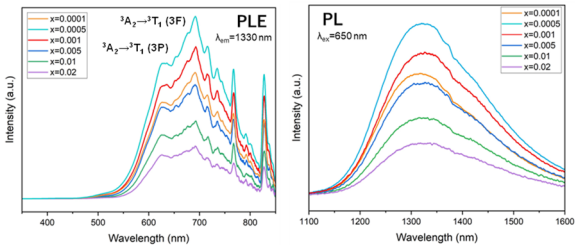

Figure 3. The concentration-dependent PLE and PL spectra of $Ca_5Ga_6O_{14}$: xCr (0-4 mol%)

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