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Structural and Optical Investigations of Tm3+/Yb3+ Doped Yttrium Pyrogermanate for Blue and NIR Upconversion

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The rare-earth germanates has attracted significant attention due to their remarkable thermal stability, low phonon energy, and structural flexibility, making them promising hosts for rare-earth ion doping in photonic and optoelectronic applications. Yttrium pyrogermanate (Y₂Ge₂O₇) phosphors were synthesized via the solid-state reaction method and doped with Tm³⁺ and Yb³⁺ ions to investigate their structural and optical properties for potential upconversion (UC) applications. The focus was on evaluating how co-doping with Yb³⁺ enhances the blue/NIR emission of Tm³⁺ under near-infrared 980 nm excitation.
Powder X-ray diffraction confirmed the formation of the tetragonal P4₁2₁2 phase for both undoped and doped samples, with no secondary phases detected. Field emission scanning electron microscopy revealed irregularly shaped particles with average grain sizes of around 1 μm, forming agglomerated clusters typical of solid-state reaction prepared materials. The diffuse reflectance revealed absorption bands around 452 nm (¹H₆⟶¹G₄), 684 nm (³H₆⟶³F₃) and 797 nm (³H₆⟶³H₄
of Tm³⁺ ions, as well as and 980 nm (²F_{7/2} ⟶ ²F_{5/2})
of Yb³⁺ ions, confirming successful doping. A notable red-shift in the absorption edge was observed in the co-doped sample.
The photoluminescence measurements excited at 355 nm exhibited characteristic blue emission at ~453 nm (¹D₂ ⟶ ³F₄) and weaker red and NIR bands at 650 nm (¹G₄ ⟶ ³F₄) and 792 nm (³H₄
⟶ ³H₆) of Tm³⁺ ions. Upconversion studies under 980 nm excitation showed weak blue emission at ~475 nm(¹G₄ ⟶³H₆) and a strong NIR emission at ~797 nm (³H₄ ⟶ ³H₆). Notably, co-doping with 2% Yb³⁺ enhanced the UC emission intensity considerably compared to the singly doped sample, confirming efficient energy transfer from Yb³⁺ to Tm³⁺ ions. This enhancement is attributed to two-photon and three-photon energy transfer upconversion (ETU) mechanisms responsible for NIR and blue emissions, respectively, with Yb³⁺ ions acting as effective sensitizer. These findings demonstrate the potential of rare-earth doped pyrogermanate phosphors as promising candidates for UC-based applications.

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