YAG-BASED HIGH-ENTROPY GARNETS: SYNTHESIS AND CHARACTERIZATION

Diana Vištorskaja[1], Artūras Katelnikovas[1], Aivaras Kareiva[1]

[1]Vilnius University, Faculty of Chemistry and Geosciences, Institute of Chemistry, Vilnius, Lithuania
diana.vistorskaja@chgf.vu.lt

The continuous engineering of advanced materials with tailorable properties remains a key scientific challenge, driven by the rapidly growing demands of modern industry and technology [1]. Since 2004, when a new alloy design strategy combining multiple elements in equimolar ratios was introduced, the term "high entropy" has become widely used. This concept led to the development of high-entropy oxides (HEOs) – single-phase solid solution with five or more elements randomly distributed on equivalent lattice sites, in which the configurational entropy by mixing works as a driving force for stabilization [1, 2]. Multicomponent HEOs combine exceptional structural stability with a wide spectrum of functional properties, making them suitable for applications in energy storage, catalysis, optics, photothermal, and ferroelectric devices [1, 3].

Yttrium aluminium garnet (YAG) is a well-established optical host material, exhibiting broad optical transparency from the ultraviolet to the infrared region, high thermal and chemical stability [4]. The garnet structure, with general formula $A_3B_2C_3O_{12}$ and cubic space group, offers exceptional compositional flexibility through three distinct cation sublattices, enabling substitution of A-site yttrium(III) ions with various rare-earth elements and B/C-site aluminium(III) ions with transition or post-transition metals. This structural adaptability allows high lanthanide doping levels without concentration quenching, making YAG a key material for multicolour phosphors, solid-state lasers, and scintillators [5].

Recently, high-entropy strategies have emerged as a promising approach to tune the structural and optical properties of garnet-based materials. However, research on high-entropy rare-earth aluminium garnets remains at an early stage. In this work, high-entropy rare-earth aluminium garnets with novel chemical compositions were synthesized by the sol-gel method at 1000 degrees C. The sol-gel synthesis method was selected due to its ability to produce multicomponent systems with a high level of phase purity and homogeneity at relatively low temperatures. Furthermore, this approach has not previously been applied to the synthesis of YAG-based high-entropy oxides, thereby offering new insight and strong motivation for the present study. The structural properties of the obtained samples were characterized using XRD and FTIR techniques, while their morphology was evaluated by SEM analysis. Elemental composition was determined by SEM-EDX and ICP-OES methods. In addition, the optical properties of the synthesized materials were investigated by recording their emission and excitation spectra.

---

[1] J. Li, M. Fiato, and Y. Wu, "Transparent high entropy garnet ceramics by SPS," Journal of the European Ceramic Society, vol. 44, no. 13, pp. 7846–7854, May 2024, doi: 10.1016/j.jeurceramsoc.2024.05.063.

[2] B. L. Musicó et al., "The emergent field of high entropy oxides: Design, prospects, challenges, and opportunities for tailoring material properties," APL Materials, vol. 8, no. 4, Apr. 2020, doi: 10.1063/5.0003149.

[3] X. Gu, X.-B. Guo, W.-H. Li, Y.-P. Jiang, Q.-X. Liu, and X.-G. Tang, "High-Entropy materials for application: electricity, magnetism, and optics," ACS Applied Materials & Interfaces, vol. 16, no. 40, pp. 53372–53392, Sep. 2024, doi: 10.1021/acsami.4c11898.

[4] B. Bettes and Y. Xie, "Synthesis and processing of transparent polycrystalline doped yttrium aluminum garnet: a review," Materials Research Letters, vol. 11, no. 1, pp. 1–20, Sep. 2022, doi: 10.1080/21663831.2022.2109441.

[5] W. Cao et al., "Highly Nonstoichiometric YAG Ceramics with Modified Luminescence Properties," Advanced Functional Materials, vol. 33, no. 14, Jan. 2023, doi: 10.1002/adfm.202213418.