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Tuning the structural, magnetic and optical properties of $EuCrO_3$ orthochromites through Dy^{3+} substitution

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Abstract. In this study, $EuCrO_3$ (ECO) and $Eu_{0.9}Dy_{0.10}CrO_3$ (EDCO) rare-earth orthochromite compositions were synthesized through the traditional solid-state reaction technique. A comprehensive investigation was conducted to analyse the effect of the substitution of 10 wt% Dy^{3+} ions on the structural, optical and magnetic properties of $EuCrO_3$. The X-ray diffraction results along with Rietveld refinement confirm the monophasic nature with an orthorhombic distorted perovskite structure for both compositions. Field emission scanning electron microscopy reveals polycrystalline microstructures with average grain sizes ranging from 269 to 327 nm for both compounds. The optical bandgap is evaluated by Tauc's relation and is observed to slightly increase from 2.24 to 2.33 eV with Dy^{3+} ions substitution. Optical parameters, including skin depth, extinction coefficient, refractive index and optical conductivity are determined and their variations with Dy substitution are analysed. Temperature-dependent magnetic analysis reveals a Néel temperature (T_N) of 177 K in EDCO composition, lower than that of pristine $EuCrO_3$ ($T_N \sim 181$ K). The magnetocaloric effect of the EDCO compound demonstrates a magnetic entropy change (ΔS) and relative cooling power of –0.27 J kg^{-1} K and 4.4 J kg^{-1}, respectively, near T_N under the application of 7 Tesla field. This study highlights the tunability of $EuCrO_3$ properties through Dy ion substitution for customized applications.

Keywords. Orthochromites; optical properties; UV/Vis spectroscopy; magnetocaloric effect.

1. Introduction

Rare-earth perovskite oxides have emerged as a noteworthy group of materials that have attracted considerable interest in diverse applications. This is mostly due to their extensive and captivating characteristics, particularly their magnetic, electrical and photocatalytic capabilities [1–5]. Rare-earth orthochromites (a subgroup of perovskite oxides) with a general formula $RCrO_3$ (where R is trivalent rare-earth metal ions) are showing a significant interest due to their magnetic properties [6–8]. These materials exhibit different kinds of magnetic interactions, such as R^{+3}–R^{+3}, Cr^{+3}–Cr^{+3} and Cr^{+3}–R^{+3} interactions. These interactions have a substantial impact on the determination of several magnetic properties, including magnetization reversal [9], spin reorientation [10], exchange bias [11] and magnetocaloric effect [12,13]. Such properties have made orthochromites the potential applicants for sensors thermally assisted random access memory, thermomagnetic switches and magnetic refrigeration [11,14]. Generally, orthochromites exhibit deformed perovskite structures along with *Pnma* space group symmetry and below their Neel temperature (T_N), they often exhibit canted antiferromagnetic arrangement in the G-type configuration. This phenomenon arises as a result of the antisymmetric Dzyaloshinsky–Moriya interaction [15]. In general, when ionic radii of rare-earth elements reduce from La to Lu, the transition temperature (T_N) of orthochromites shows a monotonically decreasing trend across 282 to 112 K [16].

In recent years, researchers have been increasingly drawn to the semiconducting behaviours exhibited by rare-earth-based orthochromites, driven by their potential applications in optoelectronic devices like photodetectors, light-emitting diodes and photocatalytic activities [2,17,18]. The exciting

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