High-purity single crystal growth of $Sm_{1-x}Y_xFeO_3$ using the zone-refining process in an optical float zone furnace

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Perovskite Oxides (ABO_3) have attracted much attention in the last few decades due to their application potential in electronics, energy storage devices, and sensors. Interestingly, many new properties surface when A or B site in the perovskite oxide is tweaked. Physical properties depend on sample preparation, composition, phase formation, and crystallinity. Crystallites in a powder sample orient randomly in almost all directions and give the average property but one expects substantially enhanced properties along specific orientations in the anisotropic single crystal. Ultra-purification by zone refining involves moving a heater along the ingot several times and segregating the impurities to the ingot end. Impurities often manifest due to precursors and sometimes from secondary phases formed during synthesis. Impurity-free single crystals are essential for many applications. Zhang et al. explained the refining process through a rigorous numerical analysis [1].

In this study, we synthesized $SmFeO_3$, an antiferromagnetic material (AFM) with a Neel temperature of about 680 K in a pure format and studied them after selectively doping [2]. Single crystals of $Sm_{1-x}Y_xFeO_3$ (x=0.3, 0.5, 0.7) were grown in an optical floating zone furnace. Four mirrors and a lamp heater (power 1.5 kW) helped to focus the heat onto the sample. Diluting Sm with Y proved effective in modifying the magnetic properties. The polycrystalline compositions contained impurities when examined by powder XRD. The impurity concentration was highest for x=0.3 (doping concentration). It decreased as the Y concentration increased. After the zone refining, crystals contained a pure phase without impurity traces. Impurities manifest in magnetic measurements.

Polycrystalline samples showed two Neel transitions at 721 K and 551 K from the desired phase and impurity, respectively. The single crystal revealed a single Neel transition at 645 K. Crystals of different compositions showed spin reorientation at different temperatures. The Γ3(Cx, Fy, Az) magnetic phase that appeared in Sm0.5Y0.5FeO3 is not usually seen in orthoferrites [3].

Interactions between Sm and Fe moments in crystal lattice led to selected spin configurations. When the Sm to Y ratio changes, different anomalies were discernible at low temperatures. The Sm-Fe interaction commences at 100 K. M-H data reveals exchange bias, the strength of which differs with the concentration of Sm. Our measurements corroborate field-induced spin switching. We will discuss a few interesting physical phenomena emerging due to variations in the composition of $Sm_{(1-x)}Y_xFeO_3$ single crystals.

References

[1] Z. Zhang et al. Crystal growth. PNAS Vol.96 No. 20
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[3] B. Mali et al. Spin reorientation to a Γ3(Cx, Fy, Az) configuration and anisotropic spin-phonon coupling in a $Sm_{0.5}Y_{0.5}FeO_3$ single crystal. Phys. Rev. B 105, 214417 (2022)