

MATERIAL DEVELOPMENT TO ENHANCE REVERSIBLE SOLID OXIDE CELLS FOR HYDROGEN PRODUCTION AND POWER GENERATION

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ABSTRACT

In electrolysis mode, reversible solid oxide cells (RSOCs) can use electricity from renewable sources to produce green hydrogen and, in reverse, in fuel cell mode, uses hydrogen to generate electricity.¹ RSOCs present a viable opportunity to solve renewable energy intermittency and achieve on-demand hydrogen and electricity production. However, multiple requirements including high catalytic activity, high ionic and electronic conductivity and cell component stability must be simultaneously satisfied for electrolytic to fuel cell mode switching to be effective in RSOCs. While the state-of-the-art materials for fabricating solid oxide cells cannot currently fulfil these multiple electrochemical requirements, an exsolution process can simultaneously improve such functionalities in these materials. An exsolution process entails the segregation of metallic cations to form catalytically active nanoparticles on the surface of a perovskite lattice (the support structure) – this results in highly active, anchored and therefore stable catalytic sites.^{2,3} Also, the growth of such nanoparticles to reside within the bulk of the perovskite lattice (bulk exsolution) has been recently shown to improve ionic conductivity.³ Therefore, this research seeks to develop new perovskite materials using surface and bulk exsolution to fulfil the multiple electrochemical requirements of RSOCs. An A-site deficient perovskite with a stoichiometric composition such as (Sr,Ca)_{1-α}(Ti,Fe,Ni)O₃, known for its ability to drive B-site exsolution in their tendency to revert to a stable ABO₃ perovskite stoichiometry,² is targeted in this research. Parameters related to the synthesis of the new perovskite have been examined at the current stage of this research. Also,

five potential precursor materials, (Fe(NO₃)₃·9H₂O, Ni(NO₃)₂·6H₂O, SrCO₃, CaCO₃, and TiO₂) have been studied to ascertain their suitability and develop a synthesis route for the new perovskite materials. The methodology adopted for the study involved the characterisation of the potential precursor materials using thermogravimetry analysis (TGA), scanning electron microscopy (SEM), and X-Ray diffraction (XRD) analysis. The TGA results revealed Fe₂O₃, NiO, SrO and CaO as the decomposition products of Fe(NO₃)₃·9H₂O, Ni(NO₃)₂·6H₂O, SrCO₃ and CaCO₃, while no substantial decomposition occurred in TiO₂.

These decomposition products have indicated the suitability of the different materials as precursors for the desired A-site deficient perovskite material. Fig. 1. shows a combine TG curve, DSC curve and temperature response for Fe(NO₃)₃·9H₂O, while Fig. 2. shows the SEM image for Fe(NO₃)₃·9H₂O. Also, the SEM images have revealed the morphologies of the respective precursor materials. Furthermore, the XRD analysis of Fe(NO₃)₃·9H₂O, Ni(NO₃)₂·6H₂O and CaCO₃ have confirmed their respective crystalline composition and shall help in understanding the complex crystal changes the precursor materials will undergo to form the desired perovskite material. Considering the decomposition temperature ranges: 50 – 400 °C, 56 – 573 °C, 600 – 850 °C, and 620 – 900 °C, respectively, for Fe(NO₃)₃·9H₂O, Ni(NO₃)₂·6H₂O, CaCO₃, and SrCO₃, it is expected that all the precursors, except TiO₂, shall fully decompose into reactive oxides before 950 °C. This indicates that the desired perovskite synthesis reaction will likely occur between the temperature range of 600 – 1000 °C, following the decomposition time of CaCO₃ and SrCO₃.

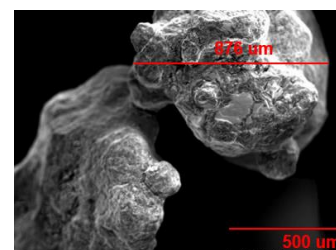
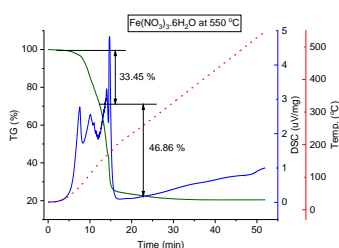


Fig. 1. A TG curve, DSC curve, and temperature response for Fe(NO₃)₃·9H₂O. Fig. 2. The SEM image of Fe(NO₃)₃·9H₂O.

Keywords: Perovskites, Exsolution, Reversible solid oxide cells, Hydrogen production, Net-zero emission.

References

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