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Research Seminar

When: February 3, 2022
Time: 12:00 p.m.
Location: via MS-TEAMS

Investigation of Electrocatalytic, Pseudocapacitive and Electrical Charge Transport Properties of K_2NiF_4-type oxides

Abstract

We have explored a few K_2NiF_4-type oxides as multifunctional materials which are capable of catalyzing both half reactions of electrochemical water splitting namely, hydrogen evolution reaction (HER) and oxygen evolution reaction (OER)[1] and storing energy as a pseudocapacitor.[2] These oxides have a layered structure, similar to the fluoride K_2NiF_4, featuring 2-dimensional layers of octahedrally coordinated transition metals separated by alkaline-earth or rare-earth metals.[3] Electrical charge transport studies of the series $SrLaFeO_4$, $SrLaCo_{0.5}Fe_{0.5}O_4$ and $SrLaCoO_{4-\delta}$ in a wide range of temperatures, 25-800 °C, indicate semiconducting behavior for all of the compounds where electrical conductivity increases as a function of temperature. The end member of the series, $SrLaCoO_{4-\delta}$ exhibits the highest electrical charge transport and the best electrocatalytic activity toward both HER and OER.[1] Chronopotentiometry experiment shows a stable response for at least 12 hours for both HER and OER. X-ray diffraction data before and after HER and OER show that the best performing material is stable after OER and HER in alkaline medium but deteriorated in acidic medium during HER. This catalyst also has the highest degree of polyhedral distortion as well as the presence of oxygen-vacancies. Investigation of the Electrical charge transport properties and electrocatalytic activities of another series, $SrLaM_{0.5}Al_{0.5}O_4$ (M = Mn, Fe, Co), also shows similar trends where $SrLaCo_{0.5}Al_{0.5}O_4$ performs the best. Pseudocapacitive energy storage has been demonstrated for three materials $SrLaFeO_4$, $SrLaCo_{0.5}Fe_{0.5}O_4$ and $SrLaCoO_{4-\delta}$ in 1 M KOH.[2] These pseudocapacitors store charges through oxide ion intercalation.[2] Systematic trends have been demonstrated, where the charge-storage properties are enhanced as a function of Co-concentration, structural distortion and oxygen-deficiency. The best performing material, $SrLaCoO_{4-\delta}$ shows a high specific capacitance, energy density and power density at a current density of 0.5 A/g. These materials are remarkably stable and maintain a nearly constant specific capacitance after 1000 cycles.

References

1. Alom, M. S.; Ramezanipour, F., Layered Oxides $SrLaFe_{1-x}Co_xO_{4-\delta}$ (x=0–1) as Bifunctional Electrocatalysts for Water-Splitting. *ChemCatChem* **2021,** *13* (15), 3510-3516.
2. Alom, M. S.; Ramezanipour, F., Pseudocapacitive charge storage in layered oxides $SrLaFe_{1-x}Co_xO_{4-\delta}$ (x = 0–1). *Mater. Lett.* **2021,** *295*, 129859.
3. Nirala, G.; Yadav, D.; Upadhyay, S., Ruddlesden-Popper phase A_2BO_4 oxides: Recent studies on structure, electrical, dielectric, and optical properties. *J. Adv. Ceram.* **2020,** *9* (2), 129-148.