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Dissertation Defense

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Perovskite Oxide Derivatives for Enhanced Electrochemical Water Splitting and Pseudocapacitive Energy Storage

ABSTRACT:

The global energy landscape is at a crossroads, characterized by surging demand, finite fossil fuel reserves, and mounting environmental concerns due to carbon emissions. To address these challenges and transition towards a sustainable energy future, this dissertation explores perovskite oxides and their derivatives for advanced electrochemical water splitting and pseudocapacitive energy storage. Efficient water splitting catalysts were investigated through the synthesis of quasi-2D oxides, $SrLaAl_{1/2}M_{1/2}O_4$ (M = Mn, Fe, Co), with the B-site incorporating transition and main group metals.[1] These materials demonstrated promise in catalyzing the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER). $SrLaAl_{1/2}Co_{1/2}O_4$ emerged as a standout performer, attributed to stronger bond covalency and advantageous electronic configuration. Refining the study to focus on materials with transition metals at the B-site resulted in remarkable electrocatalytic performance. $SrLaCoO_{4-\delta}$, in particular, showcased superior electrical charge transport and electrocatalytic activities for OER and HER, with oxygen vacancies enhancing performance.[2] The strategic introduction of oxygen vacancies in perovskite oxides led to significant improvements in electrocatalytic activity. $La_2MnCoO_{6-\delta}$ demonstrated enhanced properties for hydrogen and oxygen evolution reactions, emphasizing the importance of oxygen vacancies.[3, 4] Controlled reduction to create oxygen defects in perovskite oxides dramatically improved electrocatalytic activity for both HER and OER. Materials containing Ni also exhibited significantly reduced overpotentials and enhanced turnover frequency, highlighting the influence of oxygen-vacancy-induced changes. Additionally, the research extended to pseudocapacitive energy storage using layered oxides, demonstrating promising charge-storage properties.[5] Symmetric pseudocapacitor cells based on these materials exhibited substantial capacitance, energy density, power density, and stability after numerous charge-discharge cycles, showcasing their potential for energy storage applications.

REFERENCES:

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(5) 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.