BIOGRAPHICAL SKETCH

Devendrasinh Darbar was born in Gujarat, India. Mr. Darbar further enhanced his education by working as an intern in Bharat Sanchar Nigam Limited-India (BSNL) during 2011 and at International Thermonuclear Emission Reactor (ITER-India) in 2012, and he was an ASTRO intern for 8 months during 2018. He worked as a Senior Research Fellow at GERMI for 6 months, and as a subcontractor at Oak Ridge National Laboratory from October 2019 thru August 2021. A large portion of Mr. Darbar's dissertation research has been carried out with the Energy Storage and Conversion Group at Oak Ridge National Laboratory. Mr. Darbar has published 8 peer-reviewed journal papers with 5 as the first author and filed one patent on June 2019, which was licensed to SPARKZ energy startup company in 2020.

EDUCATION

Doctor of Philosophy
Engineering
Tennessee Tech University, December 2021 *(expected)*
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Master of Technology
Energy and Environmental Engineering
Vellore Institute of Technology
India, 2015
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Bachelor of Engineering
Electronics and Communication Engineering
Gujarat Technological University
India, 2012

FUNDING

US Department of Energy - Energy Efficiency and Renewable Energy (EERE), Vehicle Technologies Office (VTO), Tennessee Valley Authority, and the Center of Energy System Research.

College of Engineering

TENNESSEE TECH

The Department of

Electrical and Computer Engineering

Announces the Dissertation Defense of

Devendrasinh Udaisinh Darbar

In Partial

Fulfillment of the Requirements

For the degree of

Doctor of Philosophy in Engineering

September 29, 2021

4:00 p.m.

Tennessee Tech University

Zoom Link: https://tntech.zoom.us/j/87021168068

Meeting ID: 870 2116 8068

FIELD OF STUDY

Energy Storage (Li-ion and Na-ion Battery)

DISSERTATION TOPIC

Cobalt Free Cathode for Li/Na-ion Battery Technologies and Artificial Intelligence-Based State of Charge Estimation

EXAMINING COMMITTEE

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ABSTRACT

With increasing demand of electric vehicles in the coming decade, there will be a significant increase in utilizing battery technologies. This will significantly increase the demand of materials required to make them. Based on conventional cathode chemistries, materials used for commercial lithium-ion batteries are lithium, nickel, cobalt, manganese, and aluminum. Major electric vehicle automakers are looking for an alternative to cobalt because of potential risk associated with the supply of cobalt, price instability, environmental toxicity and major geographical resource concentration in certain countries. Thus, alternative cathode chemistries with no cobalt are needed to be explored. We summarize the potential candidates for cobalt free cathodes for rechargeable Li-ion (LIBs) and Na-ion batteries (SIBs).

In this dissertation, we report solution-based doping and coating strategies to improve the electrochemical performance of the Co-free layered oxide cathode $LiNi_{0.5}Mn_{0.5}O_2$ (NM-50/50). We noticed that small amounts of d^0 dopants (e.g., $Mo^{6+}$and Ti^{4+}, 0.5-1 at. %) increased the cathode's specific capacity, cycling stability, and rate capability. Effects of 1 at. % Mo dopant on the cathode structure have been studied using a suite of characterization tools including X-ray diffraction (XRD), Raman spectroscopy, transmission electron microscopy (TEM), X-ray Photoelectron Spectroscopy (XPS) and X-ray absorption spectroscopy. This work also reports the use of an inorganic $Mn_2P_2O_7$ coating which enhanced the cycling stability of Mo-doped NM-50/50, presumably through formation of a stable cathode electrolyte interphase (CEI) layer.

We also report a sol gel synthesis-based Zn-doped $Na_{0.6}Fe_{0.5}Mn_{0.5}O_2$ (NFM) cathode and the effects of Zn-doping on the crystal structure and electrochemical performance. X-Ray Diffraction (XRD) pattern analysis showed a decrease in the Na-layer thickness with Zn doping. With this understanding, we report a wet synthesis-based titanium doping strategy to improve the structural stability and electrochemical performance for P2-type $Na_{0.67}Fe_{0.5}Mn_{0.5}O_2$ layered oxide cathodes. It was observed that Ti^{4+} doping increased the Na layer thickness, minimized the lattice volume strain, showed better structural stability, minimally decreased Fe migration to the Na layer, and lowered the charge transfer resistance in these P2-type cathodes.

Last part of this dissertation discusses about accurately estimating State-of-Charge using Feed Forward Neural Network (FNN) for Na-ion battery. FNN can self-learn the weight with each training data point and update the model parameters, weights and bias using a combination of two gradient descent (Adam). The FNN successfully estimated the SOC value for highly non-linear Na-ion battery cathode cycled at different current rate- 0.05C, 0.1C, 0.5C, 1C, 2C, having the R^2 value of ~0.97-0.99 and ~0.99 for higher cycle number and at higher cut-off voltage -4.5 V vs. Na^+/Na.