Beyond “Dream” Materials – Engineering Approaches to Understand the Performance Limits of Electrochemcial Systems

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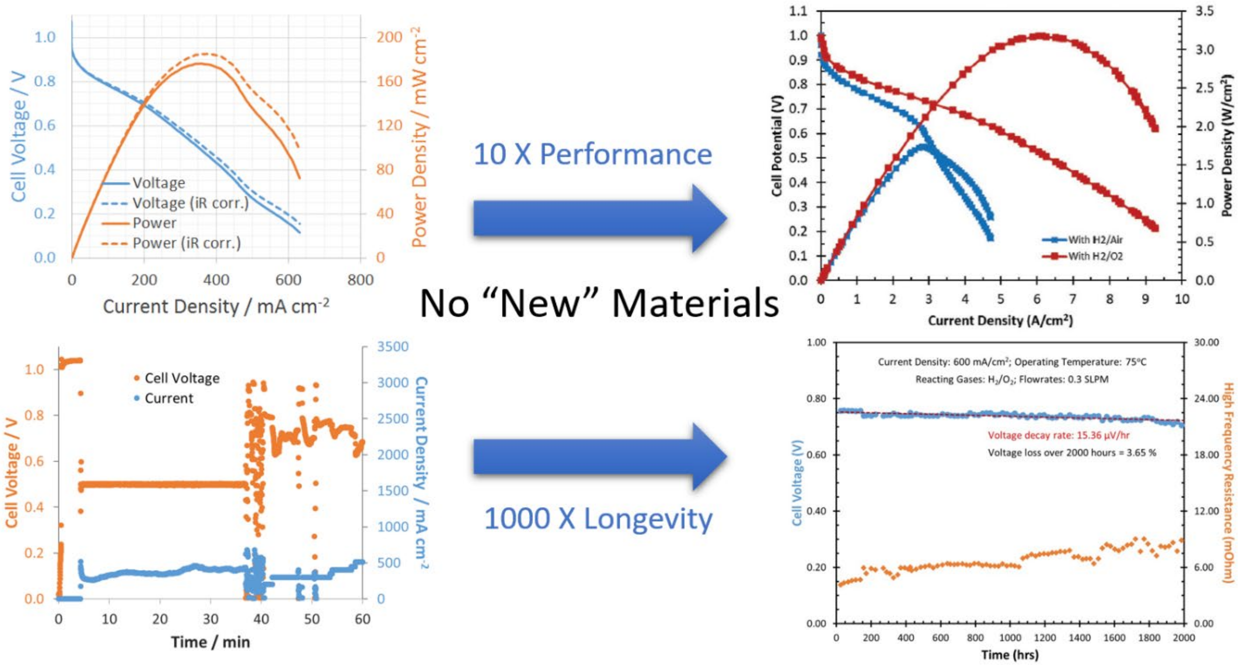
In recent years, the desire to design, create and/or discover advanced functional nanomaterials has changed the way that faculty members and graduate students approach engineering research. Though there are many technologies where these materials can (and likely will) make a significant impact, the truth is that in most disciplines, materials with highly complex structures remain on the fringes of the technology. In some cases, even when so-called “advanced” materials are discovered there are significant difficulties in transitioning the material from ex-situ tests to the real reacting environment – suggesting that we must be careful to understand that structure is one variable and often times there are other fundamental (surface composition, electronic mobility, thermodynamic barriers, etc) and engineering (porosity, mass transport, etc.) properties that drive behavior in complex environments. Additionally, there are systems where materials are being sought without a clear goal for the properties that are required of a real engineered system. Lastly, systems also exist where the achievable limits of the technology have been calculated inappropriately, leading many to explore systems without a true practical end.

In this talk, three short vignettes will be presented. The first report will detail the road to achieving high performing anion exchange membrane fuel cells. In this work, we were able to show that without any new materials that it was possible to both improve the performance of these cells by 10x (defining a new state-of-the-art in the process) as well as enable 1000’s of hours of stable operation. The second report will deal with the economics of electrochemical methane activation – something that has received a significant amount of funding in recent years. There are presently zero reports in the literature that set true targets for system operation or scale. Here, we do so using the real costs of electrochemical reactors as well as engineering economic design principles. Finally, time permitting, the last report will talk about the practical implementation of Al-based batteries. For years, researchers have sought the tempting 4000+ mAh/g capacity of Al. However, the true theoretical limit for modern Al-air and aluminum ion batteries falls far below this number and it is shown that even these theoretical limits fall below already-achievable energy density of existing cells. They also lack the demonstrated operational lifetime.

For more information about this project and the rest of our group, please visit https://www.mustainlab.com

Graphical Abstract



Biography

William (Bill) Mustain is the Director of Emerging Energy Programs at the University of South Carolina (UofSC) and Professor in the Department of Chemical Engineering. In 2017, Professor Mustain moved to UofSC from the Department of Chemical & Biomolecular Engineering at the University of Connecticut where he was an Associate Professor and the United Technologies Corporation Professor of Engineering Innovation. He joined UConn as an Assistant Professor in 2008, and was tenured and promoted to Associate Professor in 2013. Professor Mustain has worked in several areas related to electrochemical energy generation and storage including: high capacity materials for Li-ion batteries, catalysts and supports for proton exchange membrane and anion exchange membrane fuel cells and electrolyzers, electrochemical synthesis of fuels, electrochemical control of biological systems, the purposeful use of carbonates in low temperature electrochemical systems, and the electrochemical capture and utilization of CO_2. Professor Mustain has been the PI or Co-PI on approximately $11 M of externally funded research projects. He has published over 130 peer reviewed articles and three book chapters to date and has over 100 invited and conference talks. He has been the recipient of several awards including the 2009 Illinois Institute of Technology Young Alumnus Award, 2013 U.S. Department of Energy Early Career Award, 2014 Connecticut Quality Improvement Platinum Award, 2014 Supramaniam Srinivasan Young Investigator Award (Awarded by the Energy Technology Division of the Electrochemical Society), 2017 UConn Chemical Engineering Faculty of the Year Award, 2019 USC Chemical Engineering Publication Award and 2015-2016 Fulbright Scholar Fellowship.