## Manufacturing Science and Technology Group
## Room A226 - Session MS-WeA

## Science and Technology for Manufacturing: Solid State Batteries (ALL INVITED SESSION)

**Moderators:** Kelsy Hatzell, Vanderbilt University, Gary Rubloff, University of Maryland, College Park

2:20pm **MS-WeA1 The Importance of Modifying the Nothing Within 3D Electrode Architectures for Solid-State Energy Storage**, ***Debra Rolison***, *M.B. Sassin, C.N. Chervin, J.F. Parker, J. Long,* U.S. Naval Research Laboratory **INVITED**

Our team has found that an architectural design metaphor serves as a powerful guide in re-imagining materials and electrodes in electrochemical energy science [1,2]. Key consumer and military portable power sources (e.g., batteries, fuel cells, supercapacitors) must balance multiple functions (molecular mass transport, ionic/electronic/thermal conductivity, and electron-transfer kinetics) even though these functions often require contradictory structures [2]. The design and fabrication of size- and energy-scalable three-dimensional multifunctional architectures from the appropriate nanoscale building blocks for charge storage seamlessly embodies all of the requisite functions. A critical knob to turn to amplify performance—or move to a new performance curve, such as a 3D solid-state battery with interpenetrating components [2,3]—is the ability to "paint blind," to modify interiors with functional materials that do not block the internal porosity through which reactants enter and products depart. Architecture also matters with the electrocatalysts under exploration to improve oxygen redox (higher activity and lower potential energy costs to drive the reaction) in air cathodes in aqueous metal–air batteries Expressing oxygen reduction or evolution electrocatalysts in ultraporous aerogel form allows us to extract higher activity at lower overpotentials [4–6], further underscoring the importance of nothing and the unimportance of periodicity in energy-relevant nanoarchitectures [7].

[1] J.W. Long, D.R. Rolison, *Acc. Chem. Res*. 2007, *40*, 854–862.

[2] D.R. Rolison, J.W. Long, J.C. Lytle, A.E. Fischer, C.P. Rhodes, T.M. McEvoy, M.E. Bourg, A.M. Lubers, *Chem. Soc. Rev*. 2009, *38*, 226–252.

[3] J.W. Long, B. Dunn, D.R. Rolison, and H.S. White, *Chemical Reviews***2004**, *104*, 4463–4492.

[4] C.N. Chervin, P.A. DeSario, J.F. Parker, E.S. Nelson, D.R. Rolison, J.W. Long, *ChemElectroChem* 2016, *3*, 1369–1375.

[5] J . S. Ko, C . N. Chervin, M . N. Vila, P . A. DeSario, J . F. Parker, J . W. Long, D . R. Rolison, *Langmuir***2017**, *33*, 9390–9397.

[6] J . S. Ko, J . F. Parker, M . N. Vila, M . A. Wolak, D . R. Rolison, and J . W. Long, *J. Electrochem. Soc.***2018**, *165*, H777–H783.

[7] D.R. Rolison, *Science* 2003, *299*, 1698–1701.

3:00pm **MS-WeA3 Precision 3D Solid State Battery Architectures: Science, Challenges and Manufacturing Opportunity**, ***Sang Bok Lee Lee***, *G.W. Rubloff,* University of Maryland, College Park **INVITED**

This presentation describes recent findings related to the design and architectures of thin electrode materials synthesized by thin layer deposition techniques. Throughout the presentation I will describe how these techniques enable us to synthesize electrodes of interest with precise control over the structure and composition of the material. The electrochemical response of these thin electrodes will be discussed in the aspects of structural parameters, ion storage mechanism, interfacial electrochemical issues related to electrode degradation. While it is important to identify and understand mechanisms in performance and degradation, it is even more critical to design strategies and to mitigate challenging technical hurdles for developing means to implement and validate the strategies in the aspect of future manufacturing opportunity. For example, the design and the development process of precision 3D solid state battery architectures on a Si wafer will be discussed. In a nut shell, this talk illustrates how careful design of thin materials architecture can facilitate desirable electrochemical activity, resolve or shed light on mechanistic limitations of electrochemical performance in solid electrolyte systems, and eventually try to convince audience that the thin film processes using primarily existing semiconductor fabrication facilities may provide a new paradigm changing opportunity in solid state battery manufacturing technology.

4:20pm **MS-WeA7 Understanding the Electronic and Mechanical Properties of High Energy Density Anodes on 3D Structures**, ***Amy Prieto***, *J. Ma, M.C. Schulze,* Colorado State University **INVITED**

We are interested in mitigating mechanical failure in high energy density alloy anodes used for rechargeable Li-ion and Na-ion batteries by incorporating 3D architectures. We will present the use of direct electrodeposition of inter metallic alloys onto 3D current collectors, and their cycling in half cell and full cell batteries. A 3D architecture is critical for reasonable power densities in solid state batteries, and we will present our efforts moving toward a fully integrated solid state battery.

5:00pm **MS-WeA9 Enabling High Cycle Life Alkali Metal Anodes through Imposed Thermal Gradients**, *R.W. Atkinson III,* EXCET, Inc.*; R. Carter,* ***Corey Love***, U.S. Naval Research Laboratory **INVITED**

Solid state batteries promise a number of advantages over liquid electrolyte alternatives. The solid state battery will significantly improve safety by eliminating flammable electrolytes, enable high energy density by utilizing alkali metal anodes, and eliminate the weight and volume contribution from a host or alloying element at the anode. However, significant challenges remain in stabilizing metal anodes over many cycles and at high rates. Significant efforts in interfacial design and current collector structure have aimed to demonstrate the viability of the solid state battery, but these strategies often involve complex and costly manufacturing. Herein, we demonstrate the advantage of simply externally warming the anode (40 °C) and cooling the cathode (0°C) to stabilize charging or the plating of metal compared to isothermal controls (20 °C). This technique enables the high rate and long cycle-life desired for viability of the solid state configuration. Our results reveal remarkable stability over many hours (32% lower voltage hysteresis after 400 hr) of operation and fast charging with current densities up to 10 mA/cm$^2$ (competitive with 2C in conventional Li-ion). Further, a thermal gradient is easily implemented in the thermal management strategies commonly used in battery modules making the strategy commercially viable. Finally, it is likely that the thermal gradient will not only assist in realization of the metal anode but also the solid electrolyte. Solid electrolytes are challenged by low ionic conductivity which is often enhanced by heating the material up to ~80 °C. The operational benefit observed in the liquid cells and the directionality of ion movement provided suggest that application of an external thermal gradient will provide better performance than isothermal heating alone.

Carter, R.; Love, C. T., Modulation of Lithium Plating in Li-Ion Batteries with External Thermal Gradient. *ACS Applied Materials & Interfaces* **2018,***10* (31), 26328-26334.

Mistry, A.; Fear, C.; Carter, R.; Love, C. T.; Mukherjee, P. P., Electrolyte Confinement Alters Lithium Electrodeposition. *ACS Energy Letters* **2018**, 156-162.

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