From Nanostructures to Mesoscale Architectures: 
Electrochemical Storage for Smart Things

Gary Rubloff

Distinguished University Professor and Minta Martin Professor of Engineering 
Director, Nanostructures for Electrical Energy Storage (NEES), a DOE EFRC 
Director, Maryland NanoCenter 
University of Maryland

Precision multistep synthesis has enabled the creation of heterogeneous electrochemical nanostructures, involving multiple materials to confer the needed multifunctionality and to understand how design influences electrochemical behavior at the nanoscale and the energy storage performance of nanostructures. Thin film process technologies are increasingly enablers of this design and fabrication flexibility. Guidelines for effective designs include thin ion storage layers available over large accessible electrode surface area, integrated current collectors, robust structure to withstand volume changes during charge/discharge, and dense packing of such structures, with these lessons shown in Li-ion and beyond-Li-ion battery chemistries using liquid organic electrolytes.

Thin film fabricated all-solid-state batteries increasingly present an attractive focus for next-generation electrical energy storage, offering much improved safety, 3D design flexibility from nano to macro scale, and a materials and process knowledge and technology base at the heart of semiconductor and related industries. When combined with microfabrication and patterning to produce 3D scaffolds, thin film processes enable exploration of high performance 3D architectures of dense micro- and nano-scale solid state electrochemical structures, for which we foresee broad applications in energy storage and emerging possibilities in information storage. A recent achievement has been interdigitated electrode structures made by multilayers of conformal ALD deposition for electrode, solid electrolyte, and current collector materials, leading to a fully conformal 3D solid state battery that demonstrates the benefits of 3D architectures. These results suggest a wide range of applications from biomedical and IoT devices to electric vehicles, and in turn, they raise the question of what role thin film fabrication will play in future battery manufacturing, either as single processes (e.g., ALD) inserted into conventional battery fabrication, or as a completely new manufacturing paradigm.

This work has been supported by Nanostructures for Electrical Energy Storage (NEES), an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Award Number DESC0001160.