Engineering Vapor-Deposited Polymers for Energy Conversion and Storage

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Globally, we are pacing towards a cleaner energy economy as we recognize the limits on fossil fuel supplies and the environmental pollution they produce. To mitigate these issues, new technologies harvest energy from cleaner albeit intermittent natural resources like the sun, wind, and water. These energy resources in turn require new technologies for storing energy that can power anything from electronics to vehicles on demand.

With new technologies for energy capture and storage come significant challenges related to the intrinsic materials and architectural design of these energy devices. Polymers, with their vast chemical and physical tunability, offer a unique platform for enabling more efficient alternative energy solutions in solar cells, fuel cells, batteries, and capacitors.

Many of these electrochemical systems rely on high surface area architectures containing nanoscale pores or features to enhance conversion efficiency and energy density. However, with these nano-architectures, it is often difficult to find effective ways to interface them with polymeric materials. Conventional methods, like spin casting or dip coating, that use pre-made polymer liquid solutions frequently suffer from surface tension and wettability issues that lead to non-conformal coatings and poor integration.

To overcome these challenges, my laboratory has been developing new methodologies for engineering electronic polymers for energy conversion and storage that improves materials interfacing and device integration. Central to these efforts is the use of liquid-free chemical vapor deposition (CVD) pathways that effectively integrate polymers in nanostructured electrochemical energy systems and improve on device efficiency and operability.

In this context, my talk will discuss our efforts in engineering polymer electrolytes for next-generation solar cells and conducting polymers for supercapacitors. Critical to this work are two unique CVD approaches, initiated CVD (iCVD) and oxidative CVD (oCVD), that enable (1) the direct chemical synthesis of true polymers from their monomer building blocks – this is typically not achievable with other CVD methods like plasma polymerization – and (2) the tandem formation of the polymers as conformal thin films with well-controlled thickness and morphology – this is generally difficult with liquid phase polymer processing.

Fundamentally, a solid understanding of the competing processes of reactant diffusion and polymerization kinetics is key for enabling conformal growth of polymers on nanoscale pore surfaces and features. Our hypothesis is that better polymer interfacing and integration improves interfacial dynamics in these nanostructured energy systems. My talk will demonstrate how this ultimately translates to enhanced device performance and brings us closer to more viable and robust sustainable energy technologies.