ASSEMBLING NANOSCALE BUILDING BLOCKS THROUGH ELECTROPHORETIC DEPOSITION FOR BATTERIES, SUPERCAPACITORS, CATALYSIS, AND PRINTABLE ELECTRONICS

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Our research group works to gain a fundamental understanding of how to program and process nanoscale building blocks into functional structures, and the structure-property relationships of the resulting nanostructured materials. We seek to develop new nano-materials and methods for batteries, supercapacitors, fuel cells, and printable electronics. For building blocks we utilize monodisperse nanoparticles made through organic-phase colloidal chemistry. One issue that has yet to be adequately addressed for colloidal nanoparticles is their adherence to each other and to an electrically conductive substrate. In this talk I will discuss our results overcoming critical challenges to create functional assemblies from nanoparticles using electrophoretic deposition (EPD).

For batteries, we have found that EPD can be used to form additive-free battery electrodes from colloidal nanoparticles. Typically, polymeric binders are necessary to adhere the particles to each other and the substrate, and carbon additives are necessary to increase conduction. These additives, however, generate a weight increase of 10−40%. We have found that EPD creates a strong electrical and mechanical bond for nanoparticles adhesion, enabling the batteries to perform at maximum capacity. Using EPD methods we have made additive-free nanoparticle electrodes for supercapacitors. This nanoparticle electrodes deliver higher power density and energy density than comparable electrodes. For electrocatalysis, we compare EPD-deposited nanoparticle films to the conventional dropcast method. We find that the electrophoretically deposited nanoparticles outperform the dropcast films by as much as 2.5× for the oxygen reduction reaction and 2.6× and the oxygen evolution reaction when accounting for both surface area and mass. We have applied these techniques to make printable electronics: Using our surface treatment methods to link the nanoparticles, and the EPD method for deposition, we form copper sulfide films with high mobilities and high electronic conductivities that are on par with many bulk copper sulfide films (~75 S·cm-1), without the need for heat-treatments.