Nanostructure Electrodes for Lithium Ion Batteries Using Biological and Chemical Scaffolds

Dr. Yun Jung Lee

Pacific Northwest National Laboratory

Yunjung.lee@pnl.gov

Development of materials that deliver more energy at high rates is important for high power applications including portable electronic devices and hybrid electric vehicles. For lithium ion batteries, reducing materials dimensions can boost Li^+ ion and electron transfer in nanostructured electrodes. Therefore, there is a growing need for nanostructured electrodes for lithium ion batteries to boost electron transfer for high power applications. There have been efforts to electrically address electrode materials with poor electronic conductivity through nanoscale wiring of active materials. However, the wiring tools used so far were functionalized for a single component, either active materials or conducting materials. The wiring did not completely exploit specificity but depended on random occurrence of contacts between either conducting networks or active materials. Here, we present two research directions that utilized biological and chemical template for achieving intimate nanoscale electrical wiring to active material. Facilitated by biological system, M13 virus, a novel strategy was developed for specifically attaching electrochemically active materials to conducting carbon nanotubes networks through biological molecular recognition. By manipulating two-genes of the M13 virus, viruses could be equipped with functional peptide groups with affinity for SWNTs on one end as well as peptides capable of nucleating amorphous iron phosphate (a-$FePO_4$) fused to the viral major coat protein. High power lithium ion battery cathode materials were fabricated using this genetically programmed biological system. Organic-inorganic interface was engineered to use 2-dimensional chemical template graphene as a platform in self-assembled hybrid electrodes. Organic surfactant was used to assist the stabilization of graphene and facilitate the self-assembly of in-situ grown nanocrystalline TiO_2 with graphene. When investigated as anodes for Li-ion battery, these nanostructured TiO_2-graphene hybrid materials showed significantly enhanced lithium ion insertion/extraction properties especially at high rates. The improvement may be attributed to the increased electrode conductivity in the presence of a percolated graphene network embedded into the metal oxide electrodes.