Nanostructured Materials: Exploring the Energy Frontier

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ABSTRACT

Nanotechnology is a revolutionary area that has impacted several areas of materials science and materials technology. The influence of reduced grain sizes and nano-structures has induced a remarkable impact on the electrochemical properties of materials for use in energy storage systems, particularly, lithium-ion batteries, super-capacitors, direct methanol fuel cells and hydrogen storage. The impact of nano-structured materials in three relevant energy storage systems of the present and future will be discussed in this presentation. These include lithium-ion batteries, super-capacitors and direct methanol fuel cells.

Since the discovery of tin oxide nano-composites for use as lithium-ion anodes by Fuji in the late-1990's there has been a surge of activity to develop alternative anode materials for lithium-ion applications. Efforts have been focused at developing approaches to fabricate nano-sized clusters of silicon and tin showing remarkable lithium-ion charge storage capacity to the extent of 4000 mAh/g, representing a ten-fold increment in capacity in comparison to graphite, the traditional anode material. New nano-composite particulate systems have been synthesized at Carnegie Mellon using high energy mechanical milling, which display capacities as high as 700 mAh/g. Thin film systems have also been developed which exhibit near theoretical capacities of 4000 mAh/g.

Super-capacitors have been targeted for providing high power densities for use in hybrid energy storage systems involving batteries and fuel cells. Most of the studies however, have been focused on traditional materials systems such as carbon and ruthenium oxides. Our research has been directed towards developing novel approaches for synthesizing transition metal nitride nano-particles. Tailoring the nitride composition, the crystallite size and the electrochemical potential window, capacitance and stabilities exceeding that of RuO_2 have been achieved.

Direct methanol fuel cells have long been considered as attractive alternatives to hydrogen fuel cells due to the lower cost and ease of transportation of methanol. However, poor kinetics and the efficiencies of the noble metal catalysts have necessitated higher loadings which limit the overall potential of these attractive systems. New non halide based sol-gel approaches have been developed to synthesize nanosized electrocatalysts exhibiting specific surface area on the order of 140 m^2/g. Results of the materials and electrochemical characterization appear quite promising.

This presentation will highlight the salient scientific and technological aspects of the different nano-structured materials for use in the above three energy storage systems.