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Novel materials for advanced supercapacitors and Li-ion batteries

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High power energy storage devices, such as supercapacitors and Li-ion batteries, are critical for the development of zero-emission electrical vehicles, large scale smart grid, and energy efficient cargo ships and locomotives. The energy storage characteristics of supercapacitors and Li-ion batteries are mostly determined by the specific capacities of their electrodes, while their power characteristics are influenced by the maximum rate of the ion transport. The talk will focus on the development of nanocomposite electrodes capable to improve both the energy and power storage characteristics of the state of the art devices. Advanced ultra-high surface area carbons, carbon-polymer, and carbon-metal oxide nanocomposites have been demonstrated to greatly exceed the specific capacitance of traditional electrodes for supercapacitors. In addition, selected materials showed the unprecedented ultra-fast charging and discharging characteristics. Intelligently designed Si-C composites showed up to 5 times higher specific capacity than graphite, the conventional anode material in Li-ion batteries. Achieving stable performance of Si anodes is commonly a challenge. Recent experiments suggest that individual Si nanoparticles and thin films below a critical size do not fracture and exhibit high reversible capacity for Li. The often observed rapid degradation of Si-based anodes is related not to the intrinsic property of Si but to the loss of electrical contact within the anodes caused by the large volume changes that takes place during Li insertion and extraction. Successful synthesis of high capacity nanocomposite Si-C particles that do not exhibit volume changes during Li insertion and extraction allowed us to achieve stable performance. In order to overcome the limitations of traditional composites precise control over the materials' structure and porosity at the nanoscale was required.