4th International Symposium on
Energy Challenges & Mechanics
- working on small scales

11-13 August 2015
Aberdeen, Scotland, UK

Engineering Carbon Nanostructured Architectures for High Performance and Multifunctional Electrodes

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Accepted for publication on 13th December 2014

Over the past decade, researches on sp^2 nanostructured carbon materials (CNT, graphene, nanostructured graphite) designed for high performance electrode materials in advanced energy storage systems have made remarkable progress. However the fabrications of tightly controlled electrodes that harness 2-3 dimensional and multiscale architectures of organized carbon nanostructures have remained largely elusive. Such methodologies will allow multifunctional and high performance energy storage systems and functional electronic devices. Here we present some of our recent progresses in building highly organized and controlled carbon nanomaterials based 2-3D architectures and their hybrid systems by combining state-of-the art synthesis, molecular level engineering and transfer based nanomanufacturing strategy developed in our laboratory. For examples, a generic synthetic approach to rationally design extremely short tubular carbon nanostructure, called carbon nanocup, inside anodic aluminum oxide templates will be presented. Using extremely short nanochannels, 3D architectures engineered from graphitic carbon, revealing unique morphologies of nanoscale cups and large area connected nanocup film were fabricated. The nanocups are highly effective to contain other nanomaterials and polymers enabling multi-component and multifunctional carbon nanostructured systems for flexible and transparent solid-state thin supercapacitor films. We also demonstrate precisely-controlled and well-defined allotropic transformations and formation of their molecular junctions over large area of networks using controlled alternating voltage pulses. Small-diameter single-walled carbon nanotubes (SWCNTs) can be selectively transformed into (1) larger diameter SWCNTs, (2) multi-walled carbon nanotubes, (3) multi-layered graphene nanoribbons, and (4) structures with sp^3-bonds. This re-engineering of carbon bonds evolves via a coalescence-induced reconfiguration of sp^2-hybridizion, terminating with the negligible introduction of defects and remarkable reproducibility.

Keywords: Nanostructured graphite, Nanotube, Nanomanufacturing, Supercapacitor, Flexible Devices