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Hierarchical Three-Dimensional Carbon Materials with Vertically Aligned Nano-structures for Efficient Energy Applications

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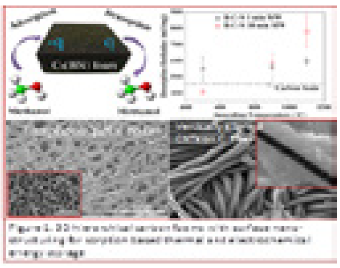
Carbon based structural materials are attractive for energy applications owing to their fascinating thermal and electrical conductivities, excellent mechanical properties and efficient catalytic activities. The sp2 hybridization in graphitic carbon lattice are responsible for such properties. The defect-free graphitic carbon structure is crucial for superior carrier transport and mechanical properties whereas the structural or heteroatom induced defective sites are desirable for efficient catalytic activities. However, the catalytic activities in defect-rich carbon materials are not always straightforward and depend on various factors, such as, type of defect, its density, surface morphology of the material, its porosity, surface area and activeness of surface defects. Furthermore, in case of hierarchically porous and three-dimensional (3D) carbon materials with abundant junctions between sp2 and sp3-hybridized carbon lattices, the understanding of catalytic and other physical properties is more difficult but important for advancement of energy storage technologies in 3 dimensions. We have opted different experimental techniques to fabricate different hierarchical 3D carbon materials. We have grown vertically aligned few-layer graphene (petals) and carbon nanotubes (CNTs) to increase the intrinsic surface area in 3D structures. Moreover, we established an innovative technique to effectively functionalize those structures to incorporate active surface defects through heteroatoms (N, B) doping, for enhanced sorption based thermal energy recycling and electrochemical energy storage applications. The active carbon surface demonstrated about 6 to 8-fold increase in methanol sorption enthalpy. We fabricated CNT, graphene and CNT-graphene hybrid-foams with ultra-low density (~4mg/cc) which showed 200 % increased Li-ion storage capacity as binder-free anode. Vertically oriented CNTs grown on carbon-textiles and proper functionalization indicated high areal-capacitance of 107 mF/cm2 with excellent flexibility. We conducted experiments to understand and correlate the thermal transport and catalytic properties with structural details. Furthermore, we observed that the porosity is not always a dictating factor for thermal transport in 3D carbon structures rather the crystallinity and junctional properties determine the transport properties.



Biography

Dr Rajib Paul has extensive expertise in carbon material synthesis, fabrication and rational designing for efficient energy storage and conversion applications. He has developed a facile microwave radiation assisted functionalization technique for carbon based 3D porous structures. He is pioneered in nano-structuring of carbon surface through various plasma induced and thermal CVD methods. His additional research interest is related to thermal and mechanical properties evaluation in 3D hierarchical carbon structures. The foundation is based on understanding the junctional interfaces in 3D hierarchical carbon materials which play crucial roles in dictating transport and catalytic properties. He has demonstrated that the surface morphology, surface active states, and availability of carbon lattice edges evaluate the overall properties in 3D carbon structures.

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