ABSTRACT

NANOSTRUCTURED GRAPHENE NANOPATELETS FOR ENERGY STORAGE APPLICATIONS

There is an increasing demand for high performance compact batteries for diverse applications ranging from portable electronics to electric automotive vehicles. This need has driven the direction of research towards newer materials, improved synthesis and architectured assembly. This research addresses the gravimetric and volumetric density challenges as well as the cost issues faced by energy storage devices by developing structured graphitic materials, aiming at better electrochemical performance, improved energy density and reduced cost.

The few layer graphene nanoplatelets (GnP) used in this study can be produced from natural graphite in thicknesses from 1-10 nm and in widths from 0.3 to 50 microns via an acid intercalation/thermal exfoliation process. The GnP serves as an inexpensive alternative to carbon nanotubes and single graphene sheets. The ability to nanostructure GnP and tailor its inherent properties for lithium storage and electrical conductivity, allows it to be used for customized applications in three different lithium ion battery components viz., active anode material, current collector and conducting additive.

Metal nanoparticle doped GnP in which nanosized metal particles are coated onto the GnP basal surface, have been assembled to make a ‘pillared’ nanostructure in which the particles maintain a fixed distance between adjacent GnPs facilitating improved transport and enhanced lithium storage capacity, especially at faster charge rates. Graphene nanoplatelets synthesized with different sizes of metal nanoparticles effectively create a nano-architected GnP multilayer assembly with flexible interlayer spacing. The creation of a lithium ion battery anode with controllable GnP interlayer spacing facilitates lithium ion diffusion through the electrode, and this in turn leads to improved transport and enhanced capacity.
Graphene nanoplatelets are also intrinsically excellent electrical conductors, which can be assembled into continuous conductive thin films to replace metal foils as current collectors for electrochemical applications. Self-standing, binder-free, flexible and porous paper is prepared by a simple filtration process using an aqueous suspension of GnP. This GnP paper is an attractive alternative current collector to replace copper in lithium ion batteries, because of its lower areal density, desirable electrical conductivity and good electrochemical stability. The performance of GnP as a current collector with different electrode materials and its role in reducing the overall battery cell weight has been investigated.

The third application combines the benefits of electrical conductivity and nanostructuring of GnP to function as a conducting additive for different electrode materials. An investigation of the use of different sizes of GnP as a conducting additive for lithium titanate electrodes and as a conducting host/matrix for lithium sulfur batteries has demonstrated its applicability here also.