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Nanostructured Carbons as Multifunctional Materials for the Advancement of Energy Storage Application

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Carbon tends to get a bad rap these days, but I think it is amazing material. It plays a huge role in the world we live in, from the carbon dioxide in the air to the graphite in your pencil, to diamond in jewelry, to your body, you'll find its figure print everywhere, just need to open our eyes. In the earth's crust, it is the 15th most abundant element and fourth most abundant universal element by mass after oxygen, hydrogen and helium. Can you believe that there is another carbon material that is stronger than steel, unbreakably elastic, resistant to chemicals and high temperature, a better conductor of electricity than silver, and a better heat conductor than diamond? So, nanotechnologists have been fascinated with potential of this material in all fields starting from aerospace to medical. Currently these carbon powders are incorporated in diverse commercial products ranging from rechargeable batteries, automotive parts, and sporting goods to boat hulls and water filters including supercapacitors, actuators, and lightweight electromagnetic shields. For example, carbon nanotube (CNT) has high stiffness, strength, thermal conductivity, electrical capacity and thermal stability. Even though CNT has excellent mechanical properties, its incorporation in polymer matrices does not necessarily result in dramatically improved composites. The storage modulus of the multiscale composite in polyester matrix as well as the pull out strength of CNT-coated carbon fiber (CF) is improved by as much as 33 and 88%, respectively. Another example the composite of oxidized CNT and polypyrole exhibits a gravimetric capacitance of 305 F g^{-1} with a gravimetric energy density of 42 W h kg^{-1} in 5 M KOH (aqueous) electrolyte, which is the highest reported in this study. An area specific capacitance of 376 mF cm^{-2} in 1 M

$LiClO_4$ acetonitrilic electrolyte exhibited by the composite of exfoliated graphite nanosheet poypyrole with an area specific energy density of 209 µWh cm^{-2}. A volume specific capacitance of 5428 mF cm^{-3} in 1 M $LiClO_4$ acetonitrilic electrolyte exhibited by carbon nanoplate coated CF with a volume specific energy density of 753 µWh cm^{-3} is the highest reported among the various supercapacitors (SCs) manufactured in our group. The electrically conducting, highly flexible unidirectional CF (UCF) exhibits lowest specific gravity when compared to that of various metals and the mass of SCs can be significantly be reduced if UCF is used as current collector. Incandescent bulb filaments, consisting of CNT coated CF (CNTCF), were fabricated and their incandescent properties were studied. For comparison, CF and tungsten filaments were also studied under similar conditions. CNTCF filament of 10 Ω resistance exhibits an illuminance enhanced by a factor of ~ 400 as compared to tungsten filament of 17 Ω resistance for an applied voltage of 18 V. At an input power of 70 W, CNTCF exhibits an enhancement by a factor of ~3.6 in the illuminance as compared to CF filament. Hope to see much more miracle applications in the next decade.

Keywords: Carbon, polyester, modulus, supercaacitor, polypyrole, capacitance, energy density,

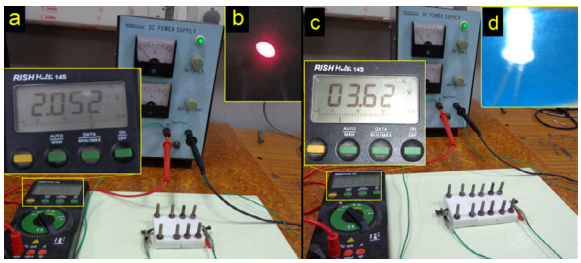

Figure 1: Digital photograph of SC-M-A while (a) charging and (b) discharging through a red LED

References:

[1] Published results from Advanced Nanoengineering Materials Laboratory, IIT-Kanpur, Kamal K Kar et al, India