

L.3: Carbon aerogel based supercapacitor for energy storage application

Supercapacitors, also known as ultracapacitors, have attracted lot of attention as an electrochemical energy storage device due to their high power density, faster charging-discharging rates and long durability compared to batteries. It has potential to be used as alternative power sources in the portable electronic device, electric hybrid vehicles, UPS, etc. It works on the principle of electric double layer capacitor (EDLC) and require electrodes having large surface area and good electrical conductivity. EDLC stores energy by accumulating the opposite charges on the double layer at the electrode/electrolyte interface through electrostatic force. A number of high surface area carbon materials, such as activated carbons, carbon nanotubes and carbon aerogels have been widely used as electrode materials for EDLC. In spite of the high surface area availability and low cost, activated carbon is not a preferred choice due to abundant micropores (<2 nm) and limited ionic mobility. Carbon aerogel, on the other hand, have the advantage of good electrical conductivity, high surface area and interconnected pore-structure, which can be tailored to achieve high mesoporosity (2-50 nm). Carbon aerogel (CA) having specific surface area of (1500 – 1800 m²/g) have been developed at NFM Lab, LFMD.

The gelation is carried by aqueous medium based resorcinol (R), formaldehyde (F) sol-gel polymerization at 80 °C for ~60 hours. The R-F gel obtained is generally dried by critical point method (CPD) without any collapse of pore structure. CPD being time consuming, expensive and cumbersome, ambient pressure drying method was adopted as an alternative, where the gel was exchanged with low surface tension acetone and was subsequently allowed to evaporate under ambient conditions. The dried R-F gel obtained was pyrolyzed at 800 °C in inert atmosphere and CA having surface area of ~700 m²/g was obtained. Further, surface area enhancement of CA was performed by activation under controlled CO₂ atmosphere at 900 °C. The CA obtained showed specific surface area of 1500-1800 m²/g with > 40% mesopore area contribution. To improve its conductivity, additive based gelation using graphene, etc. have been tried. Recently, high temperature treatment of CA performed at 1300 °C showed increase in conductivity from 120 to 160 S/m mainly due to micropore collapse. However, slight (~5%) reduction in surface area was observed.

Electrodes were synthesized using the conductivity enhanced high surface area CA pasted on graphite sheets using poly-vinyl alcohol binder. A capacitor cell was assembled using two such electrodes with average CA loading ~1.6 mg/cm² in

parallel plate manner with a separator sandwiched between them. These were filled with organic electrolytes (1 M TEA-TFB in propylene carbonate) and encapsulated to form the CA capacitor cell. The capacitor cell was tested for its galvanostatic charge-discharge profile, constant current discharge and electrochemical series resistance (ESR) using potentiostat (Autolab, PGSTAT 302N). Capacitor cell having total CA loading of 0.35 g showed highly reversible charge discharge profile (Figure L.3.1(a)). Capacitance (*C*) of ~8.7 F with corresponding specific capacitance of 97 F/g was evaluated using formula $C = I \cdot \Delta t / \Delta V$, where, *I* is the discharging current (50 mA), ΔV is the voltage drop during the discharge interval Δt . ESR of 0.3 Ω was obtained from Nyquist plot (Figure L.3.1(b)) attributed to the enhanced electrical conductivity of CA. Multiple cells were assembled in series and 4 F, 4 V operation was achieved (Figure L.3.1(c)).

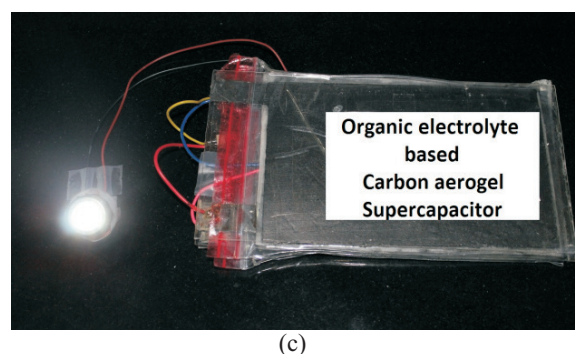
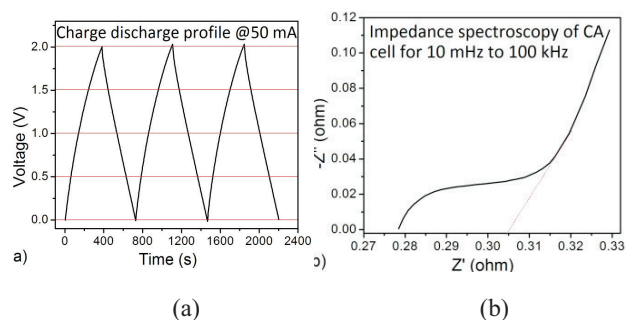


Fig. L.3.1: (a) Constant-current charge-discharge profile. (b) Nyquist plot. (c) CA cell operation for LED lighting.

For scale up, flexible metal foil support will be utilized and rolled to form cylindrical shape capacitor for a compact design.

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