L.6: Development of 4.5 kJ supercapacitor module using in-house synthesized Nitrogen-doped carbon aerogel

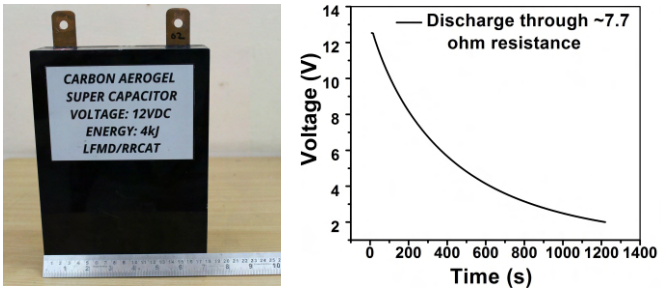
Development of clean, sustainable, and efficient energy storage devices is one of the urgent necessities worldwide in the current scenario of ever increasing energy demand. Among the different energy storage and conversion technologies being pursued, supercapacitors also known as ultracapacitors, have attracted lot of attention due to the higher power density, faster charging-discharging rates, longer durability and wider operating temperature range as compared to batteries. Working on the principle of electric double layer formation at the interface of electrode and electrolyte, a super-capacitor stores energy in electrostatic manner. It does possess advantages that counterbalance the many deficiencies of the contemporary commercial energy storage devices and hence has aroused great interest both academically and commercially. Nano-form carbon materials such as graphene, activated carbon, carbon nano-tubes, carbon nano-fibers and resorcinol-formaldehyde based carbon aerogels (CAs) are being explored as electrode materials for their non-toxicity, highly accessible channels and high chemical stability. Among these, CAs manifest many excellent features owing to their 3D interconnected porous structure, high surface area and good electrical conductivity, which can provide continuous unobstructed transportation channels required for fast movement and large adsorption of electrolyte ions. Carbon aerogel of different characteristics have been developed and achieved high specific capacitance of ~ 240 F/g for optimum 10.6% nitrogen doped carbon aerogel (N-CA). Having more heterogeneous species, N-CA shows improved wettability with aqueous electrolytes as compared to non-polar CA. Incorporation of electron rich N into CA network increases electrical conductivity of N-CA. Preparation of N-CA with specific surface area of ~1800 m^2/g has been carried out in bulk quantity.

Super-capacitor (SC) modules were fabricated using N-CA as electrode material. Each module has 18S-2P cell configuration (18 in series, 2 in parallel) with capacitance of ~450 Farads per cell. 6M aqueous KOH has been used as electrolyte in the cell (Figure L.6.1(a)). Capacitance measurements of these modules were carried out using constant resistance discharge method (Figure L.6.1(b)). Equivalent series resistance (ESR) and cold cranking current of these modules have been measured by Meco make vehicle battery system meter. The main parameters of the module are: Capacitance of 61 F, voltage of 12.5 V, total energy storage of ~ 4.5 kJ and ESR (DC) of ~5.5 mΩ. For ESR (AC) measurements, square wave input voltages were applied by function generator at various frequencies and the response of module in terms of current was recorded at oscilloscope. These parameters are well comparable to the similar module (16 V, 60 F) of Maxwell Technologies, a world-renowned SC fabricator. Various measured and evaluated parameters of module are given in Table 1.

Table 1: Crucial parameters of CA SC module.

Sr.No.	Parameter	Value
1.	Module No.	CAT/UC/01
2.	Vo (Volt)	12.5
3.	Discharge time for 0.37Vo (s)	476
4.	Capacitance (F)	61.80
5.	RC time constant(s)	0.9
6.	Cold cranking Ampere(A)	507
7.	Leakage current (mA/F)	0.6
8.	ESR DC (mΩ)	5.50
9.	ESR AC (mΩ) at 10 kHz	15
10.	Energy stored (kJ)	4.5

Carbon aerogel based super-capacitor (CA SC) module is shown in Figure L.6.1(a) and its utility for cranking a car engine of 998 cc was demonstrated. Ignition current of ~208 A was drawn from the module to start the engine.



(A) (B)

Fig. L.6.1: (a) CA SC module and (b) discharge profile of SC.

In future, surface treatment of bulk producible porous carbon materials such as activated carbon, pet coke, etc. will be performed to make these suitable as low-cost alternatives for capacitor electrode. Energy density of super-capacitor module can be further enhanced by an order in similar size using organic electrolytes such as tetra ethyl ammonium tetra fluoro borate in propylene carbonate ($TEABF_4$/PC) with increased operating cell voltage.

Reported by:
Ashish K. Singh (ashishk@rrcat.gov.in)