CPCPC Success Story

Nanoporous Carbon Derived from Coal Tar Pitch for Ultracapacitor Applications

Collaborators: The Pennsylvania State University, Rohm and Haas Co.

Description: Ultracapacitors or Electrochemical double layer capacitors (EDLCs) are energy storage devices that are capable of delivering very high power densities (~1KW/kg) and high cyclability (10^5 cycles). The device is based on the principle of formation of electrical double layer at the electrode/electrolyte interface and the double layer capacitance is proportional to the surface area of the electrode. Activated carbon with tunable apparent surface areas as high as 3000 m^2/g is commonly used as the electrode material for this application. In addition to surface area, it is also critical to control the pore size distribution of these carbons in order to get the optimum gravimetric and volumetric specific capacitances. Typically, carbon with surface areas greater than 1500 m^2/g with mean pore size of 1-3 nm is required to meet these criteria. In order to generate such controlled porosity, chemical activation using KOH or NaOH is normally used. However, the activated carbons prepared using this method require a subsequent washing procedure to remove impurities and hence become cost intensive. CPCPC sponsored us to investigate the use of coal tar pitch as low cost precursor to develop high surface area carbons with controlled porosity for ultracapacitor applications. Modification of character of the coal tar pitch (purchased from Koppers, Inc.) using oxidizing agent such as sulfuric acid resulted in polymerizing the low volatiles in the pitch and thereby creating significant amount of disorder in the resultant carbon after pyrolysis. The pyrolyzed carbon was then activated using CO_2 at 900°C to create carbons with surface areas greater than 1500 m^2/g that have a mean pore size of about 1nm and bulk densities as high as 0.75 g/cc. Two-electrode double layer capacitors were fabricated with these carbons using aqueous sulfuric acid as electrolyte. The samples demonstrated gravimetric specific capacitance as high as 180 F/g and volumetric specific capacitances of 80 F/ml. The performances of these carbons were comparable to that of commercially available BP-20 carbon that is used for making high volumetric energy density capacitors. These carbons with tunable porosity should also be suitable to be used in making high energy density capacitors using organic electrolyte.

Coal tar pitch is commonly used as graphitizing precursor. However, it was shown that inducing significant amount of disorder in the pyrolyzed pitch can result in the formation of microporosity in the pitch derived carbons. The disorder was created by modifying the character of the pitch precursor such that aromatic condensates in the pitch were oxidized and polymerized using sulfuric acid before pyrolysis. Tetrahydrofuran soluble (THFS) and insoluble fractions (THFI) of the pitch were both modifieda using this approach. Pyrolysis of this modified pitch under argon atmosphere at 800°C results in a disordered nanoporous carbon with mean pore size of 0.5 nm. This carbon was further activated using CO_2 at 900°C. THFI derived carbon had surface areas greater than 1500 m^2/g with bulk densities of about 0.7 g/cc and mean pore size of 1 nm. THFS derived carbon had slightly smaller mean pore size of 0.6 nm with surface areas greater than 1200 m^2/g and bulk density of 0.8 g/cc. Unlike most activated high surface area carbons which have bulk densities of 0.25 g/cc, these have higher bulk densities due to controlled pore size distribution and hence are ideally suited for high volumetric energy density ultracapacitor applications such as hybrid vehicle applications. This carbon ultracapacitor development effort supported by the CPCPC has resulted in filing an invention disclosure to the Intellectual Property Office (2006-3203) at The Pennsylvania State University. Presently, we are actively looking to commercialize these carbons for ultrcapacitor applications.

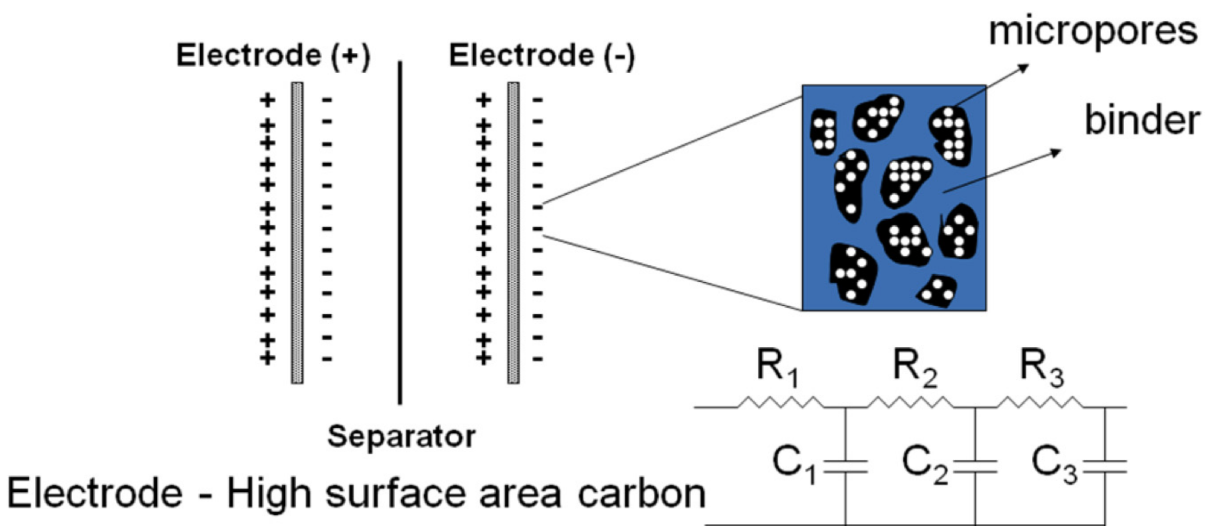

Figure 1. Schematic representation of carbon electrode made using CTP derived activated carbons used in ultracapacitors.

Contact: Ramakrishnan Rajagopalan, The Pennsylvania State University, Materials Research Institute, 270 MRL Bldg., University Park, PA 16802, Ph: 814-863-1880, E-mail: rur12@psu.edu