PROJECT FACTS

UNIVERSITY OF KENTUCKY CENTER FOR APPLIED ENERGY RESEARCH

ELECTROCHEMICAL POWER SOURCES

Asymmetric Electrochemical Capacitor Derived from Coal

Electrochemical double-layer capacitors (EDLCs), often referred to as super-capacitors or ultracapacitors, are electrochemical energy storage devices capable of storing and delivering energy at higher rates than most batteries, including advanced Li-ion. Electrochemical capacitors typically possess lower energy densities than batteries, but have many advantages, including higher power densities (i.e. rapid charge and discharge), extended cycle life and undergo no chemical or structural changes during charge and discharge. Typical electrode materials for super-capacitors are based on activated carbons, which are characterized by high surface area, and a porous structure which allows electrolytes to infiltrate into the pore volume. High surface area is desired, as capacitance, C is directly proportional to the surface area, A, of the carbon ($C = \kappa\varepsilon_o(A/d)$), where ε_o is the dielectric constant of the medium between the parallel plate electrodes and d is separation between the electrodes. Activated carbons are typically prepared by either physical (i.e. steam or CO_2) or chemical activation, where the carbon precursor is mixed with chemical agents such as KOH or $ZnCl_2$ and heated to high temperatures under an inert atmosphere to produce micro- and meso-pores. Material under investigation at the CAER is bituminous and anthracite coal. By exposing coal (in ground form) to steam at 900 ^oC for 20 minutes or less, porous carbons suitable as active materials for electrochemical capacitors can be prepared. Energy densities exceeding 120 Fg^{-1} in both lithium nitrate and sulfate electrolytes have been achieved for coal-derived carbons, including activated coal tar pitch fiber. Further enhancement in the energy density is expected with improved activation processes and electrode/electrolyte wetting.

Porous carbons derived from coal are used as electrode materials in a novel asymmetric electrochemical capacitor using aqueous electrolyte. The capacitor uses a lithium-doped manganese spinel electrode as the positive and an activated coal carbon as the negative. Lithium nitrate serves as the electrolyte. The capacitor operates by the insertion and extraction of Li ions in the manganese spinel lattice during discharge and charge, respectively while the activated carbon electrode stores charge through Li^+ and anion adsorption/desorption. The asymmetric system uses low-cost, environmentally benign, nontoxic electrode materials and mild electrolyte (4M $LiNO_3$). The operating cell voltage of the capacitor is over 2V, with an estimated gravimetric energy density of about 25 Whg^{-1} based on active materials only. The Li manganese spinel/carbon capacitor can compete with other aqueous based systems, like the lead dioxide/sulfuric acid/carbon capacitor currently under commercial development in the US and Russia. The Li manganese spinel/carbon system has several advantages over the PbO_2/carbon capacitor in that it uses nontoxic materials and electrolyte, has a higher cell operating voltage (> 2.3) and involves solid-state ion transport as the storage mechanism for the positive electrode resulting in no phase change during charge and discharge.

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