Carbon based electrochemical capacitors: beyond capacitive storage

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Electrochemical capacitors EC (named also electrical double-layer capacitors or supercapacitors) are the devices based on the reversible storage of energy by electrostatic (capacitive) attraction of ions. Performance of EC are strongly governed by the type of carbon materials but also kind of electrolytes, namely aqueous (acidic, basic, neutral), organic and ionic liquids. As a consequence, practical voltage range of EC in these electrolytes varies from 0.8 V to 3.5 V, respectively. The type of current collector will also affect EC voltage values.

Capacitive charge storage can be increased by faradaic reactions, frequently called pseudocapacitive effects. It must be underlined that only redox reactions which present capacitive behavior should be considered, i.e., capacitance should be proportional to the charge accordingly to formula $C = dQ/dE$. Faradaic contribution can be originated from electrode materials but also from electrolytic solutions. Typical electrode materials with pseudocapacitive character consist of: i) electrically conducting polymers, ii) carbon materials rich in heteroatoms (oxygen, nitrogen, sulphur), iii) carbon with electrosorbed hydrogen.

Exploring redox active species from electrolytic solution is another possibility for energy increase by pseudocapacitive effects. Practical application of such redox pairs will be determined by reversibility, pH of solution, concentration, price, availability, toxic character. Some of them can be used only as additive to electrolyte. Taking into account their redox potential and size, different species could be used for positive and negative electrode. Porosity of carbon materials plays a crucial role, hence, it should be adapted to redox species. In some cases, carbon pores are drastically blocked depending on the electrode polarity during long-term cycling.