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Opinion

Electrochemical Supercapacitors. Opinion

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Opinion

Recently, a diversity of new types of capacitors has been developed, which are based on different electrochemical processes. According to the generally accepted definition first introduced by Conway, Electrochemical Supercapacitors (ECSC) are the electrochemical devices in which quasireversible electrochemical charging-discharging processes occur whose galvanostatic charging-discharging curves have nearly linear form. In other words, their form approaches that of the corresponding dependences in ordinary electrostatic capacitors [1]. The electrochemical supercapacitors are subdivided in the Electrical-Double-Layer-Based Supercapacitors (EDL-supercapacitors) [1,2], pseudocapacitors [1,2], and hybrid supercapacitors. The EDL-supercapacitors are based on the charging of the electrodes' electrical double layer. They comprise electrodes on the basis of highly dispersed carbonaceous materials with high specific surface area (~500-2500 m^2/g). The highly dispersed carbonaceous materials include activated carbons, carbide carbons, aerogels, xerogels, carbon blacks, nanotubes, nanofibers, graphenes, etc. In the pseudocapacitor electrodes, fast quasi-reversible electrochemical reactions occur. These electrodes are based on electrically conducting polymers (polyaniline, polythiophene, polypyrrole, et al.) or some metal oxides possessing several oxidation degrees (RuOx, MnOx, et al.). The electrochemical supercapacitors have the following advantages over batteries: (1) Higher power. (2) Higher cycle life comparable with that of traditional capacitors (hundreds of thousands and even more than one million cycles for highpower electrochemical supercapacitors). (3) The electrochemical supercapacitors, mainly EDL-, well operate at extreme temperatures from –50 to +60 °C because they are governed by the regularities of electro physics, rather than are limited by the electrochemical kinetics. (4) Basically, the energy efficiency of EDL-supercapacitors can approach 100% because, unlike the batteries, the EDL-supercapacitors are free of energy losses caused by the electrode reaction polarization. The energy efficiency of the EDL-supercapacitors is limited solely by Ohmic losses. The very high energy efficiency (the ratio of the charging energy to the discharging one) allows using the electrochemical supercapacitors in numerous devices for accumulation, storage, and output of the energy of power supply systems and for the load-leveling therein. (5) Different types of the electrochemical supercapacitors can be charged or discharged for a time ranged from fractions of a second to some hours (6).

Additionally, many types of electrochemical supercapacitors have one more advantage: they are environmentally friendly. The matter is that billions of worn out lead acid, alkaline, and lithium storage batteries are terminating their life in trash or soil. They bring forth therein such poisonous elements as lead, nickel, lithium, fluorine, sulfur, etc. By contrast, electrochemical supercapacitors with carbonaceous electrodes and aqueous electrolyte solutions are practically harmless, hence, environmentally benign. (7) Electrochemical supercapacitors of all types are hermetically enclosed. The disadvantages of the electrochemical supercapacitors as compared with storage batteries are as follows: lower specific energy and stronger self-discharge. To lower the self-discharge, the development of high-purity electrochemical supercapacitors is required because soluble impurities in electrolyte and electrodes can lead to the self-discharge. The electrochemical supercapacitors are used in electrical vehicles, cars, diesel locomotives with combustion engines as starter-controlled devices, as well as in some electronic devices. When used in electrical vehicles, the electrochemical supercapacitors can be combined fuel cells, to induce augmented mode. The electrochemical supercapacitors are subdivided into two principal types: the power-type (or pulse) ones, with high specific power, and the energy-type ones, possessing high specific energy. Correspondingly, each type of electrochemical supercapacitors has its inherent field of application.

As described above, one of the main advantages of Electrochemical Supercapacitors (ECSCs) over batteries is their significantly higher power density. For accumulators, these values vary from several tens to ~ 200-300 W/kg. Previously, it was found in works on ECSC that the specific power at sufficiently high values of the specific energy is in the limit ~ up to 2 kW/kg. However, recently there have been publications that describe supercapacitors, the specific power values of which reach tens and even hundreds of kW/kg. Such ECSC can be called supercapacitors with ultrahigh power. The main factors leading to the achievement of these very high values of the specific power of ECSC are the optimal porous structure of the electrodes, the use of carbon nanotubes and graphenes as the basis for carbon electrodes. Figure 1 illustrate the heavenly wide range of the charging–discharging characteristic times. In the figure we give Ragon diagrams for different rechargeable electrochemical devices We see from the figure that the operation range of the electrochemical supercapacitors spreads out over 7 orders of magnitude of the characteristic times, which exceeds the operation range of any battery type by many orders of magnitude.

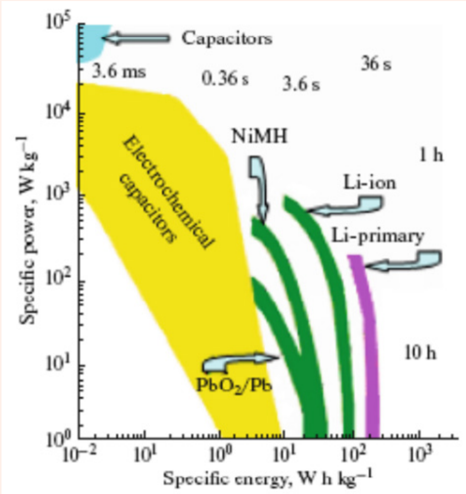

Figure 1: Ragon diagrams for different electrochemical rechargeable devices [2].

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