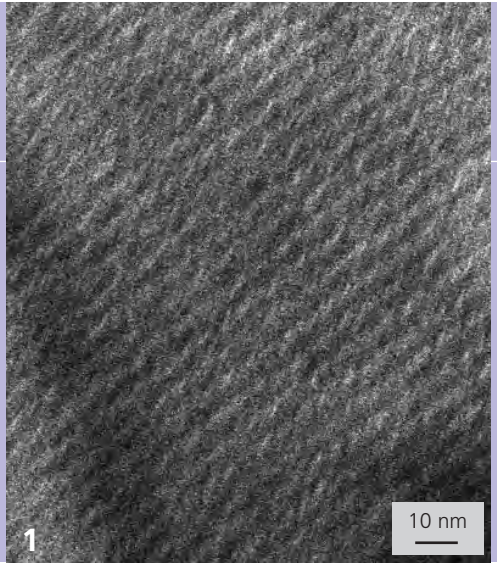

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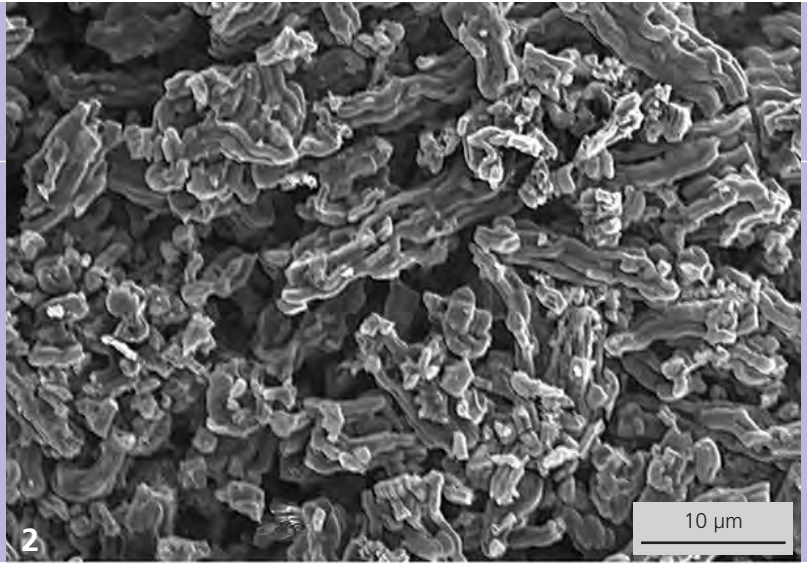


2

NEW MATERIALS AND PROCESSES FOR ELECTRICAL ENERGY STORAGE

THE TASK

The storage of electrical energy is simultaneously key and bottleneck for many future technology fields including electric and hybrid vehicles. Electric double layer capacitors (EDLC) are, in addition to the battery, a key component for electromobility.

EDLCs offer high power densities and lifetimes (cycle stability) and thus ideally meet the power requirements during starting, acceleration and energy recovery during braking in electric and hybrid vehicles. EDLCs can be combined with batteries and provide relief by handling power peak loads. This extends the lifetime of the battery and also offers the option to use smaller battery units.

However, further development is necessary to increase the power density of EDLC cells and modules. A significant increase in power densities in energy storage is only possible via principally new material concepts. For example, EDLCs can be substantially improved by a special pore design in the highly porous carbon materials that is used to build these devices.

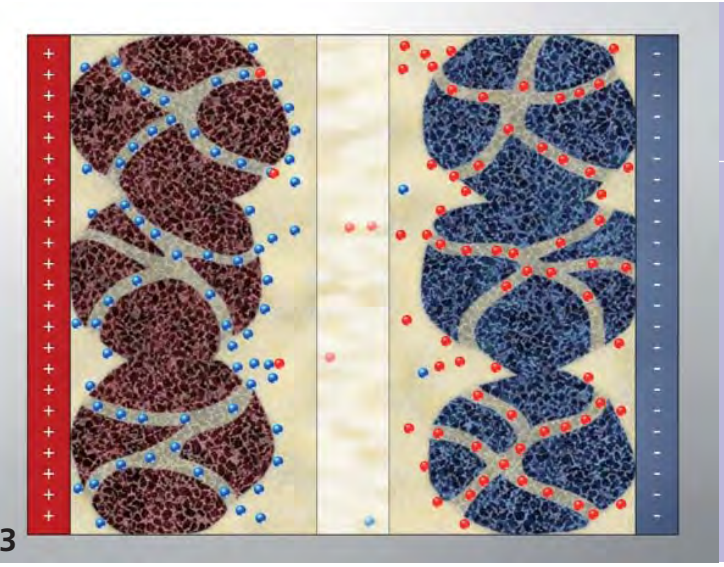
More efficient production technologies primarily aim at cost reduction. Fraunhofer IWS engineers address these challenges by developing solutions in material design and process development for electrical energy storage applications. A particular example will be discussed in the following paragraphs.

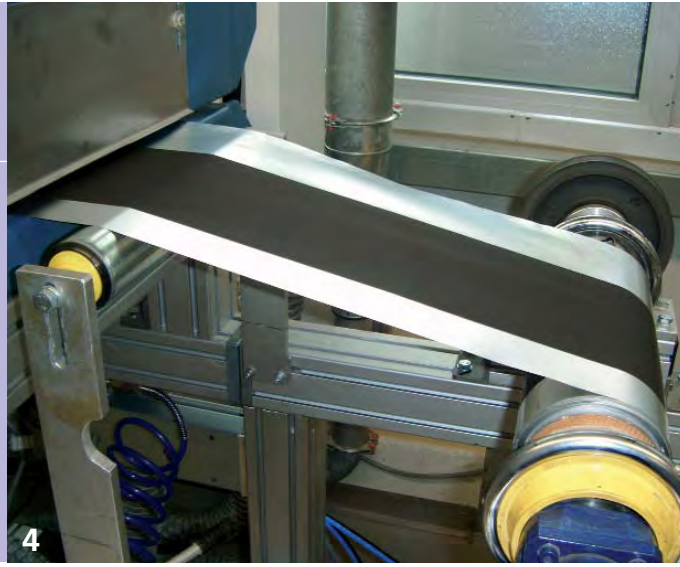
OUR SOLUTION

The specific surface area and pore geometry of carbon materials significantly determine the performance parameters of electric double layer capacitors. These devices use electrodes made from porous carbon materials that are coated onto metal foils (current collector). A spacer wetted with an electrolyte separates every pair of electrodes. During the charging process electrolyte ions accumulate in the electrochemical double layer at the surface of the electrodes (anions at the positively charged electrode, cations at the negatively charged electrode). Large surface areas yield high capacitances. Open pores with diameters > 2 nm aid a fast transport of charged particles. The transport of electrolyte ions in the pore system determines the inner resistance of the capacitor and thus the maximal possible power.

Mesoporous ordered carbon materials (OM-CDC), which are synthesized from carbides, have excellent properties for this application. CDCs are chlorinated from carbides (i.e. silicon carbide) at temperatures > 600 °C. The silicon is extracted as $SiCl_4$, which leaves a highly porous carbon material with micropores diameters < 1 nm and surface areas > 1000 m^2 / g.

A template synthesis process produces silicon carbide with hexagonally ordered mesopores. Chlorinating this material leads to OM-CDCs and also to carbon materials that have ordered mesopores in addition to high micropore volumes. This synthesis route yields specific surfaces of up to 2800 m^2 / g. This class of materials provides a perfect test bed to study the influence of different pore geometries for electrode applications in supercaps. In comparison to conventional materials OM-CDCs are expected to provide significant performance increases.

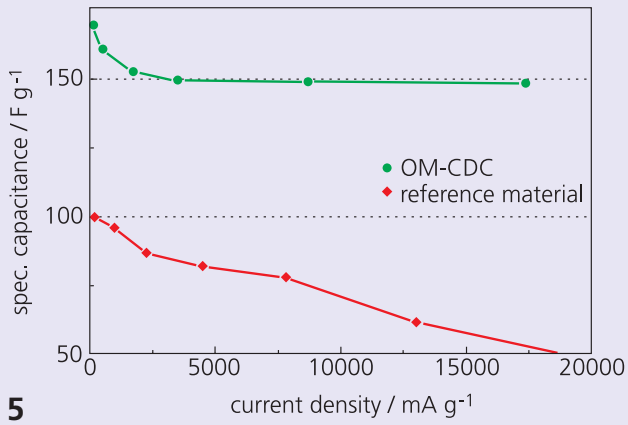




RESULTS

The carbon materials were electrochemically studied using a two-electrode configuration and an organic electrolyte. OM-CDC materials indeed show a significantly improved power performance compared to the porous carbon materials that are conventionally used in supercaps. Conventional materials have specific capacitances of up to 100 F / g. Measurements on OM-CDCs yielded values exceeding 150 F / g. The high surface area of the OM-CDC primarily explains the difference. The advantage of the mesoporous structure becomes evident when testing with higher charging current densities. Conventional materials clearly reduce their capacitance with increasing charging current densities. The capacitance of OM-CDC materials remains nearly constant up to current densities of 20 A / g.

Specific capacitance versus current density



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This behavior is explained by the fast kinetics of the charge carrier transport in the electrolyte. The ordered mesopores enable a fast transport and good accessibility of the material for the electrolyte ions. For double layer capacitor applications OM-CDC materials simultaneously increase the energy density (proportional to the capacitance) and the power density.

This is just one example of electrode and electrical energy storage development activities at the Fraunhofer IWS. It focuses on innovative materials. Another emphasis is the development of scalable manufacturing processes to facilitate the possibility of a midterm industrial implementation. A new IWS laboratory has been set up to fabricate electrodes in a roll-to-roll process. All necessary equipment is installed to produce the materials and to characterize the results.

1 Transmission electron microscopy image (nanostructure) of the mesoporous CDC material
2 Scanning electron microscopy image (microstructure) of the mesoporous CDC material
3 Schematic design of a double layer capacitor
4 Roll-to-roll coater to produce supercap electrodes

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