Project “Super-Kon”
Novel Capacitors for Energy Storage

PLAN

According to the aims of the energy policy of the German Government the share of renewable energies in the total energy consumption should considerably increase in the next years. However, the problems of renewable energies related to their generation, utilization and their feeding into the public electricity grid are very diverse. For example, the yield of wind and solar energy is strongly dependent on weather and time of the day; the load of the electricity grid is also very variable. Due to the lack of efficient energy storage devices only part of the available potential of sustainable energies can be exploited.
As an answer to these requirements the idea of the “Super-Kon” energy storage device was born. It is based on the physical storage of electric energy in thin film components. For this aim we will develop a novel innovative capacitor module which initially targets to local market requirements. This new capacitor will be an efficient, flexible, ecological and safe system for energy storage with a special focus on renewable energies (wind energy, energy harvesting, photovoltaics).
The research takes place within the framework of the ForMaT program of the German Federal Ministry of Education and Research (BMBF). With this program the BMBF wants to utilize results from public research in a better and faster way and wants to promote the transfer of knowledge and technology.

STATE OF TECHNOLOGY

Up to now, rechargeable batteries are mostly used for energy storage purposes. Because of their electrochemical working principle, they have specific properties which can be problematic (limited lifetime, memory effect, limited usable temperature range, problems with overcurrent spikes and deep discharges, warming during fast charging and discharging cycles, ecologically not harmless).
In contrast to this, capacitors can be very quickly charged/discharged and allow thousands of charging/discharging cycles. Up to now, the stored energy densities are still much smaller than for rechargeable batteries.
Currently, mainly multilayer ceramic capacitors, film capacitors and double-layer capacitors are used. All types own specific advantages and disadvantages (multilayer ceramic capacitors: high permittivities, temperature-stable, capable of high frequency operation, brittle, hard to process; film capacitors: higher breakdown voltage, low electric conductivity, easily moldable and processable, only lower permittivities; double-layer capacitors: low charging voltage, limited usable temperature range). It is essential to overcome the disadvantages.

AIMS

The main objective of the “Super-Kon“ project is to achieve with novel capacitors made from composite materials (0–3 composites) comparable energy densities as for double-layer capacitors (supercaps) which are available but have a limited range of application. At the same time, the specific advantages of the “Super-Kon” capacitors shall be utilized. The advantages are mainly:

- robust
- no noticeable aging, very high lifetime
- distinctly higher charging voltage (> 10 V)

- thermal stability (operating temperature > 60 ℃ r ealizable)
- no cooling units necessary (thus, higher energy amounts per weight or volume achievable)
- fast charging/discharging cycles
- high efficiency
- ecologically harmless, protection of the environment
- low cost of production, low cost of maintenance, no expendable parts.

RESEARCH

To overcome the disadvantage of capacitors of only low energy storage capacity, it is necessary to develop dielectric materials having a high permittivity, a breakdown voltage as high as possible, and a low density.
The innovative approach of our concept is based on the application of composite materials as dielectrics. By the production of novel 0–3 composites the positive properties of both classes of materials, ceramics and polymers, will be combined.
For this purpose, nanoparticles of well-established dielectrics, such as $BaTiO_3$ as well as new compounds, with specific surfactants, will be embedded in an organic or inorganic matrix. Afterwards, these materials are processed to thin films, which will be electrically contacted by deposition of thin metal electrodes.
Preliminary work and theoretical calculations have shown that embedded composites allow a drastic increase of the storage capacity in comparison to the pure matrix material, while the technical processability remains comparable to pure polymers.
The scalability of the capacitor systems will be enabled by its modular construction. A large number of small identical capacitors will be combined into larger modules. The advantages of this approach are the easier technical realizability as well as the low repair and maintenance costs. The latter is due to the fact that in case of technical failure only the single module has to be exchanged and not the whole unit.
Another advantage of our concept is the use of ecologically harmless materials, especially in comparison to classic ceramic capacitors which are mainly based on lead-containing compounds as lead circonate titanate.
The work will take place in the framework of a newly established innovation lab which consists of scientists of the participating working groups. It should combine the expertise of the collaborators and create synergy effects. The research in the innovation lab will be divided into four parts: synthesis, film deposition, electrical contacting and physical characterization with a direct feedback to the module optimization. All steps are closely coupled to each other. The main focus of the research in the *AG Festkörperchemie* (Solid State Chemistry) is the synthesis and modification of dielectric materials, their embedding into a suitable matrix and the production of thin films made of these composite materials. The working group at the *Interdisziplinäres Zentrum für Materialwissenschaften* (Interdisciplinary Center of Material Sciences) is dealing with the processing of test structures, their structural diagnostics and the fabrication of a laboratory prototype of the complete capacitor structure. The *AG Physik ferroischer Materialien* (Physics of Ferroic Materials) concentrates on the physical characterization of the dielectric layers with the embedded nanoparticles. They focus their attention on electric and dielectric measurements and FEM modeling calculations of theoretical capacitor properties.
In the second half of the project period, the results of the laboratory research will be scaled-up. The build-up of a technical pilot plant station should be started within the lifetime of the project.

In addition to the research work the business-related project support is an important component of the work within the innovation lab. Their tasks include identification and evaluation of commercialization strategies, coordination of the property rights strategy and public relations. Additionally, an external project advisory council supports the scientists during the development process and promotes the creation of networks. This council consists of representatives mainly from local companies.
As outcome of the project a "Super-Kon" demonstrator will be developed and built, which is based on novel dielectric composite materials.

COOPERATION

Martin-Luther-Universität Halle-Wittenberg

PD Dr. Hartmut S. Leipner (Interdisciplinary Center of Material Sciences)
(project leader)
Prof. Dr. Stefan Ebbinghaus (Institute of Chemistry)
Prof. Dr. Horst Beige / Dr. M. Diestelhorst (Institute of Physics)

head of innovation lab: Dr. Alexandra Buchsteiner

business-related project support: Dipl.-Kff. Kristin Suckau

CONTACT

Dr. Alexandra Buchsteiner
Martin-Luther-Universität Halle-Wittenberg
Interdisziplinäres Zentrum für Materialwissenschaften
Heinrich-Damerow-Str. 4
06120 Halle (Saale)
Germany

Tel.: +49 - (0)345 / 55-28484
E-Mail: alexandra.buchsteiner@super-kon.uni-halle.de

Web: www.super-kon.uni-halle.de