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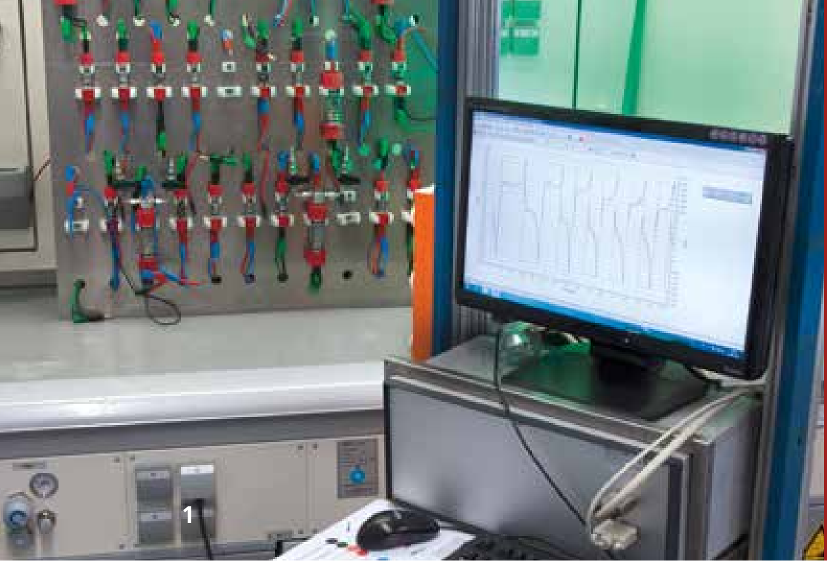
FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

BATTERY MATERIAL RESEARCH AND CELL DEVELOPMENT



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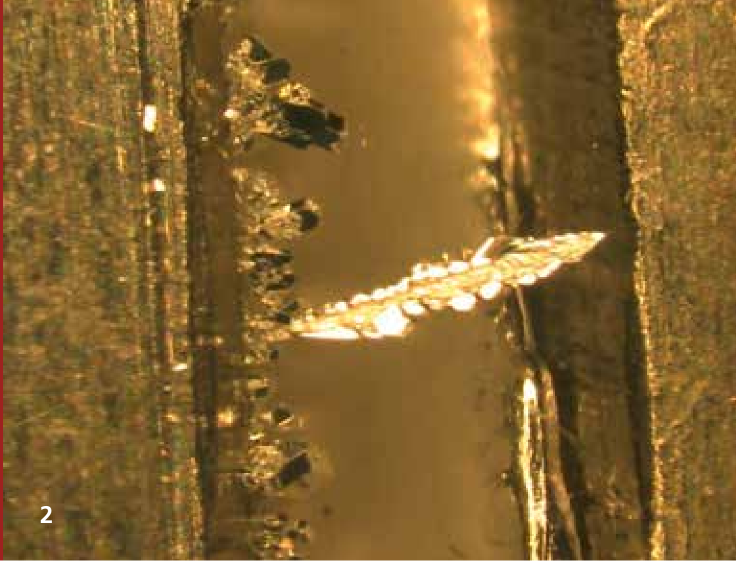

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The energy sector places great importance on electrical energy, because it can easily be converted into other forms of energy such as heat, electromagnetic radiation or mechanical energy. Electrical energy therefore plays an important role in almost every area of society. However, its storage poses a particular challenge in terms of efficiency, energy density and price.

For the past four decades, Fraunhofer ICT has been working on various electrochemical energy storage devices, and can consequently offer its customers extensive knowledge and experience. Its know-how encompasses primary non-rechargeable cells, secondary rechargeable cells and their setup, and the evaluation and testing of complex multi-cell battery systems. It also draws on its competences in the monitoring and energy management of these cells, as well as in causal investigation in the event of a failure.

The energy density of lithium-ion batteries has been significantly increased since their introduction to the market by Sony in 1991. The reduction of passive weight (current collector, separator, cell casing), the increase of the active mass and active fraction in the electrode, better active materials (NCA, NCM, LFP) and improved electrochemical properties (electrolyte, additive, active material structure) have led to an increase in the energy density of lithium-ion batteries to a maximum of 240 Wh/kg and 700 Wh/l at cell level. Future high-energy cells will surpass even these exceptional levels by deploying even thinner separators and denser active materials with a higher areal capacitance. At present, however, commercially available active materials - which are based on an intercalation reaction - still have limits, especially with regard to their gravimetric energy density.

Future battery systems have the potential to overcome these limitations and achieve energy densities two to three times higher than those of established lithium-ion systems. The near unlimited supply of natural resources and the electrochemical properties of active materials such as sodium, silicon, sulfur or oxygen mean that these materials have a high potential as cost-effective electrodes.

Fraunhofer ICT has consequently been investigating commercially available lithium-ion systems for many years, while at the same time conducting research on next-generation systems.

■ **Lithium sulfur (Li-S) and sodium sulfur (Na-S)** | With sulfur cathodes it is possible to achieve substantially higher capacities than with lithium-ion cathodes. Fraunhofer ICT´s know-how in the fields of reaction mechanisms and electrolyte and electrode degradation allows it to improve the performance of sulfur cathodes. Starting from commercially available materials, we aim to produce low-cost sulfur cathodes for high energy densities at the cell level while maintaining high cycle numbers.

■ **Sodium-oxygen (Na-O_2) and lithium-oxygen (Li-O_2)** | Oxygen as a cathode material does not have to be stored in the battery; it can be extracted from the surrounding air. This permits a significant increase in the energy density of lithium-ion batteries. A current research aim is to optimize the electrochemical conversion of oxygen, and to achieve a better understanding of the reaction mechanism. The use of sodium-oxygen batteries enables a considerable decrease in polarization and therefore an increase in efficiency; however, these batteries are still in the research stage. In this area, research at Fraunhofer ICT focuses on the development of suitable electrolytes.


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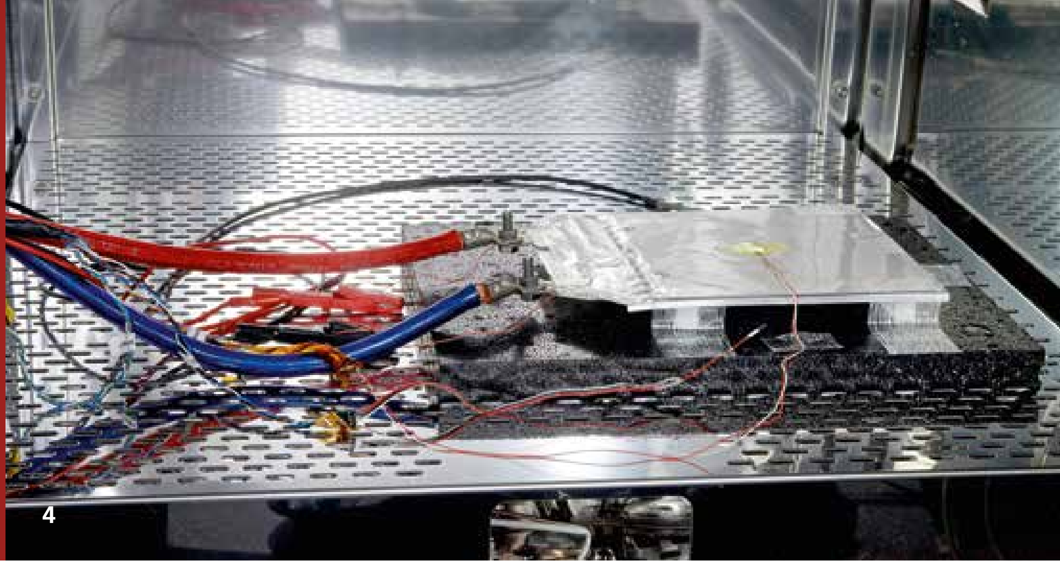
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Sodium metal (Na), lithium metal (Li), silicon (Si) | Graphite anodes are used in almost all lithium-ion cells because of their high cycle stability. With anodes made from metallic sodium, lithium or silicon, the energy density of the respective cells can be increased significantly. Fraunhofer ICT is therefore working on an improved, more homogeneous deposition of metal anodes, and on the development of better electrolytes for silicon anodes. Using scanning electron microscopy it is possible to investigate electrode materials and thus gain a better understanding of the electrochemical processes. At Fraunhofer ICT, post-mortem and in-situ investigations of these air-and moisture-sensitive materials are carried out.

Super-capacitors | The industrially relevant weak points of conventional lithium-ion energy storage devices are often insufficient stability at high temperatures, relatively short life cycle duration and unacceptable charging times. Electrochemical capacitors, on the other hand, have considerable potential for energy recovery, as their physical charging processes permit ultra fast energy storage coupled with a longer service life. In order to increase the often insufficient energy densities, Fraunhofer ICT is developing novel hybrid capacitors on behalf of its customers. Another step towards improving performance is the application of various ionic liquids as electrolytes and inorganic oxides as electrode materials.

Electrolyte, separation and solid ion conductor | Drawing on its comprehensive expertise in the field of organic, inorganic and ionic liquids as electrolytes for sodium- and lithium-ion cells, Fraunhofer ICT can benchmark separators and electrolytes against materials available on the market. Problems concerning the stability of organic electrolytes can be avoided in future systems by using Li^+ and Na^+ conductors and employing solid ion conductors as separation systems.

Material analysis | Electrodes, electrolytes and the reaction mechanisms of various electrochemical systems can be investigated and characterized through the use of ion chromatography, gas chromatography, mass spectrometry, energy dispersive X-ray radiation at the scanning electron microscope (REM-EDX), and RAMAN and Fourier transform infrared spectroscopy (FTIR).

Testing and benchmarking | At Fraunhofer ICT, mechanical, electrical and thermal safety tests are conducted on commercially available cells, electrode coils and electrodes. Our portfolio is completed by electrochemical tests to investigate the number of cycles, temperature and performance, and physical investigations of thermal conductivity and thermal capacity for simulation calculations. These results are used to conduct simulations or analyses on behalf of customers.

Measurement cells and measurement processes | At Fraunhofer ICT, various measurement cells with 2, 3 or 4 electrode positions for electrodes with different diameters and geometries are available, as well as cells for oxygen cathodes, optical in-situ measurements, in-situ determination of the electrolyte composition, and multi-layer pouch cells as demonstration objects.

Do not hesitate to contact us – our equipment and measuring systems can be tailored according to your requirements.

1 *Electrochemical battery material tests.*
2 *Na-dendrite in $NaClO_4$ in EC:DMC electrolyte.*
3 *Traction battery module.*
4 *Battery cell test in the climate chamber.*

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Fraunhofer Institute for Chemical Technology ICT

Joseph-von-Fraunhofer Strasse 7
76327 Pfinztal (Berghausen)
Germany

Director:
Prof. Dr.-Ing. Peter Elsner

Contact

Dr. Markus Hagen
Phone +49 7 21 46 40-716
markus.hagen@ict.fraunhofer.de

Thomas Berger
Phone +49 721 4640-319
thomas.berger@ict.fraunhofer.de

www.ict.fraunhofer.de

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