Fraunhofer

IFAM

FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

ELECTRICAL ENERGY STORAGE

CHARGING THE FUTURE SAFELY

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WE UNDERSTAND MATERIALS

THE FRAUNHOFER-GESELLSCHAFT

Practice-oriented research and development is the principal task of the Fraunhofer-Gesellschaft. Founded in 1949, the research organization performs applied research and development for the benefit of economics and society. The customers and contractual partners of the Fraunhofer-Gesellschaft are industrial enterprises, service providers and public authorities. At present, the Fraunhofer-Gesellschaft operates 66 research institutes with a total staff of 22 000, the majority of whom are qualified scientists and engineers.

SHAPING AND FUNCTIONAL MATERIALS

The institute's Shaping and Functional Materials division concentrates on developing customized material solutions with optimized production methods and processes at its facilities in Bremen, Dresden and Oldenburg.

The research and development activities range from the materials themselves through shaping to the functionalization of components and systems. Customized solutions are requested by such diverse sectors as the automotive industry, medical engineering, aerospace, machine and system engineering, environmental and energy technology, and the electronics industry.

Fraunhofer IFAM follows an integrated concept with three core areas in the field of electromobility. Work focuses on energy storage and electrotraction technology, as well as the testing, verification, evaluation and optimization of complete systems. The Electromobility Model Region Bremen/Oldenburg is currently laying the foundation for new vehicle and traffic concepts.

Shaping Technologies at IFAM are focussing on the development of economic and resource-efficient production processes for increasingly complex high-precision and standard components. Utilizing cutting edge powder and casting technologies, research work centers on increasing the functionality of parts and components. The range of services includes simulation of component design and shaping processes, implementation of production engineering and the appropriate training of company personnel.

In the field of Functional Materials, IFAM focuses on the improvement and extension of material properties and material processing. The functional materials can either be integrated directly in the component during the production process or applied to surfaces. They provide the component with additional or completely new properties, for example electronic or sensorial functions. By exploiting the specific properties of cellular materials, hybrid materials, fiber composites and biomaterials it is possible to realize a broad variety of applications.

ELECTRICAL ENERGY STORAGE

Electrical energy storage plays a crucial role for achieving climate-friendly energy supply and mobility. New material concepts are needed to increase storage capacities, efficiency, security and economy. The Fraunhofer IFAM Project Group for Electrical Energy Storage pursues these aims.

Material and process development for new energy storage systems - a holistic approach

Over the past 20 years, the development of electrical energy storage systems has been defined by the breakthrough in lithium-ion technology, which resulted in technical and economic solutions in various fields of application. Today this technology continues to offer on-going development potential.

Metal-air batteries may offer another revolutionary step forward in electrical energy storage technology, which would be particularly essential for electromobility market penetration. These provide significantly higher theoretical energy densities compared to commercially available batteries. Although primary cells have been developed already, there still does not exist a comprehensive material concept for rechargeable cells with high cycle stability.

This is exactly, where the project group for Electrical Energy Storage solutions comes in:
With broad and long-lasting experience in material and process development, Fraunhofer IFAM is breaking new ground in the formation of electrodes, cells and battery stacks, particularly for metal-air systems, while taking into account the usual aims of any battery development, such as improvements in:

- specific storage capacity
- service life/cycle stability
- operational safety
- cost-benefit ratio

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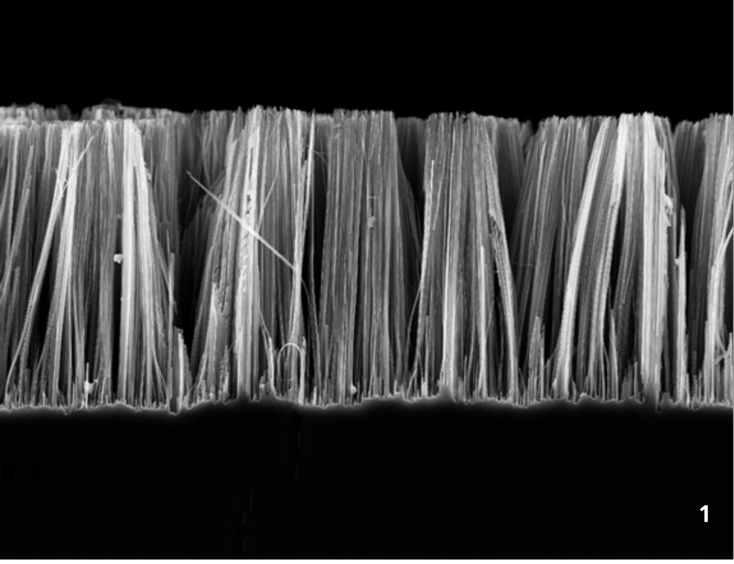


MATERIAL DEVELOPMENT AND NANOSTRUCTURED ELECTRODES

In material research for Electrical Energy Storage Systems we are viewing the electrochemical cell as an entity. Any material development must be mirrored with all other components of the storage system.

Negative electrodes

In the current state of technology, graphite is used as the standard material for negative electrodes in Li-ion batteries. On the other hand, the electrode capacity can be significantly increased by using silicon or Si/C composites. Fraunhofer IFAM is therefore focussing on processing nanostructured silicon. For that purpose our researchers are deploying chemical vapour deposition (CVD), reactive ion-etching (RIE), and conventional coating technologies for processing Si-based pastes.

Positive electrodes

Carbon-based gas diffusion electrodes are the preferred choice as positive electrodes in metal-air batteries. The focus here is on the structural and electrochemical demands on the carbon material. While, for example, in alkaline zinc-air batteries corrosion issues are at the forefront, in aprotic lithium-air systems the porosity, essential for storing the solid discharge products, requires further optimization. We examine and analyse the influences of material properties (e.g., specific surface, pore volume and pore size distribution, as well as electrical conductivity) on cycle stability and electrochemical performance. In this context we use carbon xerogels as a model system for optimizing pore structures together with bi-functional electrocatalysts that are controlling the chemical processes.

Electrolytes

The use of new electrode materials implies adapting and modifying electrolytes accordingly. Screening analyses are used to select from liquid, gel-type or solid electrolytes. Solid electrolytes are brought into the system by wet-chemical processes, thermal evaporation or sputtering.

Large image: Electrode manufacturing from powder to battery.

Figure 1: Electron microscopy of nanostructured silicon.

Figure 2: Thermogravimetry, FTIR-spectroscopy coupled to mass spectroscopy.


Mathis

PRODUCTION OF CELL COMPONENTS

The process chain of turning raw materials into batteries is fairly long. Process technologies therefore are playing an important role in material development.

Large image: Roll-to-roll coating device used for electrode production (© Mathis AG).

Figure 1: Glovebox line for manufacturing electrochemical storage systems under inert gas conditions.

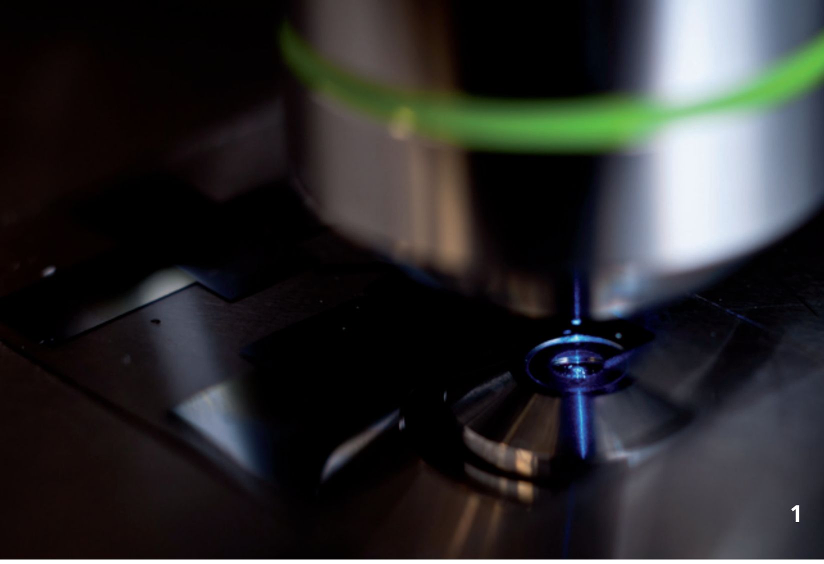
Paste formulation and processing

The performance of electrical energy storage systems is largely influenced by the electrode configuration and employed production methods. Electrodes are usually composed of active materials, binders and electrically conductive additives. The active material is processed into homogeneous pastes together with suitable solvents, binders and additives. We develop and test new paste formulas, while taking the required battery performance into consideration. Thick film moulding is used for coating the electrically conductive foils with the paste followed by drying and calendaring steps.

Cell production

In prototypic cell development, the coated electrodes are die-cut, stacked, packed and sealed resulting in so-called pouch cells. At Fraunhofer IFAM we have developed a semi-automatic and adaptable process chain for this type of battery cells to correlate material and manufacturing parameters with specific electrochemical performance of the resulting test cells. We also develop various cell types in order to validate the suitability of customized material samples.

The first charging of a newly prepared cell is very time-consuming, but has a crucial effect on battery lifetime and performance. We are studying this so-called formation process to determine the factors, which are influencing cell performance.



BATTERY CHARACTERISATION AND ELECTROCHEMICAL ANALYSIS

Figure 1: Raman spectrometer for in-situ analysis.

Figure 2: Test bench for electrical testing of battery cells and packs.

It goes without saying that in order to improve a system it has to be well-known. We want to perfect such systems – that's why we record every detail.

Electrochemical in-situ analysis

Understanding electrochemical processes is important for tailoring cell electrodes. Our (electro-) physico-chemical laboratory is equipped with Raman- and IR-spectroscopy coupled to mass spectroscopy for in-situ analysis of the employed materials and processes. Versatile spectro-electrochemical test cells allow us to conduct such analyses during cell operation. Given the complexity of the electrochemical processes within a battery cell, these tools are essential for any material and process development in this field.

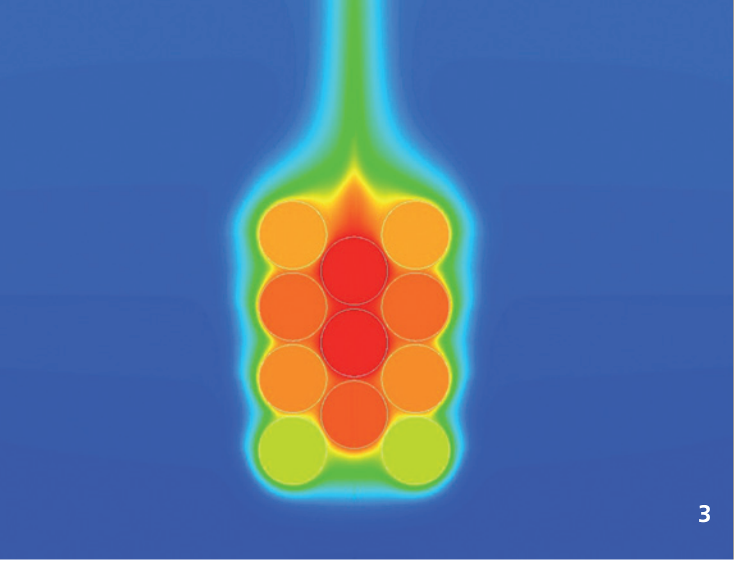
Inspection and testing systems – an overview

We are operating battery testers in a range of performance classes for electrical and cycle testing of cells, modules and batteries. Our facilities allow cycling at temperatures between - 20°C and 100°C including electrochemical impedance spectroscopy (EIS). We also deploy a RRDE system for hydrodynamic voltammetry.

We use the following diagnostic methods in particular for investigating the electrochemical properties of materials and components:

- electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV)
- rotating ring-disc electrode (RRDE)
- laser microscopy for surface inspection
- Raman/AFM
- thermogravimetry/mass spectroscopy/FTIR spectroscopy

Of course, depending on the issues at hand, we also use the exceptionally broad range of other analytical methods available at Fraunhofer IFAM for physical and chemical properties diagnostics.



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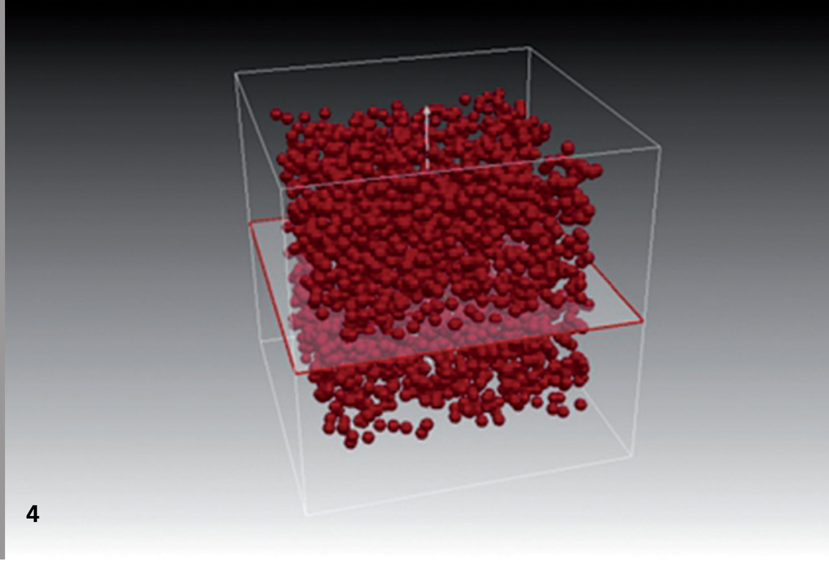

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SIMULATION AND MODELING

Computer simulation provides detailed insights in processes in electric storage systems and helps in finding the optimal battery design.

Figure 3: Modeling heat propagation in a battery pack.

Figure 4: Computer model of a carbon xerogel.

Material simulation

The development of novel materials for use in electrical energy storage systems is exceptionally time-consuming and costly. Acceleration of the development process is in many cases possible by describing the underlying electrochemical or physical system mathematically and to simulate the relevant processes. The results can later be used for more specific analysis or as a preliminary step towards implementation in battery systems.

We carry out simulations at various time- and length-scales, particularly for the following purposes:

- creating models for customized cell chemistries
- providing suitable algorithms for solving the resulting differential equation systems
- studying the parameters of lithium-ion batteries based on Newman models
- transferring methods from theoretical physics/chemistry (MD, DFT, Monte Carlo)

Modeling battery systems

With the aid of computer models we are able to efficiently create the thermal and electrical design of battery packs and specify operating parameters. Utilize our expertise in the following areas to your benefit:

- heat transport in battery packs with FEM/CFD
- electrical modelling, equivalent circuit diagrams
- development of models for performance and service life prognosis


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OUR SERVICES

Figure 1: Vacuum chamber for thin-film deposition within the Glovebox.

Figure 2: Rotating ring disc electrode (RRDE) for electro-chemical analysis in a mobile glovebox.

In addition to the utilization of our comprehensive analytics for individual queries, we offer assistance and support in all aspects of material development for primary and rechargeable battery systems.

For partners from industry and various other sectors we provide the following services:

- material research and process development for electrical energy storage systems
- design and testing of battery cells with customized materials
- battery and aging tests at cell and module level for all sizes and types (up to 6 V or 50 V), and for large battery systems (up to 1000 V)
- research, evaluation and expertise for all battery-related issues

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We are a multi-disciplinary and motivated team of scientists and engineers devoted to support you in implementing new ideas and concepts. It is needless to add that confidentiality, discretion and trust form the backbone of our partnerships. If required, we also draw in the expertise of additional partners from the Fraunhofer-Alliance »Batteries«.

OUR COMPETENCE
SHAPING AND FUNCTIONAL MATERIALS

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