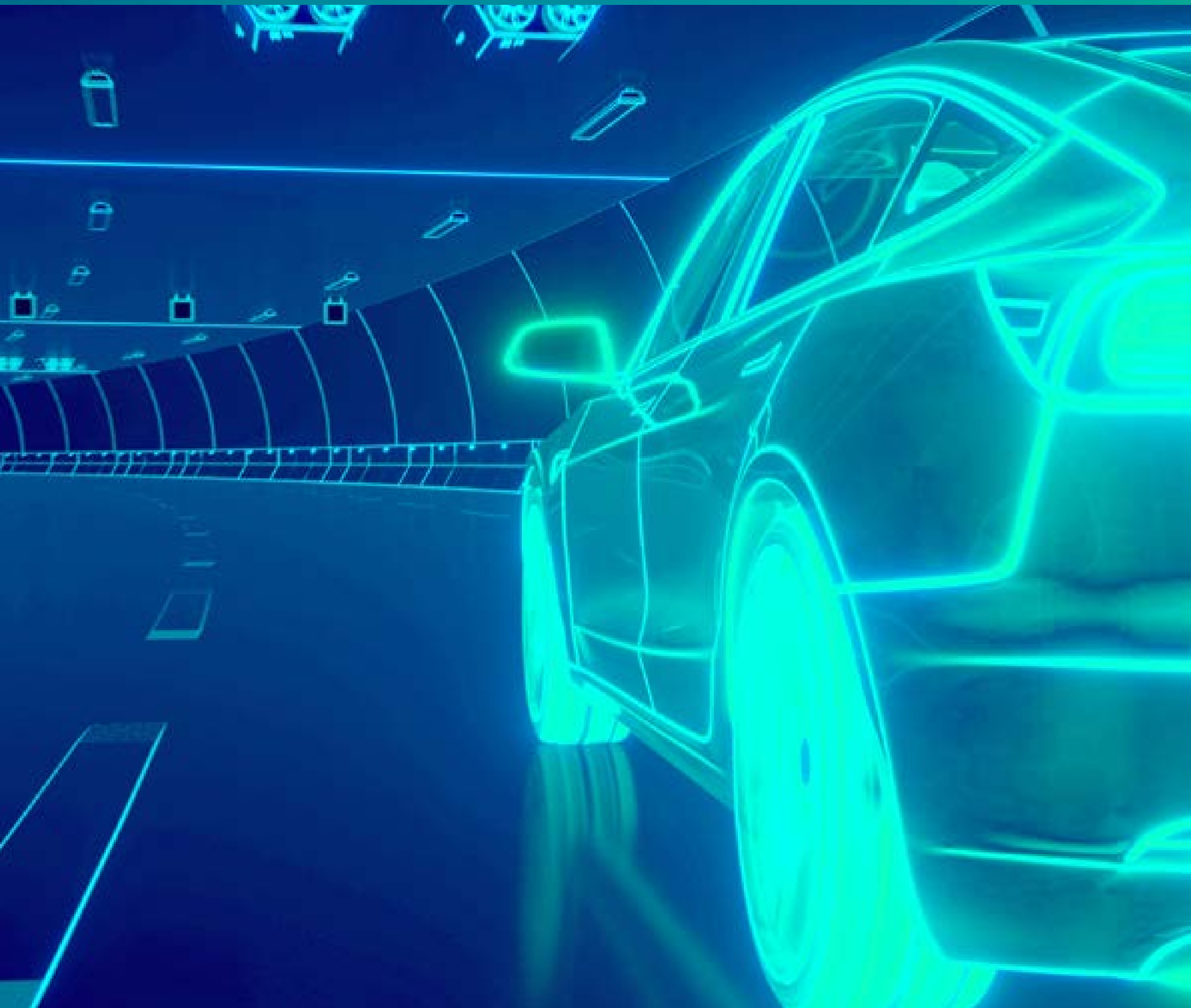
FRAUNHOFER RESEARCH INSTITUTION FOR MATERIALS RECYCLING AND RESOURCE STRATEGIES IWKS

CLOSING THE VALUE CHAIN IN ELECTROMOBILITY

RECYCLING FOR THE ENERGY OF TOMORROW



Fraunhofer IWKS, Hanau

Fraunhofer IWKS, Alzenau

Research focus

The Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS stands for a responsible use of resources. The aim of the research of Fraunhofer IWKS is to establish a closed circular economy. Therefore, the scientists work at recovering recyclable materials and introducing them into a new product cycle or to substitute valuable materials through sustainable alternatives.

Therefore, Fraunhofer IWKS develops innovative processes in the area of functional materials (magnet materials, energy materials, analytics) and functional materials (urban mining, biogenic systems, material flow management).

Recycling of batteries and PV modules

Combining photovoltaics and electromobility is mandatory for decentralised power supply. The German government is calling for one million electric vehicles on Germany's roads by 2022 and as many as 6 million by 2030.

Electric mobility as we know it today requires large quantities of traction batteries. First and foremost are the high-performance lithium-ion batteries, the production of which requires large quantities of valuable raw materials, which should be preserved in the material cycle as far as possible after the batteries have reached their end of life. This requires a closed recycling chain including expandable logistics solutions.

With the trend towards more and more private households with photovoltaic systems and ever cheaper storage systems, the use of PV in combination with electromobility is becoming increasingly worthwhile, and the number of installed photovoltaic modules is increasing not only in Germany.

Fraunhofer IWKS is taking on the challenges of recycling PV modules and traction batteries in connection with the technological revolution. The topic is also becoming more important, as the first solar modules have now reached the end of their at least 25-year lifespan.

Europe's dependence on imports is a situation that is aggravated by the increasing electrification of our vehicles. Not least against this background, it is imperative to establish a functioning recycling chain for these traction batteries and to maintain essential material flows in Europe.

Please do not hesitate to contact us.

Yours,
Prof. Dr. Anke Weidenkaff
Executive Director, Fraunhofer IWKS

„THINKING IN ENTIRE MATERIAL LIFE CYCLES AND OFFERING AN EFFICIENT MATERIAL FLOW MANAGEMENT AS A ONE-STOP SOLUTION FOR CUSTOMERS AND PARTNERS IS ONE OF THE BIGGEST STRENGTHS OF FRAUNHOFER IWKS."

BATTERY RECYCLING IN ELECTROMOBILITY

From energy-efficient recycling of battery materials, to intelligent recycling of traction batteries from electric vehicles to a targeted connection along the entire battery value chain.

Rechargeable batteries are used in a wide variety of applications and are becoming increasingly important. In addition to usage in mobile devices, power tools and stationary energy storage devices, applications in electromobility are particularly noteworthy. Large-format traction batteries made of high-performance lithium-ion cells are the heart of modern electric vehicles and thus a key technology for the European automotive industry.

These batteries contain valuable and, in some cases, critical resources such as cobalt, lithium, nickel and copper, which mostly have to be imported from countries outside the EU. They also contain substances that would endanger our environment and health if disposed of improperly. Effective battery recycling is therefore of great relevance from both an economic and an ecologic point of view. But how can valuable resources be preserved in the value chain?

Research projects

In the collaborative project AutoBatRec2020 (Automotive Battery Recycling 2020), scientists at Fraunhofer IWKS have been working on the intelligent recycling of traction batteries from electric vehicles since the beginning of 2018. Work is underway to intelligently recycle used batteries from electric vehicles and to identify ecologically and economically advantageous ways of efficiently recycling batteries, including upscaling for industrial application. The entire recycling chain is to be improved in such a way that the valuable raw materials are recovered and thus secured for the European industry. The aim is to evaluate the individual processes with regard to their efficiency and profitability as well as their sustainability and to establish an economically interesting value chain through their intelligent combination and further optimization. Consequently, the end-of-life management of traction batteries will be developed in the direction of circular economy and sustainability.

Project NEW-BAT

Lithium-ion batteries are a key technology for energy system transformation and electric mobility. The widespread use of these energy storages leads to a high volume of discarded batteries and rechargeable batteries, which are a valuable source of raw materials. Currently, energy-intensive metallurgical recycling methods are applied for used batteries and waste from battery production. However, only elementary metals can be recovered in this way. The added value is therefore usually based only on the metal values of nickel, cobalt or manganese, for example.
It would be more valuable to recover the actual battery materials that have already been produced with great effort from the basic elements, such as high-quality lithium metal oxides and carbon compounds that were previously not recyclable. This would save energy and costs and sustainably secure valuable resources such as lithium. This is exactly where NEW-BAT comes in.

Project ECO COM'BAT (»Ecological Composites for High-Efficient Li-Ion Batteries«)

The project addressed the demand for better materials and technology solutions for sustainable mobility and the reduction of critical raw materials in batteries. The aim of the ECO COM'BAT project is to combine the latest developments in green and high-performance materials into new composite materials for the next generation of lithium-ion batteries, high-voltage batteries. To this end, material production must be upscaled to pilot and industrial scale. This upscaling includes improved quantity, efficiency and sustainability of production processes. An upscaling of sustainable materials from TRL (Technology Readiness Level) 5 to TRL 7 has been achieved.

RAW MATERIALS SOURCE SPENT BATTERIES

„The recycling of electric car batteries is extremely important in view of the impending shortage of raw materials. Cobalt and nickel, for example, can be recycled at a rate of over 90 percent from a used battery. With lithium, it's a little more difficult, you can realistically recover 70 percent of the original material.“

"Recycling companies are very interested in batteries, and they should be. If we do not implement sufficient capacity, we will have a major problem in five to ten years' time."

Dr. Jörg Zimmermann, Head of Department Energy Materials at Fraunhofer IWKS

Battery recycling is currently attracting a great deal of attention from industry and research. According to the current forecast of the National Platform Future of Mobility (formerly National Platform for Electromobility), approximately one million electric cars are expected to be registered in Germany alone by 2022. Experts estimate that the number of electric vehicles in Germany will rise to 2 to 3 million by 2025. The service life of their batteries is limited for automotive applications and ranges from a few years to ten years or longer, depending on type and work load. This means that a steadily growing number of used traction batteries can be expected in the near future. "At the moment, however, the complete recycling of e-car batteries is very cost and energy intensive and therefore not yet economical. Therefore, the current focus is only on the recovery of the most valuable ingredients such as cobalt. The process must be mechanized and automated and then the recycling of batteries becomes more economical with increasing quantities", explaines Dr. Jörg Zimmermann, Head of Department Energy Materials at Fraunhofer IWKS.

"There are two different basic approaches to recycling a lithium-ion battery. One is the pyrometallurgical route, where the module is opened by heat and the cell is completely melted. On the other hand, there is an increasing trend towards mechanical processes in which the batteries are shredded.

Finally, you have to work with chemicals in the end to extract the cobalt, for example. We are going one step further and are working on the selective separation of the material fractions directly at the beginning of the process chain in order to make the process more efficient."

In order to overcome these challenges and establish forward-looking recycling processes in good time, increased and joint research and development work is necessary.

Challenges and solutions

- Digitization and automation of battery disassembly as far as possible
- Development of alternative dismantling solutions through innovative shredding technologies
- Material-selective fragmentation of battery cells in a liquid medium for passivation of pollutants and efficient separation of composite materials
- Enrichment of recyclable materials - especially active materials - through innovative separation and sorting processes in the first stage of recycling
- Recovery and processing of functional materials (already synthesized compounds) instead of metallurgical separation into individual elements
- "Design for Recycling" and "Design for Disassembly" of the batteries by unification of the design forms, easily separable connections as well as labels and markers

BLUE GOLD PV MODULES

RECYCLING OF PV MODULES

The International Organization for Renewable Energy, Irena, estimates that almost 100,000 tons of solar waste will be generated in Germany by 2025. This corresponds to almost five million current standard modules. By 2030, the amount of waste is expected to grow to around 400,000 tons.

Growing PV module waste represents a new generation of environmental challenge, but at the same time it offers opportunities to create value and break new ground. This includes the recovery of raw materials.

Valuable metals in waste incineration
A solar cell consists of several hundred grams of silicon, a few grams of lead, zinc, tin and sometimes even small amounts of silver - all valuable raw materials. The challenge of recycling lies, among other things, in the complex separation of the recyclable materials from the plastic film in which they are embedded. As a result, most of them end up in waste incineration plants and the materials are irretrievably lost.

The focus is therefore on improved recycling processes, more efficient production processes and new substitutes for strategic materials for energy conversion, storage and saving.

Fraunhofer IWKS develops innovative processes for the recovery of valuable elements and connections from PV modules. The aim is to gently separate different fractions and thus enable the recovery of materials of high purity.

Various fragmentation, separation and chemical treatment processes for handling the PV modules are being investigated. This also includes the adequate analysis of materials and components in all process stages.

Research focus

- Innovative separation processes for complex composites (e.g. electro-hydraulic fragmentation - EHF)
- Wet chemical digestion and separation processes
- Separation and purification of recyclable materials by means of gas phase transport reaction
- Biological processes for the enrichment of critical metals (e.g. bioleaching)
- Regaining and processing of functional materials

Picture: PV modules - EHF

If the amount of PV modules with a lifetime until 2030 were to be converted into cash equivalents by recycling and extracting materials, this would result in about 400 million euros. This waste, in turn, could produce 60 million or 18 GW of new panels. And by 2050 this figure will rise to 15 billion dollars per year. From this amount of waste, 2 billion PV modules can be produced, equivalent to 630 GW.
Source: www.solarify.eu

ELEKTRO-HYDRAULIC FRAGMENTATION

FRAGMENTATION - SEPARATION - SORTING

Mechanical fragmentation

Fraunhofer IWKS owns a large number of fragmentation technologies with different types of stress on a laboratory and pilot scale. The material can be coarsely and finely fragmented and homogenized as required. The technologies can be used for different materials: Soft, fibrous, hard and brittle samples in wet and dry condition can be processed. Sorting and sieve analyses according to grain size and shape as well as density are also possible.

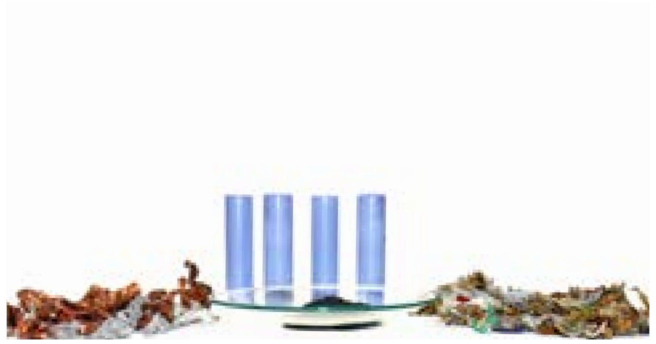
- Impact crusher
- Jaw crusher
- Rotor mill
- Cutting mill with cyclone
- Planetary ball mill
- Vibrating tube mill
- Cryogenic mill
- Sieve tower
- Wet separation table
- Optical particle size analysis

Electro-hydraulic fragmentation (EHF)

A particularly innovative technology for the fragmentation of materials is the so-called electro-hydraulic fragmentation by means of shock wave technology. Here, the material to be shredded is placed in a reactor in a liquid medium (e.g. water). An electrical discharge generates shock waves which propagate in the reactor with the aid of the liquid and thus cause the material to be separated along phase boundaries. These short but violent mechanical shocks attack weak points in the material: The separation takes place at macroscopic joints or at microscopic bounderies . In the Fraunhofer IWKS pilot plant, an EHF system is in operation on a pilot scale.

Here, tests are carried out with your material in the EHF plant and the process parameters are optimised for your material. The test results are evaluated in detail and the starting and final materials physically and chemically analyzed.

In the end, the respective process is considered to be economical according to customer requirements and can thus be scaled up to industrial standards.



Picture: 18650 batteries as they are used in electric cars before and after the electro-hydraulic fragmentation

Fraunhofer IWKS

Material Competence and Process Know-how

MAGNET PILOT PLANT AT FRAUNHOFER IWKS

For the production and recycling of rare earth containing high performance permanent magnets. The existing equipment can be used to produce and test magnets from new alloys with improved properties.

"Permanent magnets containing rare earths are the driver of our future. A breakthrough in electro-mobility without them is just not imaginable."

Dr. Jürgen Gassmann, Head of Department Magnetic Materials at Fraunhofer IWKS

In the development of technical materials for high-end applications, the reduction of resource capacities is of great importance. Limited resources not only have a strong impact on price, but also endanger the continuous supply of the desired raw materials. Therefore, the use of primary raw materials should be reduced to a minimum or even avoided altogether. In consultation with you, researchers at Fraunhofer IWKS develop and optimize materials for your specific application with a view to the intelligent use of raw materials. To this end, Fraunhofer IWKS is equipped with state-of-the-art equipment covering a broad spectrum of materials processing technologies. The portfolio ranges from classical heat treatment, melting of alloys, powder grinding to the generation of amorphous or nanocrystalline structures by rapid solidification or hydrogen treatment.

Nd-Fe-B sinter magnets

In terms of the Nd-Fe-B market, they have a market share of over 85 %. Production via the powder metallurgical route offers the advantage that simple geometries can be produced in a wide range of sizes. The pilot line for magnet production is designed for processing up to 10 kg of magnet material per test.

The magnetic alloy is inductively melted in a strip caster to set the desired microstructure and rapidly solidified into flakes. The resulting material is first embrittled in a hydrogen autoclave and then ground to fine powder (particle sizes in the single-digit micrometer range) in a counter jet or target mill. This is aligned and pressed in a uniaxial press with transverse field. The green body thus obtained is sintered into a compact body in a sintering furnace and then annealed to optimize its magnetic properties. In-house analytics make it possible to check the chemical composition, microstructure and physical material properties before, during and after the manufacturing process.

Nanocrystalline magnets

Nanocrystalline hot-formed magnets currently only have a market share of less than 5 %, but offer the advantage of near-net shaping. By manufacturing under mechanical pressure, the magnet takes on the shape into which it is pressed without sintering shrinkage. With the existing equipment, hot formed magnets in the range of several 100 g per test series can be produced.

To produce hot-formed nanocrystalline magnets, the material is inductively melted in a melt spinner and rapidly solidified. This produces nanocrystalline material in the form of short strips (so-called flakes). This is ground to a coarse powder in a mill. The resulting powder is processed in a hot press into hot-pressed or hot-formed magnets. Due to the coarse grain size of the powder and the special alloy composition of hot-formed magnets, the powder and the finished magnet are much more resistant to corrosion than a powder for sintered magnets. The production of these magnets is therefore possible in air.

The respective application will be scrutinized with regard to economical parameters and scaled up to INDUSTRIAL STANDARD.

Image: Amorphous metals after rapid solidification

DEVELOPMENT AND RECYCLING OF PERMANENT MAGNETS

The researchers at Fraunhofer IWKS are working on key functional materials for the breakthrough of electromobility.

Strip-caster, pilot plant at Fraunhofer IWKS

The Strip-caster is a plant for the production of flakes containing rare earth elements with an optimized microstructure. The magnetically charged alloy is melted inductively and poured onto a water-cooled copper wheel, which allows the microstructure of the materials to be adjusted.

The plants for the production and recycling of rare earth-containing permanent magnets are optimally matched to each other. A system of transport containers and glove boxes enables sample transfer between the systems with oxygen rejects.

Technical equipment of Fraunhofer IWKS

Sinter oven

The magnetic materials department comprises analytics, the manufacturing of magnets and the development of technologies for recycling old magnets, production waste and components with magnets, for example from hard disks.

Analytic services

- Magnetic properties and domain structures
- Scanning electron microscopy (SEM)
- Elemental analysis (ICP)
- Analysis of light elements (O, N, H and C)
- Thermo-optical analysis of sintering behavior
- 3D Atomic Probe Tomography
- Determination of corrosion behaviour
- Density measurements

Fraunhofer IWKS focuses on the following material recycling routes:

- Recycling by hydrogen treatment to produce sintered and plastic bonded magnets
- Recycling by melting and rapid solidification for the production of sintered, plastic-bonded and hot-formed magnets

Furthermore, the dismantling of magnets from entire assemblies and motors by hydrogen treatment and the recovery of rare earths on an elementary basis using biochemical methods (bioleaching) is being investigated.
The furnace for sintering and annealing of permanent magnets is directly connected to a glovebox. A gas cooling enables a very high cooling speed.

HOW CAN WE ASSIST YOU?

Are you an entrepreneur or do you work in the research department of a company? Would you like to promote your product with the help of research? As an experienced partner for companies and other research institutions, Fraunhofer IWKS offers a range of different opportunities for cooperation in research and development (R&D).

Bilateral cooperation and R&D projects

- Individual tasks
- Short- and long-term contract research
- Direct knowledge transfer through in-depth cooperation on site
- Support during implementation in production

Publicly funded joint projects

- Network of research and industry partners
- Medium and long-term research projects
- Partial financing through public project funds
- Pre-competitive development of application-oriented fundamentals

Industrial joint projects

- Complementary partners (e.g. users and suppliers)
- Use of the extended pool of methods and competences
- Reliability of exploitation through IP generation

Industrial working groups

- Joint finding of solutions in a low-competitive field of action
- Long-term projects
- Reduced costs for the individual, as joint financing of the research work is ensured

If you have any questions about concrete cooperation and financing possibilities, please do not hesitate to contact us.

www.iwks.fraunhofer.de/en

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