Fraunhofer IZM

Fraunhofer Institute for Reliability and Microintegration IZM

Department

Environmental & Reliability Engineering

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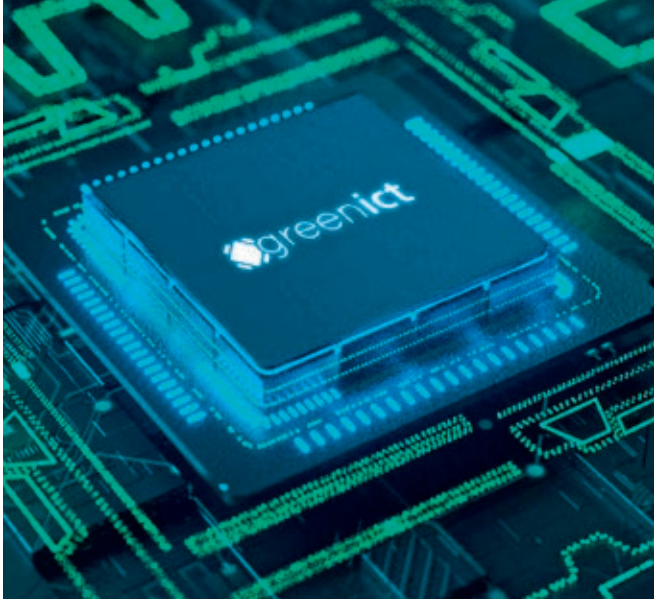
Environmentally Friendly, Reliable and Fail-Safe Electronics



Resource and energy consumption in semiconductor production

The Fraunhofer Institute for Reliability and Microintegration IZM is working on the development and implementation of new concepts for the construction of highly integrated electronic and photonic systems. Through its application-oriented research, Fraunhofer IZM builds a bridge between suppliers of microelectronic components and manufacturers of technical systems in numerous sectors, such as automotive, energy, industrial and medical technology.

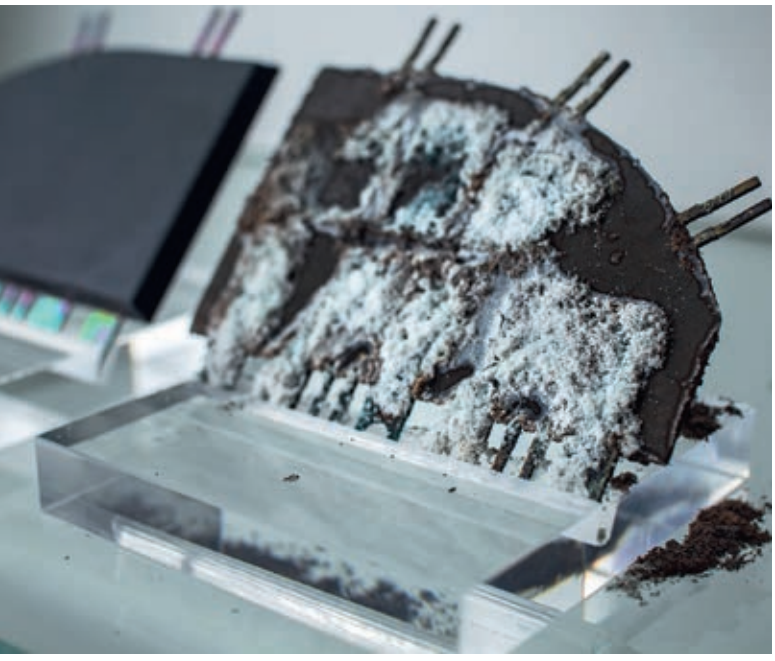
The range of services offered by the Environmental and Reliability Engineering (ERE) department, which has around 50 employees, extends from consulting to testing and evaluating materials and systems through to simulating reliability factors. We support you in technical developments on the path to market maturity through environmental and reliability studies – from nanocharacterization to evaluation and optimization at system level.

We work closely with Technische Universität Berlin (Research Center for Microperipheric Technologies), particularly on joint European projects.

Against the backdrop of global growth and limited resources, each new generation of technology and products must generate more functionality and assured reliability from lower resource consumption. Without adequate reliability, the economic success of an application is jeopardized anyway, and, at the same time, the environmental balance of microelectronic products, which are typically production-intensive, is massively worsened by premature failure or replacement. Sustainable electronics technologies must therefore be both environmentally friendly and reliable.

The focus of our research is on, for example

- Ecodesign and circular technologies (Green ICT, Circular Design Lab)
- Ecological assessment for electronic systems
- Digital technologies and data for the circular economy
- Environmental legislation: RoHS, WEEE, Ecodesign
- Model approaches for the development of digital twins
- Reliability: Simulation, testing and optimization
- Application-specific system evaluation
- Corrosion, electrochemical migration, moisture diffusion
- Condition monitoring of electronic systems



Signs of corrosion and migration on assemblies

Highlight

Optimization, monitoring of mechatronic systems with a digital twin

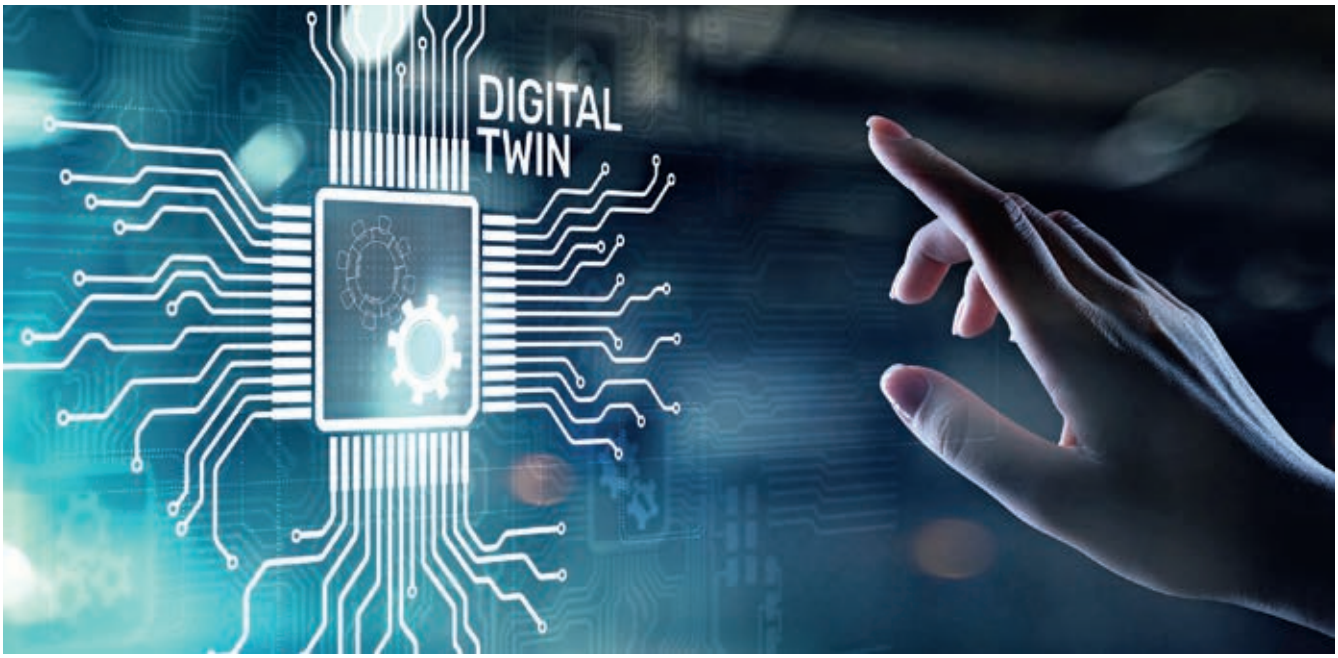
The use of a digital twin of mechatronic systems enables design optimizations, virtual tests and validations during the development phase as well as continuous monitoring during operation. By integrating trustworthy data sources, the theoretical behavior of the digital twin or the assembly-specific digital fingerprint is analyzed and compared with the real application.

The AI-based self-validation of electronic systems based on innovative hybrid model approaches is being continuously expanded for this purpose. For functional structures in the automotive, rail technology and aviation sectors, corresponding hybrid models are realized using both open source and commercial software environments. With the grey-box models developed to complement the hardware, the system level can be fully mapped right down to the assembly and connection technology.

Main research areas

- Multi-domain system simulation: Electrical, thermal, mechanical modeling
- Hybrid grey-box modeling (combination of physical and data-driven model approaches)
- Integration of failure mechanisms to evaluate the remaining useful lifetime (RUL)
- Development of efficient dynamic simulations using model order reduction (MOR, ROM)

Development of a hybrid approach for the self-validation of safety-critical electronic applications



System Reliability Assessment

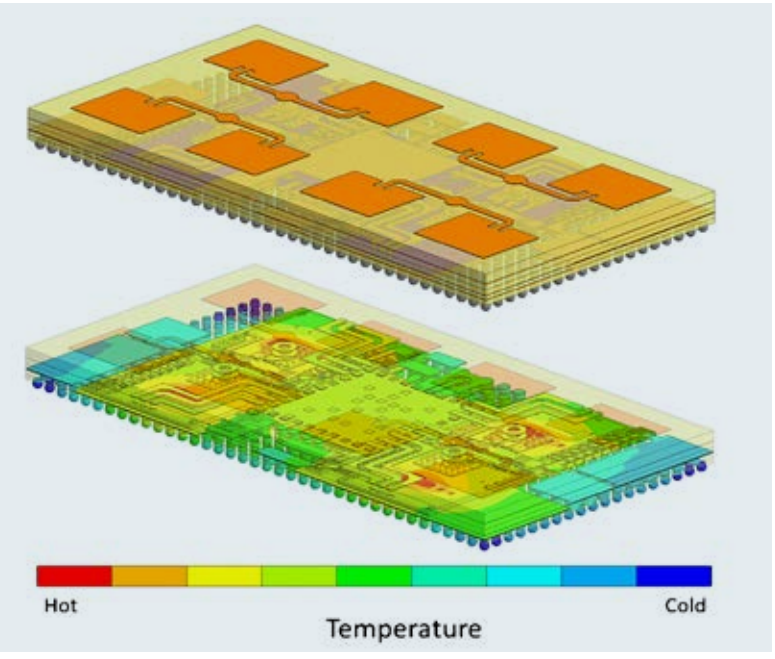
Development of customer-oriented solutions for robust, reliable and sustainable electronic systems

In transdisciplinary teams, we develop innovative, customer-oriented solutions for robust, energy-efficient and sustainable electronic systems. We ensure reliability through application-specific system design, qualification, weak-point analysis and optimization at system, component and technology level. We use experimental and simulation methods and develop them further.

We are increasingly using hybrid modeling approaches ("grey-box") to assess reliability and detect tampering in complex electronic systems. We extend functional circuit structures with physically based model approaches and data-based, AI-supported evaluation methods. This allows us to use digital twins to achieve a more precise and effective assessment of system reliability and tamper detection.

With our technological expertise and the company's versatile analytical resources, we also support our customers in analyzing faults and causes in electronic assemblies, systems and power electronic modules. We also offer a wide range of defined load tests to evaluate reliability and robustness. We develop load scenarios and new test profiles based on application-specific mission profiles in order to achieve meaningful results.

We also offer our customers comprehensive advice and support in the selection and integration of electronic components and technologies. We analyze the requirements and goals of our customers and find tailor-made solutions to maximize the performance and efficiency of their electronic systems.



Simulation for thermal management of an assembly

Main research areas

- Application-specific system evaluation
- Reliability: Simulation, testing and optimization
- Corrosion, electrochemical migration, moisture
- Condition monitoring of electronic systems
- Model approaches for the development of digital twins
- Ensuring the reliability of used, refurbished or repaired electronics
- Object-oriented system simulation with compact models and multiscale methods
- Digital Thread; system mapping: AAS, SysML, FMI

Range of services

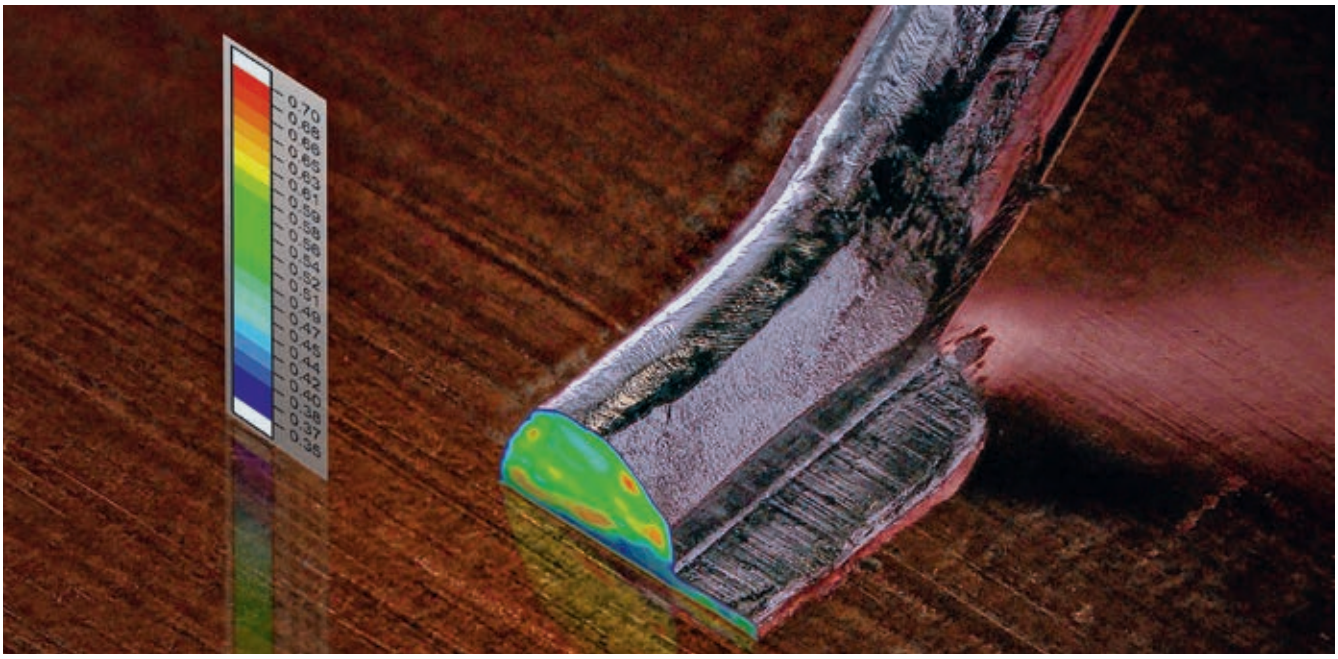
- Reliability assessment of electronic systems
- Design evaluation and optimization with FEM
- Corrosion, electrochemical migration, moisture
- Thermal characterization, system design
- Vibration measurements and tests
- Structural analyses, material characterization
- Condition monitoring of electronic systems

We also take cost optimization and time-to-market aspects into account in our solutions to ensure economic success.

Our team of experts works closely with customers to understand and meet individual needs. We are also happy to offer training courses and workshops to expand the knowledge and skills of our customers and their employees in the field of electronic system development. This close cooperation enables us to develop and successfully implement innovative solutions together.

Overall, we strive to help our customers overcome technological challenges, increase their competitiveness and create sustainable, robust electronic systems that meet current and future requirements.

Simulation of shear tests of innovative, aluminum-based thick-wire connections



Policy, Ecodesign and Circular Materials

Closing loops and sustainably optimizing product design

The Policy, Ecodesign and Circular Materials group focuses on the contribution made by product design to greater sustainability in the economy and society. With the Circular Design Lab, we have the methodological expertise and technological knowledge to make applications and services more sustainable. We conduct research into the recycling of materials in electrical and electronic applications and focus equally on the requirements of product design and the possibilities of high-quality recycling.

We contribute our technological expertise and our knowledge of the impact of electronics applications along the life cycle to the development of regulatory product requirements. In the areas of ecodesign, energy efficiency labeling, material restrictions and the circular economy, we are the point of contact for companies, associations, legislators and specialist authorities and enable innovative, fact-based policy approaches.

Main research areas

- Product ecodesign and circular business models
- Recycling of plastics in electrical and electronic applications
- Innovative policy approaches to promote ecodesign, resource efficiency and the circular economy
- Development and standardization of life-cycle assessment methods

Range of services

- Ecodesign concepts for electronics applications
- Application and evaluation of ecological assessment methods, including supply chains (Scope 3.1)
- Product group analyses as a basis for environmental policy
- Advice and series of events on the status and trends of environmental legislation

Standardized charging connections and modular device design promote the circular economy

Life-Cycle Modeling

Modeling expertise along the product life cycle

In addition to the pure quantification of environmental impacts, life-cycle assessments (LCA) and ecological evaluations provide the basis for well-founded ecodesign that targets the hotspots in the product life cycle. The Life-Cycle Modeling group offers modeling expertise along the product life cycle of electronic components, products and systems.

Our institute offers comprehensive support in analyzing and evaluating the environmental impact and costs associated with raw materials, manufacturing processes, components and products. In addition, we actively support the collection of data both within the client's own organization and from their suppliers. Another focus of our work is the processing of methodological issues in the field of life-cycle assessment and the development of assessment indicators. Changes in product use and business models in the context of the circular economy – such as the inclusion of repair and reuse in product assessment or the mapping of obsolescence in ecological assessments – require an adaptation of the approach.

Main research areas

- Environmental and cost assessment of raw materials, manufacturing processes, components and products
- Obsolescence
- Life-cycle assessments and evaluation indicators

Range of services

- Life-cycle assessment and carbon footprint of electronic products
- Life-cycle assessment review

The findings of a well-founded life-cycle assessment help to make design decisions and derive priorities for the ecological optimization of individual manufacturing processes

Sustainable Networks and Computing

Life-cycle assessments and ecodesign for green ICT – from the carbon footprint of mobile communications and artificial intelligence to the Ecodesign Regulation for Sustainable Products and the Digital Product Passport

The SNC group's research addresses the increasing energy requirements and carbon footprint of ICT infrastructures such as telecommunications networks and data centers. It includes the modeling, analysis and evaluation of the life cycle-related environmental impact of individual appliances and complex systems. Telecommunications networks, servers and data storage are extremely diverse in terms of technology and continue to develop rapidly. The preparation of life-cycle assessments and the implementation of ecodesign require a high level of theoretical and technical knowledge in this area. To support these tasks, the group has developed what is known as the 5K method – a guideline for the structured creation of life-cycle inventory models for complex ICT systems. The ecological assessment precedes any ecodesign. Ecodesign topics include, for example, energy and resource-reduced thermal management with the aim of using waste heat in the data center. Other topics include repairability, recyclability and the use of recycled materials.

Main research areas

- Life-cycle assessments for telecommunications engineering and networks, servers and data storage (LCA, PCF)
- Ecodesign of telecommunications and computer systems
- Ecological assessment of technologies (mobile communications, photonics, computing)
- Digital solutions for environment-related production, circular products and product data (DPP, Digital Twin)

Range of services

- Support, training and implementation of ICT-specific life-cycle assessments (LCA)
- Applied ecodesign with product analyses, technology and strategy development (Green ICT)
- Consultation on the status, trends and implementation of environmental legislation incl. digitalization and information obligations

We are investigating how moving IT services to the cloud is changing the use of natural resources and impacting the climate

Equipment / laboratories

Electronics Condition Monitoring Lab

- Vibration tests on electronic assemblies by excitation (sine, noise, shock) and in combination with humidity and temperature stress
- Non-contact vibration measurement for design optimization, weak point analysis and troubleshooting
- Determination of the functional limits for temperature, temperature change and vibration using the HALT method
- Shock testing and continuous measurement of peak acceleration, pulse duration and shape on the level drop tester

Micro Materials Characterization Lab

- Static and dynamic materials testing with tensile, pressure, flexure, torsion
- DMA, mDMA, nano-indentation
- Thermoanalytical methods (m)TMA
- Structural analyses (SEM, FIB, EBSD, EDX)
- Deflection measurements of components (3D), 3D topography analysis AFM
- Fracture mechanic testing, material modeling

Corrosion Analysis Lab

- Evaluation of the corrosion behaviour of different materials and components by electrochemical investigations
- Evaluation of corrosion behavior under different acceleration factors (e.g. different media, temperatures)
- Investigation of electrochemical migration (e. g. THB-Test, SIR-Test)
- Stress tests for power modules under humidity and bias (e. g. H^3TRB-Test)

Moisture Lab

- Dilatometric swelling analysis
- Sorption analysis

Power Electronics Testing Lab

- Active power and passive load cycling tests for power semiconductors in a range of form factors and technologies
- Calibration of the barrier layer temperature and monitoring of parameters for every sample
- Thermographic monitoring during active testing

Thermal and Environmental Analysis Lab

- Heat flow optimization for heat sinks and thermal distributors via wind tunnel or dynamic fluid simulation tests
- Component and system analysis to establish surface temperatures (infrared thermography) and thermal resistance (transient tester)
- Measurement of the thermal resistance and heat conductivity of thermal interface materials (films, pastes, adhesives, phase change)
- X-ray fluorescence analysis for rare earths and other metals used in microelectronics
- Analysis of the dismantlability and reparability of electronic products

Circular Design Lab

- Strategic Design
- Eco-Design & Circular Design
- Design Research

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