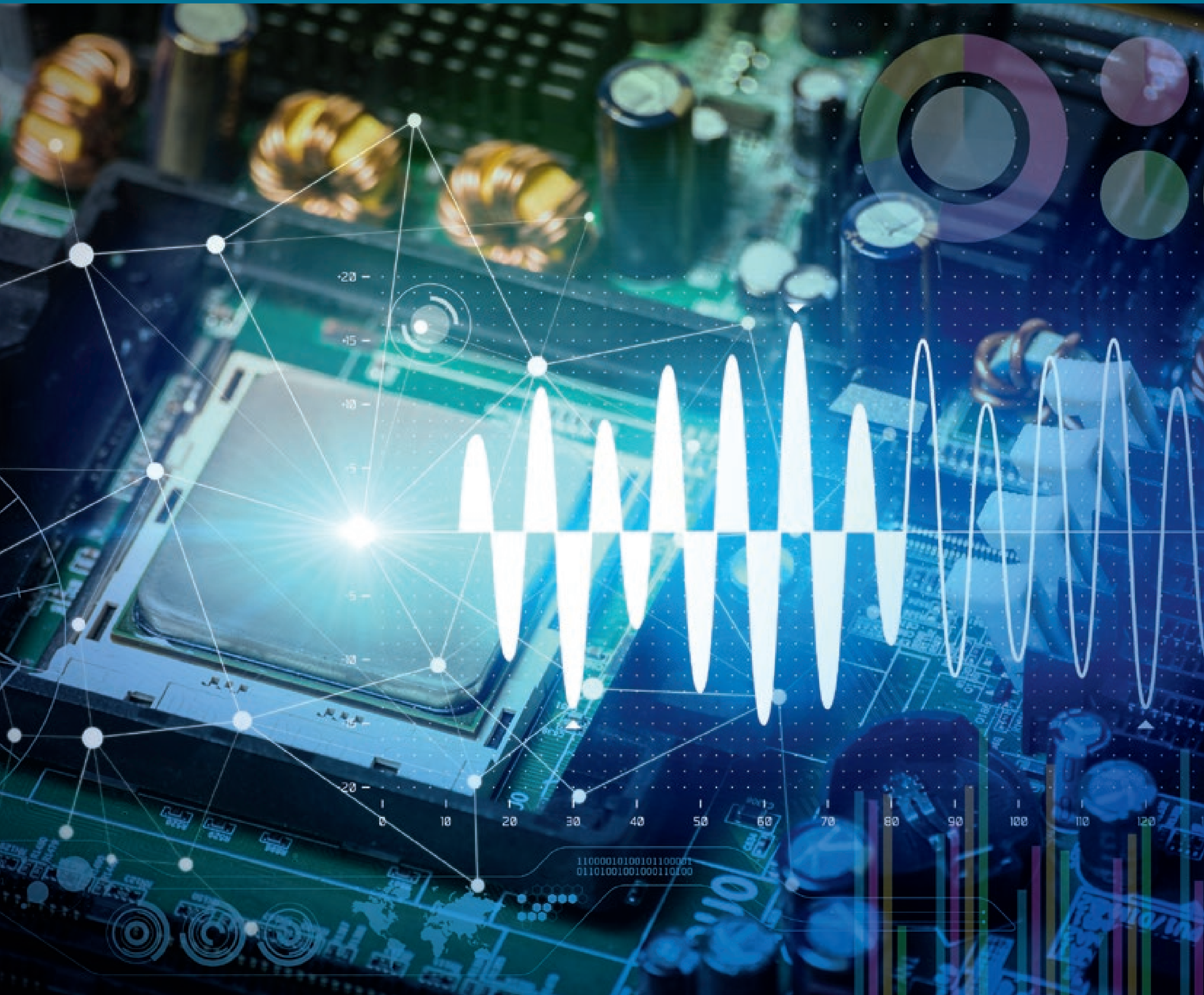
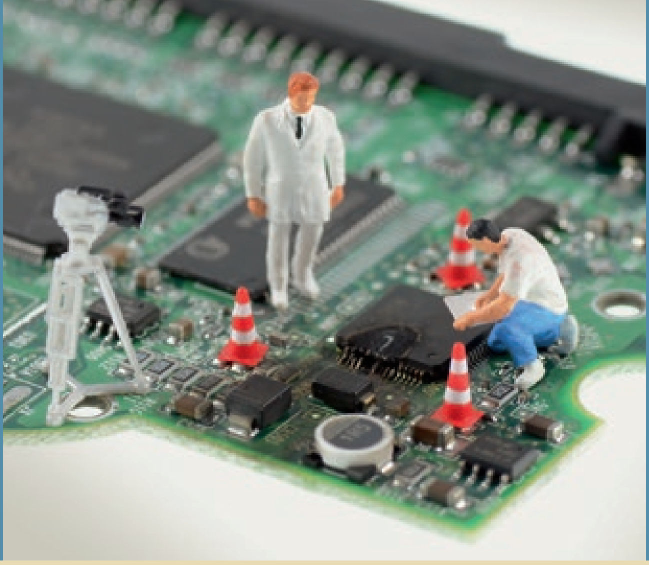
FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

# DEPARTMENT
# ENVIRONMENTAL AND RELIABILITY ENGINEERING



# PROFILE



## FRAUNHOFER IZM

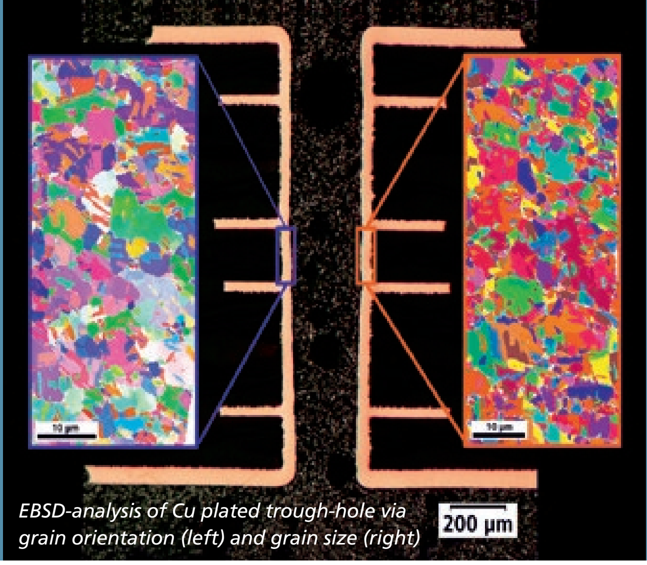
The Fraunhofer Institute for Reliability and Microintegration IZM is one of 72 Fraunhofer institutes doing research in applied natural sciences and engineering. Working hand-in-hand with industry and government institutions, the institute has many years of experience in developing cutting-edge packaging technology and smart system integration techniques. Its goal is meeting the demand for higher reliability and multifunctionality while reducing manufacturing costs. As a first step in meeting this goal, Fraunhofer IZM uses innovative methods to address application requirements early in the design process, thus ensuring this phase of product development is as efficient as possible.
With its application-oriented research Fraunhofer IZM bridges the gap between microelectronic component providers and technical system manufacturers in a broad range of industries, such as automotive, energy or medical technologies, as well as industrial engineering.
More than 350 researchers, interns and students work at the sites in Berlin and Dresden. The institute cooperates closely with the Research Center for Microperipheric Technologies at the Technical University of Berlin, especially in the realms of joint European projects and basic research in material science for packaging and interconnection technologies.

The institute's key technology foci are:
- Integration on wafer level
- Integration on substrate level
- Materials, reliability and sustainable development
- Design methodologies and system design

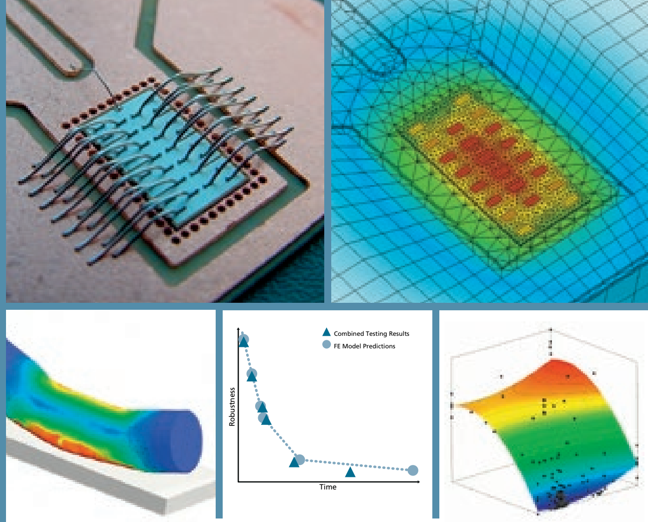
## DEPT. ENVIRONMENTAL AND RELIABILITY ENGINEERING

New products and technologies have to comply with an increasing range of strict requirements, and at the same time have to be cost-efficient and environmentally friendly. The Department Environmental and Reliability Engineering supports technological developments until they reach market maturity with environmental and reliability investigations reaching from nano-characterization level to evaluation and optimization at the system level. Under the joint leadership of Dr. Nils F. Nissen and Dr. Olaf Wittler, a unique combination is achieved between the established cross-sectional specialist fields of reliability and sustainability.
In view of worldwide growth and limited resources, every new generation of products and technologies must generate more functionality and assured reliability while consuming fewer resources. Without adequate reliability, the commercial success of an application is always at risk, and at the same time the environmental balance of typically production-intensive microelectronics is made much worse by premature failures or the need for replacements. Sustainable electronic technologies must therefore be reliable and have a low environmental impact. Our range of services comprises:

- Material characterization and modeling
- Reliability assessment, testing and optimization
- Thermal management
- Methods of system evaluation
- Reliability management in the product life-cycle
- Condition monitoring of electronic systems
- Technologies for resource-efficient electronic systems
- Environmental evaluation and ecodesign
- Consulting on status and trends in environmental legislation (e. g. RoHS, WEEE, EuP/ErP)




*EBSD-analysis of Cu plated trough-hole via grain orientation (left) and grain size (right)*



*Numerical and experimental assessment of a wire-bonded system*

## MATERIAL CHARACTERIZATION AND MODELING

Microelectronic systems are exposed to many different environmental forces during their life-time. Factors like temperature and humidity have a direct impact on their reliability. This makes comprehensive data about how materials develop faults and eventually fail essential for predicting the reliability of complex systems on micro and nano scale. In order to be able to reproduce and describe the deformation, degradation, and fracture processes of individual materials or compounds with precision, these forces need to be tested under meaningfully realistic conditions. Thermo-mechanical simulations produce relevant failure criteria and models for a dependable reliability assessment of real-life modules and are one essential building block for optimizing their design and construction.

We can assist you with:

- Material characterization and modelling
- Development and application of new characterization methods at micro and nano scales
- Simulation of material behaviour (multi-scale simulations, molecular dynamics)
- Combined measurement methods
- Structural analysis to evaluate material behaviour
- Input data in material data base

Important aspects of our work are the empirically verified results and the combination of individual testing methods to validate our simulations with real geometry systems.

**Contact**

Dr. Hans Walter
E-Mail: hans.walter@izm.fraunhofer.de
Phone: +49 30 46403 184

## RELIABILITY ASSESSMENT, TESTING AND OPTIMIZATION

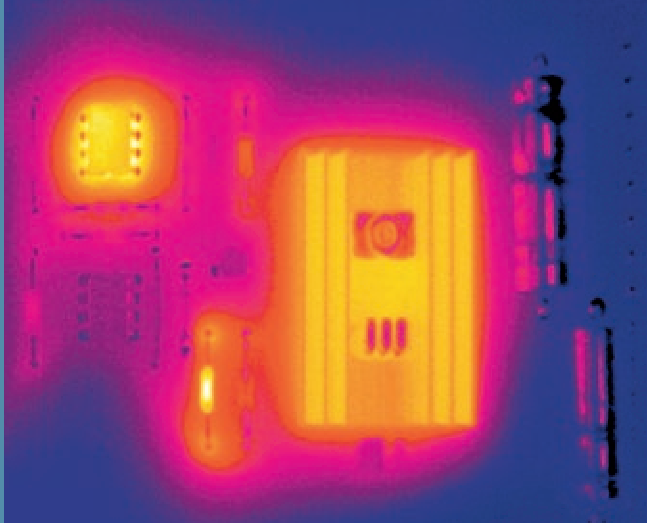
To achieve a holistic "design for reliability" from technology to system level with consideration for the specific needs and requirements of the client, a range of numerical and empirical methods can be applied. Using application-specific global and local stress profiles, we identify potential failure causes, -modes and -effects and evaluate reliability concerns using life-time models. Our accelerated and combined life-time tests simulate realistic usage scenarios to define precise modelling parameters and reliability indicators and pinpoint any weaknesses in the system. The design principles derived from these evaluations support optimize existing products and develop new products with ensured reliability.

We can assist you with:

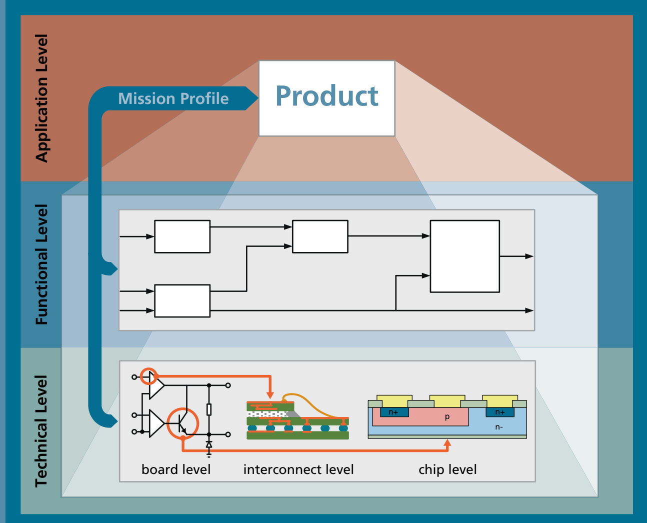
- Multi-physics simulation of failure mechanisms on technology, component and system level:
  - … (Thermo-)mechanical fatigue
  - … Wear-out and overstress due to mechanical, thermal, chemical, and electrical loading
  - … Delamination and fracturing
- Application-specific test plan management
- Combined and accelerated stress tests (temperature, humidity, vibration, current/voltage)
- Active power cycling tests
- Remote condition monitoring technology
- Aging and failure analyses

**Contact**

Dr. Johannes Jaeschke
E-Mail: johannes.jaeschke@izm.fraunhofer.de
Phone: +49 30 46403 223



*Contactless temperature monitoring*




*Concept for comprehensive system analysis*

# THERMAL MANAGEMENT

Designers of innovative microelectronic components, such as power modules or lighting systems, are facing one major challenge: power dissipation in tightly packaged systems with increasing power density. The heat generated in these systems needs to be diverted and channelled away in order to maintain reliability. Thermal management is defined by the development and application of methods to solve these problems and provides a fundament for reliable operation of the application.

We can assist you with:

- Thermal optimization simulation (static, transient, flow modelling)
- Characterization of Thermal Interface Materials (TIM) and encapsulation materials for electronic power components
- Component and system analysis for analysing surface temperatures (infrared thermography) and thermal resistance (transient tester)

Numerical thermal analysis allows us to model electronic systems efficiently and rapidly to match the given application specifications. The finished design can be constructed immediately and empirically verified at the institute. The solutions are developed in close cooperation with our project partners and with due consideration for all relevant project objectives (including product costs, reliability, electromagnetic conformity, power usage, and environmental footprint).

**Contact**

Arian Grams
E-Mail: arian.grams@izm.fraunhofer.de
Phone: +49 30 46403 138

# APPLICATION-SPECIFIC SYSTEM EVALUATION

To understand the quality attributes (such as reliability, robustness, and user safety) of electric, electronic, and mechatronic systems; production and business processes need to be analysed holistically and comprehensively, covering the entire lifecycle of the product. When optimizing and qualifying a system environmental conditions and application scenarios (mission profiles), as well as functional aspects need to be considered.

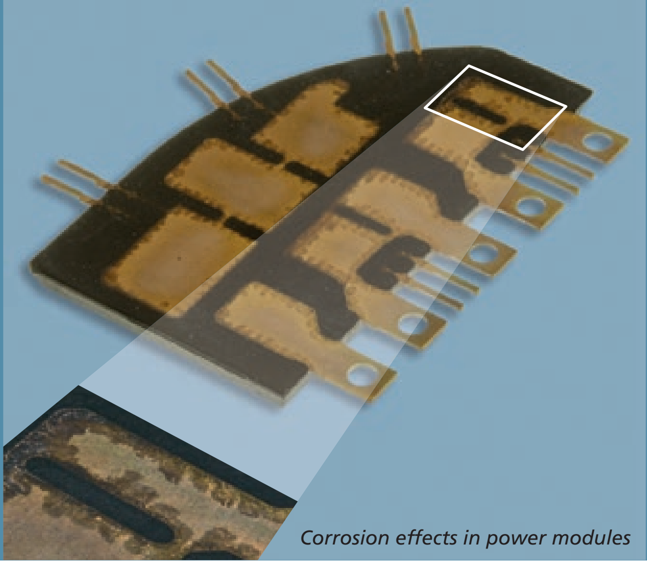
We can assist you with:

- System-wide requirements analyses
- Definition of mission profiles
- Identification of dominant failure mechanisms and analysis of relevant influences
- Identification of weaknesses and failure causes (root cause analysis)
- Analytical system modelling (e. g. state modelling)
- Failure prevention and effects analyses (e. g. FTA, FMEA)
- Calculation of failure rates (e. g. MTTF)
- Obsolescence management (including EcoReliability, discontinuation of components, and long-term storage)

Our goal is to evaluate and optimize your product holistically or in detail. We can offer standard compliant processes and analyses as well as individual solutions for specific requirements outside of the scope of standards. The results of our systems evaluations can be fully verified with our extensive laboratory facilities.

**Contact**

Daniel Hahn
E-Mail: daniel.hahn@izm.fraunhofer.de
Phone: +49 30 46403 7960



*Corrosion effects in power modules*

*Autonomous micro system technology sensor for condition monitoring applications*

# CORROSION, ELECTRO-CHEMICAL MIGRATION & HUMIDITY DIFFUSION

Modern electronic systems are increasingly exposed to constantly changing environments in terms of humidity and variations of temperature cycling and thermal shocks. At the same time, the ongoing trend of miniaturization results in smaller designs, components and by that more tightly packaged systems. Extra space that could buffer external stresses like humidity becomes smaller; diffusion paths by that become shorter. This leads to higher/quicker/faster electrochemical degradation, an effect long ignored by the industry. Generally, this type of degradation leads to failure of the electric circuit.

It is essential to test these materials used for encapsulation in terms of their reliability and possible characteristic changes during life-time. Additionally, the need to consider the forces exerted and possible residues left behind during production should be considered from the start.

We can assist you with:

- Identification of the driving forces and parameters affecting failure mechanisms relating to corrosion or migration effects
- Optimization of designs for harsh environments
- Assistance during the selection and qualification of suitable materials
- Simulations for a cost-efficient evaluation of design changes and their potential improvement over existing layouts

**Contact**

Dr. Stefan Wagner
E-Mail: stefan.wagner@izm.fraunhofer.de
Phone: +49 30 46403 609

# CONDITION MONITORING OF ELECTRONIC SYSTEMS

For electronic systems in service both, environmental loads and operating stages are strongly determined by the individual use-case scenario. As a consequence the remaining system life-time considerably depends on the sensitivity of the system-specific aging mechanisms towards these mission profiles and their history.

Concepts for system health monitoring are based on the identification and tracking of physical states that can be allocated to the underlying failure mechanisms. The aim of integrating condition-based predictive maintenance approaches opens up new perspectives with respect to reliability assurance and eco-efficient usage of electronic systems.

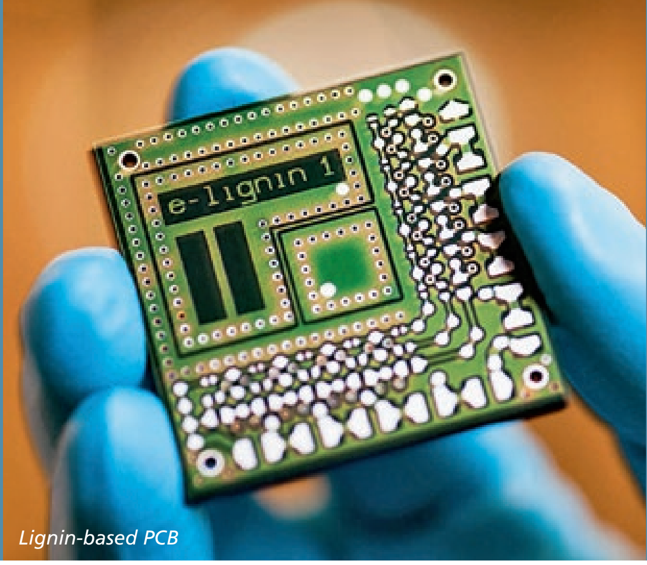
Recent developments in wireless sensor technology with autonomous energy supplies ("Energy Harvesting") provide the technological basis for the practical implementation of these concepts.

We can assist you with:

- Development of algorithms and models for system condition diagnostics
- Physical implementation of measurement concepts, data acquisition and processing
- Transfer of the developed condition monitoring approaches to robust Cyber-Physical Systems (CPS)

**Contact**

Kathleen Jerchel
E-Mail: kathleen.jerchel@izm.fraunhofer.de
Phone: +49 30 46403 7936



*Lignin-based PCB*


*Comparing the recyclability of tablets*

# TECHNOLOGIES FOR RESOURCE-EFFICIENT ELECTRONIC SYSTEMS

Increasingly complex requirements are being placed on the environmental compatibility of electronic systems. In the past, the main considerations were energy conservation, some heavy metals in the assembly, and certain flame retardants. Today the discussion is focused on critical resources (e.g. rare earth metals and conflict materials) in view of foreseeable supply bottlenecks and the environmental impact of mining, as well as on halogenated flame retardants. The demands for increased resource efficiency present particular challenges for technology developers in times of scarce resources and rising prices.

The goal of the research is the more efficient use of fossil fuels, metals and other resources by means of innovation in the production processes, during use, and/or at the end of the life-cycle (including recycling). Technology development can be approached at various levels: Electronic components, individual products, or groups of devices, such as LED products.

We can assist you with:

- Solutions for the efficient use of resources by means of substitution, increased reliability, longer durability and design for recycling
- Evaluation and comparison of technologies and materials in terms of resource efficiency
- Minimizing the environmental impact of processes in packaging and interconnection technology
- Estimation of the environmental impact of subsequent series production (Lab to Fab)

**Contact**

Dr. Lutz Stobbe
E-Mail: lutz.stobbe@izm.fraunhofer.de
Phone: +49 30 46403 139

# ENVIRONMENTAL EVALUATION AND ECODESIGN

Evaluation of the environmental performance of products requires detailed knowledge of the design, production and the product's use. Only then is it possible to ensure that all relevant factors are taken into consideration. Life-cycle modeling, with LCA or carbon footprint analyses, identifies the environmentally relevant life-cycle phases and the influential parameters. In addition to generating own environmental assessments, expertise in methodology and electronics is used to accompany and review external life-cycle assessments in accordance with ISO 14040 and ISO 14044 within the evaluation process.

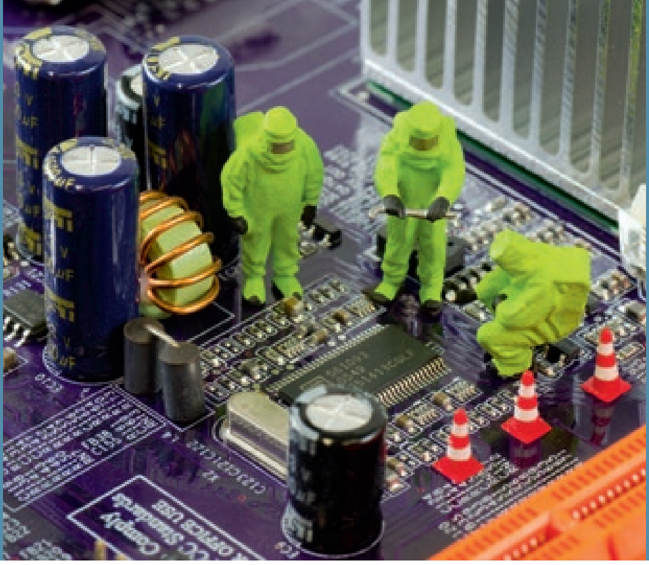
Minimizing environmental impact has to start in the design phase for new products. Based on methods of environmental evaluation and product analysis, environmental aspects are considered in the early stages of product development.

We can assist you with:

- Ecodesign: methods and product analyses
  - environmental optimization of products
  - integration of environmental aspects in the development
- Life-cycle modeling
  - environmental analysis of processes
  - life-cycle analysis and critical reviews
  - screening approaches, parameterization for LCA
- Carbon footprinting
  - Determining carbon footprints of products and critical review
  - Product category rules for electronics
- Eco reliability

**Contact**

Karsten Schischke
E-Mail: karsten.schischke@izm.fraunhofer.de
Phone: +49 30 46403 156



# ENVIRONMENTAL LEGISLATION (E. G. ROHS, WEEE, EUP/ERP)

Product-related environmental legislation is increasingly affecting electrical and electronic products. In recent years the European Commission, with its RoHS, WEEE und EuP/ErP Directives, has placed considerable restrictions on substances such as lead, mercury, cadmium, chromium (VI), and the flame retardants PBDE and PBB and has regulated the recycling of waste electrical and electronic equipment. Furthermore it has also initiated a broad process of life-cycle related product optimization with the Ecodesign Directive. The EuP/ErP Directive is meanwhile closely integrated with the Energy Efficiency Labeling Directive and the EU Environmental Label.
We support the legislative process by providing necessary technical-economic analyses and help companies to develop suitable compliance strategies.

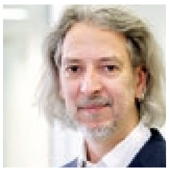
- Preparatory studies on the ecodesign of selected product groups for the European Commission
- Development of strategies for recycling-optimized product design and for determining real recycling rates
- Assessment of applications for RoHS exemptions for the European Commission
- Substituting harmful substances in electronics
- Global effects and trends of product-related environmental legislation
- Advising companies and authorities on conformity with RoHS, WEEE and EuP/ErP
- Proactive environmental product optimization beyond the scope of legislation

**Contact**
Dr. Otmar Deubzer
E-Mail: otmar.deubzer@izm.fraunhofer.de
Phone: +49 30 46403 157

# WORKING GROUPS

Karsten Schischke
**Product Ecodesign and Circular Materials**
E-Mail: karsten.schischke@izm.fraunhofer.de
Phone: +49 30 46403 156

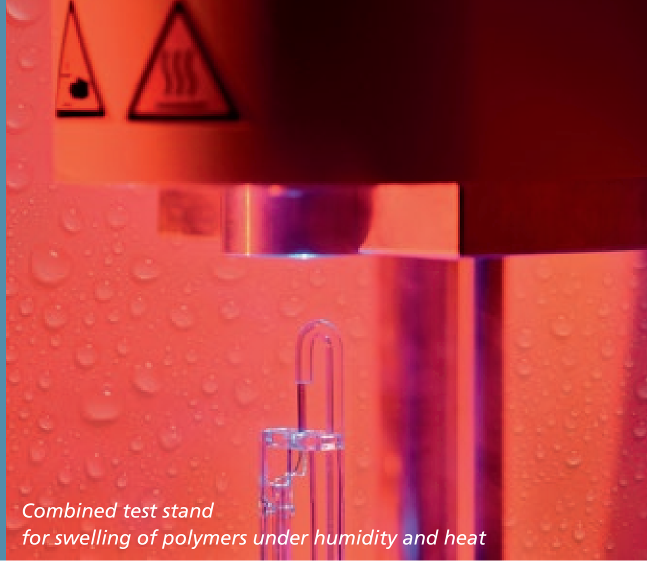
Dr. Lutz Stobbe
**Sustainable Networks and Computing**
E-Mail: lutz.stobbe@izm.fraunhofer.de
Phone: +49 30 46403 139



Dr. Stefan Wagner
**Failure Mechanism and Technology Analysis**
E-Mail: stefan.wagner@izm.fraunhofer.de
Phone: +49 30 46403 609

Dr. Johannes Jaeschke
**System Analysis and Testing**
E-Mail: johannes.jaeschke@izm.fraunhofer.de
Phone: +49 30 46403 223

# SERVICE & CONTACT



*Combined test stand for swelling of polymers under humidity and heat*

### ELECTRONICS CONDITION MONITORING LAB

- Excitation vibration tests for electronic modules (sinus, white noise, shock), combined with humidity and temperature stresses
- Contactless vibration testing for design optimization, weakness analysis, and fault detection
- HALT testing to establish failure limits for temperature, extreme temperature variation, and vibration
- Level drop tester for shock tests and continuous monitoring of max acceleration, impulse duration, and impulse characteristics

### 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)
- Identification 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
- Disassembly and repair analysis of electronic products

### MICRO MATERIALS CHARACTERIZATION LAB

- Static and dynamic materials testing with tensile, pressure, flexure, torsion
- DMA, mDMA, nano-indentation
- Thermoanalytic methods (m) TMA
- Structural analyses (REM, FIB, EBSD; EDX)
- Component deflection measurement (3D), 3D topography analyses AFM
- Fracture mechanic testing, material modelling (molecular dynamics)

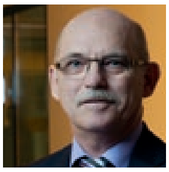
Concept & editing: Fraunhofer IZM, Berlin · Design: J. Metze/Atelier f:50 Berlin · Copyright photography: Fraunhofer IZM together with: Chombosan, fotolia (Cover), Volker Mai (page 5 right, and page 6 left), Maik Schulze (page 7 and page 8, bottom), all others Fraunhofer IZM. ERE 18/03-3e

### MOISTURE LAB

- Dilatometric swelling analysis
- Sorption analysis
- Humidity AFM, Moisture (m) DMA, mZug

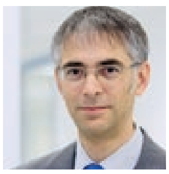
### POWERLAB FOR POWER ELECTRONICS

- Active and passive load alternation 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



**Fraunhofer IZM**
**Head: Prof. Klaus-Dieter Lang**
Gustav-Meyer-Allee 25
13355 Berlin
Phone: +49 30 46403 153
Fax: +49 30 46403 123
E-Mail: info@izm.fraunhofer.de
URL: http://www.izm.fraunhofer.de

**Head of Department**
**Environmental and Reliability Engineering**



**Dr. Nils F. Nissen**
Phone: +49 30 46403 132
Fax: +49 30 46403 211
E-Mail: nils.nissen@izm.fraunhofer.de

**Dr. Olaf Wittler**
Phone: +49 30 46403 240
Fax: +49 30 46403 211
E-Mail: olaf.wittler@izm.fraunhofer.de