Corrosion in PE Systems – Environmental Testing, Corrosion Detection and Protection

ECPE Workshop, Bremen June 06, 2019

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Fraunhofer Institute for
Integrated Systems and
Device Technology

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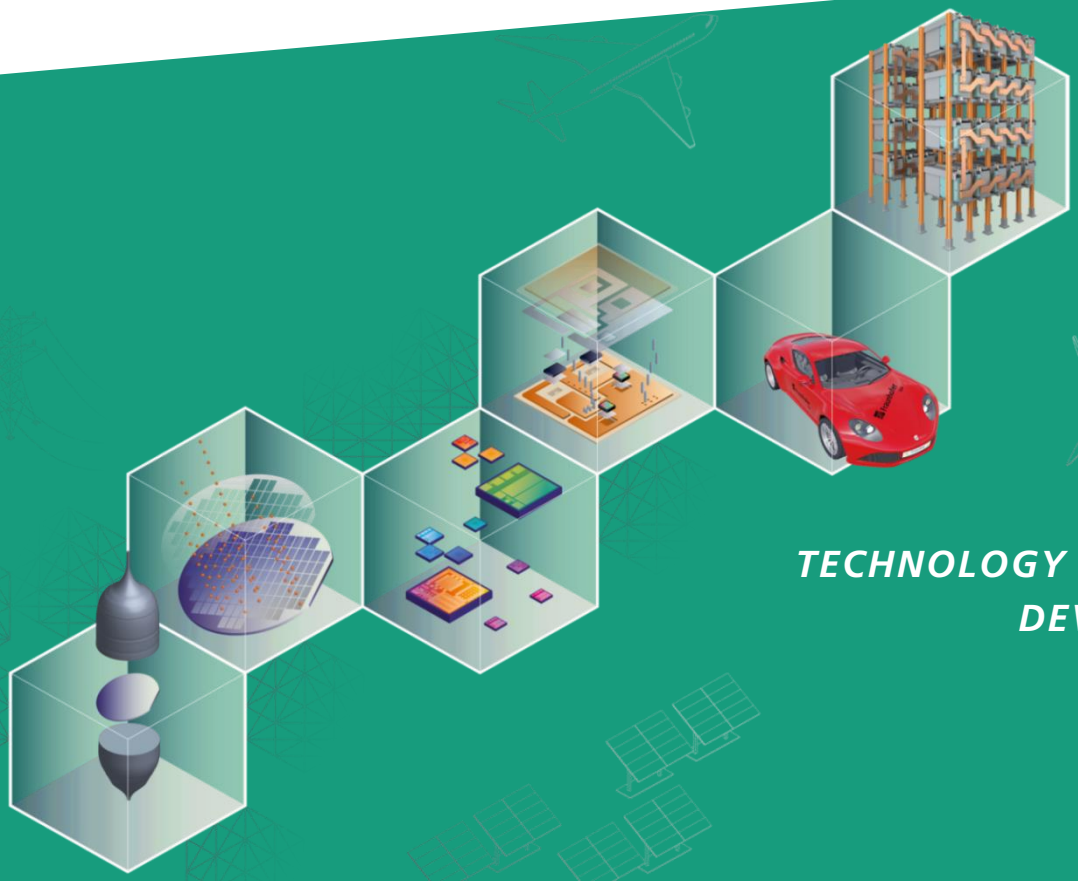
POWER ELECTRONIC SYSTEMS

From Material to Power Electronic Applications

Create Value beyond Borders



SIMULATION
MATERIALS
TECHNOLOGY AND MANUFACTURING
DEVICES AND RELIABILITY
VEHICLE ELECTRONICS
ENERGY ELECTRONICS

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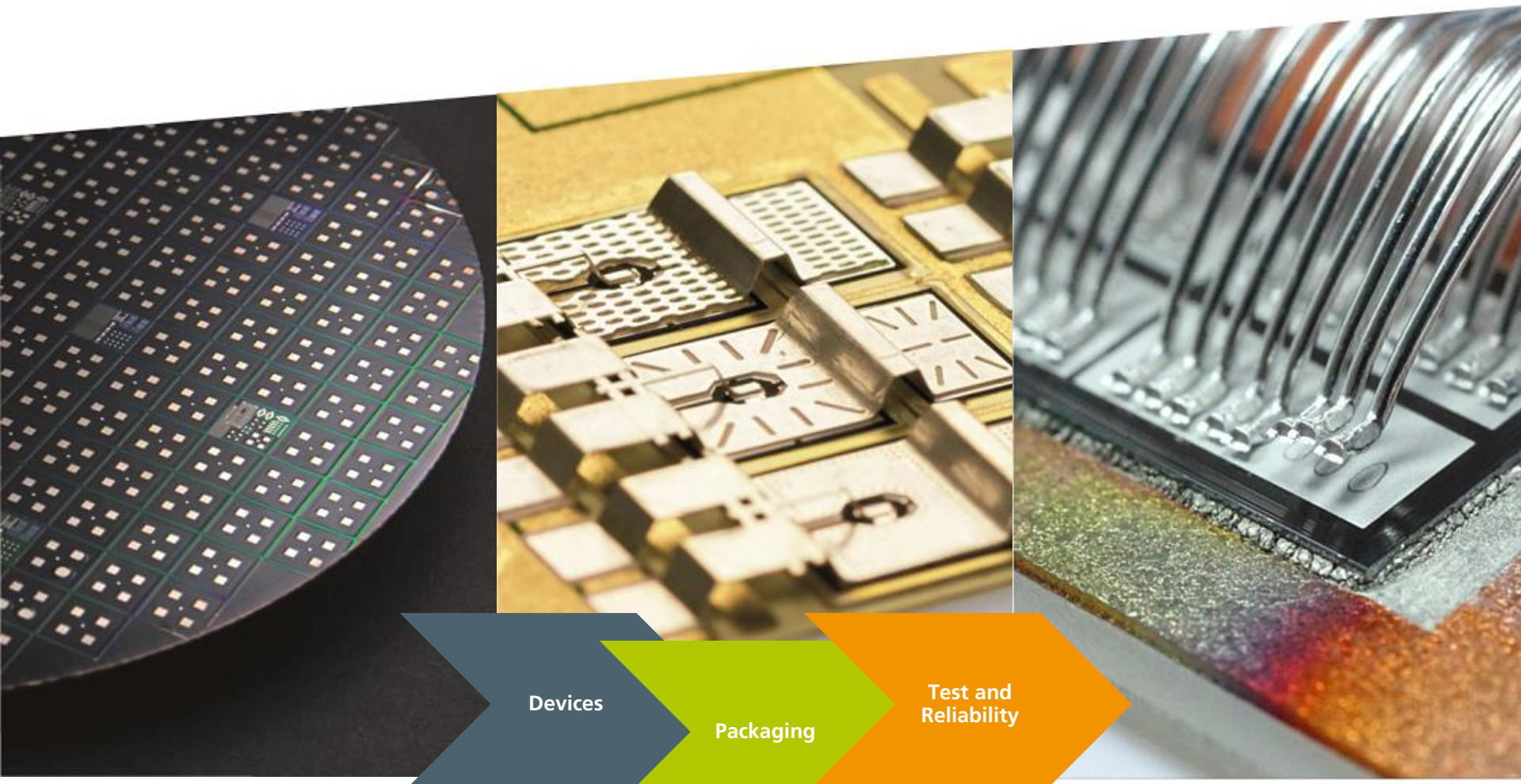
PACKAGING AND RELIABILITY

Fields of Competence



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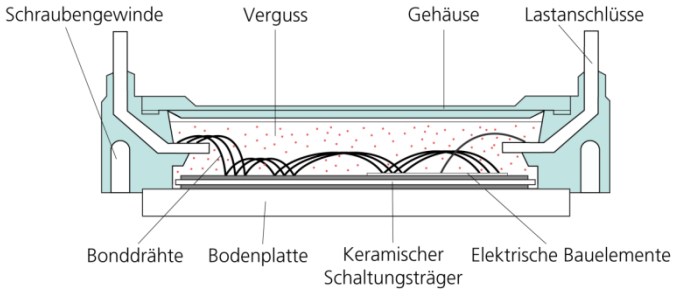
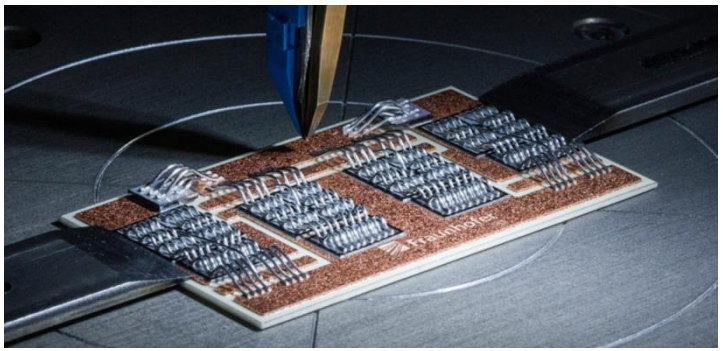
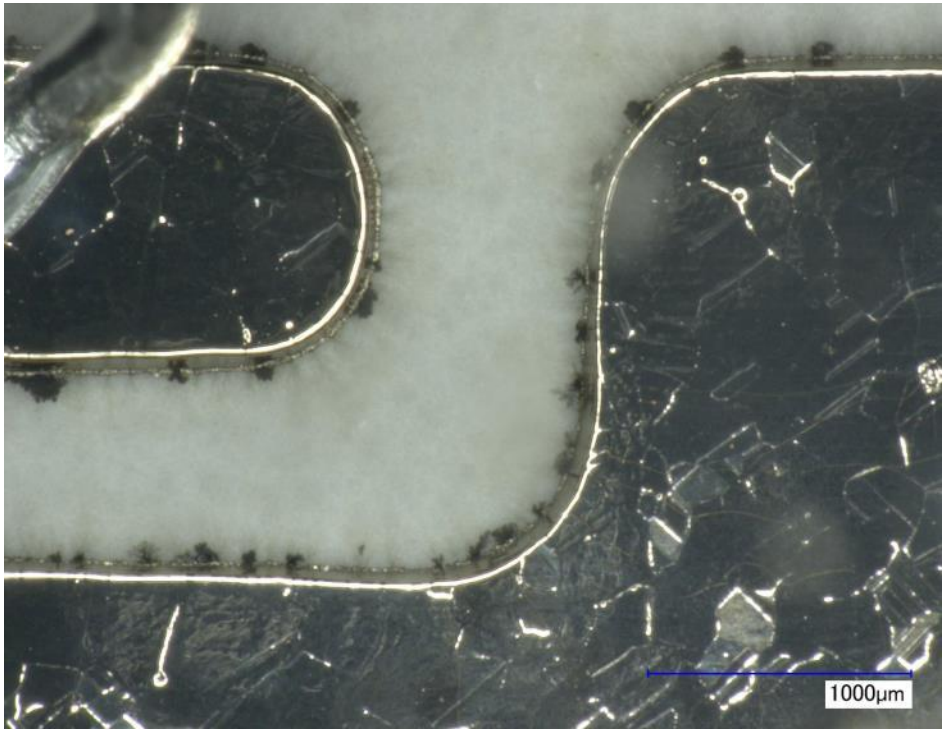
Field Returns
Electronic Modules in Harsh Environments

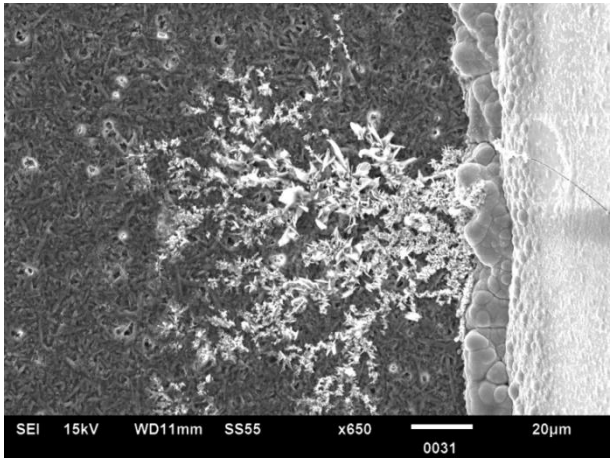
- Investigation of the issue
- Corrosion attack / dendrite formation within the ceramic insulation gap



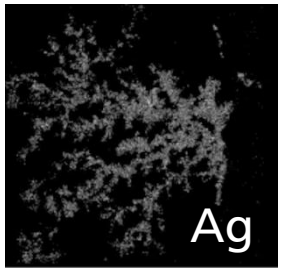


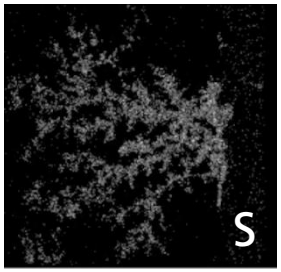


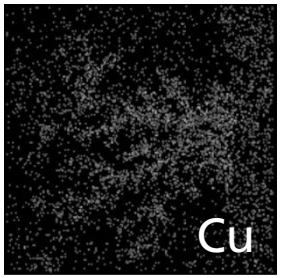
Field Returns
Analysis



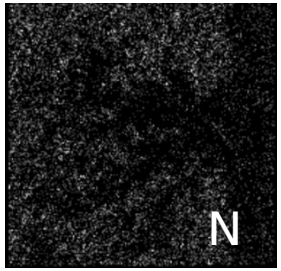
- SEM and EDX
  - dendrites

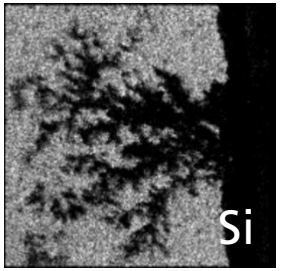






  - ceramic substrate





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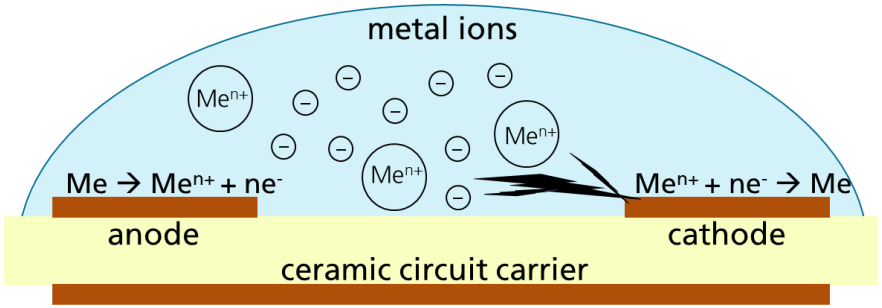
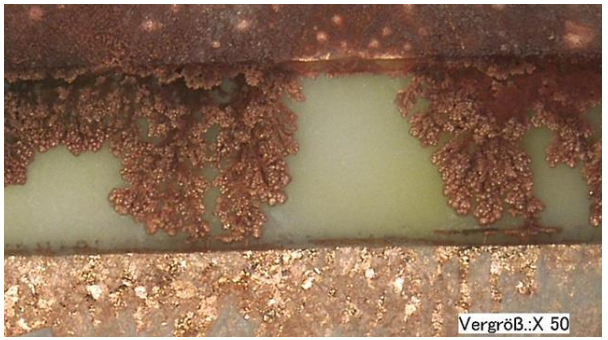
Basic Mechanism of Electrochemical Migration (ECM) and Dendrite Growth

- Metal ions dissolve at the anode and migrate towards the cathode
- Deposition of metal ions at the cathode → dendrite growth from cathode towards anode
- Dendrites can bypass the insulation gap → short circuit → device failure





- Pre-conditions: applied voltage, humidity, gap in potting material, material combination (e.g. Cu or Ag)
- Acceleration by aggressive ions and corrosive gases

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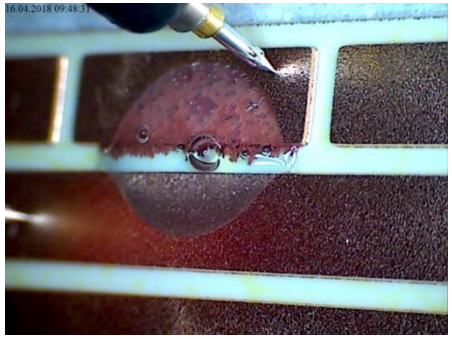
Basic Mechanism of Electrochemical Migration (ECM) and Dendrite Growth

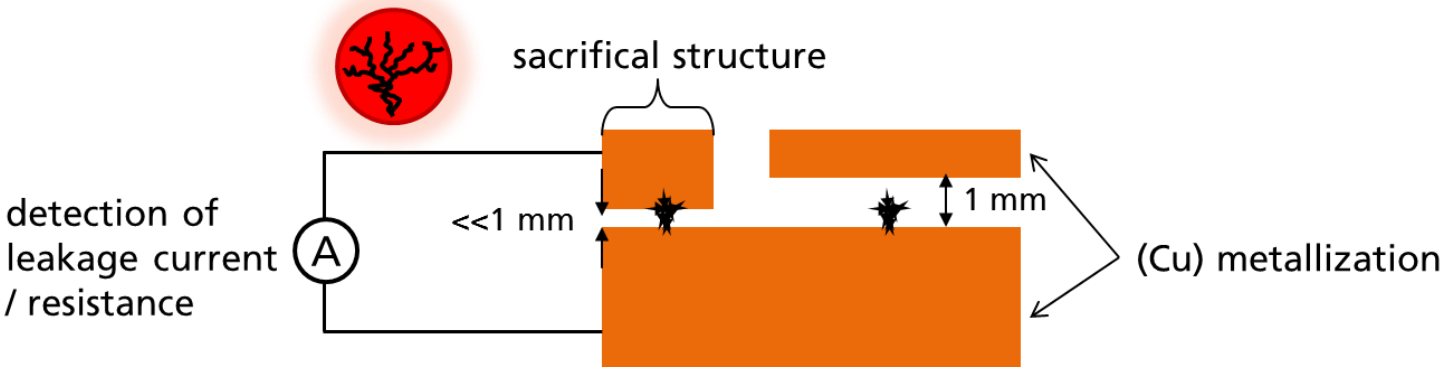
Research on Corrosion Mechanism

- Water droplet test
  - Different insulation materials → no influence
  - Different metallization → big influence
  - Different electrolytes → big influence
    (tap water, DI-H_2O, H_2SO_4, HCl, Na_2SO_4, NaCl)
    - Variation of pH value
    - Variation of ion concentration
- Comparison of PCB and DBC substrates

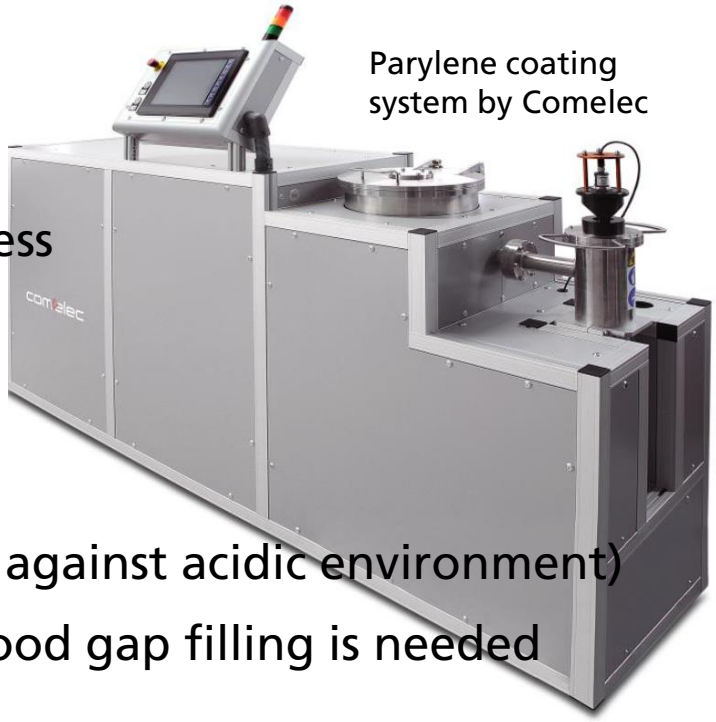


Early Corrosion Detection by Humidity and Corrosion Sensors (Project ZuLeSELF)

- i.a. for e-mobility application
- Development of humidity sensors
  - Measurement of humidity by change of capacity
  - Printed Ag structures on different polymer foils
- Development of corrosion sensor
  - Sacrificial structure by etching / laser ablation
  - Measurement of leakage current or resistance

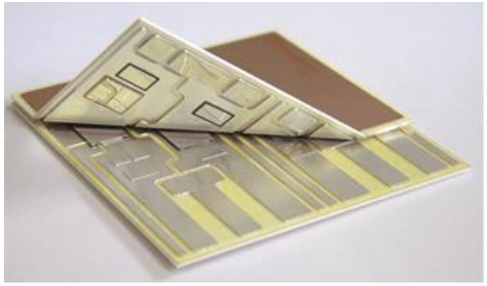


Corrosion Protection by Parylene Coating (Project IsoGap)



Parylene coating system by Comelec

- Parylene (type F)
  - Polymer coating applied by CVD process
  - HT resistance
  - Good dielectric strength
  - Good gap filling properties
  - Good corrosion protection (especially against acidic environment)
- Coating of double sided modules where good gap filling is needed
- Testing of
  - Adhesion
  - Corrosion resistance
  - Gap filling
  - HT reliability



ULTIMO Module for double sided cooling

Harmful Gas Requirements (ECPE Joint Research Program)

- Mostly required classification for outdoor applications of PE is **IEC 60721-3-3 Class C2** (urban regions with industrial activity and heavy traffic)
- Problems:
  - Discrepancy of European (IEC 60721-3-3) and US (ISA 71.04) standard

	Class from IEC		Class from ISA			conclusion
	3 C2		G1 „mild“	G2 „moderate“	G3 „harsh“	
Gas type	Mean C (ppm)	Max C (ppm)	Max C (ppm)			
H_2S	0.071	0.36	0.003	0.01	0.05	IEC values >> ISA values

  - Current gas concentrations measured by different institutes show lower values than the IEC standard
- Detailed overview of data for atmospheric contaminants (H_2S, SO_4, NO_2, Cl_2) by literature research and completion by experiments

Environmental Testing

Setup of Environmental Lab at Fraunhofer IISB

- Corrosive gas (single and mixed gas) testing → e.g. DIN EN 60068-2-42
- Salt spray testing → e.g. DIN EN 60068-2-52
- Damp heat testing → e.g. DIN EN 60068-2-67
- Thermal shock / temperature cycling → e.g. DIN 60068-2-14
- Highly accelerated stress test (HAST), pressure cooker test → e.g. DIN EN 60068-2-67
- Combined with applied voltage
- Power cycling testing → e.g. DIN EN 60068-2-67

Summary

From field returns and first industrial projects to

- Basic research of corrosion mechanism
- Research projects concerning
  - detection of humidity and corrosion
  - corrosion protection
  - harmful gas requirements and standard development
- Setup of an environmental lab

Acknowledgments

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Thank you for your attention