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FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY

1 *Dendrites on a ceramic circuit carrier*

ENVIRONMENTAL TESTING, CORROSION, FAILURE ANALYSIS

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Environmental testing

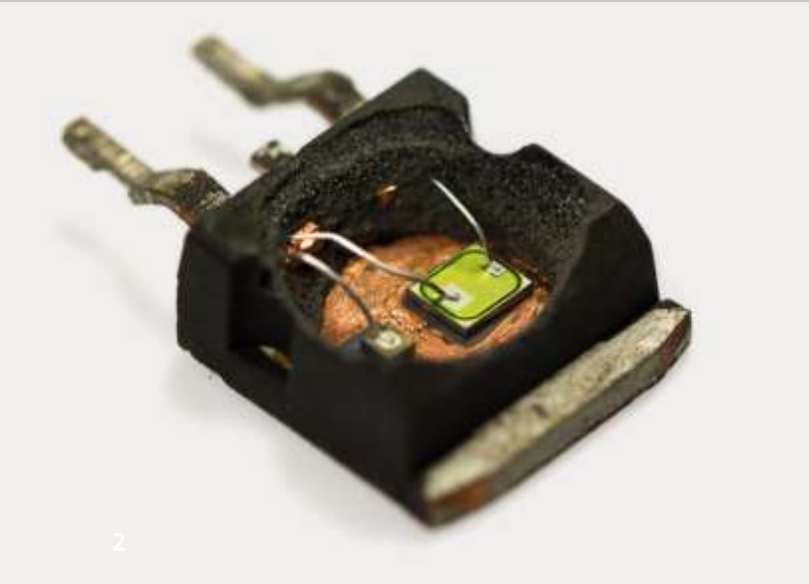
- Important tool in the field of corrosion analysis
- Investigation of influences like temperature, humidity and (toxic) gases on degradation and corrosion of el. devices and materials
- Simulation of various fields of applications with their different conditions (e.g. offshore, aerospace)

Testing methods (performed at Fraunhofer IISB)

- Salt spray (e.g. DIN EN 60068-2-52) or damp heat testing (e.g. DIN EN 60068-2-67), thermal shock, temperature cycling (e.g. DIN EN 60068-2-14)
- Corrosive gas (H_2S, NO_2, Cl_2, SO_2 and mixed gas) (e.g. DIN EN 60068-2-42)
- Highly accelerated stress test (HAST), pressure cooker test (PCT) (e.g. DIN EN 60068-2-67)
- Combined with voltage treatment (power cycling) (e.g. DIN EN 60068-2-67)

Electrochemical corrosion of power electronics is in the focus because of

- Steadily increasing demands in terms of higher packaging densities
- Demand for applications of power electronic modules under extreme environmental conditions is rising
- Assemblies that are exposed to changing environmental influences e.g. in automotive, aerospace, telecommunications
- Electrochemical migration (ECM) that leads to dendrite formation is one important form of corrosion in power electronics



Mechanisms of ECM

- Potential and humidity between metallic structures is present
- Metal ions dissolve
- Positive metal ions migrate from the anode to the cathode
- Ions are captured at the cathode
- Dendrites grow from the cathode to the anode

ECM occurs immediately in electronic packages if the following is given

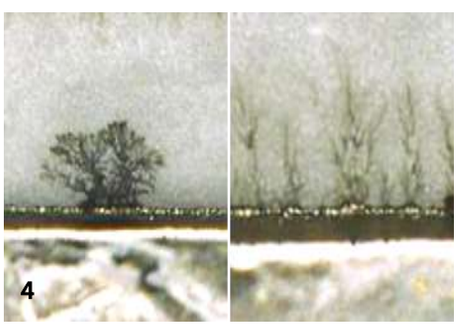
- Gaps exist (due to delaminated insulating potting material)
- Metals and metal combinations tend to corrode and form dendrites
- Humidity is present
- A sufficient voltage load is given (several volts)

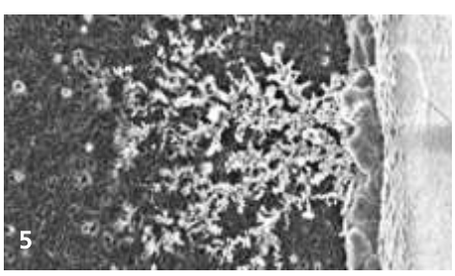
Corrosion protection

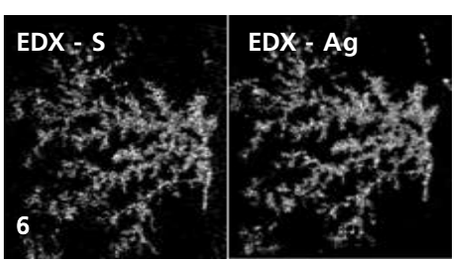
- Concepts for corrosion protection
- Cleaning, chemical corrosion inhibition and adhesion promotion
- Protective coating: potting and parylene
- Coating material characterization → analyzing methods

Failure analysis

- Partial discharge measurement
- Optical microscopy for searching for dendrites
- Laser interferometry (for analysis of coating quality and coating thickness)
- Cross-sectioning by sawing, grinding, polishing, as in figure 3
- Cross-sectioning by femto-laser curing
- Comparative tracking index
- Scratch test
- Decapsulation of mold compounds as well as silicone gels, e.g. as in figure 2
- Scanning electron microscopy (SEM) and elemental analysis with energy dispersive X-ray spectroscopy (EDX), distribution and quantity, as in figures 5 and 6
- Focused ion beam (FIB), high speed cutting by plasma
- Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC)
- Fourier-transform infrared spectroscopy (FTIR)
- Radiography/ computer tomography







2 *Removal of mold compound by etching (left) and by laser (right)*

3 *Cross section of IGBT power module*

4 *Dendrite formation and electrical treeing*

5 *SEM picture of dendrite on an IGBT module*

6 *EDX analysis of dendrite, element maps of S and Ag*