



1 *Dendrites on a ceramic circuit carrier*

ENVIRONMENTAL TESTING, CORROSION, FAILURE ANALYSIS

Environmental testing

- Investigation of influences like temperature, humidity and (hazardous) gases on degradation and corrosion of electronic devices and materials
- Simulation of various fields of application with their different conditions (e.g. offshore PV, rail and automotive, 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)
- Also available for (reverse) biased devices

Electrochemical migration of power electronics is in the focus

- Steadily increasing demands in terms of higher packing 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 and energy
- Electrochemical migration (ECM) that leads to dendrite formation is one important form of corrosion in power electronics

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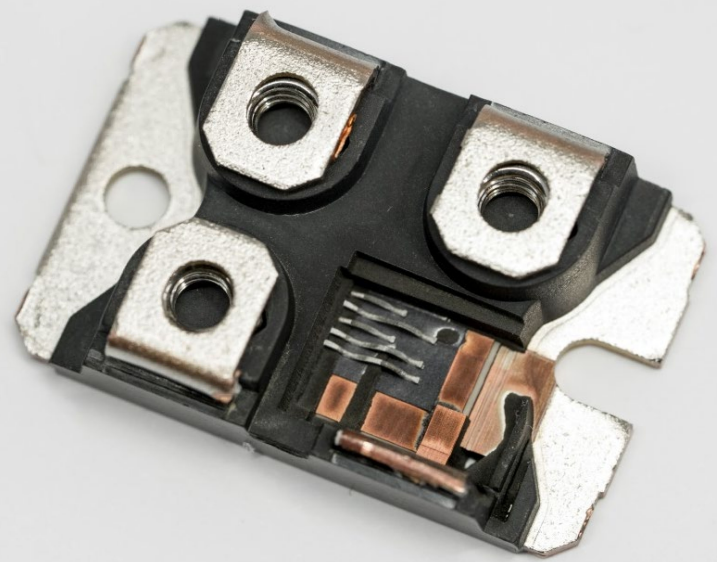
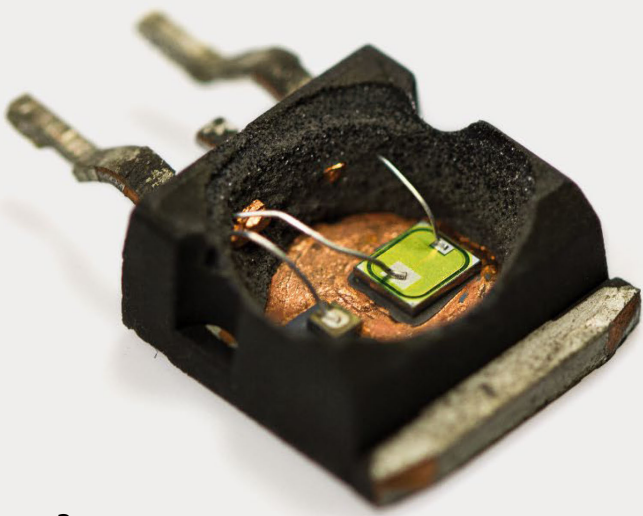
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Mechanisms behind ECM

- 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

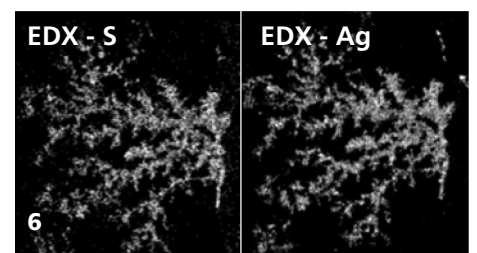
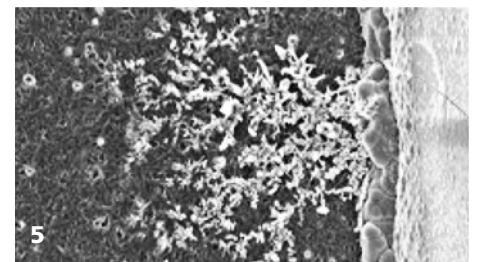
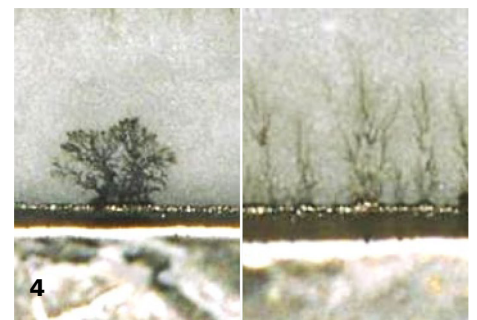
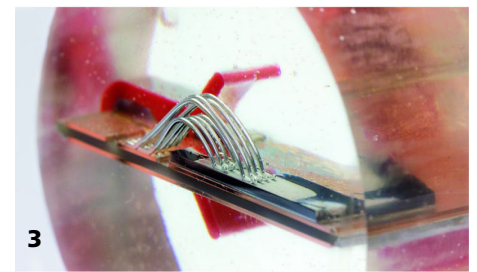
- Gaps exist (due to delaminated insulating potting material)
- Metals and metal combinations tend to corrode and form dendrites
- Humidity is present
- A sufficient voltage load is given (several volts)

Measures against corrosion

- Cleaning and adhesion promotion
- Chemical corrosion inhibition
- Protective coatings: potting and parylene
- Coating material
 - Processes
 - Characterization

Failure analysis

- Partial discharge measurement
- Optical microscopy for dendrite localization and shape analysis
- 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 cutting
- Comparative tracking index (CTI)
- Scratch test (Cross-cutting 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