Technical Facts and Details

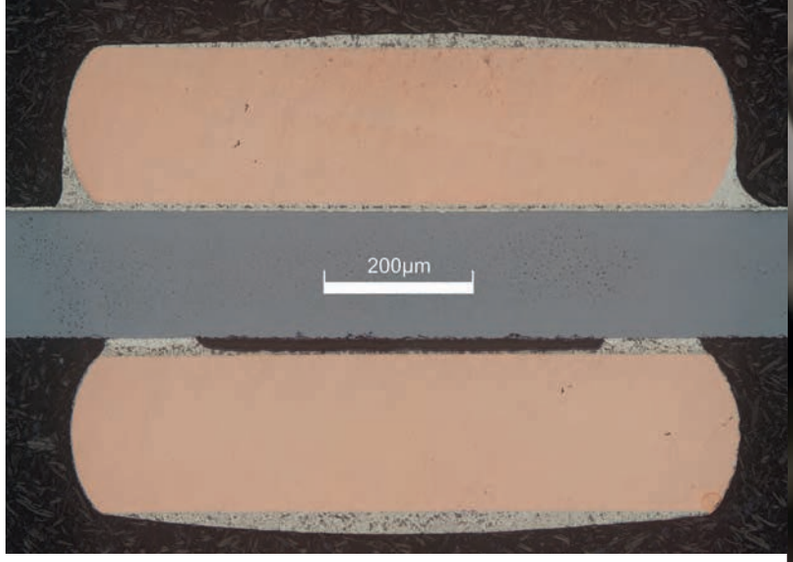
With the characterization equipment in the Module-TEC laboratory, Fraunhofer ISE can develop and analyze soldering, welding, laser bonding and gluing processes in a highly flexible manner. We also carry out tests on innovative materials from proof-of-concept through to industrial prototyping. These include:

- flexible interconnection processes for a wide range of surface conditions and materials
- interconnection of battery cells by resistance projection welding and laser bonding
- soldering of PERC, SHJ, TOPCon and tandem solar cells even with Pb-free solder alloys
- interconnection by electrically conductive adhesives (ECA's) for thermomechanically gentle connections realized at low temperatures
- detailed characterization of joints after production and after aging at defined conditions
- identification and implementation of process and material improvements
- analysis of the long-term stability even under extreme operating conditions (temperature, current, humidity, vibrations, etc.)

Further informations

Module-TEC

Lead-free interconnection



Metallographic cross section of a solder joint on a bifacial Si solar cell.
Cover photo: Peel tester for characterization of strength between soldered, glued or welded joints.
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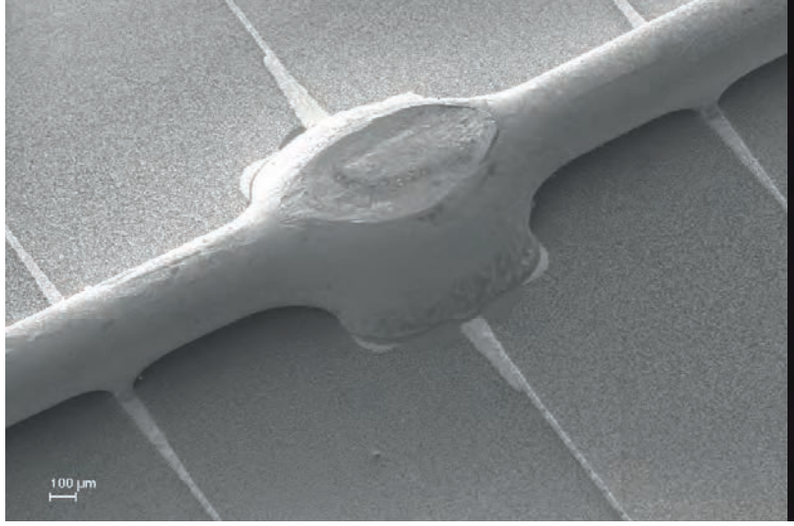
Interconnection Analysis

Characterization of Joints for Solar and Battery Cell Interconnection

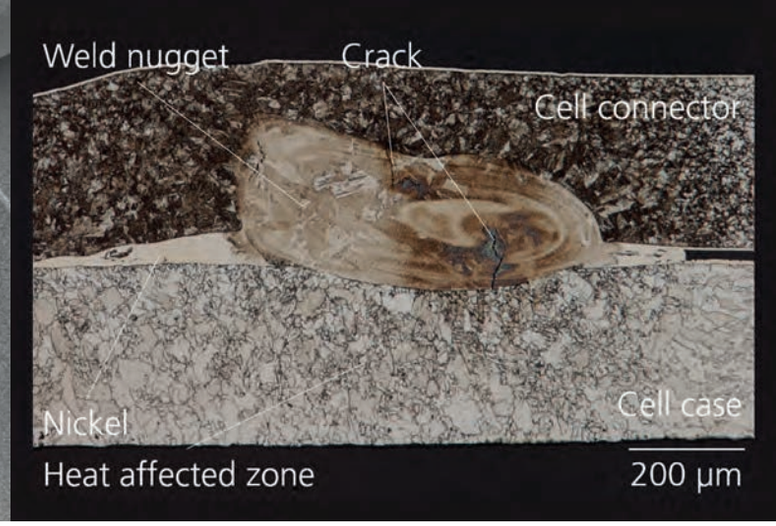
R&D for the Energy Transition

Characterization of Interconnection Joints

Characterization by scientific analysis of the material composition and the mechanical and electrical performance of interconnects is key for understanding interconnection processes. With this in-depth knowledge, interconnection processes can be optimized to improve the performance and long-term stability of joints of solar and battery cells.



SEM image (35° tilt) of soldered wire on solar cell to characterize positioning and wetting.



Metallographic cross-section of a weld nugget after etching to make the grain structure layerable.

Our Service Offer

Mechanical and electrical characterization
- peel tests with variable peel angles and peel speed
- tensile tests
- (die) shear tests
- (specific) contact resistivity measurement by transfer length method (TLM)
- (contact) resistance of specific interfaces by four probe measurements
- analysis of fracture surface by top view microscopy

Microstructure analysis
- metallographic analysis by cross sections of weld nuggets and solder joints e.g., by using etching techniques to visualize the grain structure
- analysis of metallographic cross sections by scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) spectroscopy

Microstructure analysis
- quantification of intermetallic phases and diffusion zones
- preparation of µ-CT images of X-ray analysis data
- Scanning Acoustic Microscopy (SAM)

Quality assurance, long-term stability and simulation
- process development for various interconnection technologies
- Magnetic Field Imaging (MFI) to analyze the electromagnetic flux density
- infrared thermography for process control
- force sensors and distance measurement sensors
- material characterization by DMA, DSC, TGA, FTIR
- isothermal ageing
- temperature cycle test
- modeling of the joining process by FEM simulations
- dimensioning of interconnectors

Interconnection Analysis of PV-Modules and Battery Packs

The interconnection process is a key technology in the production of PV modules and battery packs. The quality of the interconnection joint has crucial impact on the performance in operation and on the long-term stability. To realize a fast and reproducible interconnection, it is essential to understand the process parameters' impact on the joint formation and composition as well as the behavior of the joints material composition with regard to temperature cycles, vibrations or moisture. Furthermore, a better scientific understanding of the interconnection holds a high cost saving potential as it enables high throughput and reduced material consumption.

Offering a wide range of characterization possibilities and many years of experience in process development, Fraunhofer ISE supports industry partners to identify and quantify the improvement potential of solar and battery cell interconnections and implement the improvements in industrial production. The large variety of characterization methods enable us to gain a profound understanding of the joint properties. This knowledge helps us to improve the joint quality and optimize the process parameters.