TA.TEC Engineering Insights #007

Why Does Cracking Progress Faster at the Heel?

Crack initiation in Al wire bonds under power cycling

Under power cycling, cracks initiate at both ends of the bond-wire contact, with faster initial crack propagation at the heel than at the tip.

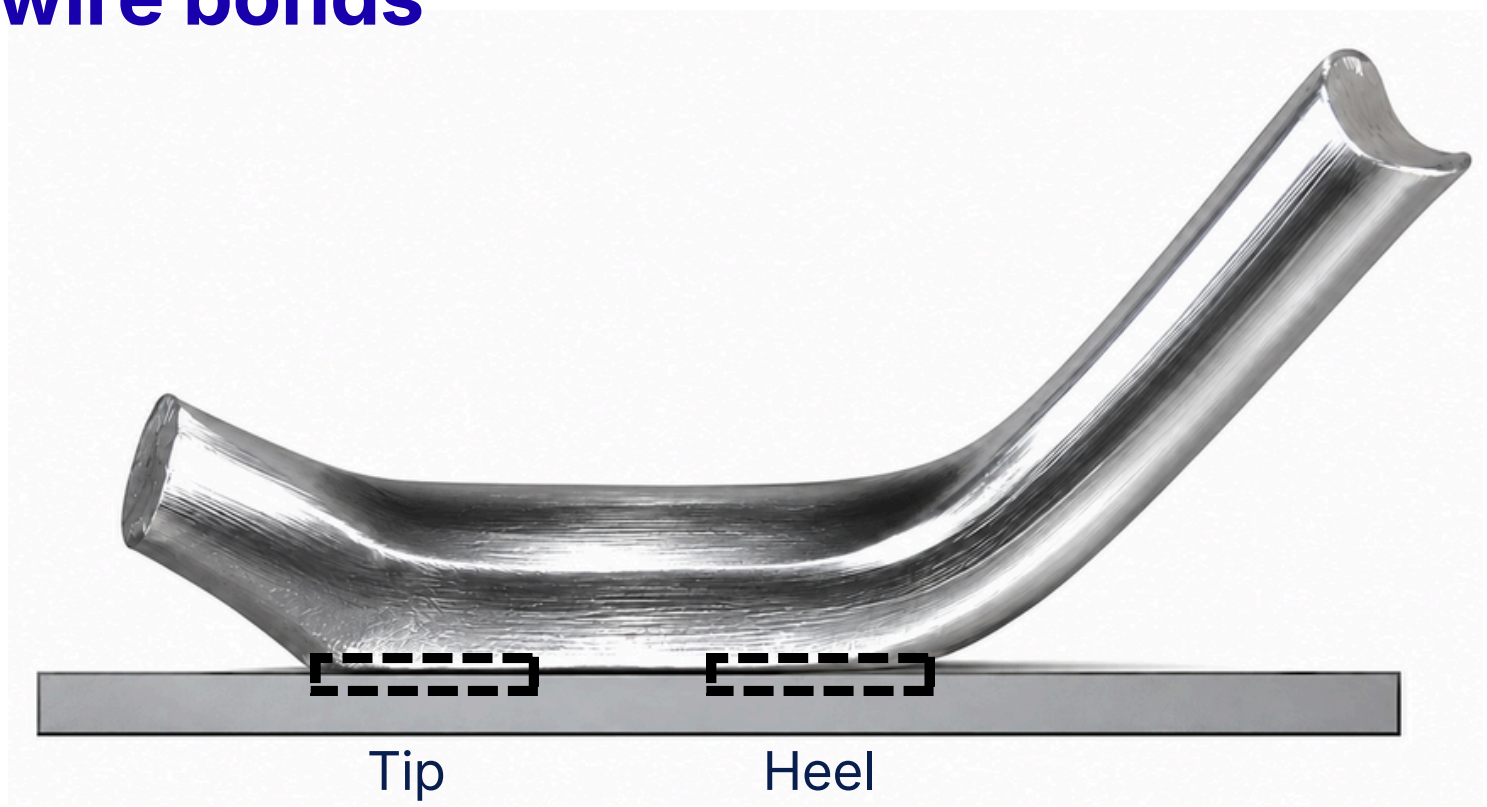


fig. 1. Analyzed zones

What does the microstructure reveal?

Different crack behavior at the heel and tip is accompanied by distinct microstructural evolution.

Note: *Fig.1 is an AI-generated schematic based on the study, not an exact reproduction of the original geometry or experimental data.*

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Same Bond. Different Crack Behavior.

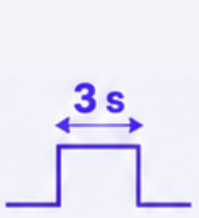
Investigated System

- SKIM63 IGBT power module (Semikron)
- Ultrasonically bonded aluminum wires
- Investigation focused on the wire region immediately above the chip metallization
- Microstructural characterization using EBSD

Power-Cycling Conditions

Junction temperature swing (ΔTj)
110 °C

Minimum junction temperature (Tj,min)
55 °C



Power-on duration (t_{on})
3 s



Power-off duration (t_{off})
6 **s**

The heel and tip were analyzed separately to investigate their different crack propagation behavior.

Note: *The wire diameter and the bonder model are not specified in the paper.*

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Two Crack Origins. Unequal Propagation.

Where and how do cracks develop?

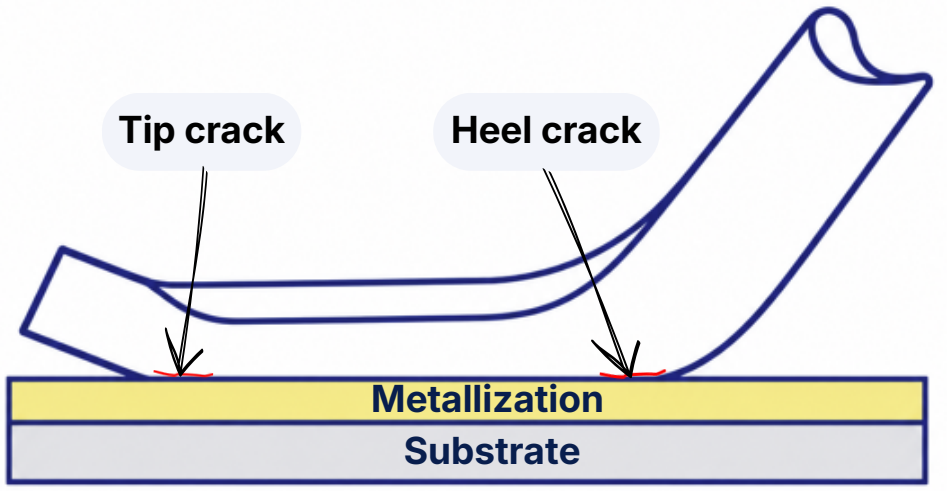
Under power cycling, cracks initiate at both ends of the bond-wire contact.

- **Heel:** Faster initial crack propagation.
- **Tip:** Slower initial crack propagation.
- **Crack path:** From both contact edges toward the center, inside the wire just above the metallization.

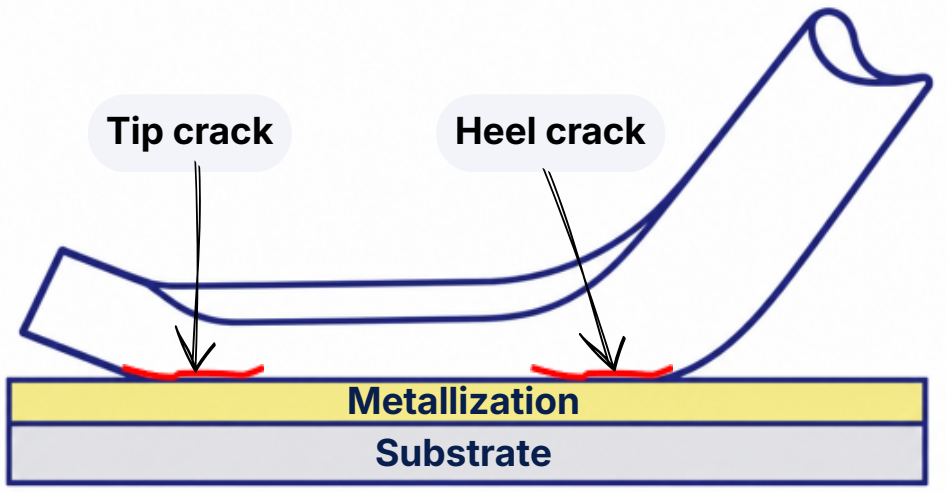
Crack propagation is faster during early cycling and slows down at advanced cycling stages.

N_f = Number of cycles for the module's complete failure.

10 % N_f
(early cycling)



50 % N_f
(Further crack development)



Cracks propagate from both contact edges, but their initial propagation is faster at the heel.

Note: *AI-generated schematic illustrations based on the study. Crack lengths and geometry are illustrative, not measured or reproduced from experimental data.*

Heel vs. Tip: Different Microstructural Evolution

What does Electron Backscatter Diffraction (EBSD) reveal at 10% N_f?

Power cycling leads to different changes in the microstructure at the two ends of the bond-wire contact.

HEEL

- Deformation texture components increase strongly and become dominant.
- Higher deformation-component fractions than at the tip.
- Faster crack initiation.

TIP

- Recrystallization texture components increase strongly.
- Deformation texture components decrease, resulting in lower volume fractions.
- Crack formation remains weak at this stage.

Microstructural Interpretation

The authors associate the stronger deformation-related evolution at the heel with enhanced crack initiation.

At 10% N_f, deformation-related textures dominate at the heel, while recrystallization-related textures dominate at the tip.

Notes: *This slide summarizes EBSD-based observations and the authors' interpretations at 10% N_f.*

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Engineering Insight

Local Microstructure Matters for Crack Propagation

1 Paper Findings

- Cracks initiate at both ends of the bond-wire contact, with faster initial propagation at the heel.
- At 10% Nf, deformation-related texture components dominate at the heel, while recrystallization-related components dominate at the tip.
- The authors associate the stronger deformation-related evolution at the heel with enhanced crack initiation.

2 Engineering Synthesis

- The bond-wire contact should not be treated as a microstructurally uniform region when interpreting this failure mechanism.
- Heel and tip should be evaluated separately in microstructural failure analysis, considering local texture evolution and crack behavior.

3 Study Scope & Limitations

- Findings are specific to SKIM63 IGBT modules under the tested power-cycling conditions.
- Transferability to other wire materials, geometries, metallizations, module designs or cycling profiles was not established.

Different local microstructural evolution at the heel and tip accompanies their unequal crack propagation under power cycling.

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Research Behind This Engineering Insight

Mustafa Shqair · Zoubir Khatir · Ali Ibrahim · Ayda Halouani · Mounira Berkani

Microstructural evolution during the crack propagation at the bond-wire contact area of IGBT power modules upon power cycling

Microelectronics Reliability, Volume 138 (2022), Article 114635

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