Power devices, EV/HEV cars, Drones, Aerospace, 5G/6G communication

Detecting early-stage failure by AE monitoring in WBG electric power conversion devices

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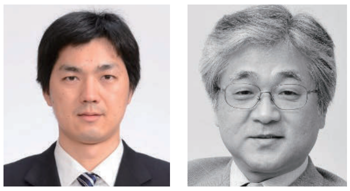

Abstract

In the article, acoustic emission (AE) was applied to monitor the wear-out failure in discrete SiC Schottky barrier diodes devices with a Ag sinter die attach to successfully monitor the real-time progress of failure of Al ribbons for the first time. AE signals were successfully collected for the SiC devices during a power cycling test. AE counts that correspond to one of the time-domain parameters of AE signals increased with power cycling, thereby corresponding to the observed fatigue cracks in Al ribbons leading to lift-off failure. Based on the relationship between an AE count rate and fatigue crack growth rate, the results indicate that AE monitoring can be used to understand the fatigue propagation in Al ribbons (i.e., failure mechanism) and also as an early warning before catastrophic lift-off fracture for power electronic devices.

Background & Results

The emergence of power electronic devices using silicon carbide (SiC) semiconductors has facilitated more compact designs and high energy efficiency due to its superior material properties . However, compared to traditional silicon (Si), the raised energy density of SiC-based power electronic devices requires high-temperature operation and results in many reliability issues. In SiC-based power electronic devices, wear-out failure after long-term operation is mainly caused by the failure in packaging components, such as bond wire lift-off, substrate delamination, and die attach cracks. However, the current failure precursor monitoring such as ON-state resistance, collector–emitter voltage, forward voltage, is limited for application in power electronic devices. In this article, AE was applied for the first time to real-time monitoring of wear-out failure of discrete SiC Schottky barrier diode (SiC-SBD) devices during PCT. The collection of AE signals during PCT and relationship between the observed damage and acquired AE signals is presented.

A number of AE signals were successfully detected during PCT prior to reaching final failure. The source of AE signals is attributed to the initiation and propagation of fatigue cracks in Al ribbons. This demonstrates that AE monitoring exhibits excellent sensitivity to fatigue cracks. The AE acquisition can be used as a sensitive early warning method via detecting fatigue cracks that lead to catastrophic lift-off failure in the ribbons.

Significance of the research and Future perspective

This study used acoustic emission during power cycling tests to monitor in real time the complete failure process—from the earliest stages—in silicon carbide Schottky diodes. This development will help solve wear-out failure problems that are limiting advanced applications in computers, solar cells, and many other devices. Future studies will focus on development of AE monitoring system using the packaged piezoelectric element inside power module to ensure reproducibility and price competitiveness.

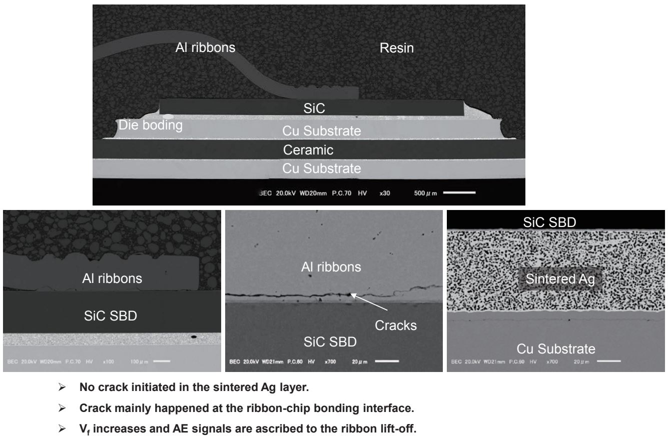

Fig.1 The cross-section of SiC power module and the crack extension and deterioration at the wire joint interface during the power cycling test

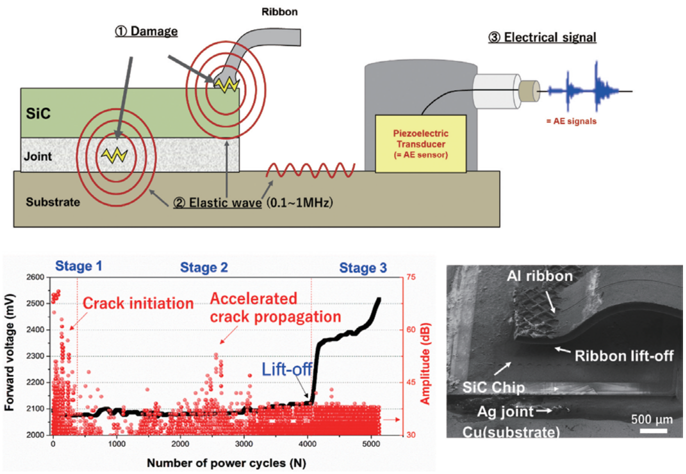

Fig.2 Deterioration detection technology by AE(Acoustic-Emission) sensor in the power module wires caused by the thermal fatigue

Patent

Treatise Choe, C; Chen, C; Nagao, S et. al. Real-time acoustic emission monitoring of wear-out failure in SiC power electronic devices during power cycling tests. IEEE Transactions on Power Electronics. 2021; 36 (4): 4420-4428. doi: 10.1109/TPEL.2020.3024986.

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Keyword power electronics, AE sensing, failure diagnosis, Ag sinter joining