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Guidelines for Acoustic Emission Measurement during Mechanical Testing

Developed by the members of the SMT Attachment Reliability Test Methods Task Group (6-10d) of the IPC Product Reliability Committee (6-10) of IPC.

Users of this publication are encouraged to participate in the development of future revisions.

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1.0 SCOPE

This guideline document establishes an Acoustic Emission (AE) method to enhance evaluation of the performance and reliability of surface mount attachments of electronic assemblies during mechanical loading. Mechanical loading may include stressors such as four-point bend test, spherical bend test, back-end manufacturing and test steps post surface mount attachment and drop/shock test. The current focus for this measurement method is to identify the printed board pad cratering mechanism and printed board material performance. This approach may eventually be extended to examine other failure modes depending on the guideline's evolution and adoption, as this method remains in development.

1.1 Purpose The purpose of this document includes:

- Detection of crack/mechanical damage initiation: initial damage from strain may precede electrical detection of failures such as pad cratering damage during a mechanical stress test.
- Identification of the failure initiation location and propagation through detection of AE signals generated due to stress-induced physical damage.
- Estimation of the strain at which the mechanical failure event is observed acoustically, which can be used as a design guideline.
- Provision of standardized test guidelines and reporting procedures.

1.2 Background Pad cratering typically initiates prior to detection by existing electrical monitoring test methods. There are limited instrumentation techniques that are currently available that can identify non-electrical damage and its location to a high degree of accuracy. Alternative methodologies often require large sample sizes to estimate these virtually undetectable failure modes.

1.3 Performance Classification The specific reliability requirements need to be established by agreement between customer and supplier.

1.4 Definition of Terms The definition of all terms used herein **shall** be as specified in IPC-T-50, ASTM E1316, and as defined below.

1.4.1 Acoustic Emission (AE) The class of phenomena whereby transient stress/displacement waves are generated by the rapid release of acoustic energy from localized sources within a material, or the transient waves so generated.

1.4.2 Acoustic Emission Count The number of times the acoustic emission signal exceeds a preset threshold during any selected portion of a test.

1.4.3 Acoustic Emission Signal An electrical signal obtained by detection of one or more acoustic emission events.

1.4.4 Average Signal Level The rectified, time averaged AE logarithmic signal, measured on the AE amplitude logarithmic scale and reported in dB_{AE} units (where 0 dB_{AE} refers to 1 μV at the preamplifier input).

1.4.5 Channel An assembly of a sensor, preamplifier or impedance matching transformer, filters, secondary amplifier or other instrumentation as needed, connecting cables, and detector or processor.

1.4.6 Couplant A material used at the structure-to-sensor interface to improve the transmission of acoustic energy across the interface during acoustic emission monitoring.

1.4.7 Effective Velocity Velocity calculated on the basis of arrival times and propagation distances determined by artificial AE generation. This quantity is used for computing the location of the AE.

1.4.8 Energy, Acoustic Emission Signal The energy contained in an acoustic emission signal, which is evaluated as the integral of the volt-squared function over time.

1.4.9 Evaluation Threshold A threshold value used for analysis of the examination data. Data may be recorded with a system examination threshold lower than the evaluation threshold.

1.4.10 Event (Emission event) An occurrence of a local material change or mechanical action resulting in acoustic emission.

1.4.11 Hit The detection and measurement of an AE signal on a channel.

1.4.12 Location Accuracy A value determined by comparison of the actual position of an AE source (or simulated AE source) to the computed location.

1.4.13 Location, Computed A source location based on algorithmic analysis of the difference in arrival times among sensors.

1.4.14 Peak Amplitude The maximum excursion of the rectified acoustic emission signal (the absolute value of the raw signal) during an AE hit referenced to 1μV at the AE-sensor before amplification.

1.4.15 Pencil Lead Break (PLB) Source An artificial AE source which uses the fracture of a brittle graphite lead on the surface of a material to simulate an AE event as a result of the sudden displacement that results in a lead break. This is performed with a 0.3 mm, 2H lead pencil.

1.4.16 Sensor A detection device, generally piezoelectric, that transforms the particle motion produced by an elastic wave into an electrical signal.

1.4.17 Signature A characteristic set of reproducible attributes of acoustic emission signals associated with a specific test article as observed with a particular instrumentation system under specified test conditions.

1.4.18 Absolute Energy This is a value derived from the integral of the squared voltage signal divided by the reference resistance (10k-ohm) over the duration of the acoustic emission signal. As a time-based feature, it reports the energy in the time driven data rate interval. The range is from 0.00093aJ to 1310.25nJ for one type of equipment used for generating this data reported in publication by Bansal et.al. [1], [2], and [3].

2.0 APPLICABLE DOCUMENTS

The following documents are applicable and constitute a part of this specification to the extent specified herein. Subsequent issues of, or amendments to, these documents will become a part of this specification. Documents are grouped under categories such as IPC, American Society for Testing and Materials (ASTM) and others depending on the source.

2.1 IPC[1]

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC/JEDEC-9702 Monotonic Bend Characterization of Board-Level Interconnects

IPC/JEDEC- 9703 Mechanical Shock Test Guidelines for Solder Joint Reliability

IPC/JEDEC-9707 Spherical Bend Test Method for Characterization of Board-Level Interconnects

2.2 JEDEC

JESD22-B110 Mechanical Shock – Component and Subassembly

JESD22-B111 Standard for Drop Test Reliability of Chip Scale Packages

2.3 ASTM[2]

ASTM Standard E976 – 10 Standard Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

ASTM Standard E1316 – 11 Standard Terminology for Non-Destructive Examinations

2.4 ASNT[3]

Nondestructive Testing Handbook, Volume 6, Acoustic Emission Testing

3.0 SAMPLE SIZE

This is a guideline to be used along with a variety of mechanical stress standards, wherein the relevant sample sizes will be addressed. It is recommended to follow sample sizes based on the testing standard that is being used.

4.0 APPARATUS AND SETUP

4.1 AE Sensors This guideline involves the use of AE sensors that **shall** have a peak resonant frequency of 300KHz or higher. Mounting of the sensors can be accomplished using clamps with a couplant or an adhesive couplant. Couplant examples are water-based gel, petroleum jelly, bees wax, accelerometer wax, other waxes, cyanoacrylate, epoxy, glue or glycerin. See Appendix A for some practical considerations in sensor selection, mounting and use.

1 www.ipc.org
2 www.astm.org
3 www.asnt.org