Design of a Mechanical Cycling Reliability Test Program for Thermal Interface Materials Designed for Semiconductor Test Requirements

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A mechanical reliability test program has been designed in four phases for evaluating durability as well as thermal resistance performance of specialized thermal interface materials (TIMs). These specialized TIMs have been developed specifically to meet requirements for semiconductor test and burn-in requirements, which are extreme; cycling with multiple contacts for a single TIM (up to thousands of cycles) is a long-sought development goal for the semiconductor test equipment industry. Development of a mechanical reliability test for evaluating durability as well as thermal resistance performance (based on an industry survey of equipment manufacturers and semiconductor manufacturers to determine reliability test requirements) will be described. Test results for Rth, thickness change, and mechanical contact cycling will be presented, with analysis.

Thermal interface materials evaluated for semiconductor test and burn-in must meet demanding requirements not commonly considered by TIM manufacturers. Selection of well-performing TIMs is increasingly critical for highly-specialized devices with high heat flux, such as GaN RF devices and SiC IGBT die, for a range of military, aerospace, and industrial systems applications. The TIM provides an important element in thermal control and heat dissipation during testing procedures and, for throughput and cost considerations during volume testing procedures, the TIM must survive multiple test head contacts to the device under test and, for burn-in requirements, higher operating temperatures. These mechanical and reliability requirements are distinct for semiconductor test; however, analysis of these characteristics of TIMs can also be useful in assessing proper selection for such as IGBT power semiconductors.

A servo-driven thermal interface material test stand developed to follow industry-standard test methodology is used to conduct testing under controlled test conditions. Four test phases, with progressively more challenging requirements, were designed.

Test conditions include control for:

1. Repeated contact and separation for 1,000 cycles between parallel test head surfaces at typical operating temperatures, with specified contact force applied, dwell time, and at specified temperature;

2. Combined repetitive contact and separation for 1,000 cycles between parallel test head surfaces, with thermal performance measured per ASTM D 5470-17, at a specified contact force applied; an additional test phase applies repetitive contact and separation for 5,000 cycles.

3. Repeated contact between an angled test head surface and a secondary surface, to create a strike angle equivalent to socket and gimbaled test head characteristics found in semiconductor test, with specified contact force applied, dwell time, and at a specified temperature;

4. Repeated contacts between an angled test head surface and a secondary surface, at elevated temperatures, to replicate burn-in testing requirements.

The goals of this testing program, conducted in all four phases, include:

1. Evaluation of mechanical performance, measured as number of insertion and separation cycles completed without deformation or damage at each specified force applied, for 1,000 and 5,000 cycles; contact is performed with parallel test heads and in a subsequent test phase with a specified strike angle introduced, to simulate a gimbaled test head in contact with different DUTs. This phase is designed to mimic semiconductor test procedures and conditions per the industry survey of requirements.

2. Thermal resistance, measured under specified pressure, temperature, and dwell conditions, for each program test phase;

3. Thermal and mechanical performance, over a specified number of insertion cycles completed, at elevated temperatures.

Reliability data and physical descriptions will be provided for material attributes that are important for the semiconductor test and burn-in industry, including evaluation of ease of application; presence if any of residue; and ease of removal and clean-up. Information will be presented in a practical and noncommercial manner. Test data by an independent test laboratory presented includes thermal resistance data generated per the ASTM D 5470-17 industry-standard test methodology.