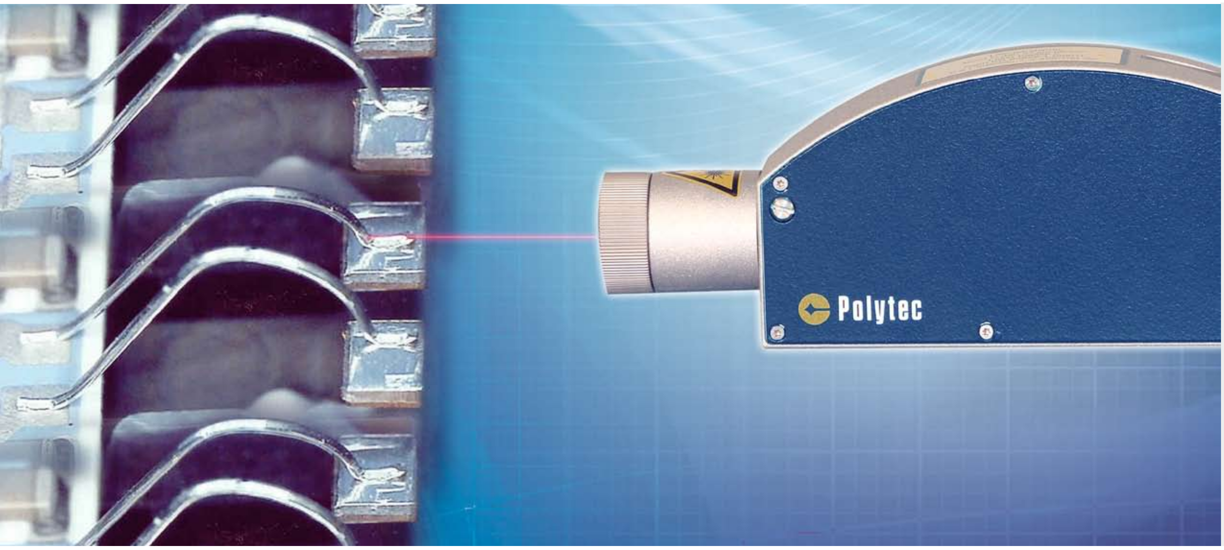
Testing Power and Microelectronic Interconnects



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A Highly Accelerated Mechanical Test Technique for Life Time Assessment of Micro-Joints

An accelerated test system for power and microelectronic interconnects is presented that offers fast screening of product quality and reliability assessment. This test system permits diverse loading modes to test various component geometries and material combinations. Measurement of local velocities by differential laser-Doppler vibrometry permits calculation of displacements and accelerations acting on the structure under test. Using this method, fatigue endurance curves up to 10^9 loading cycles were obtained and lifetime was modeled by the Coffin-Manson relationship and compared with available lifetime measurements of similar micro-joints obtained in industrial power cycling tests.

Introduction

Inequalities in thermomechanical properties of materials at interfaces of a modern package lead to a rise in periodic stresses during normal operation, making these sites crucial to the integrity of the entire product. Proper lifetime analysis for highly miniaturized interconnects is a real challenge. In addition, broad application of 100% quality standards in various industries has caused a rapid growth in meeting reliability demands in the electronics packaging industry. Introduction of novel materials and a dramatic reduction in the time-to-market (down to 6 weeks) has put pressure on supply chain requirements; therefore, faster and tighter quality assessment of designed components is essential.

Commonly used thermal testing techniques are a limiting factor in quality assurance of newly developed components. Further acceleration of thermal/power cycling procedures tends to be aimless; thus, introduction of alternative methods seems indispensable. Isothermal mechanical fatigue is being considered as a very promising alternative for the microelectronic industry. Enormous reductions in test duration and energy usage are considered the most important advantages of mechanical testing techniques.

Frequently used thermal/power test techniques make use of extreme temperature excursion for introduction of excessive load level that may lead to activation of failure mechanisms different from the ones found in field failures.

The developed technique applies high frequency resonant vibration as a source of stress directly at critical sites of a modern package (Fig.1). Micro-components subject to testing can be forced to vibrate at a broad range of loads related solely to an excitation amplitude. Highly shortened test time permits usage of load levels directly comparable with the ones acting in existing products, and being unreachable for reasonable testing times in temperature based fatigue experiments.

Experimental Setup

The selection of an appropriate vibration measurement sensor is limited by the miniaturization in microelectronics. Small masses, high frequency and acceleration of investigated components require application of an ultra high precision measuring setup.

Affordable high power ultrasonic bonding equipment operating at 20 or 36 kHz is incorporated as an excitation source. In this particular case, we use Telsonic DG-2000 (20 kHz) or DG-100 (36 kHz) ultrasound generators controlled by a personal computer (Fig. 1).

In order to measure the velocity/phase difference between specimen holder and tested component, differential measurement using two vibrometers is necessary. The Polytec OFV-2500 Vibrometer Controller with high velocity and frequency levels as well as low space requirements was selected and paired with the OFV-534 Compact Laser Head. Mounted on a high precision translation stage and equipped with a 10X magnification lens, the the two OFV-534 laser heads each provide a laser spot diameter of 3 µm, small enough to meet the size range of investigated components (see Fig. 2 and Fig. 3).

The nature of the fatigue measurement requires acquisition of continuous time signals at relatively high sampling rates with simultaneous frequency analysis and data storage. Therefore, several data acquisition systems were tested and the LDS-Dactron Photon+ dynamic signal analyzer was found to complete the system. This DSP-based device is capable of performing online frequency analysis while streaming data to a hard drive at a rate of 192 kilo-samples per second for all four channels simultaneously with 24-bit resolution.

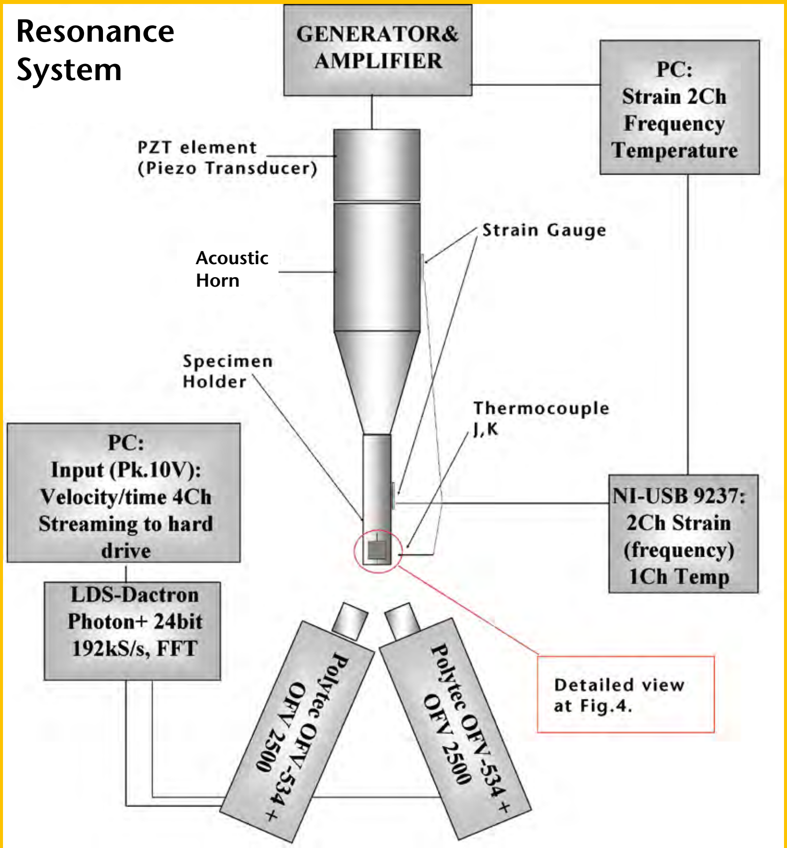


Fig. 1: Accelerated ultrasonic fatigue test setup.

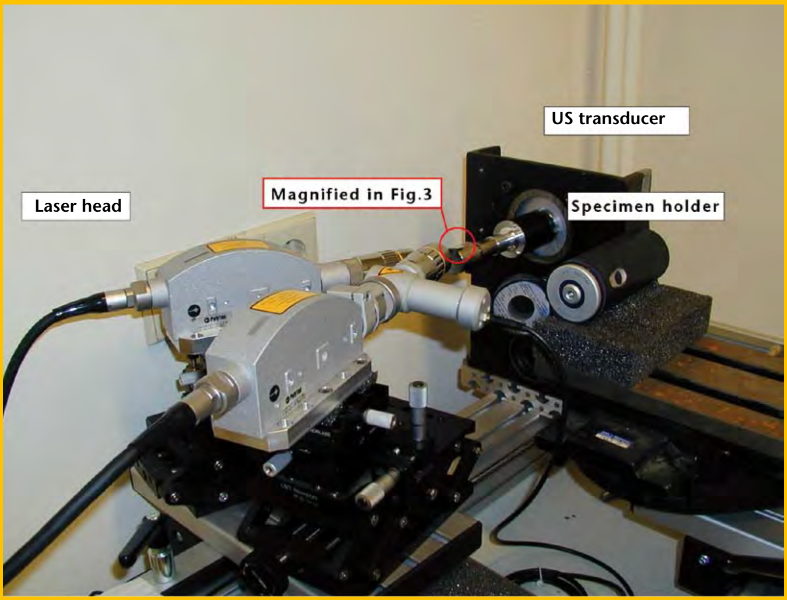


Fig. 2: Arrangement at the beginning of the measurement.

The micro component used in the presented study consisted of a single aluminum wire ultrasonically bonded to a metalized silicon chip (Fig. 4).

Results

The acquired velocity/phase difference data are used to reconstruct relative displacement of both vibrating partners, providing necessary information to calculate mechanical stress acting at an interface. Since in normal operation, thermal load originates from a difference in thermal expansion of joined materials, a simple bimetallic approach is used to establish the Coffin-Manson relationship – cycles to failure Nf versus equivalent temperature excursion ΔT. Obtained data are directly compared with results for industrial power cycling tests acquired for the same specimen quality (Fig. 5).

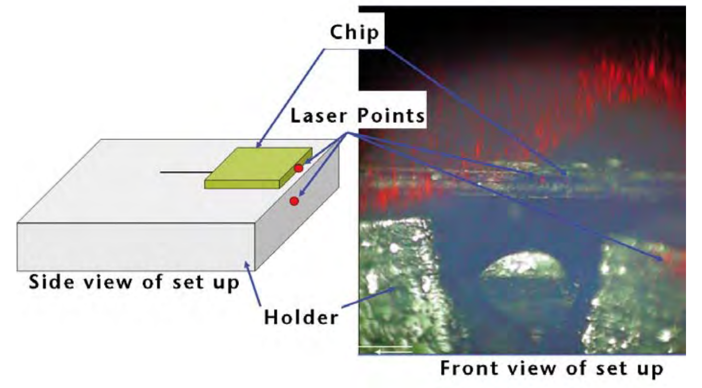


Fig. 3: OFV-534 integrated camera view (chip thickness = 70 µm).

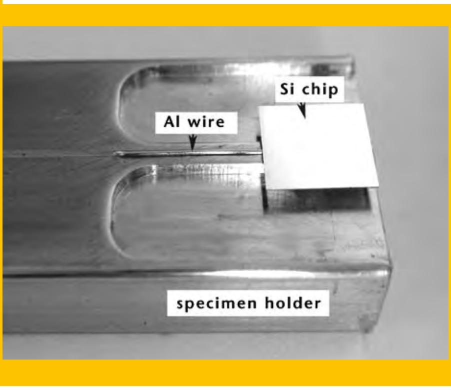
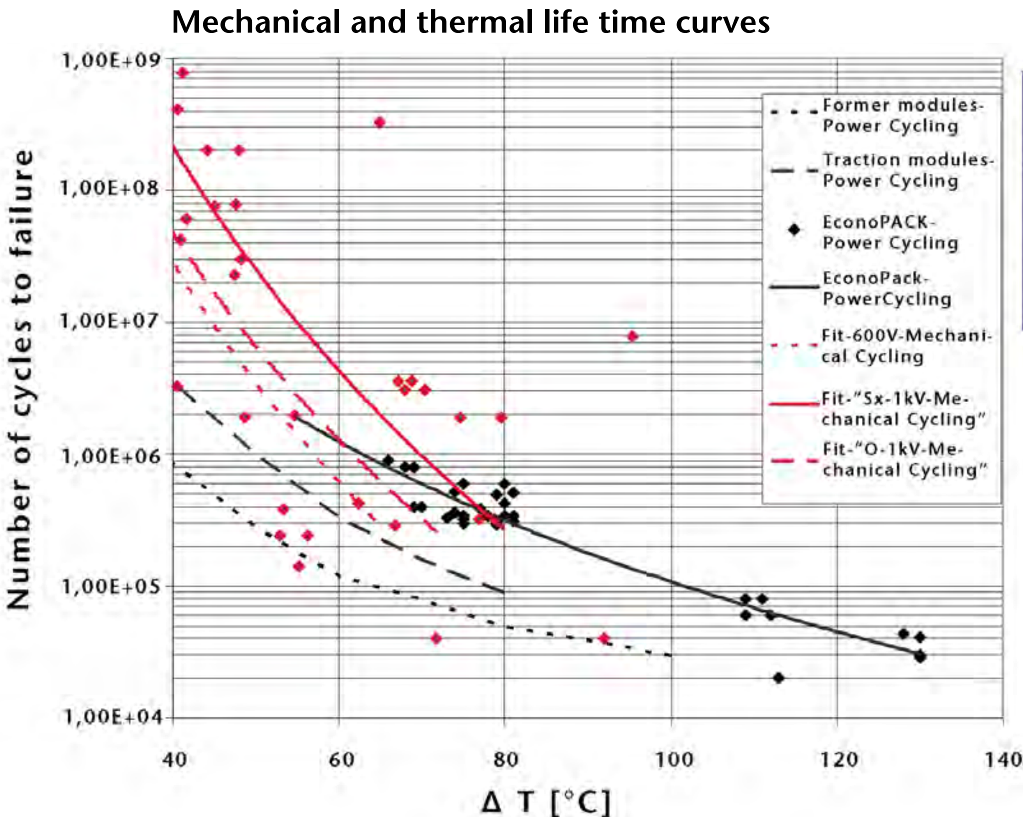


Fig. 4: Typical wire-bond specimen prepared for test.



Life time modeling:

$$\Delta\varepsilon = (\alpha_{Al} - \alpha_{Si}).\Delta T$$

$$\Delta\varepsilon \propto N_f$$

$$N_f = a.\Delta T^n$$

$$\Delta\varepsilon_{thermal} \sim \Delta\varepsilon_{mechanical}$$

Fig. 5: A comparison of power cycling and mechanical cycling results showing good agreement between the two methods of measurement. Power and mechanical results complement well.

Conclusion and Outlook

The proposed accelerated test technique was successfully applied for rapid life time estimation for various microelectronic interconnects represented by wire bonds. Results correlate well with available power cycling data; however, there is a noticeable shift between the two data sets that needs clarification. Additionally, frequency dependence of results needs to be studied in order to correct possible strain rate influence on obtained results. Due to equipment limitations, all investigations were performed at room temperature. This restriction eliminated the influence of thermal processes (creep, recovery etc.). An improved system is in the development phase that allows isothermal testing over a temperature range of 125 to 175 °C.

Our current work is focused on constructing a small and semiautomatic testing device that can be installed in a microelectronics manufacturing line to provide a very fast quality screening method for life time estimation. Further miniaturization and automation of a fatigue measurement system remains the main goal of future work.

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