Combined system for testing of joints in microelectronic packaging under thermal cycling, humidity and vibration loading

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Abstract: Generally, the low cycle fatigue induced by thermal cycling is the major concern in the reliability of joints in microelectronic packaging, but high cycle fatigue induced by vibration can also contribute significant effect, especially for applications in automobile industries. Due to the mismatch in the coefficient of thermal expansion between the substrate and the device, shear stresses inside the joint occur during the temperature cycling, whereas the out of plane vibration additionally causes tensile stresses. The partial crack or micro crack in joints can have influence on its resistance and reliability of assemblies subjected to vibration. Combined thermal cycle, humidity and out-of plane vibration loading conditions were applied to determine the electrical behavior of adhesive and solder joints. The resistance of tested daisy chains as well as temperature, humidity and acceleration were continuously monitored by own designed high speed and high accuracy data acquisition system.

Key words: microelectronic packaging, reliability testing, vibration loading, thermal cycling, data acquisition

1. INTRODUCTION

Electronic devices impact nearly all areas of life. The technologies of electronic products in automotive, consumer, telecommunication, computer, aerospace, medical and many others industries are all based on microdevices and packaging technologies. In many applications (e.g. automotive, aerospace etc.) the electronic systems has to work in harsh environments for instance temperature cycles, humidity, vibration etc. Such conditions have a large influence on joints reliability. Due to the mismatch in the coefficient of thermal expansion between the substrate and the device, shear stresses inside the joint occur during the temperature cycling, whereas the out of plane vibration additionally causes tensile stresses. The partial crack or micro crack in joints can have influence on its resistance and reliability of assemblies subjected to vibration [1, 2].

To perform reliability tests within a reasonable amount of time in a well-controlled environment, accelerated tests are commonly carried out. In accelerated tests, the devices are subjected to much higher “stress” that they would experience under normal usage conditions. The purpose is to accelerate the failure, so reliability data can be collected within a much shorter period of time. Commonly accepted accelerated stress conditions include: thermal cycling and thermal shock, steady-state thermal soaking (backing, dwell), mechanical vibration, voltage extremes and power cycling, high humidity and high pressure, and combination of the above [3].

Polymer electronics plays more and more important role nowadays. Metallic solders are replaced by electrically conductive adhesives based on polymer’s matrix. Thermo-mechanical properties of electrically conductive adhesives in comparison with metallic solders are different therefore the accelerated reliability tests could show the different behaviour of adhesives in harsh environments.

In this paper authors present the combined system for testing of joints in microelectronic packaging under thermal cycling, temperature, humidity and vibration loading.

2. TEST CONDITIONS

2.1. Test Sample

As a test sample the daisy chain of resistors has been used. The daisy chain has consisted of the 8 SMT resistors (with resistance 6.8 Ohm, tolerance 5 %) connected in serial network (Fig. 1.) by using electrically conductive adhesive delivered by AMEPOX Microelectronic. The assembled test circuit was put to oven and adhesive joints were cured 20 minutes at temperature 120 °C. The resistance of circuit was measured with using 4-point (Kelvin) method. The initial resistance of the whole daisy chain was about 55 Ohm.

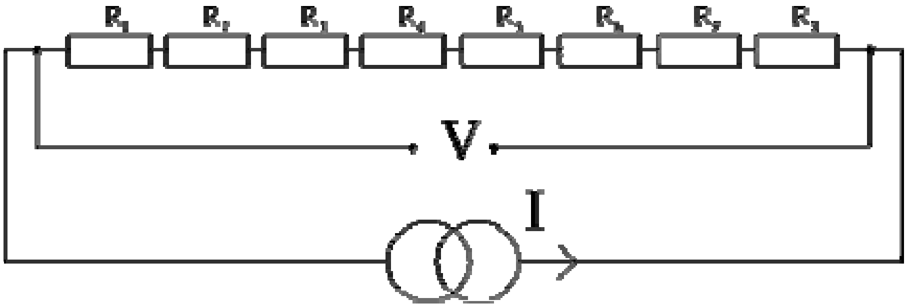

Figure 1. The tested circuit of resistor daisy chain.

2.2. Environment loading

The test of adhesive joints was carried out in climatic chamber (Challenge 250, Angelantoni Industrie S.p.A.) under thermal cycles loading. An example of the temperature cycles measured in the climatic chamber is shown in figure 2 (temperature range: from -40 °C to +125 °C, one cycle time: ~ 100 min). In this test only temperature cycling was used but it is possible to subject temperature + humidity loading as well (e.g. 85 °C/85 RH).

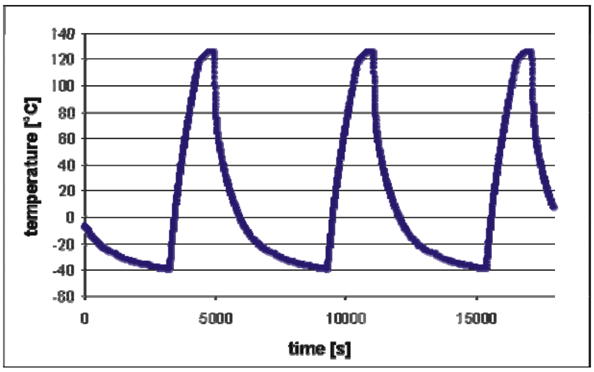

Figure 2. The temperature cycles inside climatic chamber

2.3. Vibration loading

Mechanical out-of plane vibrations were subjected to tested circuit by using acceleration exciter (Bruel & Kjaer 4809). The vibration frequency for the test was fixed at 400 Hz with an acceleration of 5 G (RMS).

Figure 3. The vibration system inside (left) and outside (right) a climatic chamber

3. TEST ACQUISITION SYSTEM

The schematic diagram of the test acquisition system is shown in figure 4. The resistance of daisy chain is measured with using 4-probe (Kelvin) method. In this system a stabilized current source were used (I = 0.5 mA). The analog voltage signal is amplified with fast differential amplifier (gain=10V/V) and then converted with a 12-bit analog-to-digital converter (40 MSPS). Due to the very large volume of generated data (over 60 MB/s), field programmable gate arrays (FPGA) ICs have been used to preprocess the data. The acquired data are preprocessed by the on-board XILINX FPGA digital processing unit (DPU).

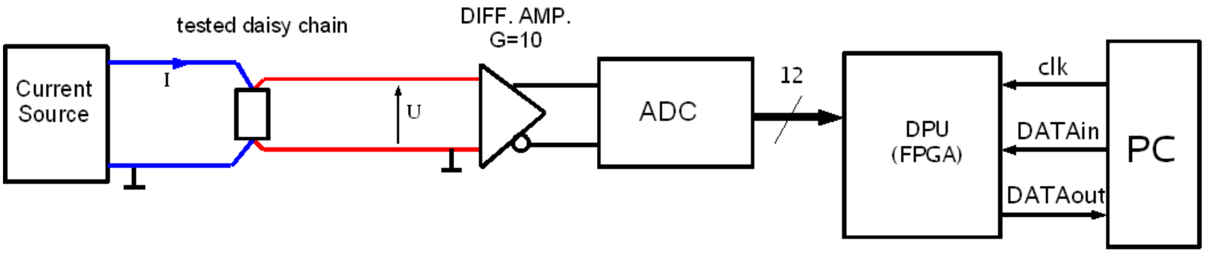

Figure 4. Schematic diagram of the test acquisition system

The acquisitions system was designed as an event detector which monitors changes in the resistance of electrical circuits continuously. It can detect even very short (~ 1 μs) growth of resistance (e.g. due to micro cracking of joints) above assumed threshold. When the resistance of tested daisy chain is greater than resistance threshold R_T for a specified period of time (i.e., the length of the pulse is greater than 1μs) the event and its maximal value of resistance is logged in PC. The threshold value of resistance (R_T) is configurable (one of the DPU registers). This value can be changed during a test, so it is possible to detect long-term, slow changes of resistance (e.g. due to thermal changes) after temporarily setting R_T to 0 during the test. The board exchanges data with a host PC via a USB or parallel interface in each vibration cycles (400 times per second).

4. RESULTS

The data collected during one-day test consisted of temperature, humidity and single channel resistance measurement results. The amount of preliminary processed and compressed data was c.a. 800 MB (megabytes). Without pre-processing, the data would take over 5 TB (terabytes) as the data stream obtained from the high-speed analog-to-digital converter is as large as 60 MBps (megabytes per second). After processing these data with our own, dedicated software it was possible to observe several phenomenas. In fig.5. the resistance changes are shown. Short-term resistance changes were mainly caused by the TCR (Temperature Coefficient of Resistance) of the daisy-chain and joint resistance chenges, while the long-term resistance changes marked as (--.--.--) and (- - - -) lines were caused by the adhesive properties changes (aging) under thermal loading. Such behaviour have not been observed when the solder joins were used. These changes are clearly visible for the lower part of thermal cycle (the resistance decreased within first 5 thermal cycles and then started to grow slowly).

The most important result is that no single resistance 'spikes' were detected during the tests, which means no temporary joint destruction took place.

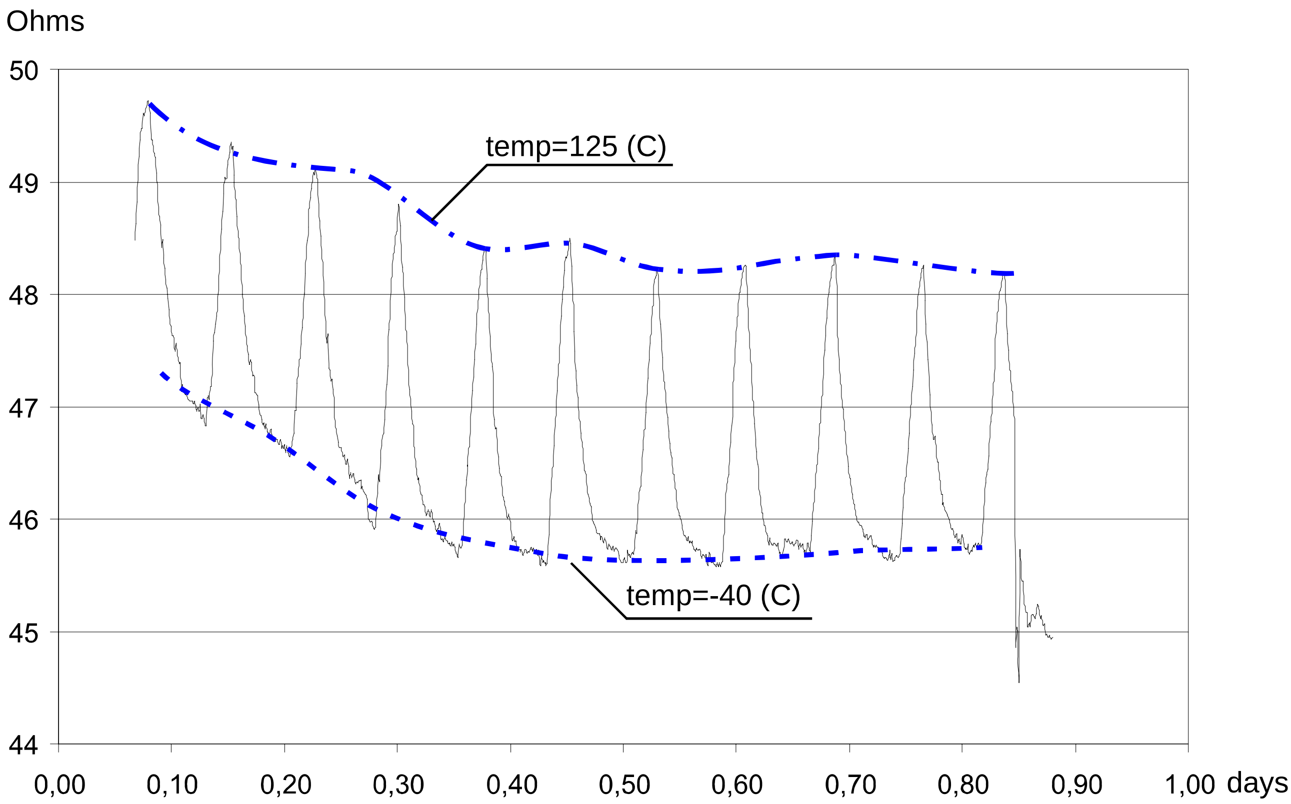

Figure 5. The resistance changes during the tests

5. CONCLUSIONS

Oppposite to classic, widely used methods of a resistance monitoring under thermal cycling, humidity and vibration loading, the solution presented in this paper provides significant improovements. With our system it is possible to continuously monitor long-term, short-term and momentary resistance values. Both high resistance-value resolution (up to 12 bits) and very high time-domain resolution (down to 15 ns) have been achieved. Using our novel data pre-processing algorithms and DPUs it is possible to store these high-resolution results of long-term measurements (for example, 120 GB disk storage can handle the results of more than 4 monts of continuous measurements of single channel).

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