Method development for the reliability testing of printed circuit boards under dynamic loads

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ABSTRACT. The reliability of printed circuit boards under dynamic loads is a key issue in the handheld electronic products industry. To be able to predict the performance of the boards in their application lifetime different tests were developed. The current industry-wide standard testing method is a drop-shock-test. In this test the boards are dropped under defined conditions till failure in the board is detected. The main failure driver is a flexural oscillation of the board due to the impact event. As this test method has a number of drawbacks in this work an alternative test method was evaluated. A cyclic-bend-test was used and the results were compared with the results of the drop-shock-test. A very good correlation between the methods could be observed, approving the applicability of the cyclic-bend-test for the determination of the drop test performance. The advantages of the alternative test method were shorter testing times and a better reproducibility.

INTRODUCTION

Dynamic loads on printed circuit boards (PCBs) are of growing interest due to the increasing market for handheld electronic products. Due to their size and application handheld electronic products are especially prone to be dropped, i.e. exposed to an impact load, during their useful service life. These impact loads can result in serious damage of the PCB interconnections and thus in malfunction of the product. To evaluate the drop performance and to develop reliable designs different board level test methods were introduced. Wong et al. were reviewing the development of the methods in their work [1]. A standardized drop-shock test JESD22-B111 was defined under the Joint Electronic Device Engineering Council (JEDEC) [2]. In this test defined drops of the PCBs are repeated till failure is detected. Despite efforts in ensuring the repeatability of this test, the rather complex test set-up and load application makes it difficult to obtain absolutely reliable and comparable results.

Thus, in this work an alternative test to determine the drop performance, expected to be advantageous, was performed and evaluated. Flexing of the circuit board, due to input acceleration created from dropping, is the primary driver for PCB failure. Therefore a cyclic-bend-test, applying a repeated and well defined flexure, was used to reproduce the loading situation. The simplified and accelerated load application should result in a more robust test method, giving faster and more reliable results.

The test method applied was based on similar ideas then the high speed cyclic bend tester (HSCBT) proposed by Shea et. al [3], but was performed with a standard dynamic testing machine under simplified boundary and loading conditions.

PCB CYCLIC-BEND-TEST DEVELOPMENT

The first step in the PCB cyclic-bend-test development was the analysis of the standard drop-shock test to get to know the critical loading parameters. A high speed camera, strain gauges and an acceleration sensor were used to characterize the test [4]. The test set-up and the fixture for the drop test is shown in Fig 1. By the evaluation of the high speed camera images, it was detected that the main failure driver in the impact test was the flexural oscillation of the board. The maximum peak-to-peak amplitude was about 5 mm and the frequency about 280 Hz.

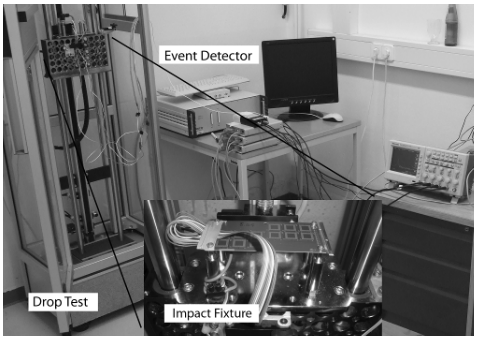


Figure 1: The test set-up of the standard drop-shock-test.

Knowing that the repeated flexing of the board in the impact test was the main failure driver a cyclic-bending-test as alternative testing method suggested itself. For the board fixation a three-point bending fixation was constructed. The board is simply placed centred on support rollers (Ø 5 mm) which have a distance of 90 mm to each other. The load is applied by a fin, which consists of two rollers (Ø 5 mm), clamping the board at half length. The clamping force was applied over spring plungers to have a defined load. It has to be regarded, that the board is not clamped at the support rollers, implicating that the load can only be applied in one direction. For the load application an electro-dynamic testing machine (Bose 3230, Bose Corporation, Eden Prairie, US) was used. This machine has the advantage of a very precise displacement control and could be used to apply the desired sinusoidal displacement amplitude on the specimen. The test set-up including the bending fixture is shown in Fig. 2.
A peak-to-peak amplitude of 3mm at a mean deflection of 2.5 mm was chosen. Thus, it was ensured, that no lift-off of the board from the support rollers could happen during the tests. It was not possible to perform the test at the oscillation frequency of the PCB in the drop test, (280 Hz) due to machine limits. To stay at the desired optimum machine displacement control precision the frequency was kept at 25 Hz.

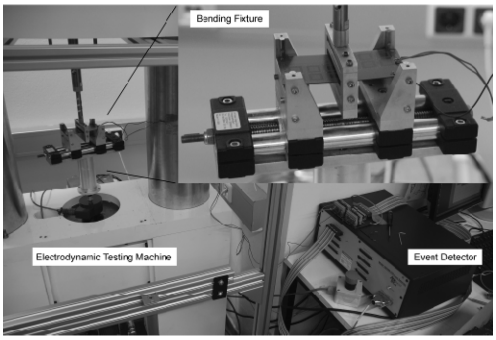


Figure 2: The test set-up of the cyclic-bend-test.

EXPERIMENTAL

Six different PCB designs were tested with the drop-shock-test and the cyclic-bend- test to be able to evaluate the method. Eight boards of every design were tested to obtain statistically relevant data. Drops in the drop-shock-test and the applied oscillation in the cyclic-bend-test were repeated till first failure was detected. Failure of the PCBs was defined as an electrical discontinuity of resistance greater than 1000 ohms lasting for 1 microsecond or longer. To be able to measure the very short lasting electrical discontinuities a special event detector (256STD, Analysis Tech, Wakefield, US) was used. The tested designs showed a wide range of different drop test performances allowing an easy correlation check with the cyclic bend performances.

To check the correlation of failures types introduced by the two testing methods a failure analysis was performed. Microsections of the expected failure locations were prepared and analyzed with a light microscope. It was checked if the same failure modes occur despite the different loadings.

RESULTS AND DISCUSSION

In Fig.3 the comparison of the drop-shock test results to the cyclic-bend-test results is presented. To compare the two tests, resulting in different parameters for the reliability, a conversion factor was introduced. The average time to failure was divided through the average number of drops till failure to obtain a proportionality factor. This factor was used to calculate fictitious times to failures for all drop test results.

A very good correlation for the mean times to failures could be observed with discrepancies only in the range of the statistical spread.

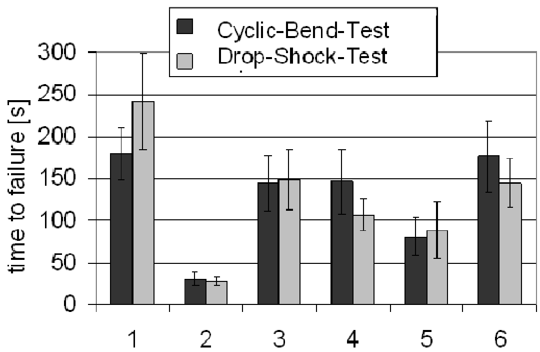
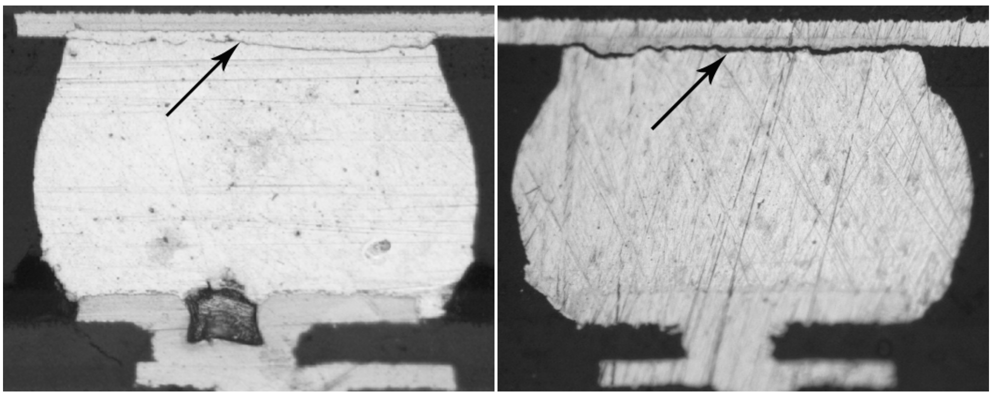


Figure 3: The comparison of the drop-shock-test results with the cyclic-bend-test results.

The failure modes checked by light microscopy also correlated for both testing methods applied. In Fig. 4 the comparison of the failure pattern of design 1 is presented exemplarily.

The results indicate that the cyclic-bend-test might be a good alternative testing method for the drop test performance.



(a) (b)

Figure 4: Light microscopy images of the failure patterns of design 1 boards tested by the drop-shock-test (a) and the cyclic-bend-test (b).

The cyclic-bend-test has the following in the development aimed for advantages compared to the drop-shock-test:

- ✓ Faster testing (no break between drops).
- ✓ Less operator-sensitive processes (e.g. no tightening of screws).

- ✓ Constant load application (no change of the impact event due to aging of the strike surface, differences in the drop height, different impact velocities…).
- ✓ Easier test simulation (simplified loading conditions allow a much easier finite element simulation of the test).

AKNOWLEDGMENT

The research work of this paper was performed at the Polymer Competence Center Leoben GmbH (PCCL, Austria) within the framework of the Kplus-program of the Austrian Ministry of Traffic, Innovation and Technology with contributions by the Institute of Material Science and Testing of Plastics, University of Leoben and AT&S GmbH. The PCCL is funded by the Austrian Government and the State Governments of Styria and Upper Austria.

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