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Dynamic parametric design and feasibility assessment for a high resistance measuring system

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ABSTRACT

A high resistance measuring system (HRMS) is used to measure the surface insulation resistance (SIR) values of the printed circuit board (PCB), and monitor whether a momentary circuit short and/or the case of current slow leakage occur, which will affect the electrical properties of electronic components. This study constructs a dynamic parameter design for optimization of the test parameters of the HRMS in order to obtain robust test results. The optimal test parameters for SIR testing are: 390 ms test time, 100 V test voltage, 100 V, 15 s charge time, and 100 s pause interval. Further investigation is conducted on the impact of the test parameters on the measurement performance.

1. Introduction

Surface mount technology (SMT) is the most commonly used process for the product of printed circuit board (PCB) assemblies used in many consumer electronics products. In the SMT process, the solder paste deposited on the bonding pad of the PCB provides the interconnection between the electronics component and the board. Solder paste contains flux that helps remove the oxide and other contaminants from the bonding surface. This is critical to ensure effective bonding during the reflow soldering process. Since the trend of PCB design is toward high functional density, the spacing of adjacent conductors on the PCB is becoming increasingly smaller in order to achieve the desired functional density [1]. The presence of flux residue on the PCB surface may decrease the surface insulation resistance (SIR) and/or the electrochemical migration (ECM) may occur (Fig. 1). ECM may cause electrical shorts between conductors, resulting in product failure.

A comb patterned test board with staggered electrodes is used to simulate the PCB during the assembly process (Fig. 2). The solder paste is deposited on the conductor area of the test vehicle. Bias voltage is then applied to the test vehicle in a high temperature and humidity environment for varying periods of time (72, 168, 500 h). A high resistance measuring system (HRMS) is employed to measure the SIR value of the test vehicle and to examine for electrical leakage.

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2. Problem statement

Guidelines for PCB design, manufacturing, and assembly specified by US Association Connection Electronics Industries are widely used in the electronics industry for corresponding SIR/ECM tests. However, the recommended parameter settings are quite different across the various standards. For example, the test standard IPC-TM-650 2.6.3.3 [2] suggests that the SIR test of the PCB should be conducted with a bias voltage of 50 V, a test voltage of 100 V, and in an environment at 85 °C and 85%RH. However, IPC-TM-6502.6.3.7 [2] defines a test condition of 25 V bias, 25 V test voltage, and an environment of 40 °C and 93%RH. In addition to the differing guidelines, parameters such as the measure cycle and the time duration of the test voltage on the test vehicle lack clear definition.

Further, IPC-TM 2.6.3.7 [2] says that the collection of data must be completed within a fixed time interval in order for the reading to be considered valid. Since the test capacity is usually limited, completing the test in the shortest time period possible while considering the effectiveness of the test system has become an important issue. In the SIR/ECM test, the insulation resistance values usually are in the range of 10^9–10^{11} ohms (Ohm). Thus, the desired conditions (bias voltage test, measurement environment) should be effective across the entire impedance range.

Zhan et al. [3] used an IPC-B-25 comb-type test vehicle with different trace spacings and evaluated the effects of the flux chemical composition, spacing between conductors, and bias voltage, on the SIR values. Tests were conducted for various test environments (temperature, humidity, and bias conditions) for long periods of

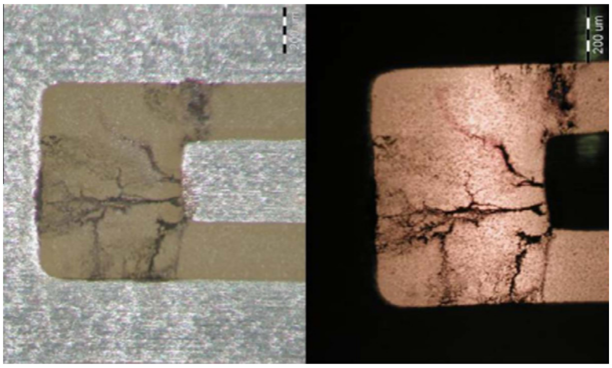

Fig. 1. ECM phenomena.

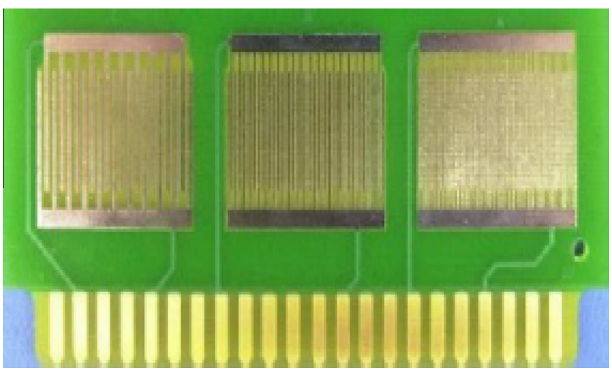

Fig. 2. Comb patterned test board.

time. Medgyes et al. [4] investigated test vehicles with different surface metallurgies under different accelerated stress conditions. Current leakage is used to explain the results, based on the data of mean time between failures (MTBF). These studies primarily focused on the effects of the PCB materials, electronic components, and the characteristics of flux residual on the assembly reliability. However, the test parameters and environmental factors used during SIR/ECM tests may impact the validity of the test results, yet these have not been assessed in previous studies. Chen and Hsiao [5] explain ion migration and dendrite generation with BGA components of fin pitch. After steady and continuous DC bias applied between two solder balls in high temperature and humidity environment for 168 h the anode metal conductor dissociates into metal ions. The latter then moves through electrolyte between both conductors and deposits into dendrite at the cathode conductor. Xu et al. [6] employs lead-free solder 96.5Sn3.0Ag0.5Cu, no-clean flux (NCF), and water-soluble flux (WSF) to weld three PCB specimens respectively for electrochemical migration testing in determining insulation reliability of flux residuals after soldering. He concludes that electrochemical migration can be traced back to cleaning craftsmanship, flux ingredients, solid contents and acidity. He recommends effective flux control measures and removing methods to make the best of flux functions in lead-free soldering technique and improve electric reliability of electronic products.

These SIR/ECM test relevant literature, employing methods commonly adopted around the world which measure specimen impedance with DC voltage. Initial impedance of them may reach 108 Ohm or greater. Take test voltage of 100 V. Current in this case may be 1 μA or lower according to Ohm's Law. Readings of impedance measurement may become more sensitive to ambient factors at smaller current including: whether electromagnetic waves exist in test environment, noises due to metal conductors and operator skills. All these have contributed to poor repeatability of insulation resistance measurements. In case of flux residual dissociation or metal ions electrochemistry migration the impedance measurements may plummet at magnitude of thousands of folds. In case of fluctuating resistance readings, the measurement system must determine timely and accurately as well as identify SIR drop and ECM in PCB effectively.

3. Research objectives

The objectives of this study are:

(1) High resistance measurement suffers from few research studies and so cannot compare its performance and contribution. This study employs high resistance for PCB surface insulation resistance measurement aiming at ensuring product compliance with safety test requirements by identifying residuals of flux or other chemicals on PCB surfaces that may hamper electronic components features.
(2) The use of a systematic approach to determine the optimal SIR/ECM test parameters such as test time and test voltage supplied. This helps to ensure the repeatability and accuracy of the test results.
(3) While the small current measured in the SIR/ECM test is sensitive to the test environment, the influences of electromagnetic waves, the metal conductor, and the operator are verified across the entire impedance range that may occur during the test.
(4) To verify that the HRMS has sufficient capability to effectively identify rapid changes in SIR and the ECM phenomenon when the ionization of flux residue and the electrochemical migration of metal ion occur.
(5) This study determines the system's maximum testing capacity using the optimal test parameters while complying with the valid reading as specified by the industry standard. We also investigate the impact on the validity of reading when non-optimal test parameters are used to cope with additional test loadings.

4. Test principle of high resistance measuring system

The major components of the HRMS include: (1) high resistance meter (Agilent 4339B) to measure the PCB's impedance value; (2) Armature multiplexer (Agilent 34922A) to distribute the single channel to multiple channels through the channel switch for successive measurements of multiple samples; (3) power supply to provide bias voltage to the test sample; and (4) multifunction switch/measure (Agilent 34980A) to control the Armature multiplexer and send the recorded data to the computer for further analysis [7,8].

The two steps of the high resistance measurement procedures are described below. Step 1: the power supply provides bias voltage to the test sample. The circuitry with the high resistance meter and the test sample remains at 'open circuit' at this time (Fig. 3a). Step 2: As the test begins, the abovementioned circuitry switches to 'closed circuit', and the high resistance meter provides test voltage to the sample. The corresponding impedance is determined according to the measured current and forwarded to the multi-function switch/measure unit for further analysis by the computer. The circuitry with the bias voltage and test sample remains 'open circuit' at this time, meaning that the reading is not affected by the bias voltage (Fig. 3b).