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Colorimetric visualization of tin corrosion: A method for early stage corrosion detection on printed circuit boards

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ABSTRACT

A majority of printed circuit board surfaces are covered with tin, therefore tin corrosion under humid conditions and movement of tin ions under the influence of an electric field plays an important role in the corrosion failure development. Tracking tin corrosion products spread on the printed circuit board assembly (PCBA) provides a basis for the mechanistic understanding of PCBA corrosion failures and leak current tracks which eventually can lead to electrochemical migration. This paper presents a method for identification of such failures at the early stage of corrosion by using a colorimetric tin ion indicator applied as a gel. The examples provided in this paper include visualization of corrosion caused by weak organic acids found in solder fluxes, corrosion profiling on the PCBAs after climatic device level testing, and failure analysis of field returns.

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1. Introduction

The reliability of electronics can be compromised by the presence of contamination on the printed circuit board assembly (PCBA) and humidity exposure during its service life [1]. Corrosion of PCBA involves local humidity build-up and formation of water layer containing ionic residues connecting metallic parts on multiple components and metallic tracks. The driving force for corrosion is usually the applied potential bias. Unlike conventional corrosion of a single surface, water layer formation and electrochemical corrosion process on the PCBA cause an interaction between components by the movement of corrosion products across the board to nearby points due to the electric field acting through the water layer. In terms of functionality of the PCBA, this represents leak current which subsequently leads to electrochemical migration failures. Tracing such leak current tracks and movement of corrosion products by visual examination is difficult due to the lower levels of corrosion products and masking effects.

Climatic testing of electronics is a part of product optimization and verification process. The climatic testing can be performed either on the actual device by exposing electronics to severe conditions expected in a user environment, or using standardized test boards under well-defined climatic profile. The IPC-TM-650 manual describes various standardized test methods for improving the reliability of electronics. For example, the corrosive effects of soldering fluxes can be assessed by methods such as surface insulation resistance (SIR) (method 2.6.3.3) [2], electrochemical migration (method 2.6.14.1) [3], corrosion (method 2.6.15) [4], and copper mirror test (method 2.3.32) [5]. During life in service and device level testing, the intermittent failures and faults are common under humid and condensing conditions; however, the detection of such failures is more difficult once the surface of the PCBA dries and the functionality of the device partly recovers. Mostly such failures in the field are reported as 'no-fault-found' [6,7].

The majority of the PCBA surface is covered by tin (Sn) or tin-based alloys such as boards with hot air solder leveled (HASL) surface finish, and use of tin-based alloys for soldering and as a surface finish for contacts. In the case of tin corrosion in presence of high humidity, the precipitation of tin hydroxides can be seen; however, the appearance of tin hydroxides is similar to that of flux residues introduced by soldering processes. Therefore, identifying precipitation of tin corrosion products on the PCBA surface is an important part of understanding the susceptibility of a PCBA design to corrosion as a result of exposed climate conditions.

The aim of this paper is to demonstrate a method for tracing tin corrosion even at tiny levels on the PCBA surface. The method consists of the use of a colorimetric tin ion indicator in the form of a gel and application of the gel on the PCBA for corrosion inspection. The paper illustrates examples of gel application on standardized test boards and on device PCBAs. The detection of tin corrosion in its early stage reveals regions of PCBA most susceptible to failures due to humidity exposure. If combined with accelerated testing, such information would provide useful input for design modifications or taking remedial measures.

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2. Materials and methods

2.1. Climatic exposure tests

An "Espec PL-3KPH" climatic chamber with the specified accuracy of ±0.3 °C/±2.5% RH was used for climatic exposure tests. Climatic testing was carried out on the test boards with well-defined amounts of ionic residues, and on device PCBAs with contamination levels naturally present from the manufacturing processes. After climatic testing, all the boards were tested for the occurrence of tin corrosion using a gel with tin ion indicator. The temperature/humidity conditions used for specific testing are provided in the corresponding sections of Results and discussion.

2.2. PCBAs used for analysis

2.2.1. Test PCBA

Visualization of tin corrosion using tin ion indicator in a gel was performed on the standardized test boards with known surface mount components and SIR comb pattern, and on the actual device PCBAs. The test board contains chip capacitors and chip resistors connected in parallel in rows of 10 components, and two SIR patterns. The surface finish of the SIR pattern was HASL with SN100C solder alloy. The dimensions of SIR pattern were 13 × 25 mm, while the width of conducting lines and the distance between them were 0.3 mm. The geometry related nominal square count of the SIR pattern was 1476. A detailed description of the test board can be found elsewhere [8].

2.2.2. Device PCBAs

A set of results was obtained on actual device PCBAs. The detailed information about the device type, application or electrical functionality is not provided here; however, all the devices which were tested are designed to operate under high humidity conditions typically seen in outdoor applications. The PCBAs are without a conformal coating or potting, thus the climatic reliability of devices greatly relies on the design of electronic enclosures. However, in this paper, the main focus was on the corrosion reliability of PCBA itself, thus the actual testing was performed without electronic enclosures.

2.3. Precontamination of the test boards

For the investigations carried out on the test PCBAs, the precontamination of surface mount components and SIR comb patterns was done by dispensing a defined volume of weak organic acids (WOAs) dissolved at 10 g/L in isopropyl alcohol solution. The WOAs namely adipic, succinic, glutaric, DL-malic, and palmitic, were used for investigation, and the selected acids are representing the contamination from WOA based soldering fluxes. For the application of the WOAs, the ratio between surface area and volume was fixed, so that the resulting contamination of WOAs on the surface was 100 μg/cm^2. For a set of experiments performed on a device PCBA, the precontamination with

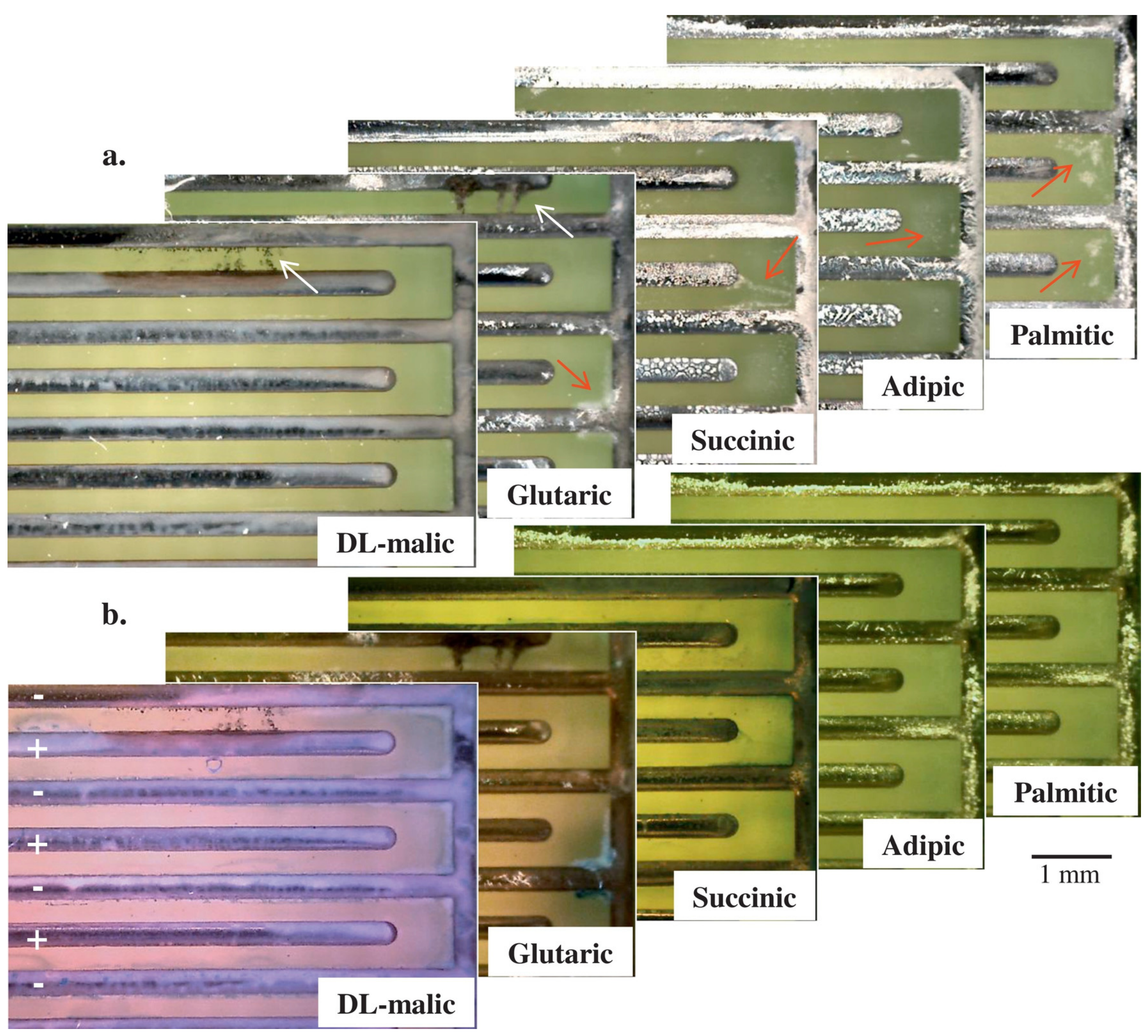

Fig. 1. Optical micrographs of SIR patterns contaminated with different WOAs: a. after humidity testing and b. followed by applying tin ion indicator gel (white arrows indicate tin dendrites, red arrows indicate locations with white residues). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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