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Failure Analysis of Solder Joint on A Single Sided Printed Circuit Board (PCB)

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Abstract: This study mainly focuses on the investigation of the corrosion effect by different concentration of corrosion agent on the single-sided printed circuit board surface. The objectives of this study were to measure the change of the voltage, current and resistance that lead to the failure by a corrosion product on a single-sided printed circuit board (PCB) surface. For a corrosion test experiment on the PCBs solder joint, various concentration of sodium chloride (NaCl) (0.5M, 1.0M, 2.0M) was used as corrosion agent solution. All sample was then immersed in all concentration of solution within 21 days. The corrosion effect for all sample was assess based on a comparison of voltage, current and resistance magnitude between pre and post immersed. Overall, on a single-sided printed circuit board, the corrosion product (solder) formed on all sample surface. It was found that there are gradually change of all measurement parameter. As the concentration of corrosion agent increase, both of voltage and current values are gradually reduce while the resistance gradually increased. A longer period of immersion test, would shows that the formation of corrosion layer is rapidly increase as the corrosion agent solution concentration increase. In this scenario, corrosion product can cause the malfunction of the microelectronics components due to the higher likelihood and factors that can cause the printed circuit board to corrode easily.

Keywords: Failure Analysis, Solder Joint, Single-Sided PCB

1. Introduction

Corrosion of electronic systems has become a major problem in the electronic industry recently. One factor limiting the corrosion reliability is the variety of materials used [1]. Another factor that has made it simpler for components to interact in corrosive environments is the shrinking of the space between components on a printed circuit board (PCB) as a result of device miniaturisation. There is currently very little knowledge available regarding electronics corrosion issues [2]. The demand for reliability has increased concurrently with increased use of electronics. Serious corrosion issues have

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been caused by the demand for miniaturisation, the variety of materials used, the impact of process residues, and the unpredictable user environment [3].

The development of printed circuit boards is regarded as being of utmost importance in the field of microelectronics. An electronic system's core is made up of the board and its parts [4]. All of the crucial parts of a design must be held and connected by PCBs in order to create a small, sturdy package that can be produced. This indicates that today's printed circuit boards are extremely important to every electronic device [5]. The corrosion that develops on printed circuit boards has never stopped, and in recent years, it has even gotten worse. Humidity, metals and alloys, temperature, and potential bias are a few factors that cause PCB to corrode [6][7].

The initial reason for investigating corrosion was to learn more about either different concentration of corrosion agent could affect the reliability of the single-sided printed circuit board. It is intended that through examining the subject in depth, a better understanding of corrosion types and their effects would be gained. Since electronic devices becomes smaller and smaller, they are also becoming increasingly vulnerable to all kinds of contaminations. Especially the identification of contaminations which are often at microscopical scale is of particular interest as they can lead to malfunction of the electronic device [8]. Knowledge about the chemical, physical and electrical properties will in most cases reveals the origin of the contamination and therefore allows effective troubleshooting [9].

The aim of this research was to investigate the change of voltage, current and resistance by a formation of corrosion product on a single-sided printed circuit board (PCB). Here, the corrosion experiment for PCBs solder joint was conducted by using various sodium chloride (NaCl) concentration (0.5M, 1.0M, 2.0M) and a comparison of voltage, current and resistance between pre and post immersed is performed. The characterization of electrical properties (voltage, current and resistance) and corroded surface morphology have been characterized using conventional digital multi meter measurement method and Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (SEM-EDX).

2. Materials and Methods

In this work, the single sided PCB was immersed using three different concentration NaCl with a concentration of 0.5M, 1.0M and 2.0 M. Each PCB samples were immersed in these solutions within 21 days. As the immersion process is completed, all samples were characterized on its solder joint spot using Scanning Electron Microscopy that facilitated Energy Dispersive X-Ray Spectroscopy (SEM-EDX). Later, the values for its resistance, current and voltage for the solder joint on each PCB surface were recorded using digital multimeter and all data were compared between pre and post immersion. The potential across the circuit is 6 V by the power supply.

3. Results and Discussions

3.1 The measurement of voltage, current and resistance for pre and post corrosion agent solution (NaCl) immersion.

In this work, the measurement of voltage, current and resistance for the solder joint under all corrosion agent solution concentration (0.5M, 1.0M and 2.0M) are calculated using Ohm’s Law with the equation of V=IR. The result of these measurement for pre and post corrosion agent immersion are tabulated in Table 1.

Table 1: The measurement of voltage, current and resistance for pre and post immersed by different concentration of corrosion agent solution (NaCl).

Concentration (M)	Pre			Post		
	Voltage (V)	Re.sistance (Ω)	Current (A)	Voltage (V)	Resistance (Ω)	Current (A)
0.5	5.414	470 Ω	114×10^{-4}	4.021	477.8	8.5×10^{-3}
1.0	5.414	470 Ω	114×10^{-4}	3.291	479.2	6.9×10^{-3}
2.0	5.414	470 Ω	114×10^{-4}	2.198	481.9	4.6×10^{-3}

Based on Table 1, for the pre corrosion, the voltage, current and resistance were initially with constant value of 5.414 V, 470 Ω and 114×10^{-4}A. As the sample is immersed in 0.5M solution, the voltage slightly dropped from 5.414 V to 4.021 V. Further high concentration of 1.0M, the voltage decreased from 5.414 V to 3.291 V and it continue for 2.0M, where the voltage dropped out from 5.414 V to 2.198 V. For 2.0M, the resistance value for post corrosion shows the highest value of 481.9 Ω compared to concentration 1.0M and 0.5M which is 479.2 Ω and 477.8 Ω. From this data, the trend shows that increasing concentration of NaCl will increase the value of resistance reading respectively. The reduction of the voltage as the concentration increase could indicate that there is a formation of semi-conduction layer of the corroded area on the solder joint area.

3.2 Elemental composition analysis using SEM-EDX

According to the EDX study, the solder joint surface is mainly covered by Pb and Sn. As the sample is immersed in the corrosion agent solution using a concentration of 0.5M, 1.0M and 2.0M, it can be clearly seen that the solder joint surface is not only covered by Pb and Sn but there are some other trace elements appeared.

Table 2: Results for element composition pre and post corrosion

Element	Weight %	Weight %		
	Before corrosion	0.5M	1.0M	2.0M
Sn	74.06	21.65	39.42	41.91
Pb	25.94	31.89	26.31	22.41
Cl	0.0	3.09	16.87	13.30
O	0.0	18.34	12.34	15.85
Na	0.0	1.07	0.00	0.00
Fe	0.0	0.00	0.00	0.64

As shown in the Table 2, the element composition of the sample before immersion test shows that only two elements existed which is Sn and Pb. This is because no immersion test was conducted, and no corroded area were diagnosed around the soldering joint. This table also shows that the percentage amount of Sn over than the percentage amount of Pb that naturally PCB had which is 74.06 percent for Sn element and 25.94 percent for Pb element. However, for this 2.0M NaCl immersion test, there was some amount of Fe element that existed. This could be due to a removeable of Pb and Sn layer by the oxidation process and revealed the Fe layer underneath of the Pb-Sn layer.

3.3 Surface morphology and elemental composition analysis of the corrosion product for pre and post immersion using SEM-EDX.

Using a high-energy electron beam to scan the surface of the sample in a raster scan pattern, SEM images of the solder for pre and post immersion testing in a NaCl solution corrosion agent are shown in Figure 3.1. As shown in Figure 3.1(a), the image of pure soldering Pb and Sn structure as clean surface. Meanwhile Figure 3.1(b) exhibited rusted and rough surface as the sample is immersed in 0.5M concentration of NaCl. As the concentration increase at 1.0M of NaCl solution, the surface turn to be much finer and homogeneous surface as shown in Figure 3.1(c). At the highest concentration of 2.0M, the surface turn to be more heterogenous and cover by some porous area. This indicate that there are a gradually change of the joint solder surface as the concentration of NaCl increase. The change of these surfaces is due to the oxidation process occurred between Pb and Sn with the ionic liquid of NaCl. This layer is mainly cover by a corroded surface that act as semi-conductor layer that reduce the value of current and voltage on the solder joint of the PCB.

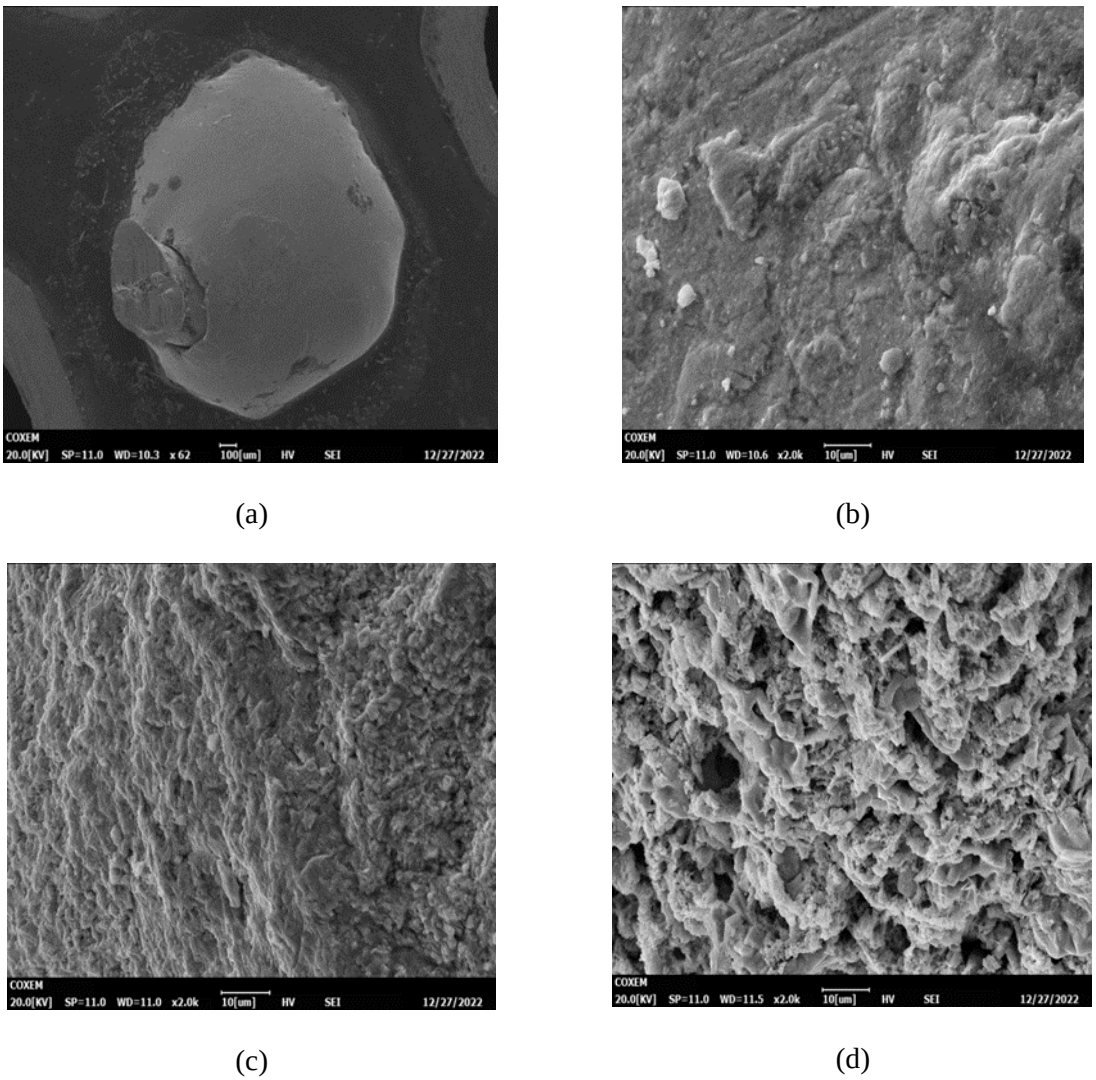

Figure 3.1: SEM imaging analysis of sample surface for (a) pure soldering Pb and Sn structure as clean structure, (b) 0.5M concentration of NaCl (c) 1.0M concentration of NaCl solution and (d) 2.0M concentration of NaCl solution.

4. Conclusions

In this study, the failure analysis of a corrosion product (solder) on a single sided printed circuit board has been performed. From the immersion test using corrosion agent liquid (NaCl) with a

concentration of 0.5M, 1.0M and 2.0 M, it shows that the formation of corroded surface at the solder joint of the PCB is increase as the concentration of corrosion agent increase as the solder joint is covered by this corrosion product, it makes reduce the electrical conductivity of this solder joint and could make the malfunction of the microelectronics components.

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