Case Study of Printed Circuit Board Corrosion and Countermeasures

Abstract

This article presents a case study of corrosion on a printed circuit board in an optical network unit operating in a hot-spring area and the results of investigating countermeasures to that corrosion.

1. Introduction

Optical network units (ONUs) are telecommunications devices installed in customers' homes to receive optical broadband services. ONU failure is frequently reported by customers living in hot-spring areas. Photographs of a printed circuit board (PCB) in a failed ONU are shown in **Figs. 1** and **2**. Figure 1 shows thru-holes (gold-plated copper) that have been corroded: a gray-colored corrosion product is visible. Figure 2 shows a place where the corrosion product has made contact with a neighboring wiring pattern (indicated by the arrow), creating a short circuit. It was inferred that this short was the cause of the ONU failure. The results of an X-ray analysis of the corrosion product are shown in **Table 1**. The corrosion products were mainly composed of copper, oxygen, and sulfur. This result suggests that copper on the board reacted with moisture and hydrogen sulfide in the atmosphere to form an oxide (copper oxide) and sulfide (copper sulfide). The hydrogen sulfide concentration in the user's home ranged between 0.05 ppm and 0.45 ppm (parts per million), which is a high concentration several tens to several hundreds times that of a normal environment.

2. Morphology of corrosion

The morphology of the corrosion is shown in Figs. 1 and 2. Corrosion of this type is called sulfide creep. In this phenomenon, a corrosion product (sulfide) of metals such as copper or silver spreads over the surfaces of metals that do not form sulfides, such as tin and gold. Sulfide creep is known as a major factor in

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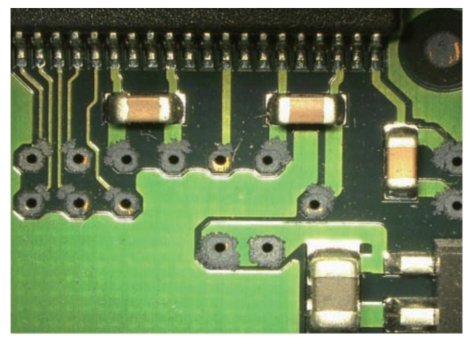

Fig. 1. Image of PCB in the failed ONU.

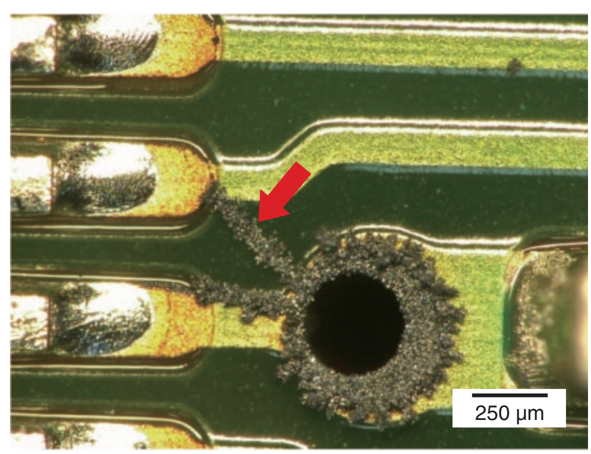

Fig. 2. Another image of PCB in the failed ONU.

Table 1. Composition of the corrosion product.

	Copper	Oxygen	Sulfur	Chlorine
Composition (wt%)	49	35	15	0.2

Table 2. Type, applications, and thickness of coating materials studied.

Coating material	Type	Applications	Thickness (this study)
A	Polyvinyl	Power meters, traffic lights, PCBs in vehicles, etc.	20–35 μm
B	Fluorine resin	Mobile phones etc.	60–150 μm
C	Polyurethane	Automobile control boards	40–90 μm

Table 3. Change in insulation resistance of interdigitated array electrodes treated with coating material (before and after exposure test).

Coating material	Insulation resistance before exposure (average value)	Insulation resistance after exposure (average value)
A	2.5×10^{11} Ω	2.6×10^{11} Ω
B	4.5×10^{12} Ω	2.6×10^{12} Ω
C	3.3×10^{12} Ω	1.6×10^{12} Ω

the deterioration of small, gold- or tin-plated contact points or terminals. It can easily occur in environments in which there is a high concentration of hydrogen sulfide, such as regions having sulfurous hot-springs, and it has been implicated in reduced lifespans of not only telecommunications equipment but also electrical products such as home appliances used in hot-spring areas.

3. Investigation of countermeasures

Various measures can be considered to tackle corrosion caused by hydrogen sulfide such as improving the environment by installing desulfurizing equipment or relocating vulnerable equipment to a location having a low concentration of hydrogen sulfide. In the case study presented here, the installation environment was not a room but an open area, and equipment relocation would have been difficult. For these reasons, a study was performed to prevent the corrosion on PCBs by applying a coating material.

4. Study of coating materials

Three types of coating materials for application to PCBs were studied taking into account their previous use in industry, as summarized in **Table 2**. The anti-corrosive properties of these materials were tested by fabricating copper interdigitated array electrodes, preparing samples by coating those electrodes with the three types of coating materials, and exposing the samples to hydrogen sulfide. This exposure test was performed for 260 hours in an environment having a hydrogen-sulfide concentration of 10 ppm, temperature of 40°C, and relative humidity of 70%. The samples were then visually inspected and the electrodes were checked for changes in their insulation resistance. The visual inspection did not reveal any corrosion for any of the coating materials, indicating that each had good anti-corrosive properties. In addition, no significant changes in the insulation resistance of the electrodes were found in any case (**Table 3**).

5. Concluding remarks

A study was performed on coating materials to prevent corrosion on PCBs caused by hydrogen sulfide in the atmosphere. Accelerated testing in a laboratory environment revealed that the coating materials studied had good anti-corrosive properties. We are planning to test these materials under actual field conditions. NTT telecommunications equipment is installed in a wide variety of environments, and the electronic components and devices used in it are increasingly being made smaller and more compact. This trend indicates a rising risk of equipment failure, which necessitates appropriate corrosion-protection measures. NTT EAST will continue to investigate countermeasures to corrosion to achieve higher levels of reliability in information and communications technology services.