Reliability Evaluation of Anti-Corrosion Printed Circuit Board (PCB) Coating

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Keywords Small diameter through-hole, Simulating circuit board, Gas corrosion acceleration test, Corrosion fatigue life

Abstract

In industrial fields of electronic products for power generation and substation facilities, we have supplied highly reliable and corrosion-resistant products for customers who operate under corrosive environments including hydrogen sulfide. As a corrosion-proof measure, a resin coating treatment is applicable to Printed Circuit Boards (PCBs) that are core elements of electronic equipment. Using a simulated circuit board as a small diameter through-hole model, we have derived a corrosion-resistant lifetime expression through quantitative evaluation of uncoated and coated simulating circuit boards against hydrogen sulfide. As a result of establishing this evaluation method, we can select the most suitable coating material considering installation conditions and can therefore, offer more reliable products to our customers.

1 Preface

For various customers who operate under different operating conditions, we have supplied various products such as power generation and substation facilities, electronic equipment, and IT products. Especially, when our products are used at sewage water treatment plants, paper mills, and yarn-making mills, there are instances in which products are installed with an atmospheric condition of hydrogen sulfide. As such, we have been working on a proactive measure against corrosion-related failures by taking various anti-corrosive preventive measures.

As one corrosion-proof measure, we apply a coating material on the surface of Printed Circuit Board (PCB). Based on such factors as product specifications on the processes of manufacturing and maintenance, we select and use several types of suitable coating materials. In the selection process, however, it is necessary to exactly define the selection standard for the coating material against corrosive gases and ambient temperatures which can be accelerating corrosive factors. In this paper, identifying hydrogen sulfide concentration and ambient temperature as accelerating factors of corrosion, we established a method of product life calculation. The following is an outline of the method of product life calculation.

2 Testing Method

2.1 Simulated Circuit Board

In order to evaluate a coating level of corrosion-resistance, we made a simulating circuit board with small diameter through-holes serially combined, which are vital parts for anti-corrosion. There are two diameters of each small diameter through-hole: 0.3mm and 0.15mm. For each diameter, 370 holes were connected in series. At the time of material selection for these small diameter through-holes, a preliminary corrosion acceleration test was carried out by using hydrogen sulfide. The selected materials were lead-free solder, eutectic solder, gold flashing, and copper. Succeeding this preliminary testing, the relative lifetime was evaluated and adopted a copper material since it has the lowest corrosion-resistant material lifetime.

2.2 Coating Agent

Four types of coating materials were evaluated. There were two types of acrylic materials and both types of urethane and silicone materials are commercially available. Each coating material was uniformly applied to both the front and rear surfaces of the small diameter through-holes of the simulating circuit board. The thickness of the coating agent film was adjusted to keep the thickness of the film constant.

2.3 Gas Corrosion Acceleration Test

Fig. 1 shows the gas corrosion acceleration test equipment. In regard to the testing conditions, the concentration of hydrogen sulfide and temperature was defined as the acceleration factors less than 80% humidity. All of the five adopted conditions are shown in Table 1.

Fig. 2 shows the electrification test performed in the gas corrosion acceleration test equipment. For each simulating circuit board, anti-corrosion lifetime was measured by using an electrification testing approach. The test voltage was applied to both terminals of wiring for small diameter through-hole connections. The resistance changing time, which is attributable to corrosion in small diameter through-hole connections caused by hydrogen sulfide, was always monitored with a data logger. The corrosion-resistant lifetime of simulating circuit boards was defined as the time when the resistance value of wiring for small diameter through-hole connections had attained twice the initial value.

Fig. 1 Gas Corrosion Acceleration Test Equipment

This shows the equipment for a gas corrosion acceleration test under high temperatures to evaluate simulating circuit boards. In an atmosphere of corrosive gases, it is possible to perform high-temperature and high-humidity testing-up to the maximum temperature of 85℃.

Table 1 Conditions for Gas Corrosion Acceleration Test

We fixed the condition for the gas corrosion acceleration test at the relative humidity in the tank at 80% and we used following five conditions of internal tank temperatures and hydrogen sulfide concentration as the acceleration parameters.

Testing conditions	Temperature (℃)	Humidity (%)	Hydrogen sulfide concentration (ppm)
①	85	80	100
②	85	80	10
③	85	80	1
④	65	80	100
⑤	50	80	100

2.4 Test Results

Fig. 3 shows the relationship between corrosion-resistant lifetime and temperature. Fig. 4 shows the relationship between corrosion-resistant lifetime and hydrogen sulfide concentration. For both uncoated and coated simulating circuit boards, the corrosion-resistant lifetime can be logarithmically approximated in terms of temperature and hydrogen sulfide concentration and we confirmed that it showed corrosion acceleration. In addition, compared with uncoated simulating circuit boards, it

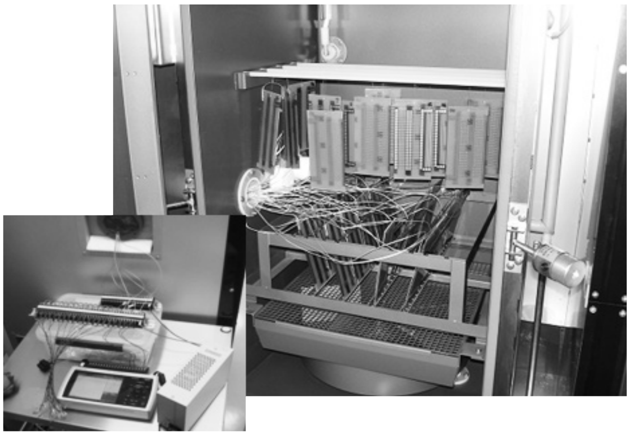

Fig. 2 Situation of Charging Test in Gas Corrosion Acceleration Test Equipment

A DC voltage was applied to small diameter through-holes connected in series. Time consumed to attain corrosion was measured in real-time.

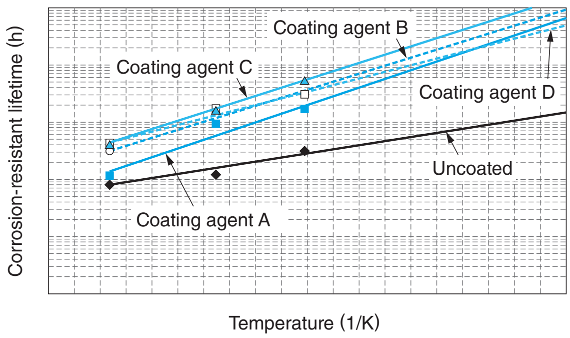

Fig. 3 Relationship between Corrosion-Resistant Lifetime and Temperature

Both uncoated and coated simulating circuit boards have a proportional relationship between corrosion-resistant lifetime and the inverse of temperature and log approximation is possible. Since coated simulating circuit boards show a larger gradient (acceleration rate) compared with uncoated simulating circuit boards, the coated simulating circuit boards are considered to have a longer corrosion-resistant lifetime.

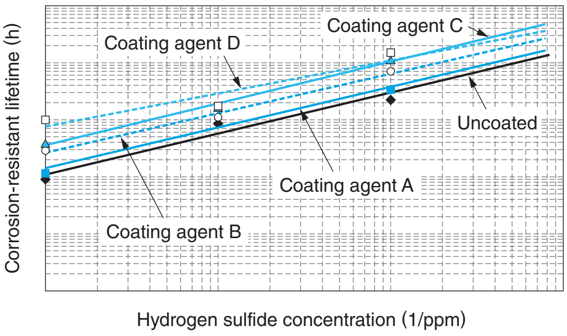

Fig. 4 **Relationship between Corrosion-Resistant Lifetime and Hydrogen Sulfide Concentration**

Both uncoated and coated simulating circuit boards have a proportional relationship between corrosion-resistant lifetime and an inverse of gas concentration; log approximation is possible. Since the coated simulating circuit boards show a similar gradient but a greater intercept compared with uncoated simulating circuit boards, the coated simulating circuit boards are considered to have a longer corrosion-resistant lifetime.

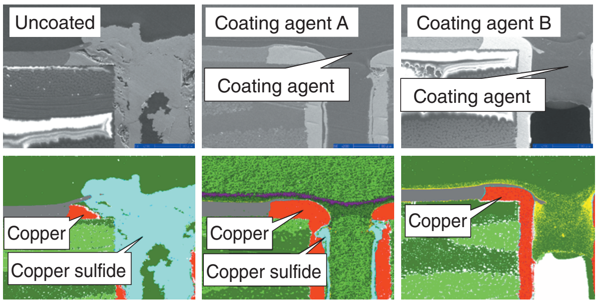

Fig. 5 **Appearances of Small Diameter Through-Holes Observed soon after Acceleration Corrosion Test under Hydrogen Sulfide**

Images of the electron microscope and element mapping images are shown in the upper section. For uncoated boards, copper sulfide generated as a result of corrosion shows its remarkable bulging from the inside. Conversely, coated boards show that the progression of corrosion has been remarkably suppressed.

became clear that any coated simulating circuit board showed an extremely high corrosion-resistant property against temperatures and hydrogen sulfide concentration.

Fig. 5 shows the appearances of small diameter through-holes observed soon after the accelerated corrosion test under hydrogen sulfide. In the case of an uncoated simulating circuit board, through-holes were corroded by hydrogen sulfide and copper sulfide was generated as a result. We confirmed where there was an extreme protrusion from the inside. Conversely, the coated simulating circuit board showed an effective suppression of corrosion around the opening of the small diameter through-holes.

Based on the Eyring model, we made approximation (temperature and lifetime expression $L_1(h) = f(c)$, hydrogen sulfide gas concentration and lifetime expression $L_2(h) = u(t)$) for corrosion resistant lifetime against temperatures and hydrogen sulfide concentration. The data are presented in **Fig. 3** and **Fig. 4** and we derived the lifetime Expression (1).

$$L(h) = A \times f(c) \times u(t) \cdots\cdots\cdots (1)$$

where, A = coefficient, c = hydrogen sulfide concentration (ppm), t = temperature (℃), and h = time

According to the aforementioned lifetime expression, the corrosion-resistant lifetime of various coated simulating circuit boards was quantified against the small diameter through-holes at various environmental temperatures in an atmosphere of hydrogen sulfide.

3 Postscript

This paper introduces our activities of corrosion-resistant lifetime calculation of various coated simulating circuit boards based on a model of small diameter through-holes in printed circuit boards. These were analyzed in an atmosphere of hydrogen sulfide. This approach is also applicable to the evaluation of influence by environmental factors such as corrosive gases of sulfurous acid and nitrogen dioxide. We will further perform pre-installation site surveys of installation environments and offer highly reliable products against an atmosphere containing corrosive gases so that the survey data feedback may be used in our stage of product design.