Research of environmental factors on SCB electrode plug corrosion

F Li, R Zhang, D X Fu, Zh H Du and H L Ma

Science and Technology on Applied Physical Chemistry Laboratory, Shaanxi Applied Physics-Chemistry Research Institute, Xi’an 710061, Shaanxi, China

Abstract: The accelerated life test of SCB electrode plugs under different environmental stresses is designed and the test results are analyzed. The results show that single temperature stress will not cause corrosion of SCB electrode plug. Temperature and humidity stress will cause slow corrosion of SCB electrode plug. If chloride ion is introduced in the environment where temperature and humidity exist, it will lead to rapid corrosion of SCB electrode plug. At the same time, the relationship between the resistance and the corrosion degree of the SCB electrode plug bridge area and solder joint shows that the deeper the corrosion degree of the bridge area and the solder joint, the larger the resistance value of the SCB electrode plug.

1. Introduction

Semiconductor bridge (SCB) pyrotechnics is a new type of pyrotechnics that has been continuously developed in recent years. It uses a semiconductor film (or metal-semiconductor composite film) as a Fire element for ignition and detonation [1,2]. SCB pyrotechnics, using SCB as a transducing component and adopting plasma ignition mechanism, has the characteristics of low ignition energy, short acting time, good safety, etc., and has certain antistatic and radio frequency resistance. It is becoming one of the representatives of the third generation of pyrotechnics [3]. SCB pyrotechnics have broad application prospects in various fields such as conventional and intelligent ammunition, aerospace equipment, and civil explosive equipment.

As a new type of pyrotechnics, the storage failure mechanism of SCB pyrotechnics is a problem that should be paid attention to by researchers in this field. A foreign research report pointed out [4] that the corrosion of SCB weld zone was found in the improved batch of semiconductor bridge detonator and igniter. According to the analysis, the corrosion may be caused by the combination of chloride and humidity contained in the bonding agent of the soldering wire, and it is observed that the resistance of the corroded SCB is about 1 ohm higher than the normal uncorroded resistance. However, the resistance was not measured before the thermal cycle,
therefore, it was not determined whether the change in the resistance was caused by corrosion after thermal cycling. After the short-term environmental test using the gold-plated SCB, the report concluded that when the aluminum layer of the SCB device is covered with a porous gold layer, if both moisture and chloride are present at the same time, corrosion is likely to occur, the degree of corrosion is related to Chloride content, corrosion does not occur only when wet. In order to study the storage failure mode and mechanism of SCB pyrotechnics, the accelerated life test of SCB electrode plugs under different environmental factors was designed to study the corrosion effects of SCB bridges and solder joints under different environmental factors. The research results are very meaningful for the design of SCB pyrotechnics production conditions or storage environment to improve the storage reliability.

2. Test Design of Corrosion Effect of SCB Electrode Plug

The SCB chip is a SCB pyrotechnic transducer, which is a key component of SCB pyrotechnics. Its structure and performance directly affect the ignition performance of SCB pyrotechnics. In this paper, the electrode plug embedded in the SCB chip was selected as the research object, and the sensitivity of the SCB pyrotechnics to the environment of temperature, humidity-humidity and introduction of Chlorine-containing ingredients under temperature-humidity was investigated.

In this paper, the accelerated life test of SCB electrode plugs at 71 °C-50%RH conditions, 80°C-95%RH conditions and 80 °C-95%RH conditions with Chlorine-containing ingredients was designed. The design of the Chlorine-containing ingredients was mainly to investigate the influence of the introduction of Chlorine-containing ingredients on the failure mode of the SCB electrode plug by the human sweat contact with the SCB electrode plug. The test plan for measuring resistance, morphology and component analysis was carried out according to sampling every 14 days.

| Serial number | Test conditions                           | Sampling time                             | test project                                      |
|---------------|------------------------------------------|-------------------------------------------|--------------------------------------------------|
| 1             | 71°C-50%RH                               | Sample test every 14 days, total 98 days  | Resistance, electron microscopy, energy spectrum |
| 2             | 80°C-95%RH                               | Sample test every 14 days, total 70 days  | Resistance, electron microscopy, energy spectrum |
| 3             | 80°C-95%RH, Chlorine-containing ingredients | Sample test every 14 days, total 56 days  | Resistance, electron microscopy, energy spectrum |

Table 1. Corrosion effect test scheme of SCB electrode plugs.
3. Test results and analysis

3.1. Test results and analysis under single temperature stress conditions

Figure 1 and table 2 show the changes in the morphology and resistance test of the SCB bridge area before storage and 4 months after storage at 71 °C-50%. It can be seen from figure 1 that the surface of the SCB bridge and the weld zone after storage is smooth and free from any corrosion. The resistance test results in table 2 also showed that the resistance did not change significantly before and after storage. It shows that short-term storage under single temperature stress has little effect on the performance of SCB electrode plug.

![Bridge zone surface change before storage and after storage.](image)

(a) Bridge zone surface change before storage and after storage.

![Soldering zone surface change before storage and after storage.](image)

(b) Soldering zone surface change before storage and after storage.

**Figure 1.** SCB electrode plugs surface change before storage and after storage.

**Table 2.** Resistance test result after different storage time.

| Storage time /d | 0   | 14  | 28  | 42  | 56  | 70  | 84  | 98  |
|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Resistance mean /Ω | 1.11| 1.1 | 1.11| 1.12| 1.11| 1.12| 1.12| 1.12|

3.2. Test results and analysis under temperature-humidity conditions

Table 3 shows the test results of the average resistance of the SCB electrode plugs during storage at 80°C -95%RH. Figure 2 shows the topography of the foot line.
Table 3. Resistance test result after different storage time.

| Storage time /d | 0   | 14  | 28  | 42  | 56  | 70  |
|-----------------|-----|-----|-----|-----|-----|-----|
| Resistance mean /Ω | 1.08| 1.06| 1.07| 1.11| 1.11| 1.22|

Figure 2. Leading wire Surface change before storage and after storage.

It can be seen from Table 3 that the resistance change at the initial stage of storage is not significant after storage at 80℃ -95%RH conditions. After 28 days of storage, the resistance has a slight tendency to become larger. Analyze the cause, and the degree of corrosion of the foot line is gradually accelerated under the action of temperature-humidity. And in the single-shot resistance test, the resistance value of the No. 9 SCB electrode plug was sharply increased from 1.17 Ω to 3 Ω during the 56-70 day storage period.

Scanning electron microscopy and energy spectrum analysis were performed on the No. 9 SCB electrode plug with resistance sharp increase and the No. 10 electrode plug with a slightly increased resistance. The result is shown in figure. 3, the electrode plug of No. 9 showed significant corrosion in the solder joint and the bridge portion. There is no change in the No. 10 electrode bridge area where the resistance changes slightly, but the solder joint portion has slightly corroded, as shown in figure. 4.

Figure 3. No.9 bridge zone and Soldering zone corrode situation.
Component analysis was performed on the corrosion and uncorroded points of the No.9 and No.10 electrode plugs. The results show that some of the corrosion points have not detected chloride ions, and some of the corrosion points have detected chloride ions, but the content is very low, about 0.2%. There is almost no chloride ion in the place where it is not corroded. It is indicated that the main cause of corrosion in the temperature-humidity environment is the effect of humidity, but a small amount of chloride ions may also accelerate. Figure 5 and Table 4 show the energy spectrum test results for the corrosion point of the No.9 sample bridge.

Table 4. Element content of No.10 different test point.

| Element content /% | C     | O     | Mg    | Al    | Si    | Cl    | Ca    | Total |
|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Spectral 1         | 26.64 | 30.51 | 0.59  | 6.84  | 34.90 | 0.19  | 0.33  | 100.00|
| Spectral 5         | 24.57 | 21.44 | 0.38  | 2.94  | 50.68 | 100.00|

3.3. Test results and analysis under temperature-humidity and chlorine-containing ingredients conditions

Table 5 shows the test results of the resistance of each storage period at 80 °C - 95%RH. Figure 6 shows the topography of the foot line.
**Table 5.** Resistance test result after different storage time.

| Test time/d | 0   | 14  | 28  | 42  | 56  |
|-------------|-----|-----|-----|-----|-----|
| No.1 resistance /Ω | 1.06 | 1.09 | 1.11 | 1.12 | 1.13 |
| No.2 resistance /Ω | 1.08 | 1.12 | 1.08 | 1.10 | 1.12 |
| No.3 resistance /Ω | 1.07 | 1.10 | 1.13 | ∞ (Bridge broken) | ∞ (Bridge broken) |
| No.4 resistance /Ω | 1.07 | 1.14 | 2.69 | ∞ (Bridge broken) | ∞ (Broken bridge) |
| No.5 resistance /Ω | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 |

**Figure 6.** the topography of the foot line after storage for 56 day.

It can be seen from Table 5 that when the chlorine-containing component is introduced, the resistance of the electrode plug increases faster than the test without introducing the chlorine component at 80 °C - 95%RH storage conditions, such as No.4 Resistance value reached 2.69 in 28 days of storage and bridge Broken after 42 days of storage. The reason is that the introduction of chlorine-containing components leads to the formation of acidic substances, which accelerates the decomposition of Bridge area and solder joint components in the temperature-humidity environment, and generates corresponding oxides so that the resistance increases sharply in a short time until it is broken and lost its function. It can be seen from figure 6 that the degree of corrosion of the electrode plug wire is the same as that under temperature and humidity.

The morphology of the No.4 electrode plug with a sharp increase in resistance and the No.5 electrode with a slight increase in resistance is analyzed after 56 days storage, and the results are shown in figure 7(a), Severe corrosion occurred in the No. 4 electrode plug joint and the bridge area, which directly led to bridge broken. Figure 8 (b) shows that the No.5 electrode plug solder joints showed slight corrosion and the bridge area was intact.
The composition of the corrosion point and the uncorroded point of the electrode plugs No. 4 and No. 5 were analyzed. The results showed that a small amount of chloride ions were sometimes detected in the place where it was not corroded, and sometimes no chloride ions were detected. Chloride ion content is usually greater than 1%, and some exceed 3% in the corrosion point. Figure 8 and Table 6 show the results of the energy spectrum test for sample No. 4.

**Figure 7.** SCB electrode plugs corrode situation for different resistance.

(a) No.4 SCB bridge zone and Soldering zone after storage for 56 day.

(b) No.5 SCB bridge zone and Soldering zone after storage for 56 day.

**Figure 8.** No.4 test point and energy spectrum.
Table 6. Element content of No.4 different test point.

| Element content% | C  | O  | Al | Si | S  | Cl | Ag | total |
|------------------|----|----|----|----|----|----|----|-------|
| Spectral 1       | 10.21 | 56.20 | 28.69 | 0.63 | 3.01 | 1.25 |    | 100.00 |
| Spectral 2       | 24.80 | 15.46 |     |    | 1.42 |    | 58.31 | 100.00 |
| Spectral 3       | 10.34 | 3.85 |     |    | 85.81 |    |    | 100.00 |
| Spectral 4       | 4.04 | 3.62 |     |    | 91.95 | 0.40 |    | 100.00 |

The relationship between the resistance and corrosion degree of the SCB electrode plug under several environmental conditions indicates that when the resistance of the SCB electrode plug is significantly increased (usually exceeding 0.5 Ω), it is predicted that the bridge region and the solder joint are corroded. When the resistance of the SCB electrode plug is not significantly increased, it is considered that the bridge region and the solder joint are less likely to be corroded, and the slight corrosion of the foot wire has less influence on the resistance. Therefore, the corrosion of the transducer element of the SCB pyrotechnics can be detected by detecting the change in the resistance.

4. Conclusion

Through the research in this paper, we can draw the following conclusions:

1. The resistance test can be used as a non-destructive testing method to detect the integrity of the SCB bridge and solder joints.
2. The performance of the SCB transducer element is very stable under the action of temperature single stress, and corrosion is not easy to occur. However, in the case of temperature - humidity double stress, the SCB transducer is prone to slow corrosion, and the presence of water affects the performance stability of the SCB transducer.
3. Chloride ion has a very strong acceleration effect on the corrosion rate of the SCB electrode plug. In the entire production process of SCB products, measures should be taken to control the introduction of chloride ions and humidity.

References

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