Research paper

402

Research on the performance parameters variations of SCB initiator with lead thiocyanate during storage

Gang An*, Wei-shun Pei**, Lei-ming Wen*, and Bin Zhou*†

*School of Chemical Engineering, Nanjing University of Science and Technology, Nanjing 210094, Jiangsu, CHINA.
Phone : +86−18061601916
†Corresponding author : zhoubin8266@sina.com

**Shanxi North JinDong Chemical Co., Ltd., Yangquan045000, Shanxi, CHINA.

Received : June 18, 2014 Accepted : November 27, 2014

Abstract

In order to find SCB initiators' performance parameters variations during storage, this paper used the accelerated life test to do performance testing. The results showed that there was no significant change in burst time and burst energy of SCB initiators. But the ignition time of SCB initiators had delayed. According to the XRD of ignition powder, decomposition of the powder results in a long time of ignition, which is mainly due to the ingredients change of lead thiocyanate.

Keywords : initiator, semiconductor bridge, accelerated life testing, storage

1. Introduction

The semiconductor bridge (SCB) initiator[1), 2)] is a kind of firing element made by semiconductor film or metal semiconductor composite film. It has many advantages such as low firing energy, short function time and high reliability[3), 4)]. Now it has been widely used in military and civilian fields due to its excellent properties. For military initiator, it is required to work normally after 15 years of storage. Until it has been used, the SCB initiator is in storage condition, and environmental stress may cause some changes to the initiator performance even failure. It is necessary to investigate the variations of SCB initiator performance parameters during storage.

W. Yurkowsky et al.[5)] present to study the reliability through accelerated life testing (ALT). They considered that ALT can shorten the test time and reduce costs.

Tu Xiaozhen[6)] has already investigated on properties of bridge wire electric detonator by ALT at the conditions of temperature 71°C, relative humidity 95% for 14 days. The results show that the function time was unqualified. The goal of this research is to find SCB initiators' performance parameters variations during storage, and find the reason of it.

2. Experimental

ALT can accelerate the speed of reaction by increasing environmental stress. The key elements of ALT process are accelerated stress, aging time and accelerated models. Currently, there are a number of accelerated life testing standards. This research mainly based on China standard Q/AH0180-93 sponsored by Shaanxi Applied Physics-Chemistry Institute.

The test sample uses typical SCB, which is n-type heavily doped polysilicon and double-V-type angular shaped with the size of 100μm (length) ×400μm (width)× 2μm (thickness). The doping element is phosphorus and doping concentration is about 1019 atoms per cubic centimeter. The resistance of SCB is about 1Ω. Figure 1 shows the package structure of SCB initiator, the ignition powder is mainly contains lead thiocyanate, potassium chlorate, and lead chromate.

The test samples were placed in a hot and humid environment (T_1, RH_1) for accelerated life test. We can get the storage time (t_0) under normal temperature and humidity conditions (T_0, RH_0) based on Eyrimg model :

$$t_0 = r_1^{\frac{T_1 - T_0}{10}} r_2^{\frac{RH_1 - RH_0}{0.05}} r_3 t_1 \qquad (1)$$

t_1 is the aging time, day ;

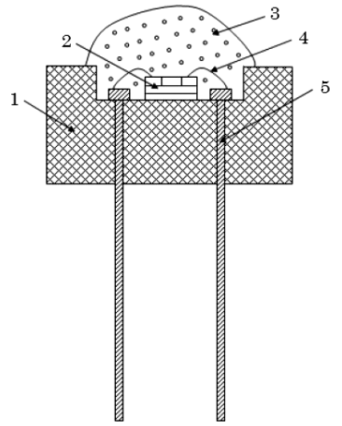

Figure 1 Schematic diagram of SCB initiator.
1-ceramic plug, 2-SCB chip, 3-ignition powder, 4-bonding wire, 5-pin

Table 1 The relationship between the storage time (t_0) and the aging time (t_1).

Aged condition [day]	The storage time [day]	The storage time [year]
0	0	0
5	2870	7
12	6887	18.8
19	10905	29.8
26	14923	40.8
33	18941	51.8

r_1 is the temperature acceleration factor per 10°C ;
r_2 is the humidity acceleration factor per 5% ;
r_3 is the temperature and humidity interaction factor.

The test samples were placed in condition of 71°C, humidity 80% and respectively taken out at the 5th, 12th, 19th, 26th, 33th day. According to the standard Q / AH 0180-93, the value of r_1 is generally 2.7, the value of r_2 is 2.0, and the value of r_3 is 1.0. Table 1 show the relationship between the storage time (t_0) and the aging time (t_1) by calculating. After recovery under normal temperature and humidity for 24 hours, the samples were tested in capacitor discharge firing experiment. A schematic diagram of the experimental arrangement for electro-exploding of SCB under capacitor discharge is shown in Figure 2. The current and voltage change was collected by current probe (CP150 150A) and voltage probe (PP005 500V), and optical signal was got by photoelectric device. All those three signals returned to oscilloscope (LeCroy Wavepro 960) ; the capacitor discharge system (ALG-CN 2) provided the firing energy, the charging capacitor was 47μF, the charging voltage was 30V. And all the data was stored in computer.

All data was plotted by origin. Figure 3 is a typical diagram of optical signal, current and voltage change. Through the curve, we can get the burst time, burst energy, and ignition time. In the voltage-time curve, the second peak results from plasma generation of the bridge material, and the time it appeared is the burst time. The burst energy is calculated by the integral of $U \cdot I$. The voltage of photoelectric device drops rapidly when light

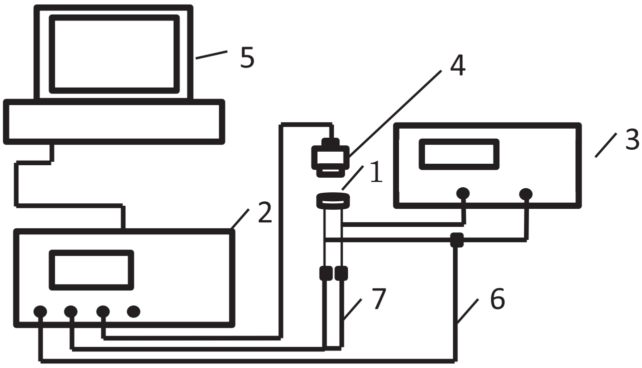

Figure 2 Schematic diagram of the SCB electro-exploding experimental setup.
1-SCB initiator, 2-Oscilloscope, 3-capacitor discharge system, 4-photoelectric device,
5-computer, 6-current probe, 7-voltage probe.

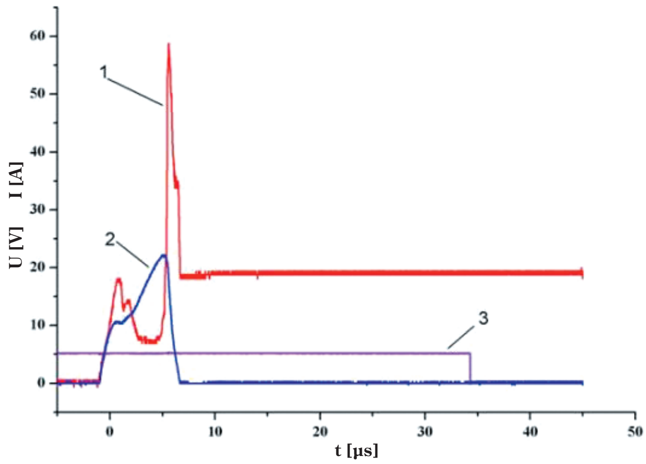

Figure 3 Typical diagram of the SCB.
1-voltage curve, 2-current curve,
3-optical curve.

changes at a certain value, where the ignition time is collected.

3. Results

3.1 Performance parameters variations of SCB chips

The results of burst time and energy are shown in Figure 4 and Figure 5. As we can see from the diagrams, there was no obvious change in burst time and burst energy. For scientific research, the data were analyzed by origin for t-test with a significance level of 0.05 ($\alpha = 0.05$) in Table 2. Results : there was no significant change in both burst time and burst energy before and after ALT. This indicates that after long time storage under high temperature and high humidity, the performance of SCB was not affected.

3.2 Performance parameters variations of ignition powder

Ignition time is the main performance parameter of SCB initiator, and it is determined by ignition powder. Figure 6 is the results of ignition time. As we can see from the diagram, the maximum of ignition time was obviously increased and the minimum was slight fluctuated. During the entire aging period, the ignition time was changed with a rising trend. At the 33th day, the ignition time was

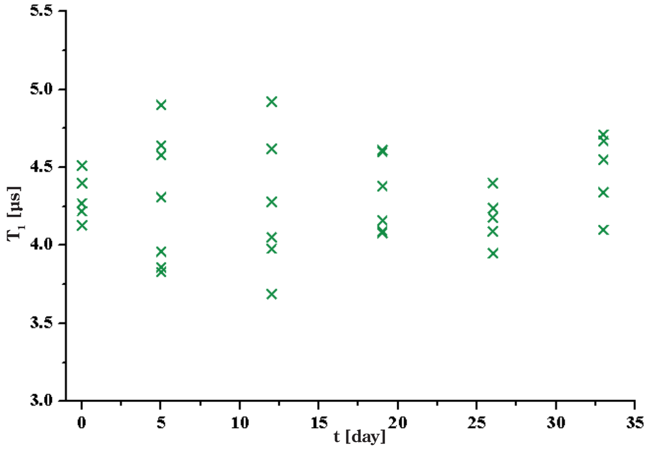

Figure 4 Diagram of SCB burst time.

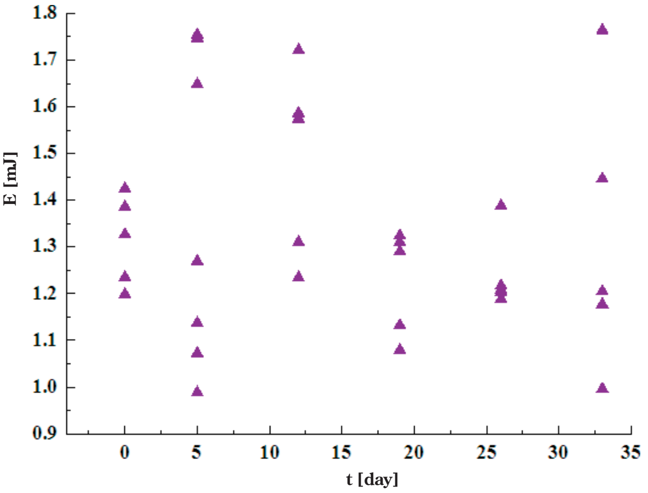

Figure 5 Diagram of SCB burst energy.

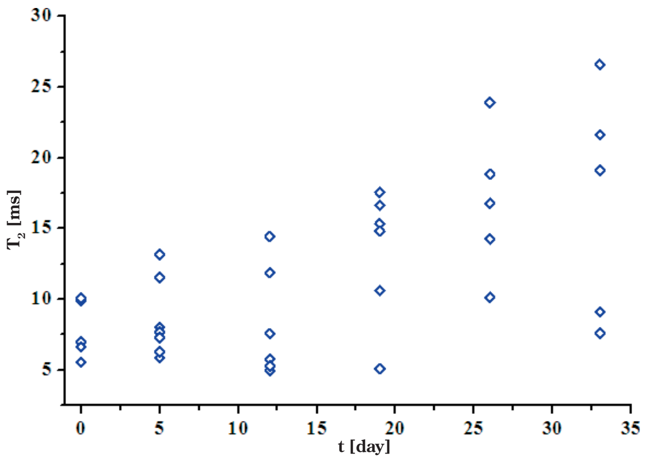

Figure 6 Diagram of SCB ignition time.

Table 3 The results of SCB initiator ignition time by t-test.

Aged condition [day]	Ignition time [ms]	S_3	Sample amount	|t|	Test result
0	7.81	2.04	5		
5	8.54	2.74	7	0.50	No significant change
12	8.31	3.95	6	0.25	No significant change
19	13.34	4.70	6	2.43	significant change
26	16.78	5.14	5	3.63	significant change
33	16.81	8.18	5	2.39	significant change

obviously delayed, and the data dispersion was increased. Table 3 is the results of SCB initiator ignition time by t-test with a significance level of 0.05 (α = 0.05). As can be seen in Table 3, there were small changes in ignition time, but the changes were not significant by t-test, which the samples were aged 5 days and 12 days. When the samples were aged 19 days and longer, the ignition time was obviously increased. There were significant changes by t-test. According to 3.1, SCB burst time and burst energy had no significant changes, SCB chips were not affected by the environment stress. The increased ignition time was due to the ingredients change of ignition powder.

3.3 Ignition powder change research

The ignition powder is igniter mixture; it contains lead thiocyanate, potassium chlorate, and lead chromate. Thiocyanate is the combustible agent, and the potassium chlorate is the oxidation agent. Ingredient changes of ignition powder have an important influence on ignition process. In order to investigate the cause of the increasing ignition time, we analyzed the ignition powder by XRD. Figure 7 is the XRD pattern of none aged ignition powder. Diffraction peaks appeared at 2θ =5.450, 4.851, 4.499, 4.116, 3.242, 3.040, 2.879, 2.699, 2.588, 2.557 were corresponding to the lead thiocyanate. Diffraction peaks appeared at 2θ = 3.481, 3.337, 2.864 were corresponding to the potassium chlorate. XRD patterns of 5 aged days and 12 aged days were little change compared to the pattern of none aged ignition powder, according to Figure 8. No changes occurred in their peak positions; however, their intensity changed a little. That means the ingredients of ignition powder were not changed and the ignition time was not significant changed.

After aged 19 days, the peak intensity of lead thiocyanate became weak (Figure 9). New peaks were

Table 2 The results of SCB initiator burst time and burst energy by t-test.

Aged condition [day]	Sample amount	Burst time [μs]	S_1	|t|	Burst energy [mJ]	S_2	|t|	Test result
0	5	4.31	0.15		1.31	0.10		-
5	7	4.30	0.43	0.044	1.37	0.33	0.38	No significant change
12	6	4.26	0.45	0.23	1.44	0.21	1.26	No significant change
19	6	4.32	0.25	0.11	1.24	0.11	1.18	No significant change
26	5	4.17	0.17	1.33	1.24	0.083	1.29	No significant change
33	5	4.17	0.25	1.27	1.32	0.30	0.024	No significant change

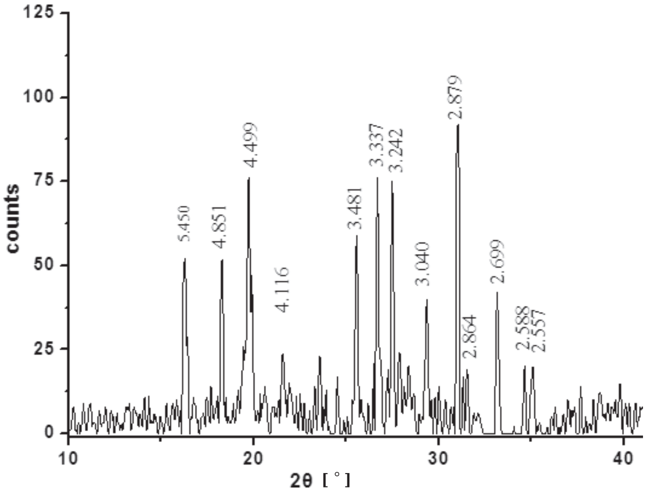

Figure 7 XRD pattern of none aged ignition powder.

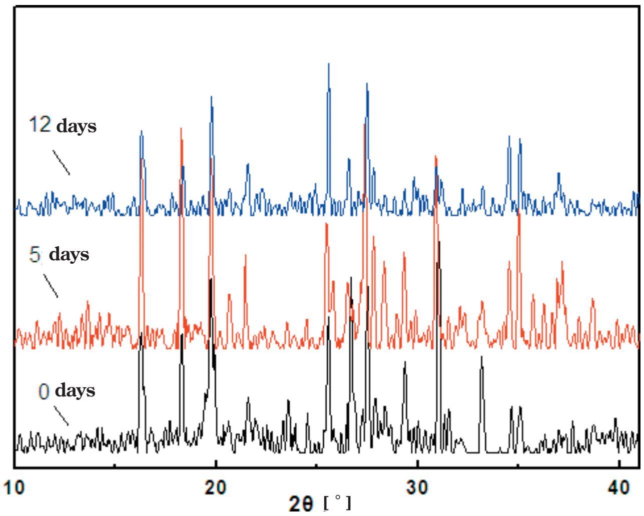

Figure 8 XRD patterns comparison of 0, 5, 12 days aged ignition powder.

corresponding to $K_2Pb(SO_4)_2$ appeared at $2\theta = 3.493$, 3.141, 2.560, 2.528, 2.067, 1.910, peaks appeared at $2\theta = 3.447$, 2.833, 2.790 were corresponding to K_2PbO_2, and peaks appeared at $2\theta = 3.357$, 3.283, 2.477 were corresponding to KPb_2Cl_5. These new peaks illustrated that the ignition powder had decomposed. Because of decomposing, the content of oxidation agent and combustible agent became less. That resulted in a longer ignition time. With increasing aged time, the peak positions did not change any more, but the $K_2Pb(SO_4)_2$ peak intensity increased (Figure 10). The oxidation agent and combustible agent were further decomposed. Therefore, the ignition time was more delayed. In conclusion, the decomposing of ignition powder under environmental stress was the real reason for ignition delay.

4. Conclusion

In this research, we investigated the variations of SCB initiator performance parameters during storage by ALT. Conclusions can be drawn as follows.

1) The burst time and burst energy of SCB chips were not changed before and after ALT. The performance of SCB chips were not affected by environmental stress through storage.
2) During the entire aging period, the ignition time was changed with a rising trend. After aged 19 days, there were significant changes in ignition time. The ignition time of SCB initiator was affected by environmental stress through storage. The decomposing of ignition powder under environmental stress was the real reason for ignition delay.

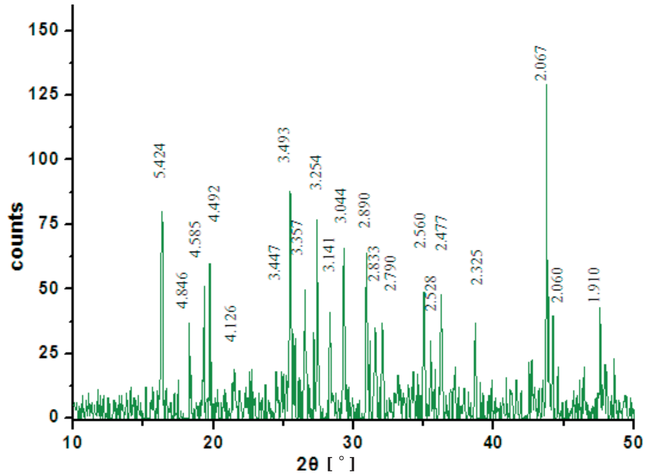

Figure 9 XRD pattern of 19 days aged ignition powder.

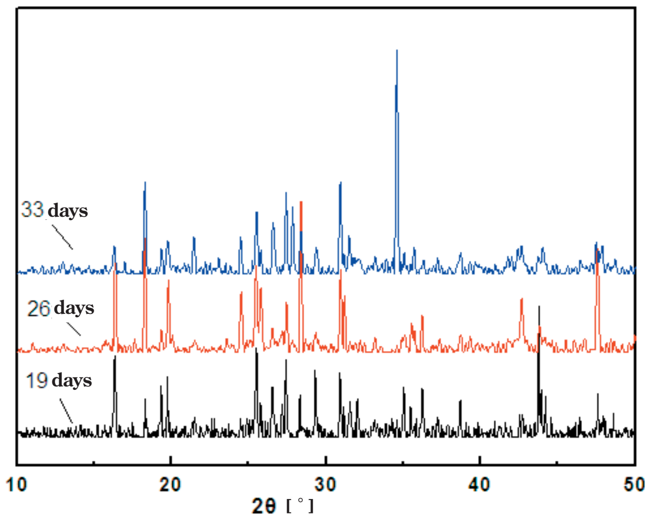

Figure 10 XRD patterns comparison of 19, 26, 33 days aged ignition powder.

References

1) Hollander Jr. and E. Lewis, "Semiconductive Explosive Igniter", U. S. Patent 3366055 (1968).
2) D. A. Benson, M. E. Larsen, and A. M. Renlund, J. Appl. Phys., 62, 1622–1632 (1987).
3) M. I. Park, H. T. Choo, S. H. Yoon, and C. O. Park, Sens. Actuators, A, 115, 104–108 (2004).
4) K. N. Lee, M. I. Park, S. H. Choi, C. O. Park, and H. S. Uhm, Sens. Actuators, A, 96, 252–257 (2002).
5) W. Yurkowsky, R. E. Schafer, and J. M. Finkelstein., Technical Report No. RADC-TR-67-420, 1–2, Rome Air Development Center (1967).
6) X. Z. Tu, J. M. Li, and X.W. Wei, Chin. J. Energ. Mater., 5, 539–542 (2008) (in Chinese).