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Failure analysis of electronic components after long-term storage

Youhu Zhao *, Guicui Fu

School of Reliability and Systems Engineering, Beihang University, Beijing, PR China

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ABSTRACT

The reasons for most failures of weapons systems are related to problems with the storage processes of electronic components. In order to analyze the impact of long-term storage on electronic components, failure analysis of NOR gate components has been investigated comprehensively in the present study. An accelerated storage degradation test was conducted to simulate a long-term storage environment. A mechanical test procedure is developed to illustrate the degradation condition of the samples. The morphology and composition of degraded parts are characterized by SEM, EDS, and FTIR. The results of our analysis demonstrate that long-term storage has little impact on the electrical properties and microstructure of NOR gate components. The main problem is oxidation of the pin's surface in a poor storage environment, which could lead to contact failures. The reason for oxidation is that the coating layer has some defects due to imperfect manufacturing processes.

1. Introduction

The storage reliability of electronic components is a long-standing problem in the military and commercial fields [1,2]. It is extremely important for weapons systems, such missile systems, which are required to operate for a very short time after being stored for a very long time (10–20 years) and exposed to humidity, temperature cycling, and mechanical shocks [3]. Electronic equipment plays a key role in a weapons system, and a digital integrated circuit is commonly used in it. Pecht and Pecht have published a book about storage reliability of electronic products to summarize failure mechanisms and assessment methods [4]. The analysis of storage degradation can help improve the reliability level of components after long-term storage.

Due to purchase limits and inventory management problems, manufacturers in China always use components stored for a long time to make products. Theoretically, using unchanged components is beneficial for maintaining the reliability and stability of a product. However, this may lead to the potential problem of degradation. Military statistical data confirm that the failure rate of a weapons system that consists of components stored for 10 years is obviously higher than that of a system that consists components stored for 5 years. The statistical data also indicate that in contrast to a weapons system stored in an excellent environment, like a thermostatic and humidistat warehouse, failures of electronic components occur much earlier and more frequently when the weapons system is placed in external fields. Extensive failures of electronic components consume a lot of money for replacement, and pull the reliability of the weapons system down sharply. It is necessary to analyze the impact of storage on components reliability.

* Corresponding author.

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NOR gate components (14-lead hermetic dual-in-line ceramic packages) are representative of typical electronic components. Their structure and function are so simple that they are very suitable as study objects. In order to comprehensively study the storage environmental effect on a NOR gate component, some new components were selected and an accelerated degradation test was utilized to accelerate the storage degradation process. The accelerated test is an important method to study storage reliability of electronic components, which was used for the research about storage reliability of the antifuse FPGA [5] and the refrigerator drawer system [6]. After the accelerated storage degradation test, several mechanical tests were conducted to evaluate the condition of the components. With intense use of optical microscopes, Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), and Fourier Transform Infrared Spectroscopy (FTIR), all the degraded and normal samples were compared and analyzed to find out the root causes for degradation.

2. Experiment

In order to study the effects of long-term storage on components in a relatively short period of time, an accelerated storage degradation test for NOR gate components was designed. Temperature was chosen as the accelerated stress, because it has the greatest impact on components during storage [7,8]. There were 35 NOR gate components in total, and they were divided into 5 groups. The first 4 groups (8 samples/group) were put into different ovens. The temperatures of these ovens were 100 °C, 125 °C, 150 °C, and 175 °C. The last group (2 samples) was placed at room temperature for comparison. The No. 33 sample was used in a seal test and internal water vapor analysis before the accelerated test to identify the initial state. It was put in Group 4. The IDs of these components are shown in Table 1. The test lasted for about one year, from April 2013 to April 2014. The major electrical parameters of these samples were detected every 2 weeks. No problems were found in the electrical inspections.

3. Results and discussions

After the accelerated storage degradation test, some components were selected to undergo several mechanical tests. The purpose of these tests was to comprehensively analyze the impact of the storage environment on components. The mechanical test procedure is shown in Table 2. Brief results of each test are included. Detailed results and discussions are described in the following sections.

3.1. Macroscopic inspections

During macroscopic inspections, severe degradation was found on the outer surface of the pins, as shown in Fig. 1. It was a typical oxidation phenomenon [9] that could cause contact failures. This indicated that various temperatures had different effects on the pins of components. The higher the test temperature was, the greater the color of the pins changed. The pins of the No. 1 sample were bright, while No. 27's pins looked very rough and black. Furthermore, since temperature in the accelerated test can be converted into time, the result of macroscopic inspections meant that long-term storage had negative

Table 1
Sample group.

Group	Sample ID	Test temperature (°C)
1	1–8	100
2	9–16	125
3	17–24	150
4	25–33	175
5	34–35	25

Table 2
Mechanical test procedure.

Mechanical test	Sample ID	Brief results
Macroscopic inspections	1–35	Color of some pins turned black
Seal test	1–35 (except 33)	Leak rate increased
Internal water vapor analysis	1, 4, 7, 9, 12, 15, 17, 20, 23, 25, 28, 31, 34	No obvious problems were found
Bond strength test	1–35	Bond strength declined
Die shear test	1–35	No obvious problems were found
Microanalysis using SEM and EDS	1–35	Outer surface of pins were oxidized; Color of die adhesive layer turned yellow
Cross-sectional and microstructure analysis	5, 13, 21, 29, 35	Outer surface of pins were oxidized
FTIR analysis	9, 17, 33, 34	No obvious problems were found