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Failure analysis of plastic encapsulated circuits after autoclaving

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ABSTRACT

Considering that moisture is a crucial factor affecting Plastic Encapsulate Microcircuits (PEMs), several test methods, including Temperature Humidity Bias (THB), autoclaving, and Highly Accelerated Stress Test (HAST), were proposed to assess the moisture resistance capacity of PEMs. To investigate the impact of moisture on PEMs, one certain type of Metal-Oxide -Semiconductor Field Effect Transistor (MOSFET) was selected as a representative of PEMs and underwent an autoclaving in this paper. The results demonstrate that the influences of moisture are diverse. Then a series of analyses, including electrical testing, Scanning Acoustic Microscope (SAM), bond pull testing, metallurgical microscopy, surface and cross-sectional analysis by Scanning Electron Microscope (SEM) and Energy Dispersive Spectrometer (EDS), were conducted to determine the failure cause. With the analyses, the increase of static drain-to-source on resistance is ascribed to surface oxidation. Besides, the moisture invading from the crack along the die side is deemed to contribute to the leakage current failure and the function failure. Finally, some suggestions are proposed to protect PEMs against moisture.

1. Introduction

Due to the advantages of cost, volume and weight, Plastic Encapsulated Microcircuits (PEMs) prevail in the device market. However, PEMs are inherently sensitive to humidity, which impedes their promotion in high reliability fields and harsh environments [1]. The swelling of the moisture absorbed within the mold compound will induce hygroscopic stress and thermal stress. In addition, the moisture will also arouse corrosion and electro-migration [2]. From the 1970s, the environmental effects on reliability of PEMs have been studied by field experiments [3] and laboratory experiments [4–5].

Most research has been conducted on theory analysis and test methods. Theoretically, various models describing moisture absorption and diffusion mainly based on Finite Element (FE) were proposed [6–8]. Besides, initiation and propagation of delamination was also investigated, in which dynamic interaction was utilized to realize the modeling of delamination and the characterization of interfacial adhesion was determined by material strength tests [9–10]. Meanwhile, several test methods, i.e., Temperature Humidity Bias (THB) [11–12], autoclaving [13], and Highly Accelerated Stress Test (HAST) [14], were proposed to assess the moisture resistance capacity of PEMs. Among those test methods, autoclaving, characterized by low costs and prominent acceleration effects, is widely adopted by the manufacturers and users of PEMs. In addition, as only electrical stress is involved in autoclaving, the failure occurring in it will be easy to analyze and identify.

Albeit considerate research has been carried out on the effects of humidity on PEMs, most of them were concentrated on the deterioration of mechanical properties. Previous analyses after the autoclaving were insufficient and the cause of performance degradation remained obscure. Therefore, a failure analysis of PEMs after autoclaving has been conducted to clarify the relationship between moisture and electrical degradation in the paper. One certain type of power Metal-Oxide -Semiconductor Field Effect Transistor (MOSFET) with D2 Pak plastic package was selected as a representative of PEMs and subjected to an autoclaving test. Various failures were found after the autoclaving. To determine the failure cause, a series of failure analyses were conducted, which include electrical testing, external inspection, Scanning Acoustic Microscope (SAM), re-autoclaving and weighing, internal

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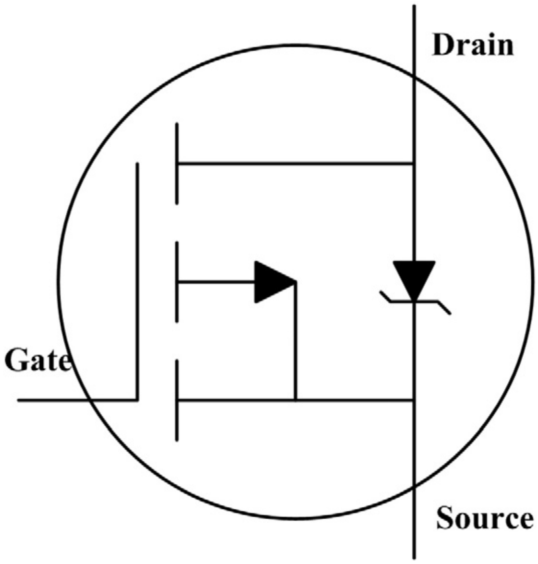

Fig. 1. Circuit schematic of the selected MOSFET.

inspection by stereoscopic microscope and metallurgical microscope, bond pull testing, surface analysis by Scanning Electron Microscope (SEM) and Energy Dispersive Spectrometer (EDS) and cross-sectioning analysis by SEM and EDS.

2. Autoclaving

The power MOSFET selected in this paper is p-channel enhanced mode MOSFET, and the circuit schematic is illustrated in Fig. 1. The exterior view was shown in Fig. 2. There were 26 samples involved in the paper in total, of which 24 samples were divided randomly into 6 groups. According to JESD 22-A102D accelerated moisture resistance – unbiased autoclave [15], the duration of each group were 24 h, 48 h, 96 h, 168 h, 240 h, and 336 h respectively. The test condition was set to 121 $\pm$ 2 °C, 100% R.H., and 20 5Kpa uniformly. Not in accordance with JESD 22-A102D, tap water, rather than deionized water, was exploited in the autoclaving to stimulate the actual environment. The rest of the samples were placed in a drying oven under fixed temperature 121 °C. The IDs of the samples and the arrangement are shown in Table 1. Prior to the autoclaving, all the samples were stored in the moisture barrier bags to control the internal ambient humidity. An optical microscope and an electrical test were performed before the autoclaving and the results showed that all the samples were normal.

3. Analysis results and discussion

After the autoclaving, all the samples underwent an electrical test, external inspection and SAM firstly. In electrical test, various failures were found. Then, some samples were selected for a series of further analysis. The brief results of all the tests are shown in Table 2. Detailed results and discussions will be described in the following sections.

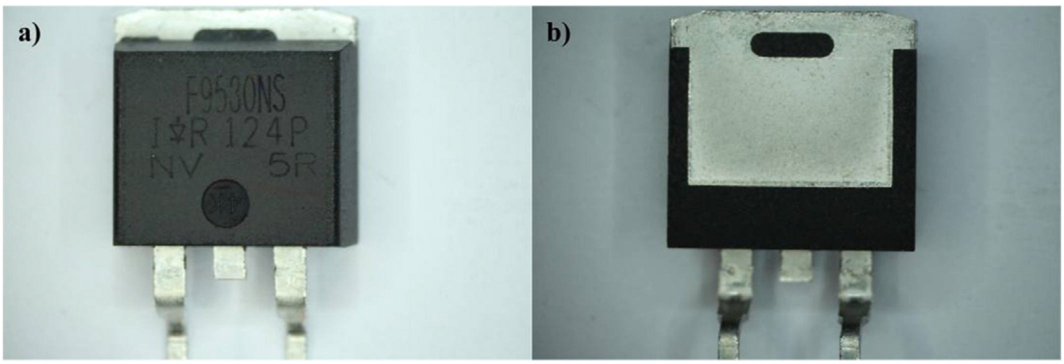

Fig. 2. Exterior view of the selected MOSFET: a) top view; b) bottom view.