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Electrical and Reliability Performance of Molded Leadless Package for High-Voltage Application

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Abstract

This paper investigates the influence on electrical and reliability performance of molded leadless package for high-voltage power integrated circuit application. Semiconductor devices are mostly encapsulated by using epoxy molding compounds which act as protection for the ICs from damage to the harsh environment. Quad Flat No Lead was selected since the application requirement for compact AC to DC portable adapter charger and more input and output pin. High-voltage package was designed based on the IPC-2221 standard specification and creepage distance was calculated under external component lead, uncoated. Two epoxy molding compounds were used namely as type A and B. Key properties of EMCs were identified such as ionic content, glass transition temperature and volume resistivity. The electrical tested at room temperature on high-voltage leakage current at 700 V showed EMC B has no failure compared with EMC A. On top of that, electrical parametric distribution showed that the Cpk of EMC B was extremely robust compared with EMC A. Reliability test was conducted for high temperature operating life test at 115˚C and EMC B was passed up to 1000 hours while EMC A was failed. Meanwhile, High Temperature Storage Life test at 150˚C and Temperature Humidity Bias Test at condition 85˚C, 85% relative humidity showed that EMC B was passed for 1000 hours but EMC A was failed at 168 hours. However, both compounds A and B were passed delamination criteria tested by scanning acoustic tomography technique before and after subjected to moisture sensitivity level 1.

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Keywords: Epoxy molding compound ; Molded leadless package ; High voltage ; Reliability

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1. Introduction

High-voltage device has been widely used in many applications such as in telecommunication, power supply, home appliances, electro-optic and many more [1,2,3,4]. Mobile phone adapter charger is one of the example possesses regulator integrated circuit (IC) and requires to be operated at high-voltage (HV) mode. Epoxy molding compound (EMC) is a compound that has been used to encapsulate plastic semiconductor packages [5] before this semiconductor device is releases as a final product. EMC contains anionic halogens such as chloride ions from epichlorohydrin compound that used for resin epoxidation while bromide ions is incorporated into this resin as a flame retardant to the molding compound [5,6]. In addition, EMC also contains cations for instance potassium (K^+), sodium (Na^+) and antimony (Sb^{+3}) which also act as flame retardant for molding compound [6,7]. However, the presence of these flame retardant elements in a high concentration in the molding compound will contribute to leakage current problem of IC device [6]. Furthermore, an increase in device current will reduce the volume resistivity (VR) value and cause failure during electrical testing. However, this VR value is one of the important property for EMC. Low and high volume resistivity is classified as magnitude of 10^{11} and 10^{13}, respectively, during the electrical testing [8]. The other key property for epoxy molding compound is glass transition temperature (T_g). Increasing in T_g value will help to improve cross-linking between polymer compound and prevent the anions and cations transportation in the EMC. Therefore, higher T_g value leads to increase the high voltage device performance [6]. However, leakage current will occur when higher voltage than T_g value was applied to the device which cause anions and cations to transport easily [9].

2. Experimental

The molded leadless package was designed using AutoCAD software LT version. The design rule was followed the Institute for Interconnecting and Packaging Electronic Circuit (IPC-2221) standard. The creepage distance was calculated based on A6, external component lead/termination, uncoated and minimum creepage gap is shown in Table 1. A5 is refer to external conductor, with conformal coating over assembly (any elevation) while A7 is refer to external component lead termination, with conformal coating (any elevation). Since the device input at high line was approximately 400 volts dc, hence the minimum creepage distance can be expressed by equation (1) [10].

$$\text{Minimum spacing (A6)} = 0.00305 \text{ mm} \times 400 \text{ volts} = 1.22 \text{ mm} \tag{1}$$

Table 1. Minimum creepage spacing based on IPC-2221 standard.

Voltage between conductors (DC or AC peaks)	Minimum spacing		
	Assembly		
	A5	A6	A7
0-15	0.13 mm	0.13 mm	0.13 mm
16-30	0.13 mm	0.25 mm	0.13 mm
31-50	0.13 mm	0.4 mm	0.13 mm
51-100	0.13 mm	0.5 mm	0.13 mm
101-150	0.4 mm	0.8 mm	0.4 mm
151-170	0.4 mm	0.8 mm	0.4 mm
171-250	0.4 mm	0.8 mm	0.4 mm
251-300	0.4 mm	0.8 mm	0.8 mm
301-500	0.8 mm	1.5 mm	0.8 mm
> 500	0.00305 mm /volt	0.00305 mm /volt	0.00305 mm /volt