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Reliability Improvement Technologies for Epoxy Molding Compounds on Lead Frame Package

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1 Abstract

Recently, there are strong requirements to improve the reliability of semiconductor packaging for automotive devices, which are increasing, and to reduce cost by eliminating moisture-proof packaging. Correspondingly, reducing delamination of epoxy molding compounds (EMCs) at the surface on a lead frame at reflow has been strongly required. In this study, the reduction of water absorption and modulus, and the improvement of adhesion strength on a lead frame were investigated. As a result, we found epoxy resins that can reduce water absorption and modulus, and new adhesion promoters. By combining these technologies, we developed new EMCs that can reduce delamination after reflow.

2 Background of the Development

In recent years, the number of built-in semiconductors has increased as electronics have become increasingly used for automobiles.1) Standards for reliability tests of built-in semiconductors, such as AEC-Q100, were established with stricter conditions relative to the conditions for consumer use.2) To pass a strict reliability test, such as the b-HAST (the biased highly accelerated stress test), it is necessary to reduce the delamination of epoxy molding compounds on the surface of the lead frame in the reflow process.

In addition, to reduce costs, we need to eliminate moisture-proof packaging not only for built-in semiconductors but for semiconductors for consumer use. Thus, we need to improve the moisture sensitivity level (MSL) against water absorption at reflow.

At the same time, the conventional gold wire has been replaced with copper wire to reduce costs, even though the latter corrodes more easily than the former. Regarding the use of copper wires, we already know that additives containing sulfur atoms used to improve adhesion with lead frames adversely affect the corrosion of the wire bonding zone.3) For this reason, additives that do not contain sulfur atoms are required.

Taking these points into consideration, in this study, we created technology that enables us to reduce delamination at reflow regardless of whether additives containing sulfur atoms are used, and developed new products as reported below.

3 Characteristics of Developed Product

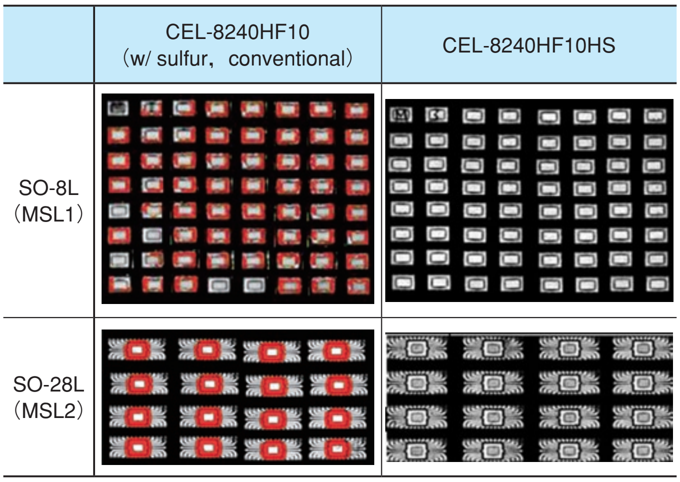
- Development of epoxy resin enabling a reduction in the modulus almost at reflow temperature resulted in a reduction in the stress at reflow and an improvement in delamination resistance at reflow.
- The improvement of adhesion promoters improved both the adhesion strength at reflow temperature and the delamination resistance at reflow.
- Adhesion promoters containing no sulfur atoms improved the delamination resistance of sulfur-free epoxy molding compounds, which are strongly requested by customers, at reflow.

4 Technical Details

It is assumed that the delamination at reflow is mainly caused when the sum of the volatile expansion stress (volatilization stress) at reflow temperature (260°C) of water accumulated in the interface between the lead frame and the epoxy molding compounds due to water absorption and the stress (thermal expansion stress) generated by the difference in the linear expansion between the lead frame and the epoxy molding compounds exceeds the adhesion strength of the epoxy molding compounds and the lead frame. That is to say, the reduction in the volatility stress and thermal expansion stress and the improvement in the adhesion strength are required for the measure preventing delamination at reflow. Since a reduction in the water absorption ratio is required to decrease volatility stress, we examined epoxy resin capable of reducing the water absorption ratio in this study. Concerning the reduction in the thermal expansion stress, we examined stress reduction due to modulus reduction almost in the vicinity of the reflow temperature in this study. Concerning the improvement in adhesion strength, we examined new adhesion promoters in this study.

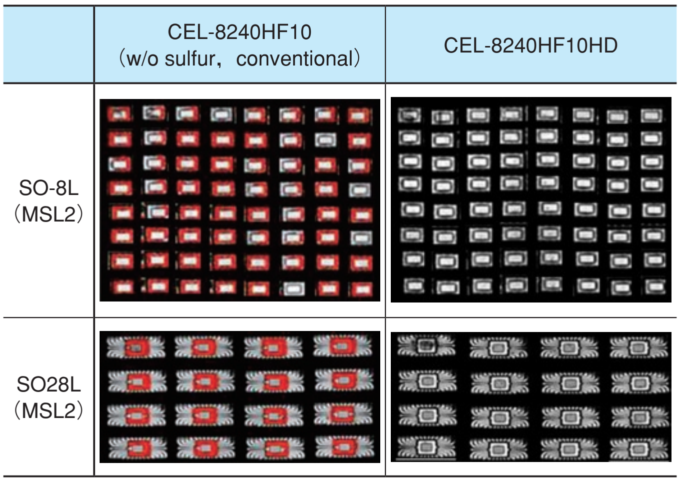
As a result, the improvement in the epoxy resin achieved a reduction in the water absorption ratio and modulus at around 260°C, and the improvement in the adhesion promoters achieved an increase in adhesion strength.

In addition, although the new standard adhesion promoters are assumed to be those containing sulfur atoms for the purpose of improving adhesion strength in the silver plated zone, sulfur-free material that is highly required from the viewpoint of the improvement of long-term reliability at high temperature in case of using copper wire has also been developed. Comparisons between the developed materials (CEL-8240HF10HS and CEL-8240HF10HD) and the conventional materials are shown in **Figure 1** and **2**, and the properties of developed materials are shown in **Table 1**.



MSL1 Condition: 85℃/85%RH/168 h，MSL2 Condition: 85℃/60%RH/168 h
Reflow Condition: 260℃ x 10 s x 3 times
Pre-bake Condition: 125℃ x 24 h
SO-28L（Cu alloy）Die pad; Ag plated，4.1 x 5.2 mm，Die size; 2.2 x 3.2 mm
SO-8L（Cu alloy）Die pad; Ag plated，2.8 x 4.3 mm，Die size; 1.5 x 2.6 mm

Figure 1 CSAM images after reflow (w/ sulfur)



MSL2 Condition: 85℃/60%RH/168 h
Reflow Condition: 260℃ x 10 s x 3 times
Pre-bake Condition: 125℃ x 24 h
SO-28L（Cu alloy）Die pad; Ag plated，4.1 x 5.2 mm，Die size; 2.2 x 3.2 mm
SO-8L（Cu alloy）Die pad; Ag plated，2.8 x 4.3 mm，Die size; 1.5 x 2.6 mm

Figure 2 CSAM images after reflow (w/o sulfur)

Table 1 Property of developed items

Item		Unit	CEL-8240HF10 （w/ sulfur, conventional）	CEL-8240HF10HS	CEL-8240HF10 （w/o sulfur, conventional）	CEL-8240HF10HD
Epoxy resin		—	Current	Modified	Current	Modified
Hardener		—	Current	Current	Current	Current
Flame retardant		—	No	No	No	No
Additives		—	Current w/ sulfur	Modified w/ sulfur	Current w/o sulfur	Modified w/o sulfur
Filler content		wt%	89	89	89	89
Spiral flow		cm	115	120	115	125
Gel time（175℃）		s	32	33	32	35
Flexural modulus at 260℃		MPa	700	600	700	500
Water absorption（85℃/85%RH/168 h）		%	0.20	0.17	0.20	0.18
Adhesion（260℃）	Cu	MPa	1.3	1.4	1.3	1.3
	Ag	MPa	0.6	0.8	0.5	0.6
$\mathrm{Cl^-}$（121℃，2 atm，20 h）		ppm	10	10	10	10
Reliability（Cu Wire）	b-HAST（130℃/85%RH）	—	336 h Pass	336 h Pass	336 h Pass	336 h Pass
	HTSL（200℃）	—	1500 h NG	1500 h NG	1500 h Pass	1500 h Pass

Values listed above are typical and should not be used for specification purpose

5 Future Business Development

- Level up of sulfur-free material by exploring the technology for adhesion promoters containing no sulfur atom
- Development of technology for improving reflow resistance suitable for high voltage

【References】

1) Latest Trend Study of Semiconductors Related Players 2015, Fuji Chimera Research Institute, Inc. May 2015

2) AEC-Q100-Rev-H, September 11, 2014

3) Hidetoshi Kuraya, Fumiaki Aga, Hideki Ishii and Kousuke Azuma: Influence of mold resin properties on high temperature storage life of Cu wire package, 24th Microelectronics Symposium Proceedings, pp. 339-342 (2014)