

An Alternative Green Packaging Solution in a fully Automated In-line Assembly-Test-Finish Operation for a Nickel-Palladium Gold (NiPdAu) Pre-Plated Frames Leadframe Based Packages

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Abstract

One of Cypress Semiconductor technology advancements in the field of backend assembly was the simplification of manufacturing operations. Factory automation or “Autoline” was introduced to improve manufacturing cycle time, productivity, operational cost, product quality, and reliability. The Autoline installed in Cypress Manufacturing Limited (CML) is a state of the art fully automated in-line Back-end Assembly-Test-Finish operation from die attach to tape and reel (TnR). Hardware and software integration was utilized and new material sets were introduced to support automation. In response to lead-free packaging, the standard assembly process of lead introduction during the plating process was replaced using a nickel-palladium-gold (NiPdAu) pre-plated leadframe (PPF). Pre-plated leadframe option was chosen to be an alternative lead-free solution to support Cypress Autoline concept and furthermore eliminating the technical issue on whisker formation. And for the fast emerging green packaging requirement, leadframe based assembled parts in Autoline using NiPdAu PPF’s should be halide-free. Thus, the objective of this study is to have a green packaging solution that will support factory automation without sacrificing package integrity and reliability withstanding the 260°C reflow lead-free requirement. Results showed that the mold compound material compatibility plays an important role in achieving the moisture sensitivity level pre-conditioning requirement for lead free applications.

Introduction

The increasing demand advancements in the semiconductor industry require the conventional assembly operation to be fully automated and integrated. Thus the concept of Cypress “Autoline” was introduced. The leadframe based Autoline installed in Cypress Manufacturing Limited (CML) is a state of the art fully automated in-line Back-end Assembly-Test-Finish operation from die attach to tape and reel. Hardware and software integration were introduced to support factory automation. The offline batch processes were then eliminated to in-line handling concepts. Shown in Figure 1 is a typical Cypress Autoline.



Figure 1. Cypress Autoline Concept

One solution for in-line assembly is the elimination of the typical off-line plating, post mold cure and dry baking processes. These can be achieved by utilizing a Nickel-Palladium-Gold pre-plated leadframes (NiPdAu PPLF) and mold compound reformulation to cater such requirement. For these reasons, new bill of materials were introduced to ensure compatibility of materials meeting the higher temperature reflow requirement. Furthermore, with the “green” packaging requirement in the semiconductor industry is almost at its peak which also requires a higher peak temperature during board mount assembly brought issues on integrated circuit (IC) package internal stress during reflow processes. The packaging materials and designs were developed even though some changes and material combinations are costly just to meet the target reliability requirement.

In this paper, different material combinations were employed to come up with a green packaging solution in consideration with the overall package strength to withstand higher reflow requirements. The chosen test vehicle in the course of the study was based on the biggest package dimension available in Cypress Autoline.

Investigation

The Small Outline IC (SOIC) package with 18 leads and a 300-mil body size was chosen to be the test vehicle having the biggest package dimension and being the highest volume runner. A 75 x 119 mils silicon die size was placed in a copper based Nickel-Palladium pre-plated leadframe with a pad size of 130 by 160 mils. Different epoxy molding compounds were utilized with varying material properties as shown in Table 1.

Table 1. Epoxy Molding Compounds Data Sheet

General Property Information							
ITEM	Unit	Control	A	B	C	D	E
Epoxy Resin	-	Bipheny	Hydrophobic	Hydrophobic	Hydrophobic	Hydrophobic	Hydrophobic
Flame Retardant System	-	Bv/Sb	FREE	FREE	FREE	FREE	FREE
Filler Content	(wt / vol %)	86	88	88	87	89	87
Filler Size (max)	microns	75	75	75	75	75	75
Filler Shape	-	Spherical(9)/Angular(1)	spherical	spherical	spherical	spherical	spherical
Spiral Flow @ 175°	cm	105	76	80	88	79	90
Gelation Time @175°	sec	24	22	22	22	22	24
Viscosity @175°	Poise	140	10	13	10	17	300
Water Absorption	%	0.27	0.25	0.24	0.25	0.23	0.2
CTE Alpha 1	ppm	1.0	0.9	0.9	1	0.8	1
CTE Alpha 2	ppm	4.4	2.7	2.7	3.3	2.5	3.8
Tg	°C	120	78	85	85	85	115
Flexural Strength @ 25°	kgf/mm ²	172	116	128	115	140	220
Adhesion Strength on NiPdAu	MPa	4.4	6.3	7.9	9	8.4	5.7

Basic assembly process in plastic IC manufacturing was followed using the Autoline concept. Post mold cure and dry baking prior pre-conditioning were eliminated to satisfy in-line assembly concept. During the molding steps, the parameters provided by the material manufacturers were followed. All the assembled units were subjected to moisture preconditioning at level 3 conditions (30%RH/60°C, 192 hours) and allowed pass to a three (3) times at 260°C reflow temperature. After the reliability test, internal package delamination in critical interfaces were inspected through a CSAM, as it will be used as the basis for the pass/fail criteria.

Interpretation

The overall stress behavior in the package that can be represented by the individual coefficient of thermal expansion (CTE) of the materials in a molded package. This is dependent on the silicon die, die attach adhesive, substrate or leadframe, and the plastic or mold compound used. Furthermore, the overall package reliability is highly dependent on the type of epoxy molding compound used. Complexity arises as we consider the effect of the environment such as temperature, relative humidity and pressure. Common weaknesses of the above mentioned complexities are interfacial delamination or separation or gap which may results to package deformation or crack. Thus, the capability of a package will depend more on the

material properties, compatibility and adhesion strength.

Matching the CTE of the silicon die and the CTE of the molding material can be achieved by increasing the filler (silica) content. This is true in this study, but increasing further will not improve its package reliability. The lowest possible absorption rate is needed with the highest value of Tg and flexural modulus are highly recommended as well. Those improvements can be seen in sample E, giving the best delamination response after moisture soak. These property is very important in the reliability of the package especially for units assembled without utilizing post mold cure and dry bake. Adhesion strength between the mold material and the leadframe is also needed to enhance further its package integrity.

Table 2. Delamination Response after MSL 3 Moisture Soak

Control		A		B		C		D		E	
DELAMINATION RESPONSE		DELAMINATION RESPONSE		DELAMINATION RESPONSE		DELAMINATION RESPONSE		DELAMINATION RESPONSE		DELAMINATION RESPONSE	
Leadfinger	Bottom	Leadfinger	Bottom	Leadfinger	Bottom	Leadfinger	Bottom	Leadfinger	Bottom	Leadfinger	Bottom
											

Shown in Table 2 the overall delamination response of the five (5) epoxy mold compound types evaluated after MSL 3 soak and three (3) pass reflow at 260 °C.

Conclusion

Leadfinger delamination observed is dependent per material interactions. Results revealed that having the right material set will indeed make the package robust. Critical properties that must be enhanced are the filler content, water absorption rate, coefficient of thermal expansion, glass transition temperature, flexural strength and the adhesion strength. Furthermore, the claim of having a higher filler loading on mold compounds from manufacturers to achieve a higher moisture sensitivity level might not be valid at all times based on the evaluation results.

Recommendations

Full manufacturability assessment of the best material on the chosen test vehicle and as well as to other package types must be done and to likewise verify its reliability consistency. Also, since delamination seen per interface is dependent per material interactions, the right material set (mold compound and die attach epoxy, improve in leadframe surface roughness) should be considered to further improve its moisture sensitivity level.

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Biography

Alvin Denoyo is a graduate of Master of Science in Metallurgical Engineering at the University of the Philippines. He worked as a Metallurgist at the Mint and Gold Refinery Department in Central bank of the Philippines before joining Amkor Technology in 1997 as a Materials Development Engineer. Currently, he is working at Cypress Manufacturing Ltd. as an Assembly and Packaging Development Manager.