

Initial Thermal Path Failures and Necessary Controls

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Abstract

Improvements in IC mold compounds and Die Attach materials have enabled improved Moisture Sensitivity Level (MSL) classifications at higher temperatures. As an example, a 48 pin HPQFP that had been MSL classified at 5a (24 hour floor life) for 235 Degree C reflow has now successfully passed MSL3 (168 hours floor life) for 260 Degree reflow. To achieve this level of improvement, both the Mold compound and Die attach needed to be changed. These materials are highly specialized compounds which are designed to perform a number of (often competing) tasks. As the properties needed for higher temperature and better MSL performance are improved, a number of trade-off's are inevitable. This paper deals with a number of these trade-offs, and the changes that were necessary to successfully implement these new materials. Specifically, the thickness of the Die Attach material and the "Resin Bleeding" performance of the leadframe surface were found to be key control items.

Article

The industry standard test method for moisture sensitivity is JEDEC J-STD-020 "Moisture Induced Stress Sensitivity for Plastic Surface Mount Devices" (MSL test). This document outlines the stress conditions, failure modes, and suggested analysis techniques for detecting moisture induced damage in IC packages due to Soldering Printed Circuit Board (PCB) assembly. In addition to electrical testing, acoustical imaging is an extremely valuable, non-destructive tool to see inside the packaged device and understand if damage has occurred due to the stress condition. The standards for this procedure are contained in JEDEC --STD-035 "Acoustic Microscopy for Non hermetic Encapsulated Electronic Components". Delamination can be detected by a number of different techniques. Each technique has advantages & disadvantages, and it is up to the analyst to use the appropriate technique for the intended purpose. Especially when looking at new materials and processes, it is important to understand the basic tests and requirements, and the relationship of these to the finished product. The MSL test is designed to evaluate damage that occurs as a result of the soldering stress exposure - it specifically excludes initial delamination as a failure criteria. This is an important distinction, because it was discovered that the materials which achieve the best MSL performance are also more prone to have initial delamination. Although existence of initial delamination may not fail the letter of the J-STD-020, it should be considered as a failure for purposes of materials development. Thru-Scan acoustical imaging is especially useful in

addition to more traditional Reflected imaging when the delamination plan is unknown. In this case not only was topside die surface of interest, but the backside surface as well.

Die Attach has typically been Polyimide or Epoxy based adhesive chemistry, often with Silver as a high conductivity filler material. Both chemistries are relatively "mature" and have properties which can be optimized to achieve a balance of purity, cure properties, adhesive strength, bulk strength, and thermal stability. Newer developments such as Acrylates and Liquid Bismaleimides (BMI) are available for IC assembly. These allow hybridized materials to achieve an even wider range of properties². In the quest for shorter cure cycles, the "Free Radical" cure system has also been developed which can allow elimination of the traditional oven cure. The properties of a BMI/Acrylate based, free radical cure Die Attach gave the best MSL performance during preliminary tests (see table 1) and was chosen for production implementation. This material exhibited the second highest room temperature shear strength, and the highest, High Temperature strength after 85 Deg C / 85% RH exposure, and has very low moisture absorption.

Table 1 data:

	MSL delamination @ 260 C		
	NiPdAu	Silver	Bare Cu
Epoxy Die Attach	50%	40%	94%
BMI/Acrylate	3%	23%	0%

The Lead(Pb)-Free product was targeted to use a NiPdAu plated leadframe, so the BMI/Acrylate showed a step-function improvement in delamination. The Die Attach change produced the most significant increase in MSL performance. The higher shear strength (~ 2x) of the new material in conjunction with a higher modulus generates a higher stress at the Die to Leadframe interface. The TCE difference between the L/F (CU) and the Si die is ~ 13 ppm per Deg C. Since the Die Attach cure temp is 220 Degrees C, this sets up a significant stress between the two when cooled to room temperature after D/A cure. Finite element modeling predicts that the peak shear stress (in the corner of the die) will be about 80 MPa at 1 mil Bond Line Thickness. Since actual testing showed that the epoxy could withstand only about 14 MPa, and the BMI/Acrylate only ~ 25 MPa before fracture at room temperature, it is clear that the bulk and surface adhesion stress on the Die Attach will be critical, and there is a risk of the die "popping off" as the die & Leadframe cool after cure. The higher strength of the BMI helps in this regard, but it also has a higher modulus, which results in a higher stress level. The cool down ramp rate after cure must be controlled to allow for some "creep" to occur in the Die Attach and relieve a portion of this stress. Bond Line Thickness is also a key control factor, and a minimum bond line thickness was

specified to further reduce the potential die to Lead frame stress. Although these phenomena are not new to this industry, the sensitivity occurs for smaller dies with the stronger adhesives or higher peak cure temperatures. A cool down ramp rate of 2-3 Degrees per minute to 80 Degrees, and a minimum Bond line Thickness of 1.5 mil (.0015") was specified for this application.

There are some additional peculiarities of the free Radical cure system. The atmosphere at Die Attach cure needs to be controlled to not allow the re-deposition of the out gassing products of the adhesive, and in some cases it also needs to be controlled to limit the oxidation of the leadframe. Epoxy Die Attach Cure ovens can often utilize Clean Dry Air (CDA) instead of CO₂ or Nitrogen as cost a savings measure. Free Radical Cure systems can be sensitive to the Oxygen content of the atmosphere during cure, and the compatibility of either Air or CO₂ should be investigated carefully. The Oxygen in the cure oven can compete with the cure chemistry, and reduce the effectiveness of the cure. In this case, Nitrogen is used to purge the Die Attach Cure ovens.

Another issue occurred with this program during start-up. When the Leadframe Supplier changed to a different manufacturing location for production, sporadic cases of delamination were seen. The majority of these were detected after board mount during system level check-out of the prototype designs. This is the worst possible time and place to discover a packaging failure. It should be noted that the failure mechanism was delamination in the thermal path only (between the die and the exposed die pad) and there was no delamination of the top side die surface, or effect on the electrical functionality of the device. There is no screening (100% of product) for thermal performance before board mount, so it is not known if the failure existed before board mount. A number of tests (most notably board assembly with and without dry baking) that were run to try and identify the source of the problem. The "Bake / No-bake" split lots showed no sensitivity (improvement) to package moisture. Separate sample monitoring using Thru-SAM showed some instances of initial die to Leadframe delamination. This was not seen during the previous Thru-SAM evaluations. A Designed experiment was then conducted which isolated the initial delamination cases to the production leadframe, and not on the leadframe from a different manufacturing location. The "hunt" for the root cause uncovered that a process had been implemented at the Leadframe Supplier without notification. This process was implemented to control Resin Bleed Out (RBO) for one of the lead frame supplier's other customers. RBO is the separation of the Die Attach Resin before cure (see Photo #1). This phenomenon is widely recognized, and TI was aware of RBO, but this was not a problem for this program. There are a number of conditions that affect the bleed rate, and the problem is often more pronounced with NiPdAu plated leadframes and rough surfaces. In this instance, the chemical used for "Anti-RBO" treatment was the same as is commonly used for Silver Spot leadframe tarnish control. The leadframe Supplier did not recognize that this could cause problems with adhesion. Further investigation verified that the BMI/Acrylate Die Attach chemistry is much more sensitive to this type of contamination than Epoxy based systems¹. Anti-tarnish and "Anti-RBO" treatment residue is not easily detectable. AUGER, FTIR, and some wetting tests

are effective for detecting these materials, but are not commonly used for leadframe testing. Even with these sophisticated analysis tools, there is some inconsistency in the results (or non-uniformity in the contamination distribution). The use of any "post plating" treatment on NiPdAu plated leadframes needs to be closely controlled as the interaction with different Die Attach and Mold compounds can be problematic. Once the "Anti-RBO" treatment was eliminated, the delamination & thermal path issues stopped. With "clean" lead frames and the new Die Attach and Mold compounds, the MSL performance was improved by 3 levels at a higher reflow temperature (from MSL5a @ 235 C to MSL3 @ 260C).

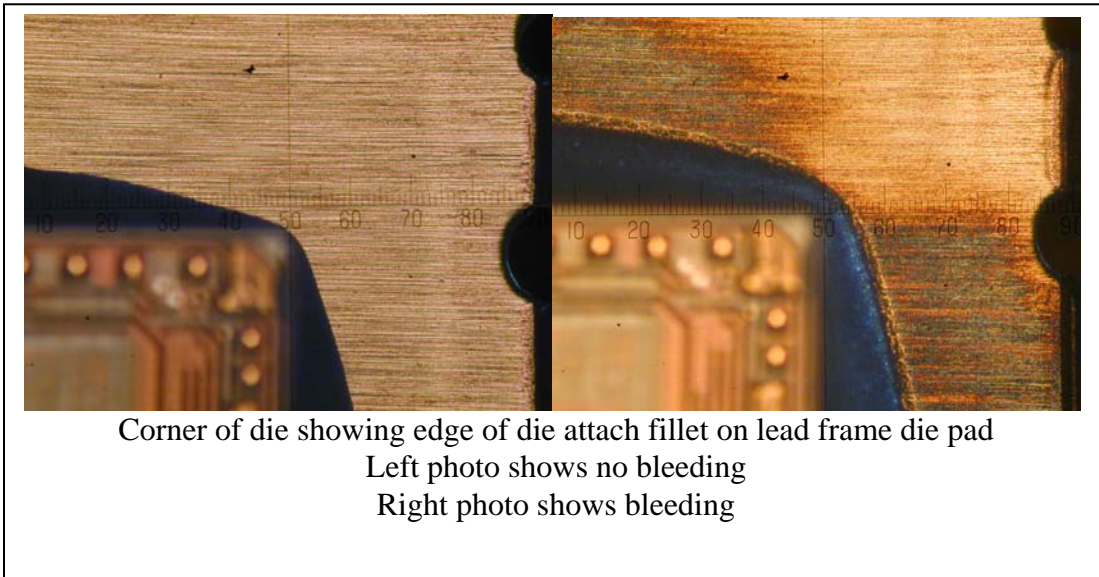


Photo #1

The use of non-epoxy based die attach adhesives allows for significant improvement in MSL performance, but additional controls need to be recognized and implemented to realize their full potential.

About the Author

John Tellkamp graduated from the University of Texas at Austin with a degree in Mechanical Engineering in 1980 and has worked with materials and IC packaging development at Texas Instruments Inc. beginning in 1981. He was elected to TI's technical Staff in 1987 and holds 3 patents in the field of IC packaging.

References:

¹ "Die Attach Adhesion on Leadframes Treated with Antioxidants" by Marvin Cowens & James Huneke Oct. 1997 IEEE/CPMT Singapore

² "Implementation of No-Bonder-Curing to Maximize Array Package Manufacturing Productivity" by Stephen J. Taylor and Rene J. Ulrich SEMICON West 2000.

