A Case Study of PEMs Susceptible to Die Surface Delamination and Their Behavior During Thermal Excursions

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Originally presented at NEPCON Southeast, 1995.

INTRODUCTION

ITT Aerospace/Communications Division has been very active in the application of commercial off-the-shelf plastic encapsulated microcircuits (PEMs) to military and high-reliability products. In such applications, timely and accurate failure analysis is critical to understanding and correcting potential reliability problems before the equipment is fielded.

One area that impacts PEM reliability is molding compound adhesion to the various elements within the device, especially molding compound to die surface adhesion. This condition should always be considered a potential failure[1], and in this case was directly linked to a failure.

This paper will summarize a case involving a 44 lead plastic leaded chip carrier (PLCC-44). The details of the relevant failure analyses will be covered, as well as the design and results of an experiment that followed.

INITIAL FAILURE ANALYSIS

A number of these devices, failing for various reasons, were submitted for failure analysis. During the course of the analysis, the parts were routinely inspected using a C-SAM acoustic microscope, and areas of delamination of the molding compound were found (although these were not failure-related). One area of particular concern was delamination of the molding compound/die surface interface [fig. l-2]. Delamination in this area was considered a reliability concern, although it was not directly failure-related in these parts. Further research into these devices was considered warranted.

Because these devices had been desoldered, it was considered important to look at some still on boards, to see if the die surface delamination was truly representative of product through ITT's manufacturing process, or if was an artifact of the desoldering. Varying amounts of die surface delamination was found on these parts [fig. 3-5]. Many areas were definitely delaminated; others appeared to be poorly or weakly bonded, based on the acoustic information[2].

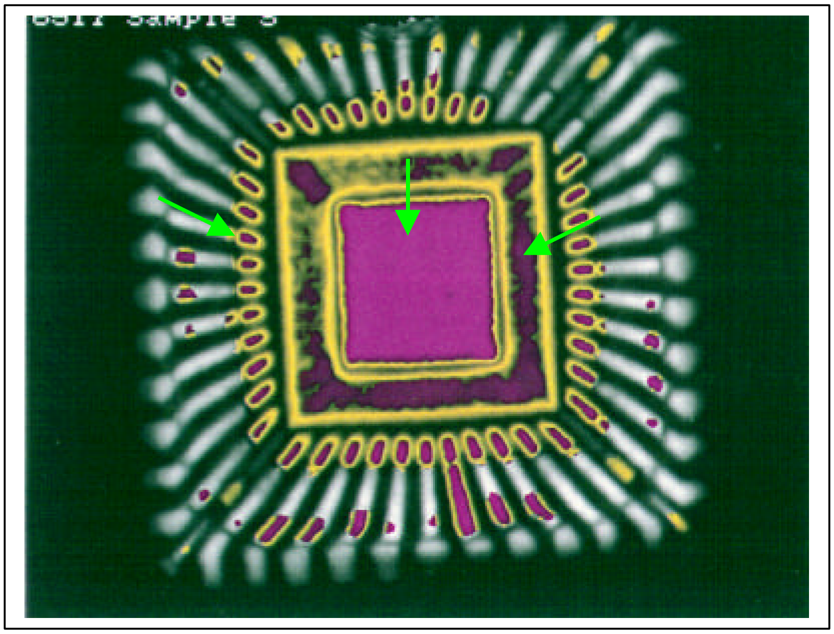


FIGURE 1 Acoustic Image of one of the failures, which was 100% delaminated over the die surface (center arrow). The top side of the die paddle was also 100% delaminated, along with numerous areas on the leadframe elements.

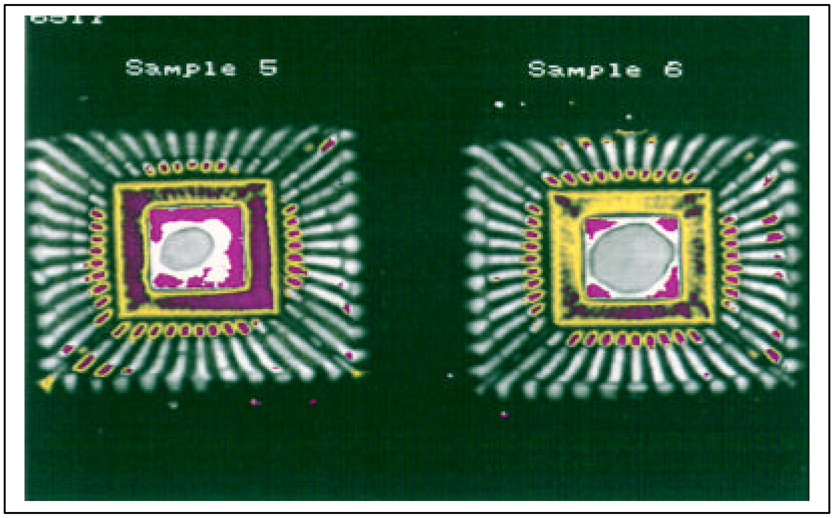


FIGURE 2 Two other failures, partially delaminated over the die surface.

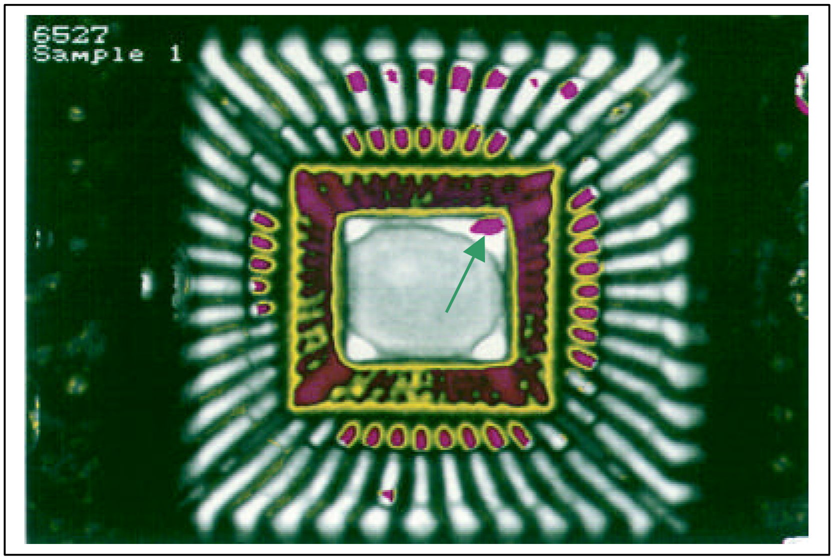


FIGURE 3 A device still attached to a board. Die surface has some poorly bonded areas (white), which transition into full delamination (arrow).

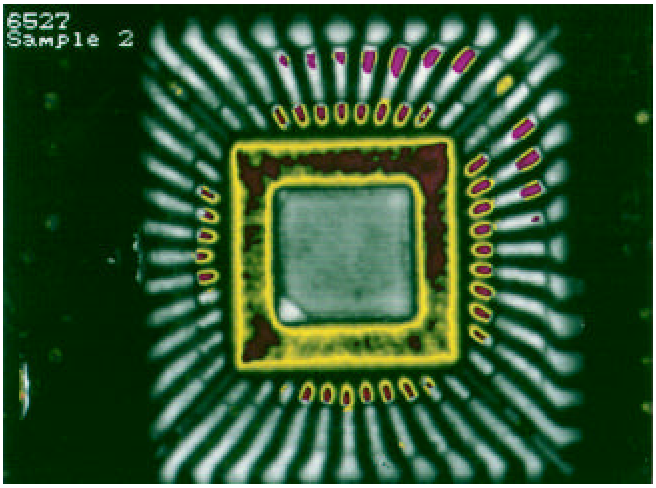
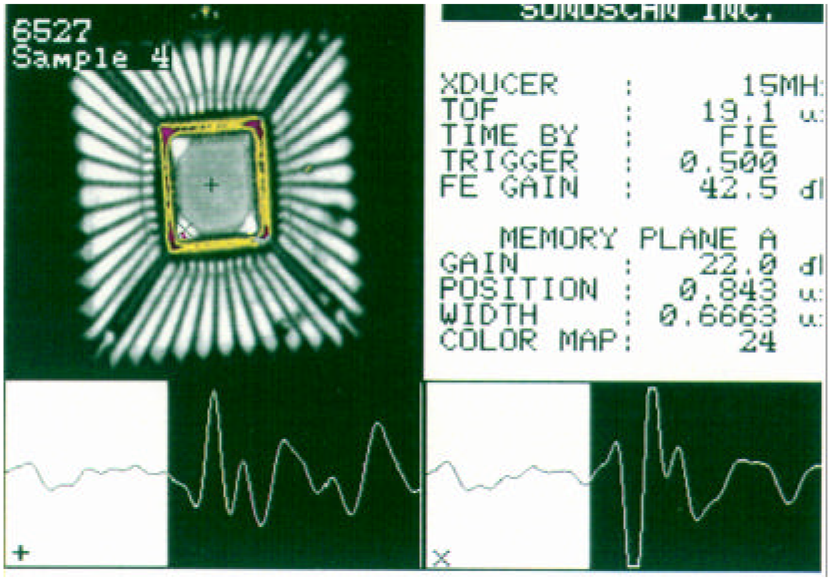


FIGURE 4 A device still on the board, with only one corner of the die surface poorly bonded.



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SONOSCAN INC.

XDUCER     :     15MH
TOF        :     19.1 u
TIME BY    :      FIE
TRIGGER    :    0.500
FE GAIN    :     42.5 d

   MEMORY PLANE A
GAIN       :     22.0 d
POSITION   :    0.843 u
WIDTH      :   0.6663 u
COLOR MAP  :       24
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FIGURE 5 This figure shows the echograms associated with the poorly bonded condition. The echogram at "+" shows the expected positive echo associated with a well-bonded area. At "x", the positive echo is preceded by a negative echo, indicating poor bonding. A delaminated area would have a fully negative (inverted) echo.

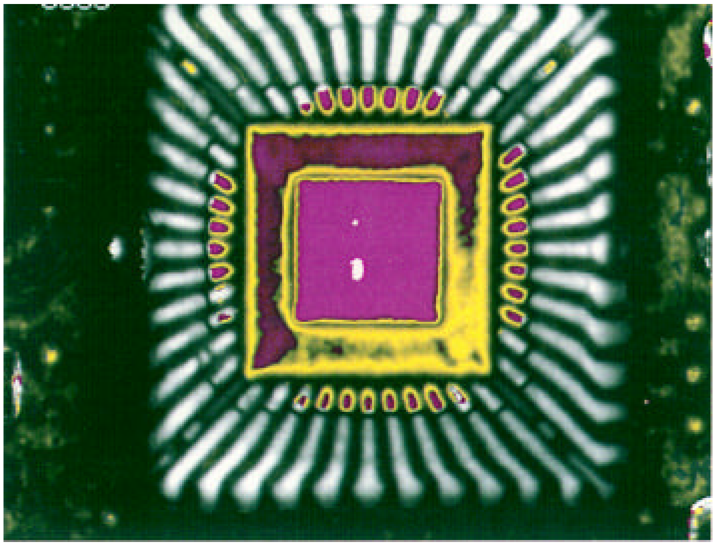

FIGURE 6 This is the device that failed due to bond damage (still on the board). Die surface is 100% delaminated.

During this timeframe, another failure was located. This time it was suspected as being related to the die surface delamination, because it was intermittently open at high temperatures. It was submitted while still on the board. C-SAM inspection confirmed the die surface was 100% delaminated [fig. 6].

Initial scanning electron microscope (SEM) inspection of the wirebonds found no defects. However, pull testing found that several bonds were significantly degraded, pulling at about 50% of the strength of a "good" bond. One pulled at zero force. These degraded bonds failed due to the lifting of the ball bond, a result of a silicon chipout [fig. 7]. This is typical of ball bond damage as a result of delamination of the molding compound at the die surface[3,4].

The conclusion was that this failure was caused by the delamination, the first of the failures to be so linked. As a result of this finding, additional numerous (non-failing) devices were C-SAM inspected while still on boards. Forty-eight percent of the samples examined showed some areas of poor adhesion (not yet delamination). Nineteen percent had some areas of actual delamination. A total of 67% of the samples showed some sort of adhesion problem at the die surface/molding compound interface.

Virtually all of the effort described above was concentrated on a single date code (D/C), 9417.

EXPERIMENT DESIGN

These findings prompted a number of questions, regarding the serious reliability concern of delamination along the die surface:

- Is this a problem with other date codes of this device?
- Where in the process does the delamination occur, or are the parts delaminated as-received from the supplier?
- Do the parts with poor adhesion eventually become fully delaminated?

An additional question was the effect of pre-baking the parts, prior to solder reflow, Conversations with the supplier regarding this defect found that they believed the problem was due to no pre-bake (the process did not include a pre-bake routinely).

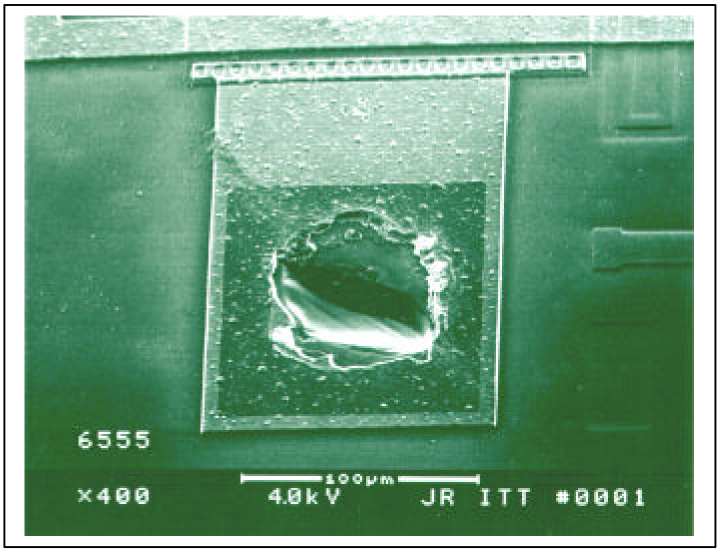

FIGURE 7 This SEM micrograph shows the bond pad that was under the bond that lifted up with zero force. The chipout in the silicon is readily apparent.

SUMMARY OF EXPERIMENT RESULTS

	INITIAL		IR		WAVE		45 T.S.		105 T.S.	
	LF	DS	LF	DS	LF	DS	LF	DS	LF	DS
9417 Pre-bake	2	15	--	1+	--	--	3 1+	1+	1+	--
9417 No bake	4	10	3+ 12	3 2+	--	--	3	--	--	--
9431 Pre-bake	4	0	2	5	4+	--	2+	--	1	--
9431 No bake	3	1	--	--	--	--	--	--	--	--
9446 Pre-bake	0	2	--	--	--	--	--	--	--	--
9446 No bake	0	1	--	--	--	--	--	--	--	--

KEY

LF : Leadframe delamination
DS : Die surface delaminations or adhesion issues
#+ : the quantity of parts (#) which showed an increase in the area of the delamination after this step
: The quantity of parts (#) which exhibited this delamination for the first time after this step
-- : No change

An experiment was set up as follows: 40 stock parts from each of three date codes, 9417, 9431, and 9446, were to be obtained, for a total of 120 parts (all three date codes used the same molding compound). All parts would be C-SAM inspected initially. The lots of 40 parts would then be split into two batches of 20 parts each, so that for each date code, half of the lot could be pre-baked(46hrs at 125 degrees C). All 120 parts would then be processed through IR reflow, a wave solder simulation, and temperature cycling (-55°C to +66°C), with C-SAM inspection after every step.

The C-SAM inspection was to be concentrated on two areas. One was the delamination of the molding compound on the die surface. The other was delamination of the mold compound on the top side of the leadframe, especially over the wirebonds. This was an area of concern, based on the number of parts found exhibiting the condition, but was considered secondary to the die surface delamination.

EXPERIMENTAL RESULTS

This was the first time a large number of stock parts had been C-SAM inspected. D/C 9417 had nine parts with poorly bonded a reason the die surface, and 16 parts with delaminated areas, for a total of 63% of the samples with die surface adhesion issues.

In contrast, D/C 9431 had one device with die surface delamination, and D/C 9446 had three devices with areas that were poorly bonded (no delamination).

The results of this experiment are summarized in Chart 1. The major changes in die surface delamination occurred during IR reflow. These were isolated to D/C 9417 and 9431 [fig. 8-12]. Significantly, only 24% of the D/C 9417 parts with die surface adhesion issues changed during IR reflow; the remainder were stable. After IR reflow, all die surface delaminations were stable, with the single exception of a small increase in size of one die surface delamination during thermal cycling.

There was no pattern associated with the parts which changed. One part which had only small areas that were poorly bonded, delaminated completely during the IR reflow; other parts which had significant areas of delamination remained stable.

There was no correlation between pre-bake and no pre-bake parts, and changes in die surface delamination. The pre-bake,

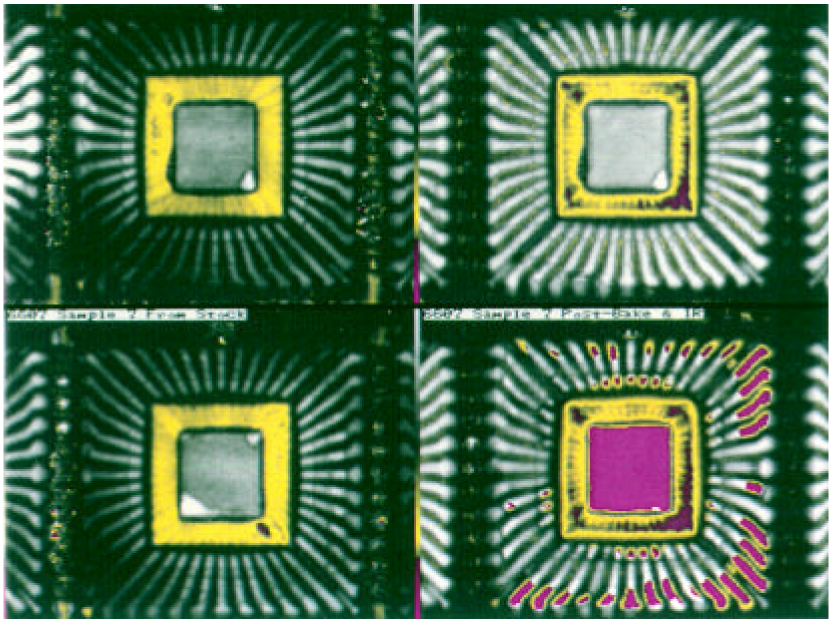

FIGURE 8 These images show the difficulty in predicting how the die surface will behave. Both D/C 9417 parts had small areas of poor bonding; the sample at the bottom fully delaminated during IR reflow, while the top sample remained unchanged. (In figs. 8-10, left images are initial, and right images are post-IR reflow.)

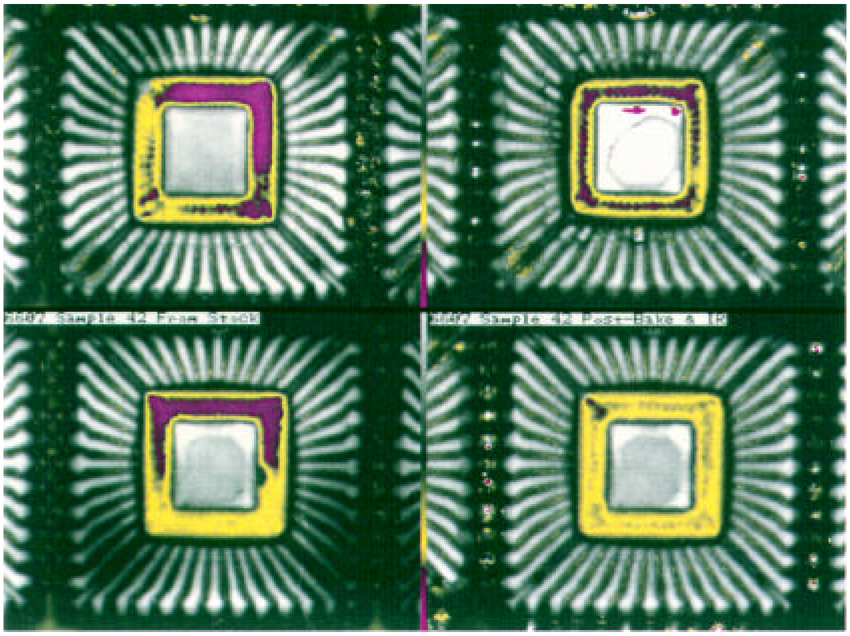

FIGURE 9 The top image shows a D/C 9431 part which has a large area of the die surface poorly bonded following IR reflow. The bottom shows a D/C 9446 part which initially showed some poor bonding, and remained unchanged after IR reflow.

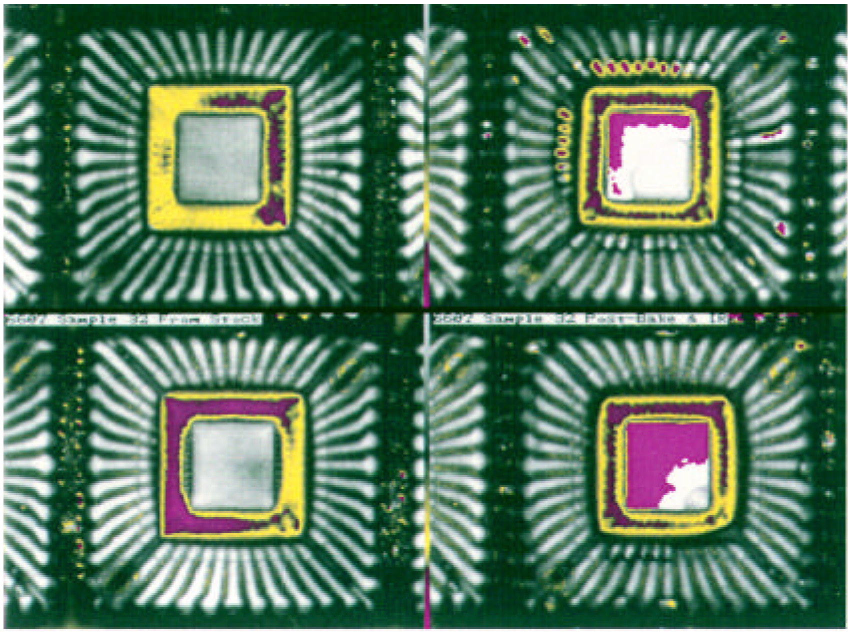

FIGURE 10 Two D/C 9431 parts which exhibited severe die surface delamination after IT reflow (both were pre-baked).

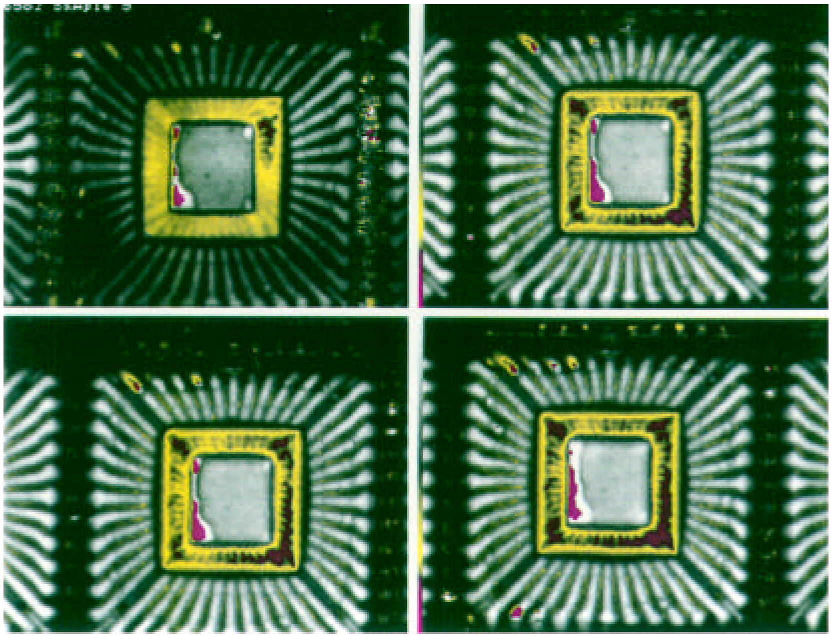

FIGURE 11 This was a D/C 9417 part which initially had die surface delamination. Upper left is initial image; upper right is post-IR reflow; lower left is after wave solder; lower right is after 105 thermal shocks. After 105 thermal shocks, there was a small increase in the area of delamination. Otherwise, the part was stable.

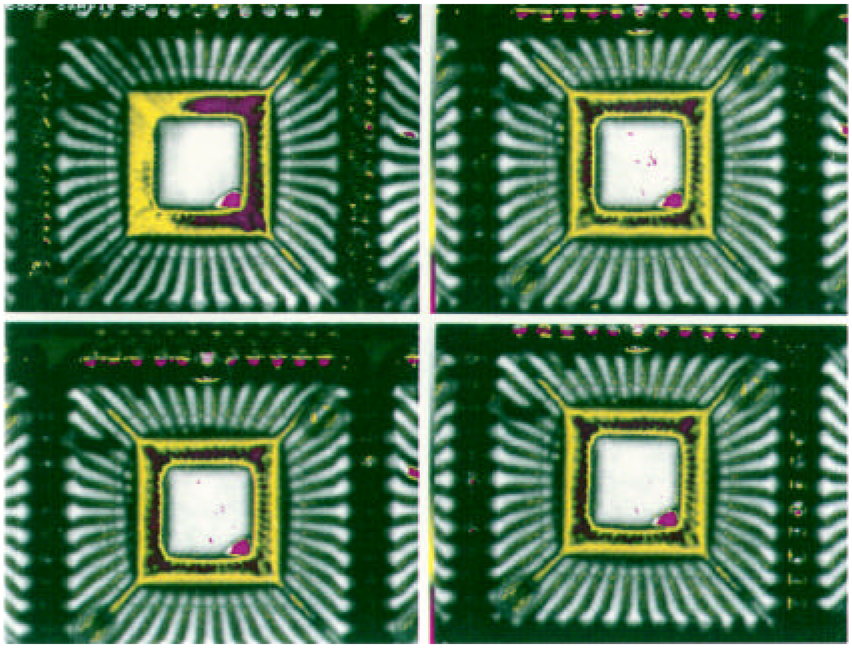

FIGURE 12 A D/C 9431 part with die surface delamination, which remained unchanged after the same four steps in figure 11.

however, did have an impact on the leadframe delaminations on D/C 9417 parts. Electrical testing after all testing was completed found no failures.

CONCLUSIONS

Several conclusions were apparent upon completion of this experiment. . The overriding factor in the die surface delamination was found to be the part date code: that is, the die surface adhesion issues were distinctive within a given date code. This means the problem is related to processing at the supplier, and indicates that a cause can be isolated and corrected. It is also only at this top level of date code that behavior can be predicted. In other words, once a suspect date code is identified, its behavior in terms of die surface delamination can be somewhat anticipated through IR reflow. l The die surface characteristics of the parts initially, whether good or bad, were not predictors of how the parts would behave throughout the experiment. Many parts with delamination remained stable, while parts that appeared good or marginal became more severe. l There was no correlation between pre-bake and die surface adhesion. In one date code, however, the pre-bake substantially improved the leadframe adhesion characteristics. l To accurately evaluate the die surface adhesion characteristics, C-SAM inspection after IR reflow is necessary. It is IR reflow that produced the most change in the die surface adhesion characteristics: it was relatively stable after all other steps. Therefore, C-SAM inspection after IR reflow will give a good indication of how the parts will look in finished product, after all testing.

REFERENCES

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2. SonoScan Inc., C-SAM Series Applications Manual, Case #8, October 1991.

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4. R. Angeles, G. Ilog, J. Nicolas, T.M. Moore, K.S. Wills, "C-SAM Analysis of Plastic Packages to Resolve Bonding Failure Mode Miscorrelations", Proceedings of the 18th International Symposium for Testing and Failure Analysis (ISTFA 92), pp316-319.