GODDARD SPACE FLIGHT CENTER

Evaluation Report

Report Number EV61261

Microcircuit (11)
Linear Technology
P/N LT1014IS
d/c 9617

Project
PEM

System
Group A/FA

Requester
G.Rose (312)

Malfunction Report

Incoming Inspected

Initiated Date
07/26/96

Purchase Specification
Commercial

Screening Specification

Investigator
A. Teverovsky

Technical Approval/Date

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Approval for Distribution/Date

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Background

Eleven Linear Technology LT1014IS microcircuits were received by the GSFC Parts Analysis Laboratory for an evaluation of their design according to the requester's plan. This included external visual and X-ray examination, decapsulation, internal visual examinations, bond pull and die shear tests, glassivation layer integrity test, and SEM/EDS examinations. Techniques used for these tests are described in Report PP61206 (DPA procedure for PEM).

Part Description

The Linear Technology LT1014IS is a quad precision operational amplifier. It consists of two identical dice mounted on a paddle using silver filled epoxy die attach material. The lead frame is made of copper which is plated with silver at bonding sites (the paddle and internal tips of the leads). Die bond pads are interconnected with the package terminals using 1.5-mil gold wires which are thermosonically ball bonded to the pads and crescent bonded to the terminals. The part is encapsulated in a 16 lead small outline (SOL) package with an epoxy novolac molding compound.

Analysis

1. Incoming inspection.

All samples were subjected to External Visual and X-ray Examinations. No defects or irregularities were found.

2. Decapsulation.

Wet chemical jet etching was performed using a B&G decapsulator, model 250. Figure 1 represents an optical view of a normally decapsulated sample (100% of the die surface and approximately 75% of the wire lengths are exposed). The following regimen was experimentally chosen for the normal decapsulation: temperature 70°C, volume 3, etching time 100 seconds. Several samples were intentionally overetched (etching time 120 - 140 seconds) to expose the wire bonding to the leads (for the subsequent examinations) and the paddle (for the subsequent die shear test and die cross sectioning). Figure 2 represents an overetched sample. To clean up the die surfaces, all samples were subjected to oxygen plasma at 50 W power for one hour.

3. Internal visual inspection.

All decapsulated samples were examined under a low power (40X) microscope and then at high power (200X). The die surfaces were clean and had no damage caused by the deprocessing (see Figure 3). No visual manufacturer's defects or any fault which could have been introduced by decapsulation were found.

4. Die shear test.

The test was performed on SNs 7 and 14 per MIL-STD-883D, method 2019. The requirement for the die strength is 2.8 kgF. Table 1 displays the test results and Figure 4 shows a view of a sample after the test.

Table 1. Die shear test results.

SN	**die**	**Strength, kgF**	**Die separation**
7	1	>2.15	shearing of the die
	2	1.15	from die attach
14	1	1.3	from die attach
	2	1.45	from die attach

All results were below the rejectable criteria. A pure separation between the die bottom side (covered with gold) and silver epoxy die attachment was found in all samples (except die 2 SN 7 where the die fractured). This suggests a poor adhesion of the die to silver-epoxy polymer which consistent with the previous cross sectioning analysis of the part (see Report EV62563).

The failures during the die shear test were possibly due to damage of the attachment material during the decapsulation. Red fuming nitride acid attacked the epoxy adhesive after the paddle had been exposed. Evidence of this effect was seen during internal examination (see Figure 5).

It should be noted that there are no specified requirements for die shear tests for plastic encapsulated microcircuits (PEM). The lack of possible die separation from the paddle during the vibration or high acceleration tests is considered as one of the benefits of PEMs.

One of the reliability concerns which may be related to a poor adhesion between a die and a die attachment material is the die-to-paddle thermal impedance. Voiding in the attachment can decrease thermal conductance and at a certain level (usually 50% of the interface area) is rejectable. An intimate contact between the die and silver epoxy would provide an adequate heat sink to the paddle. Adhesion (which depends on intermolecular forces and can be estimated by the die shear test) is not necessary. More than that, experiments show (T. Conrad, R Shook, 1994) that delaminations in low power microcircuits encapsulated in 44 pin PLCC packages resulted in a die temperature increase only of 0.6°C. Calculations gave similar results with delamination thicknesses of 2 to 10 micrometers. In our case, the delaminations were in the submicrometer range an would probably not affect the thermal impedance at all.

5. Bond pull test.

This test was performed on SNs 3, 4, and 17 per MIL-STD-883D, method 2011. SNs 3 and 4 were decapsulated normally (approximately 75% of the wire had been exposed) and SN 17 had wires which had been exposed completely. Table 2 displays the test results. The failure category for SNs 3 and 4 was a break at neckdown point (for all pins). Several wires in SN 17 failed with the same category (column SN17n in Table 2), but most of them failed at the crescent bonds (column SN17c in Table 2).

Table 2. Pull test results (gram-force).

PIN	SN3	SN4	SN17n	SN17c
1	14.2	18.1	13.5	
2	>20	>20		0.6
3	18.1	>20		0.7
4	14.7	13.1		0.1
5	17.4	14.3		0.1
6	19.4	17.9		0.1
7	>20	18.3		3.1
8	19.4	>20		0.1
9	>20	>20		20
10	>20	>20	>20	
11	>20	>20		17
12	>20	>20	16.3	
13	17.6	19.6		14.2
14	>20	>20		>20
15	>20	>20		>20
16	>20	>20	16.8	

The requirement for minimum bond strength for a 1.5 mil gold wire is 4 grams. SNs 3 and 4 passed the test and SN 17 failed. Obviously, the reason for the failure was acid attack on the crescent bonding. Nitride acid does not affect gold and aluminum but vigorously reacts with silver and copper. Figure 6 shows the distribution of pull strengths for different samples. SNs 3 and 4 had similar distributions with a median strength of approximately 20 grams. SN 17 had a bimodal distribution. Approximately half of the wire bonds which failed at crescent bonding had very low pull strength (less than 1 gram) and the others had the strength similar to those for SNs 3 and 4. Most likely the bonds which exhibited high strength had not been attacked by the acid.

The ball shear test is considered to be more sensitive than the wire pull test and to provide a better measure of ball formation reliability. To check the reproducibility of the results and the type of formed fractures, two samples were subjected to the ball shear test. The ball shear test was performed by calibrating the maximum load to 200 gram-force. The tool was manipulated behind each wire ball as closely as possible but not touching the die surface, wire, or wire ball. Then the tool was moved downward, tapped against the die surface, and was moved back to a prearranged distance from the die surface. Then it was swept forward against the ball measuring the shear force. Table 3 shows the results of the test.

Table 3. Ball shear test results (gram-force).

PIN	SN 4	SN 5
1	109.9	90.7
2	110.8	104.9
3	111.3	109.9
4	119.6	117.3
5	121.3	117.7
6	122.7	120
7		122.5
8		123.7
9		126.2
10		129.1
11		129.6
12		136.9
13		141.4

Both samples had similar mean values 115.9 gF (SN 4) and 120.8 gF (SN 5) and relatively small standard deviations 5.9 gF (SN 4) and 13.4 gF (SN 5) suggesting good reproducibility of the results. In most cases (approximately 85%) the fracture occurred through the gold ball and looked like a cut (see Figure 7) which suggested a high strength of the gold-aluminum attachment. The rest of the balls fractured partially through the ball and partially through the aluminum pad. No cratering of the bond pad on the die (which may have been introduced by an improper set up of bonding machine) or residual mechanical stresses in the part were observed.

6. Glassivation layer integrity.

Two samples (SN 17 and SN 19) were subjected to the glassivation layer integrity test per MIL-STD-883D, Method 2021. Figure 8 represents a view of a sample after the aluminum metallization at the contact pads had been removed. No other defects in the aluminum metallization except some near the pads (as expected) were found.

7. SEM inspection.

Samples SNs 14, 15, and 16 were examined using a SEM per MIL-STD-883D, Method 2018. Glassivation had been removed from SNs 15 and 16 first in a freon plasma (to remove the Si_3N_4 film) and then by wet chemical etching (to remove the SiO_2 film). Two dice from SN 14 were mechanically detached from the paddle and then subjected to cross sectioning. Figure 9 represents a view of an aluminum metallization run showing an adequate oxide step coverage. Figure 10 represents a cross sectional view. The two layers of glassivation formed a conformal, intimate contact between each other and to the underlying metallization. No rejectable defects were found during this test.

Conclusion.

Evaluation of the Linear Technology LT1014IS plastic encapsulated microcircuit did not reveal any defects which were of reliability concern. Two-layer glassivation (Si_3N_4 / SiO_2) formed a conformal nondefective coating which reliably protected underlying circuitry. Aluminum metallization had adequate step coverage. The part failed die shear tests and bond pull tests after the wires were completely exposed during decapsulation. Both failures were most likely due to the acid attack during jet etching. The ball shear test is probably a good addition to the bond pull test for bond quality evaluation purposes.

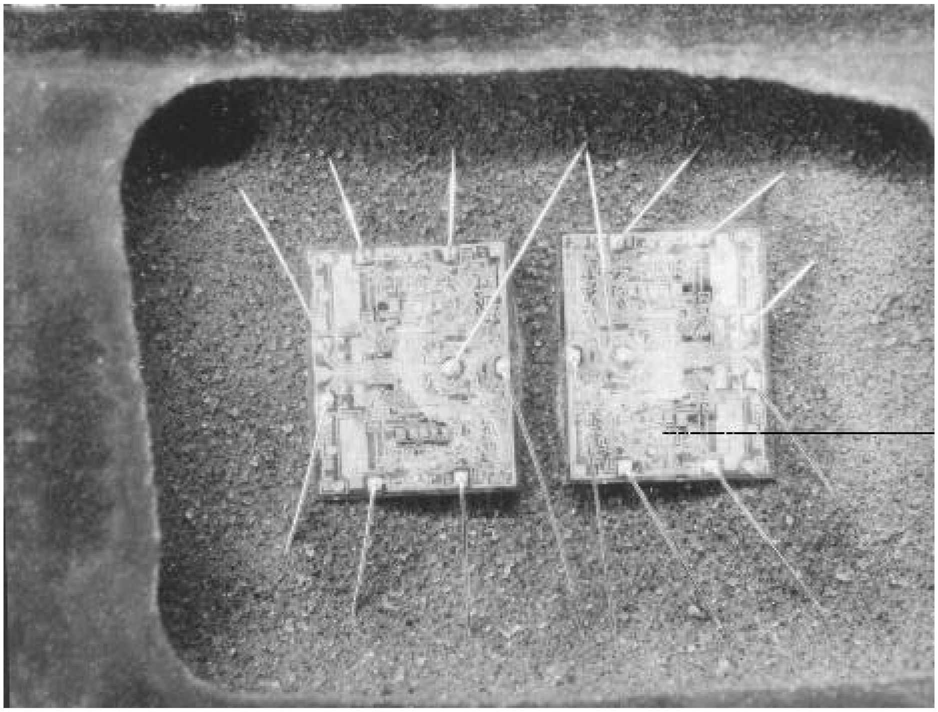

Figure 1. An overall view of a normally decapsulated microcircuit, SN 1. (12.5X)

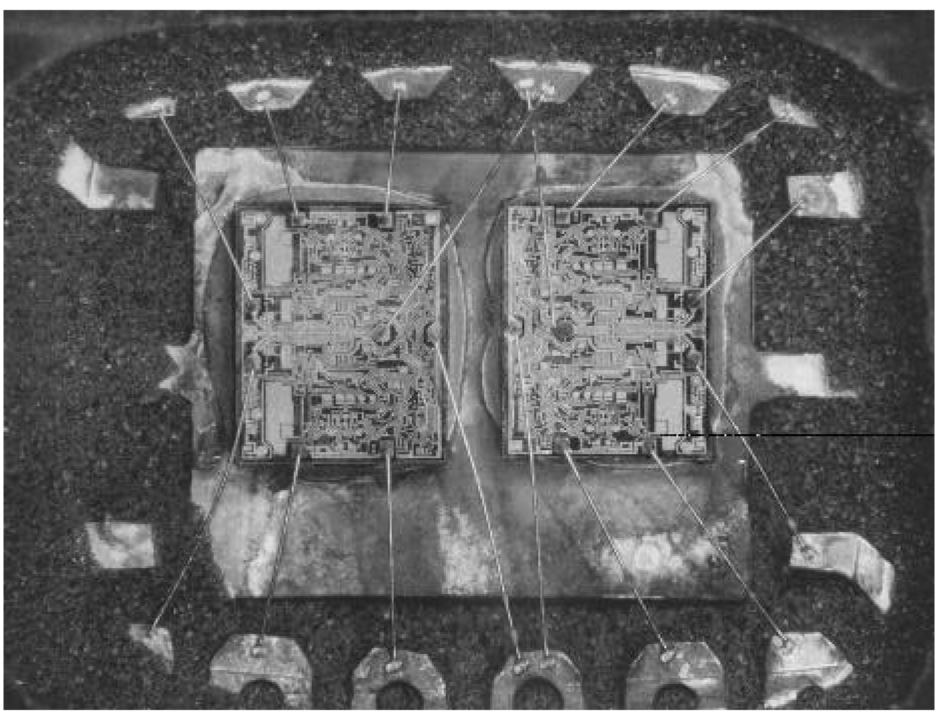

Figure 2. An overall view of the intentionally overetched microcircuit, SN 17. (12.5X)

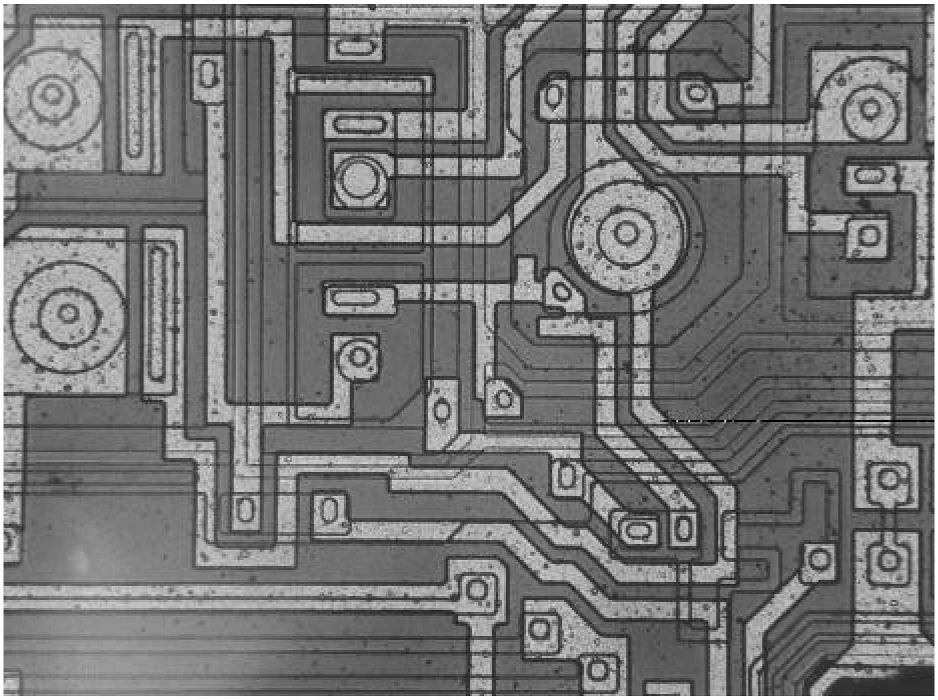

Figure 3. An optical view of the die fragment after decapsulation, SN17. (200X)

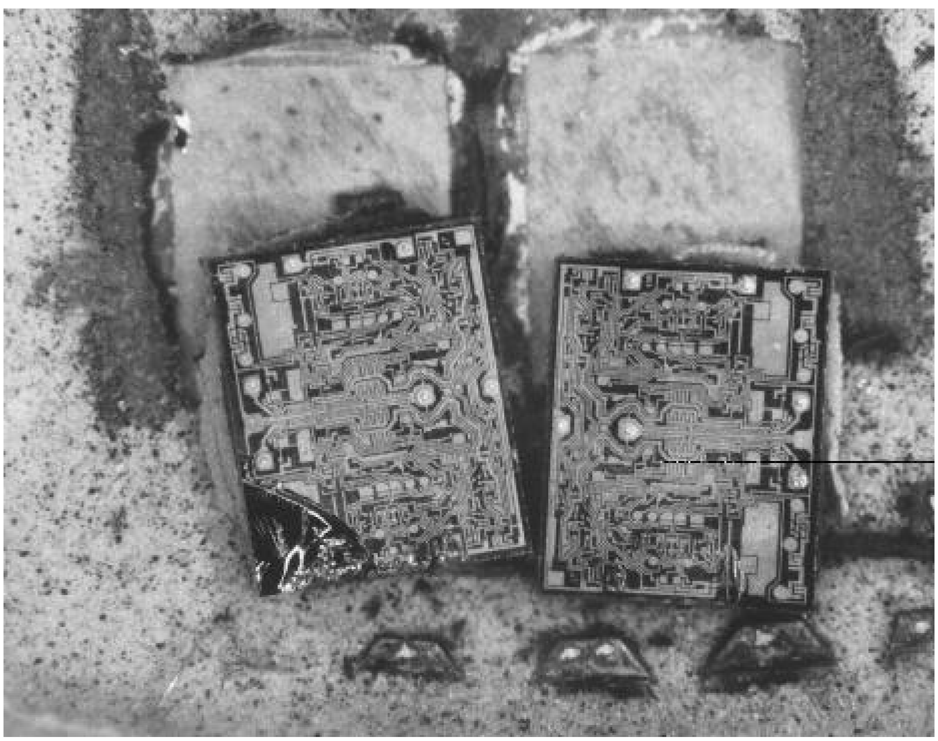

Figure 4. An optical view of the microcircuit after the die shear test, SN 7. (16X)

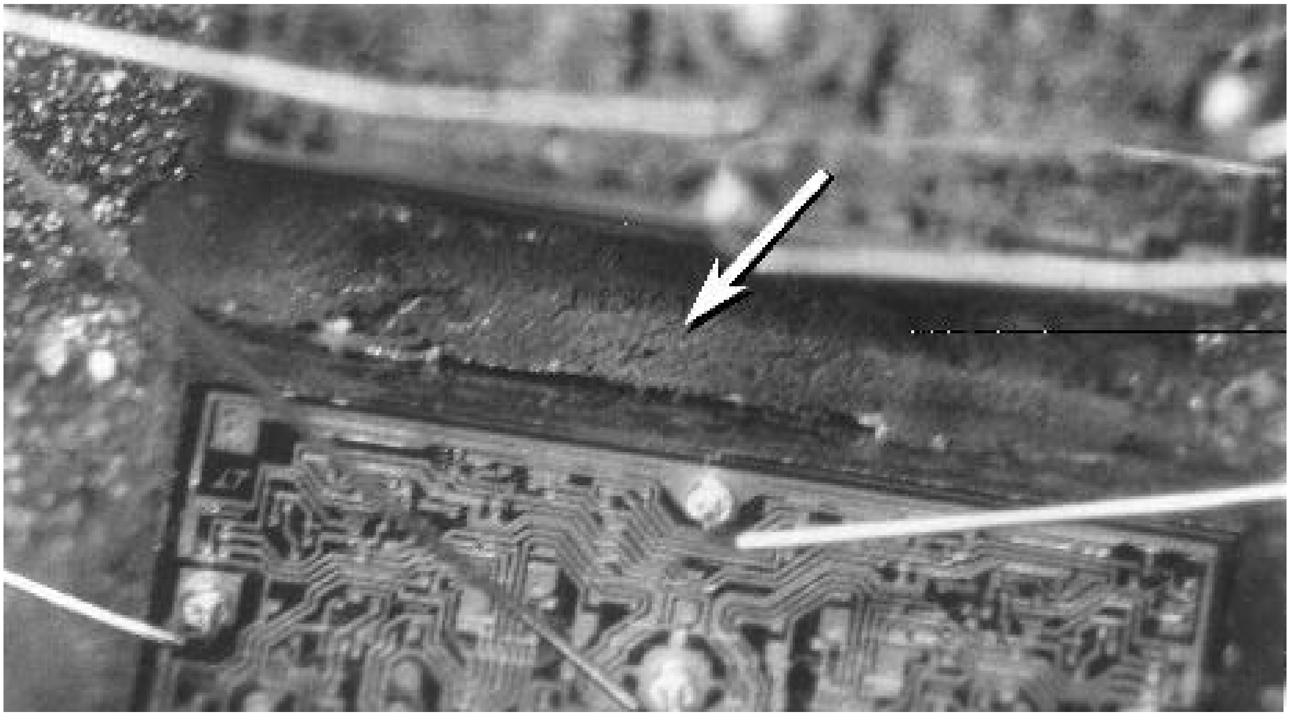

Figure 5. An optical view of die attach material which have been attacked by acid during decapsulation, SN 16. (37.5X)

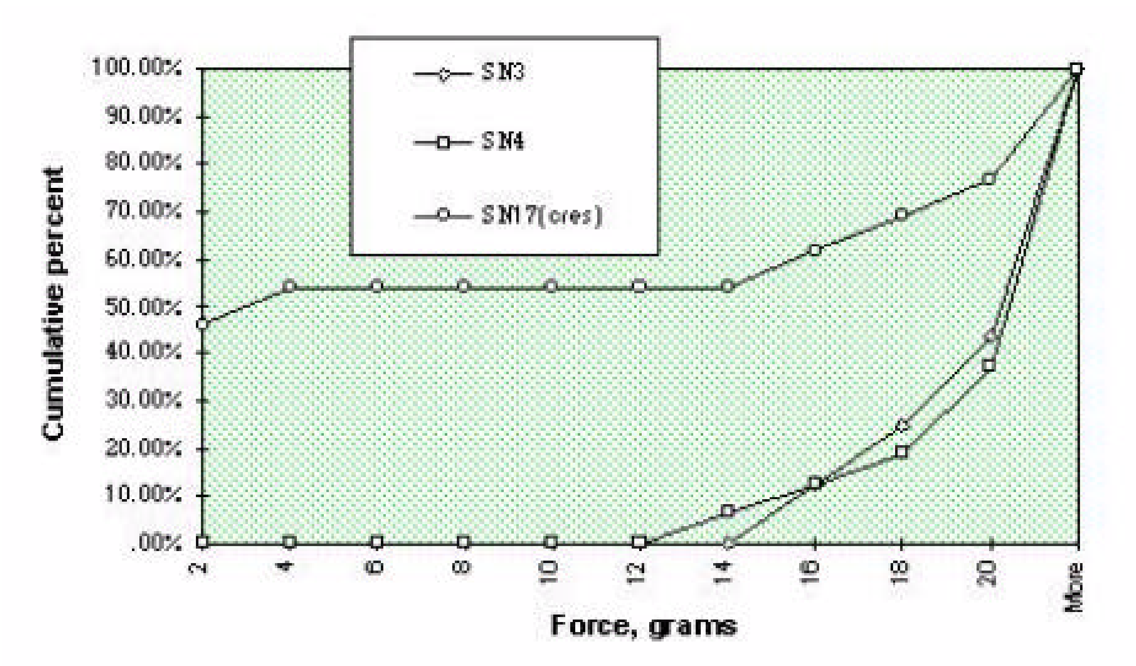

Figure 6. Bond pull strength distribution.

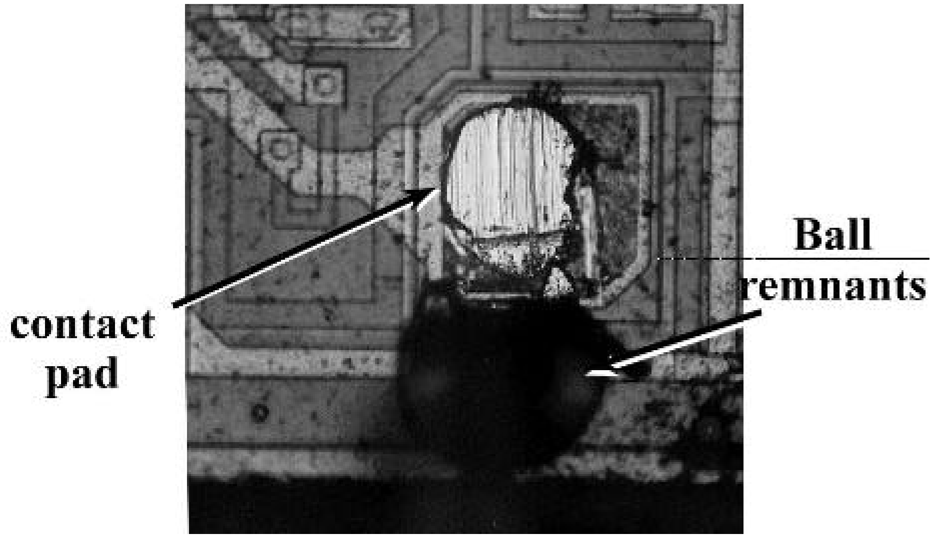

Figure 7. An optical view of the wire bonding after the ball shear test showing a shear fracture across the ball. (200X)

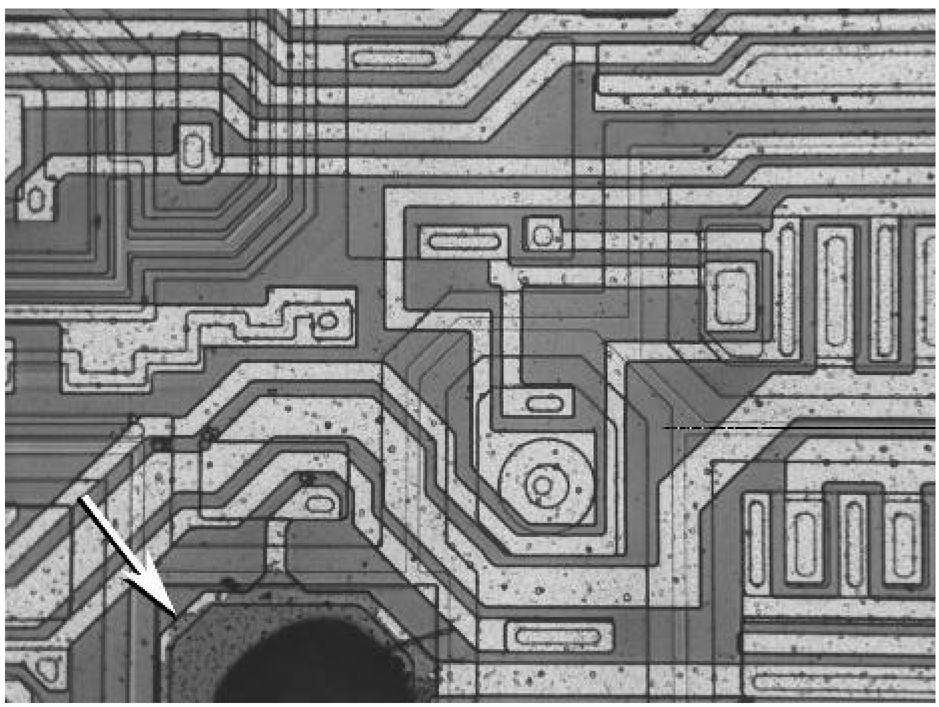

Figure 8. An optical view of the die after the passivation layer integrity test, SN 19. Arrow denotes a contact pad with an etched aluminum metallization. (200X)

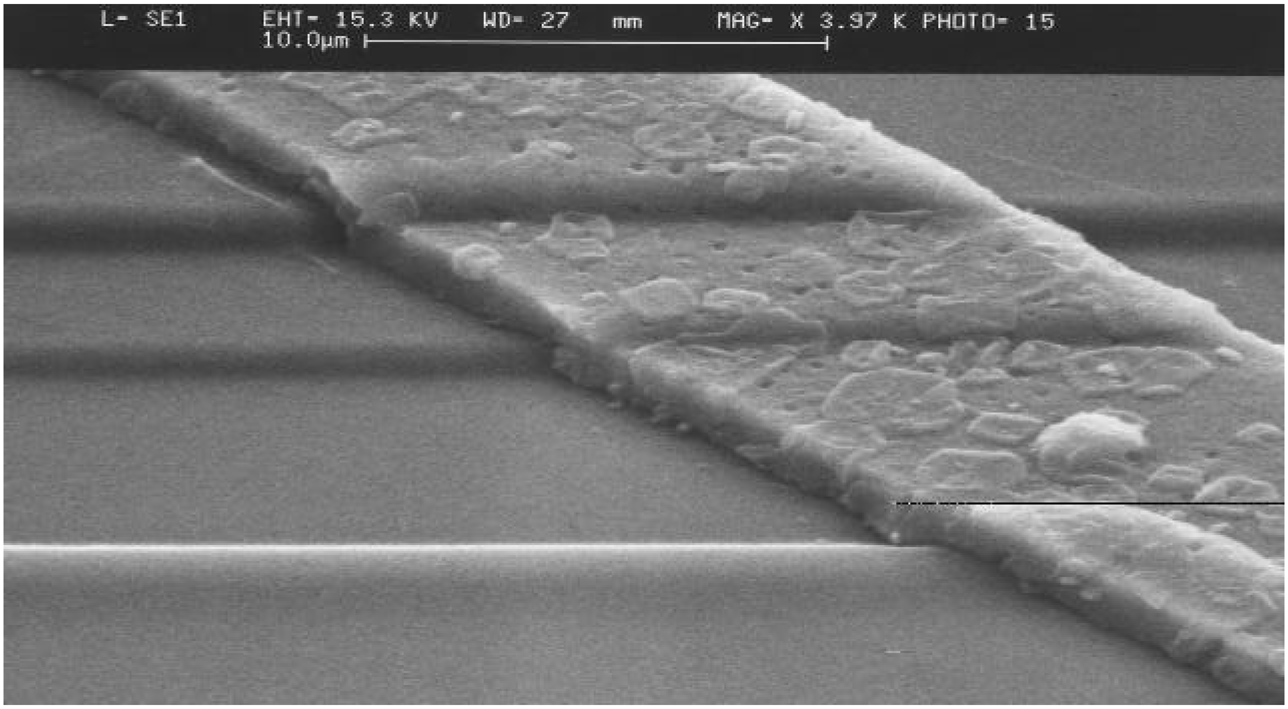

Figure 9. SEM view of an aluminum run showing normal step coverage, SN16. (3,970X)

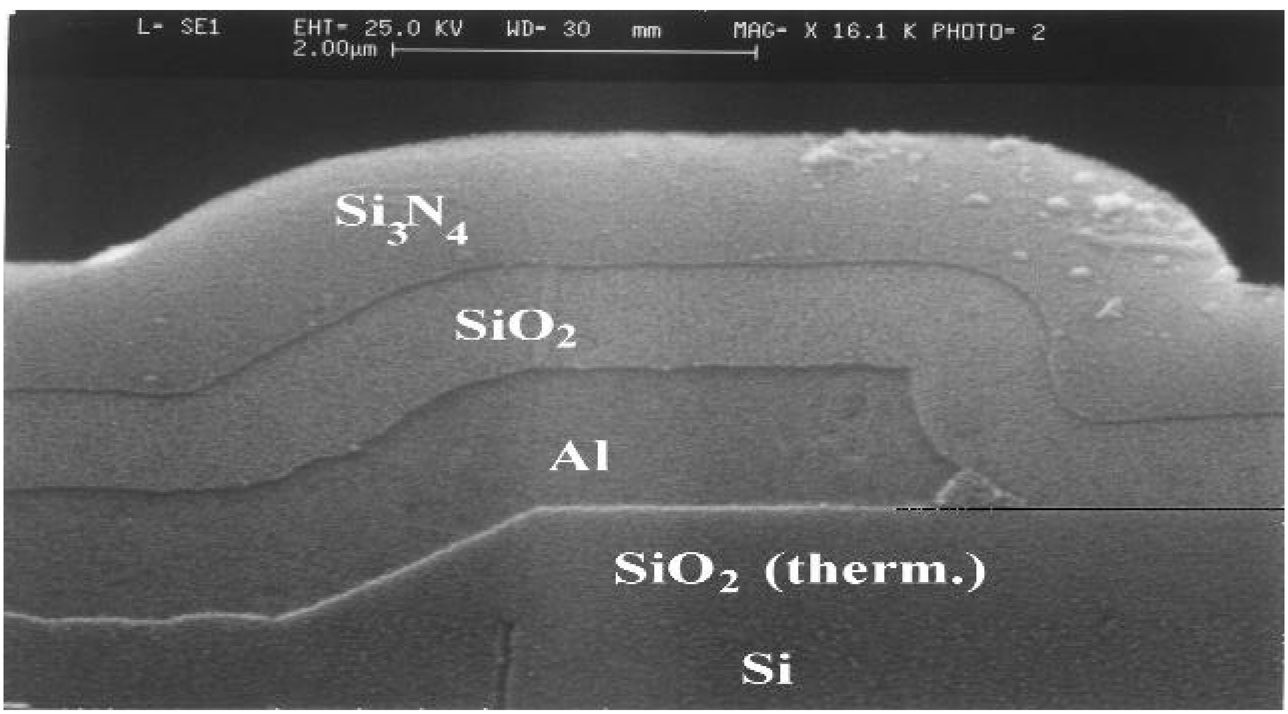

Figure 10. SEM view of the die cross section, SN 14. (16,100X)