

## Non-Destructive Test for IC Package With 8D Report

Muhammad Dinie Mazlan<sup>1</sup>, Hasliza Hassan<sup>1\*</sup>

<sup>1</sup>Faculty of Electrical and Electronic Engineering,  
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Johor, MALAYSIA

\*Corresponding Author Designation

DOI: <https://doi.org/10.30880/eeee.2022.03.01.006>

Received 20 January 2022; Accepted 31 March 2022; Available online 30 June 2022

**Abstract:** A semiconductor fabrication facility that converts wafers into integrated circuits is known as Integrated Circuit (IC) Fabrication. Since the sizes of IC are reducing, more complicated manufacturing procedures are being developed and more defect and damaged packaging is being generated. Normally, destructive testing damages the chip turning it worthless for further usage. Therefore, the 8D Report by using Non-Destructive Testing (NDT) is one of the industry's necessary approaches for tackling the IC failure problem. The purpose of NDT is to examine a component in a safe, dependable, and cost-effective way that does not result in equipment damage or production shutdown. 10 sample of IC will be used and only 3 samples of IC failure will be provided with 8D Report. In order to achieve this objective, the methodology was implemented by using an 8D Report and NDT analysis. 10 samples of IC will run with the NDT method which is the Visual Inspection Method, Functionality Test, and Electrical Test. The result of the testing was 3 IC have failure which is IC broken, pin IC broken, leakage condition, short circuit and open circuit. Therefore, the NDT testing by using 8D Report was one of the advantageous methods to identify and prevent the failure without destructing the IC. In the future, the NDT analysis could be run with the equipment NDT Test such as X-Ray, Scanning Acoustic Microscopy (SAM) and other techniques. Besides that, it needs to expand the use of 8D Report in the industry.

**Keywords:** Non-Destructive Test, 8D Report, IC Failure

### 1. Introduction

The manufacture of semiconductors was begun with Integrated Circuit (IC) Fabrication. IC Fabrication is a semiconductor fabrication facility that transforms wafers into IC. The IC packaging is getting more complex because the sizes are getting smaller and more challenging manufacturing processes are developed and more faulty damaged packaging is produced. Normally, destructive testing damages the chip and turns it worthless for further usage. It is also potential that a particular defect will not appear in any other chip. In some cases, the chip must be destroyed to do the analysis.

---

\*Corresponding author: [hliza@uthm.edu.my](mailto:hliza@uthm.edu.my)

2022 UTHM Publisher. All rights reserved.

[publisher.uthm.edu.my/periodicals/index.php/eeee](http://publisher.uthm.edu.my/periodicals/index.php/eeee)

The 8D Report by using Non-Destructive Testing (NDT) is one of the industry's mandatory methods for resolving the IC Failure problem. The purpose of the 8D methodology is to identify, correct, and eliminate recurring problems, making it useful in product and process improvement. 8D Report used an eight-step approach to solve the problem [1]. The 8D step is team formation, problem description, interim containment actions, root cause analysis, corrective actions, verification of corrective actions, preventive actions, and team recognition [2]. The 8D Methodology has the benefit of being a problem-solving strategy for identifying the cause of an issue and it is an excellent initial step in increasing Quality and Reliability when a product is defective or does not match the customer's expectations [3]. NDT's goal is to inspect a component in a safe, dependable and cost-effective manner without causing equipment damage or shutting down plant operations [4].

This paper about to identify failure in the IC package by using the NDT technique. The NDT technique will be used in this paper is Visual Inspection Method, Functionality Test, and Electrical Test. All the NDT technique will be used to identify the failure. This paper also to analyze failure in IC package based on the type of failure either Electrical Open Short (EOS) or Electrostatic Discharged (ESD). The 8D Report will be produced for selective device of failure. Each failure device will be analyzed in each of 8D Report. According to "Augmenting ESD and EOS physical with Per Pin ESD and leakage DFT" by Horaira Abu et. al [5] that Electrostatic Discharge (ESD) and Electrical Overstress (EOS) caused damages are the two major reasons. The reduction in a lifetime with ESD and EOS damage will need new methods to screen for latent damage. The loss in lifetime with ESD and EOS damage will need the development of new ways to detect latent damage. The ESD occurrences need to eliminate during the assembly process and maintain proper machine grounding and ESD controls reduces high leakage current failures of semiconductor in IC packages [6].

The overview of Non-Destructive Testing (NDT) Methods for Integrated Circuit Packaging Inspection by Pouria Aryan, et. al [4] proposed a detailed review on the common NDT methods for IC packaging addressing their principles of operation, advantages, limitations, and suggestions for improvement. The proposed NDT is showing it's worth with companies investing millions of dollars each year in expense extra cost avoidance [7]. Normally, destructive testing damages the chip and turns it worthless for further usage. For the inspection of IC packaging, NDT techniques are applied. They also different types of defects as well as the capabilities of the most used NDT methods for defect identification.

There are two types of optical visual inspection procedures are optical 2D visual detection and 3D structured light visual detection [8]. Optical 2D visual detection captures the picture of the chips with a high-performance camera and improves the light source setting to create a clear image. To assure product quality, it is critical to decrease or preferably, eliminate device leakage current failures. If the leaky unit/device continues to work, the leaky connection will ultimately deteriorate and become an open circuit, making the device unusable [9]. In the plastic IC packaging industry, the transfer molding method is frequently employed. Die cracking failures may occur as a result of the transfer molding process. Epoxy Molding Compounds (EMC) are first formed into pellets, then heated to approximately 170°C to 180°C and transferred into the mold cavity containing the substrate and silicon die [10].

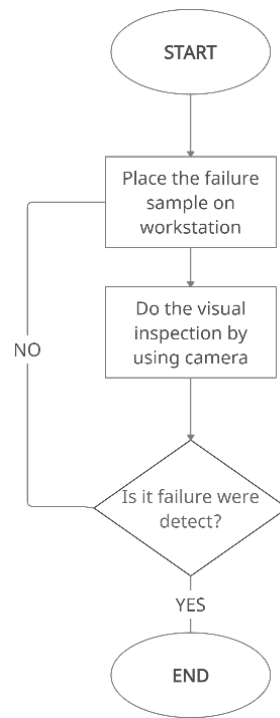
## **2. Materials and Methods**

### **2.1 Materials**

There are ten sample were used in this research but only three IC failure were recorded in 8D Report and do the analysis. The three IC failure is SN74LS76AN, SN74LS04, and 74LS10. All three samples were obtained from laboratory Faculty of Electrical and Electronic Engineering (FKEE), Universiti Tun Hussein Onn Malaysia, Johor. The analog multimeter were used to measure and test the IC.

### **2.2 Visual Inspection Method**

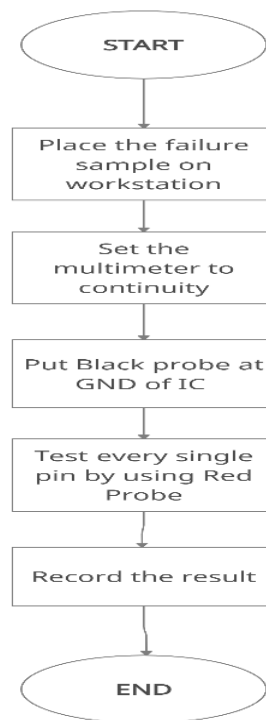
In this NDT technique which is Visual Inspection Method were used to inspect the physical damage or defect at the IC. This technique limitation is where can identify the failure only occur in physical damage, not the inner of the IC. Figure 1 shows the Flowchart of Visual Inspection Method.



**Figure 1: Flowchart of Visual Inspection Method**

### 2.3 Functionality Test

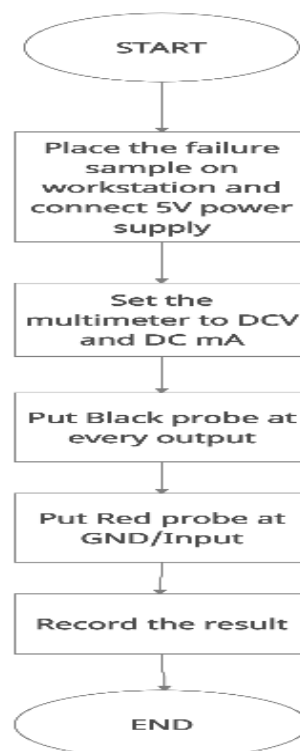
Functionality Test were method to test the functionality of the device. This test was identifying the pin of the IC were function or not after physical damage occur at the IC. The limitation of the method is it cannot detect the failure that occur in the circuit of IC. Figure 2 shows process flow of the Functionality Test.



**Figure 2: Process Flow of Functionality Test**

#### 2.4 Electrical Test

In Electrical Test, the IC were tested to identify the failure such as short circuit, open circuit, and leakage current that occur in the IC. This method will use the multimeter and the 5V power supply. Figure 3 shows process flow of Electrical Test.



**Figure 3: Process Flow of Electrical Test**

### 3. Results and Discussion

The result of the research for each IC sample has been evaluated through NDT test which is Visual Inspection Method, Functionality Test and Electrical Test. Each test were different result and failure were occurred. After running the NDT Test, the data were recorded and produce the for each sample.

#### 3.1 8D Report for SN74LS76AN

The results were show 8D Report for SN74LS76AN. All the NDT Test such as Visual Inspection, Functionality Test and Electrical Test were run to identify the failure that occur in the IC. All the data and analysis will show in the 8D Report. The IC were detected broken failure at the multiple pins. The analysis of failure in this IC is miss part/open circuit and Electrical Overstress (EOS). Figure 4 shows the broken failure were occur in the IC.



**Figure 4: Crack/broken for IC SN74LS76AN**

Investigation of the IC SN74LS76 showed that the IC have broken failure. Crack and broken form when these forces exceed the fracture strength of the molding compound. When these pressures exceed the molding compound's fracture strength, cracks develop. Normal molding pressure is 20-100bar. The open circuit failure cause from the broken wire. While short circuit cause from the wire error connection. Visual Inspection were carried out to identify the physical damage in the IC SN74LS76. The result of the inspection was crack and broken failure at the IC SN74LS76. Functionality Test were carried out to identify the pin at the IC were function or not and to identify the IC have short circuit failure or open circuit failure were occur in the IC. The result of the Functionality Test was all the pin of IC were in good condition except at pin 7 and 8 because it was broken. Table 1 shows the result of Functionality Test for SN74LS76AN.

**Table 1: Functionality Test Result for SN74LS76AN**

Item	Buzzer
1	ON
2	ON
3	ON
4	ON
5	ON
6	ON
7	OFF
8	OFF
9	ON
10	ON
11	ON
12	ON
13	GND
14	ON
15	ON
16	ON

Electrical test was carried out to identify the failure in the IC such as leakage condition, short circuit and open circuit. Table 2 shows the result of the electrical test.

**Table 2: Electrical Test Result for SN74LS76AN**

Black Probe at pin	Red Probe at pin	Reading (DCV)	Reading (DC mA)
GND	14(Q')	Infinity	0
GND	15(Q)	0	0
GND	4(J1)	Infinity	0
GND	16(K1)	0	0
GND	10(Q')	0	0
GND	11(Q)	5	3.75
GND	9(J2)	5	1.25
GND	12(K2)	Infinity	0
GND	7		
GND	8		

The result shows the electrical test for the IC. The red probe was at pin input and output to determine the failure in the IC. The reading in DCV to identify the failure if short circuit or open circuit. If the value is infinity, it means the circuit is short while 0V means it open circuit. The value of 5V shows the pin were in good condition as the input power supply is 5V. The reading in DC mA to identify the leakage current in the circuit. The leakage will appear when the pin has value when no power supply in the IC.

### 3.2 8D Report for SN74LS04 Pin 1 broken

The results were show 8D Report for SN74LS04. All the NDT Test such as Visual Inspection, Functionality Test and Electrical Test were run to identify the failure that occur in the IC. All the data and analysis will show in the 8D Report. The IC were detected broken failure at the multiple pins. The analysis of failure in this IC is short circuit, open circuit and Electrical Overstress (EOS). Figure 5 shows the broken failure were occur in the IC.



**Figure 5: IC pin 1 broken for SN74LS04**

Investigation of the IC SN74LS04 showed that the IC pin 1 have broken failure. The broken pin of IC can make the IC short circuit failure. The open circuit failure cause from the broken wire. While short circuit cause from the wire error connection. Visual Inspection were carried out to identify the physical damage in the IC SN74LS04. The result of the inspection was IC pin 1 broken at the IC SN74LS04. Functionality Test were carried out to identify the pin at the IC were function or not and to identify the IC have short circuit failure or open circuit failure were occur in the IC. The result of the Functionality Test was all the pin of IC were in good condition. Table 3 shows the result of Functionality Test for SN74LS04.

**Table 3: Functionality Test Result for SN74LS04**

Item	Buzzer
1	ON
2	ON
3	ON
4	ON
5	ON
6	ON
7	GND
8	ON
9	ON
10	ON
11	ON
12	ON
13	ON
14	ON
15	ON
16	ON

Electrical test was carried out to identify the failure in the IC such as leakage condition, short circuit and open circuit. Table 4 shows the result of the electrical test.

**Table 4: Electrical Test Result for SN74LS04**

Red Probe at pin	Black Probe at pin	Reading (DCV)	Reading (DC Ma)
1	2	0	0
3	4	5	0
5	6	Infinity	0
9	8	5	3.75
11	10	5	3.75
13	12	5	3.75

The result shows the electrical test for the IC. The red probe was at pin input while the black probe at pin output to determine the failure in the IC. The reading in DCV to identify the failure if short circuit or open circuit. If the value is infinity, it means the circuit is short while 0V means it open circuit. The value of 5V shows the pin were in good condition as the input power supply is 5V. The reading in DC Ma to identify the leakage current in the circuit. The leakage will appear when the pin has value when no power supply in the IC.

3.3 8D Report for 74LS10 Pin 8 broken

The results were show 8D Report for 74LS10. All the NDT Test such as Visual Inspection, Functionality Test and Electrical Test were run to identify the failure that occur in the IC. All the data and analysis will show in the 8D Report. The problem was described in this part which is the IC were detected broken failure at the multiple pins. The analysis of failure in this IC is short circuit, open circuit and Electrical Overstress (EOS). Figure 6 shows the broken failure were occur in the IC.



**Figure 6: IC pin 8 broken for 74LS10**

Investigation of the IC 74LS10 showed that the IC pin 8 have broken failure. The broken pin of IC can make the IC failure. The open circuit failure cause from the broken wire. While short circuit cause from the wire error connection. Visual Inspection were carried out to identify the physical damage in the IC 74LS10. The result of the inspection was IC pin 8 broken at the IC 74LS10.

Functionality Test were carried out to identify the pin at the IC were function or not. The result of the Functionality Test was all the pin of IC were in good condition. Table 5 shows the result of Functionality Test for 74LS10. Electrical test were carried out to identify the failure in the IC such as leakage condition, short circuit and open circuit. Table 6 shows the result of the electrical test.

The result shows the electrical test for the IC. The red probe was at pin input while the black probe at pin output to determine the failure in the IC. The reading in DCV to identify the failure if short circuit or open circuit. If the value is infinity, it means the circuit is short while 0V means it open circuit. The value of 5V shows the pin were in good condition as the input power supply is 5V. The reading in DC mA to identify the leakage current in the circuit. The leakage will appear when the pin has value when no power supply in the IC.

**Table 5: Functionality Test Result for 74LS10**

Item	Buzzer
1	ON
2	ON
3	ON
4	ON
5	ON
6	ON
7	GND
8	ON
9	ON
10	ON
11	ON
12	ON
13	ON
14	ON
15	ON
16	ON

**Table 6: Electrical Test Result for 74LS10**

Red Probe at pin	Black Probe at pin	Reading (DCV)	Reading (DC mA)
1	12	0	2.5
4	6	5	0
10	8	0	0

#### 4. Conclusion

Overall, in this research, the Non-Destructive Test for IC Package with 8D Report is successfully develop according to the failure analysis of IC. The 8D Report were method to resolving the IC failure problem. Based on the result of 8D Report, it shows that the failure analysis by using NDT Test were successfully to identify the failure in the IC. However, there are still a few improvements or upgrades that need be performed to increase the project's efficiency which is lack of equipment to run the NDT



Test. Using the proper equipment such as X-Ray can identify more specific failure and increase the efficiencies to identify the failure.

### Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

### References

- [1] T. S. M. Kumar and B. Adaveesh, "Application of "8D Methodology" for the Root Cause Analysis and Reduction of Valve Spring Rejection in a Valve Spring Manufacturing Company: A Case Study," *Indian J. Sci. Technol.*, vol. 10, no. 11, pp. 1–11, 2017, doi: 10.17485/ijst/2017/v10i11/106137.
- [2] "What is 8D? Eight Disciplines Problem Solving Process | ASQ." <https://asq.org/quality-resources/eight-disciplines-8d> (accessed Apr. 08, 2021).
- [3] C. A. Riesenberger and S. D. Sousa, "The 8D methodology: An effective way to reduce recurrence of customer complaints?," *WCE 2010 - World Congr. Eng. 2010*, vol. 3, no. May, pp. 2225–2230, 2010.
- [4] P. Aryan, S. Sampath, and H. Sohn, "An overview of non-destructive testing methods for integrated circuit packaging inspection," *Sensors (Switzerland)*, vol. 18, no. 7, 2018, doi: 10.3390/s18071981.
- [5] H. Abu, S. Abdennadher, B. Provost, and H. Muljono, "Augmenting ESD and EOS physical analysis with per pin ESD and leakage DFT," *Proc. - Int. Symp. Qual. Electron. Des. ISQED*, vol. 2018-March, pp. 20–24, 2018, doi: 10.1109/ISQED.2018.8357259.
- [6] F. R. Gomez, "Improvement on Leakage Current Performance of Semiconductor IC Packages by Eliminating ESD Events," *Asian J. Eng. Technol.*, vol. 6, no. 5, pp. 70–77, 2018, doi: 10.24203/ajet.v6i5.5464.
- [7] Marwan F. Basrawi, "Nondestructive Testing Technologies for Local Industries," *NDT.net*, vol. 9, no. No. 4, 2004, Accessed: Apr. 08, 2021. [Online]. Available: <https://www.ndt.net/article/mendt03/52/52.htm>.
- [8] L. Su, T. Shi, Z. Xu, X. Lu, and G. Liao, "Defect Inspection of Flip Chip Solder Bumps Using an Ultrasonic Transducer," *Sensors*, vol. 13, pp. 16281–16291, 2013, doi: 10.3390/s131216281.
- [9] "The Advantages & Disadvantages of Non Destructive Testing & Inspection." <https://www.formatndt.co.uk/advantages-and-disadvantages-of-non-destructive-testing/> (accessed Apr. 08, 2021).
- [10] D. Yang, J. Bielen, F. Theunis, W. D. Van Driel, and G. Q. Zhang, "Die fracture probability prediction and design guidelines for laminate-based over-molded packages," *EuroSimE 2008 - Int. Conf. Therm. Mech. Multi-Physics Simul. Exp. Microelectron. Micro-Systems*, no. May, 2008, doi: 10.1109/ESIME.2008.4525099.