

## Annexe A: New/Revised Course Content in OBTL+ Format

### Course Overview

The sections shown on this interface are based on the templates [UG OBTL+](#) or [PG OBTL+](#)

If you are revising/duplicating an existing course and do not see the pre-filled contents you expect in the subsequent sections e.g. Course Aims, Intended Learning Outcomes etc. please refer to [Data Transformation Status](#) for more information.

Expected Implementation in Academic Year	AY2024-2025
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Professor Chen Zhong Dr Lee Teck Kheng
Course Author Email	ASZChen@ntu.edu.sg CS-TECKKHENG.LEE@ntu.edu.sg
Course Title	Failure Analysis in Semiconductor Packaging
Course Code	MS6006
Academic Units	3
Contact Hours	39
Research Experience Components	

## Course Requisites (if applicable)

Pre-requisites	
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

## Course Aims

The aim of this course is to introduce the tools of failure analysis to identify the root cause of package failure in process and reliability. The package failure mechanism ranging from thermomechanical, chemical, physical to electrical failure will be shared. The course aims to enable you to apply this knowledge in the semiconductor industry to improve the package assembly processes and reliability. The course will give a good start in your journey in semiconductor packaging and failure analysis in the semiconductor industry. The course has an emphasis on how the materials and its assembly process affect the package reliability to meet the industry standard.

## Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Perform a review of semiconductor packaging trend to identify different package failures
ILO 2	Explain the use of material characterization and failure analysis tools in collating evidences to identify root cause failure for packages
ILO 3	Identify the materials and its assembly process affecting its package reliability
ILO 4	Explain the package failure mechanism
ILO 5	Discuss the strategies to improve assembly process and package reliability

# Course Content

## **Module 1: Package trend and its material characterization and failure analysis tools**

### 1. Introduction to IC packaging

- 1.1 Functions of Packaging
- 1.2 Review of Packaging Trend
- 1.3 Challenges of failure analysis in advanced packaging

### 2. Material Characterization Techniques

- 2.1 Introduction
- 2.2 Bulk Material Characterization
- 2.3 Interfaces Characterization

### 3. Failure Analysis Techniques

- 3.1 Introduction
- 3.2 Sample preparation
- 3.3 Package Integrity
- 3.4 Surface Topography
- 3.5 Physical Analysis
- 3.6 Chemical / Elemental

## **Module 2: Package assembly and reliability**

### 1. Package assembly and processes related failure

- 1.1 Overview of leadframe and substrate fabrication processes
- 1.2 Thickness Reduction with sub-surface defects
- 1.3 Dicing / Singulation with die chipping
- 1.4 Wire Bonding & its failures
- 1.5 Flip Chip Technologies & its failures
- 1.6 Die attach & its failure
- 1.7 Encapsulation, underfill & its failure
- 1.8 Plating surface finishes & its failure
- 1.9 Trim & Form & its failure
- 1.10 Board assembly and its failure

### 2. Reliability Management

- 2.1 Introduction
- 2.2 Package reliability tests and its stress mechanism
- 2.3 Design for reliability

## **Module 3: Package failure mechanisms**

## 1. Packages stresses

- 1.1 Introduction
- 1.2 Sources of packages stresses for failures
- 1.3 Failure modes and analysis

## 2. Thermo-mechanical Mechanisms

- 2.1 Thermo-mechanical Stresses
- 2.2 Interfacial adhesion and its degradation
- 2.3 Case studies and approaches

## 3. Chemical Failure Mechanisms

- 3.1 Corrosion mechanism
- 3.2 Case studies and approaches

## 4. Physical Failure Mechanisms

- 4.1 Failure mechanism by fracture and delamination
- 4.2 Failure mechanism by creep
- 4.3 Failure mechanism by moisture
- 4.4 Failure mechanism of intermetallics
- 4.5 Failure mechanism of kirendall voids
- 4.6 Failure mechanism of Fatigue

## 5. Electrical Failure Mechanisms

- 5.1 ESD
- 5.2 Electromigration
- 5.3 Whisker

## Reading and References (if applicable)

1. Microelectronics Packaging Handbook: Semiconductor Packaging Hardcover – 31 January 1997 by R.R Tummala, Eugene J. Rymaszewski, Alan G. Klopfenstein
2. Chiplet Design and Heterogeneous Integration Packaging Hardcover – 28 March 2023 by John H Lau
3. Failure Analysis: High Technology Devices – Daniel J. D Sullivan, Eric J. Carleton – 22 Oct 2022
4. Semiconductor Packaging: Materials Interaction and Reliability- Andrea Chen, Randy Hsiao Yu Lo- Apr 2017

## Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to IC packaging	1	Reference 1 Ch 2, 3 & 7 Reference 2 Ch1 & 2	Online	Online consultation
2	Material Characterization Techniques	2	Reference 1 Ch 2, 3, 7 & 18 Reference 2 Ch1 & 2	Online	Online consultation
3	Failure Analysis Techniques	2	Reference 1 Ch 22, Ref 3	Online	Online consultation
4	Continuous Assessment 1: Quiz 1	1, 2	N/A	In-person	Assessment
5	Package assembly and processes related failure (Part 1)	3	Reference 1 Ch 9 and Ch10 Reference 4 Ch 6-8	Online	Online consultation
6	Package assembly and processes related failure (Part 2)	3	Reference 1 Ch 9 and Ch10 Reference 4 Ch 6-8	Online	Online consultation
7	Continuous Assessment 2: Quiz 2	1, 2, 3	N/A	In-person	Assessment
8	Reliability Management	4, 5	Reference 1 Ch 5 Reference 4 Ch 5	Online	Online consultation
9	Packages stresses & Thermo-mechanical mechanisms	4, 5	Reference 1 Ch 5 Reference 4 Ch 5	Online	Online consultation
10	Chemical Failure Mechanisms	4, 5	Reference 1 Ch 5 Reference 4 Ch 5	Online	Online consultation
11	Physical Failure Mechanisms	4, 5	Reference 1 Ch 5 Reference 4 Ch 5	Online	Online consultation

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
12	Electrical Failure Mechanisms	4, 5	Reference 1 Ch 5	Online	Online consultation
13	Submission of Individual written assignment for package failure	1, 2, 3, 4, 5	N/A	Online	Individual assignment submission

## Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Online lectures	<p>You will be introduced to the package trend as well as the material and failure analysis tools for package failure. The lecture will provide an outline of the diverse approaches of the tools for failure analysis. The lectures will be used to fill in detail and allow students opportunities for questioning and critique.</p> <p>You will be introduced to the packaging assembly process and understand how these processes resulted in package failure. The lecture will provide an outline of the assembly for leadframe and substrate packages for both wirebond and flip chip packages. The lectures will be used to fill in detail and allow students opportunities for questioning and critique.</p> <p>You will be introduced to the different failure mechanisms from thermomechanical, chemical, physical to electrical mechanism. Different case studies in different package failure mechanism will be used to engage you in research and reflective discussion as well as encourage higher order thinking as well as reinforce the failure analysis approach</p>
Continuous Assessment	<p>The assessment will provide opportunities to apply and reinforcement the concept learnt in the online lectures for package failure, material and failure analysis tools to enhance package performance and identify root causes.</p> <p>The assessment will provide opportunities to apply and reinforcement the concept learnt in the online lectures for assembly process and its failure.</p>
Individual written report	<p>You will select a package failures observation which is either process or reliability related failure for an individual project assignment. You will act as a failure analysis engineer and suggest approaches to gather information and apply various failure analysis techniques to collect evidences for the failure. With the information, proposed the failure mechanism and identify the root cause and propose solutions to improve the process yield or enhance the package failure.</p> <p>This assignment aims to imitate actual failure analysis environment and provide experiential learning on package failure analysis. The project will develop skills valued by employers such as problem solving, negotiation, conflict resolution, leadership, critical thinking and time management). You will submit the 3 page assignment for assessment.</p>

# Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Test/Quiz(Continuous Assessment 1: Quiz 1)	1, 2		30	Individual	Analytic	Extended Abstract
2	Continuous Assessment (CA): Test/Quiz(Continuous Assessment 2: Quiz 2)	1, 2, 3		30	Individual	Analytic	Extended Abstract
3	Continuous Assessment (CA): Report/Case study(Continuous Assessment 3: Individual Written Report)	1, 2, 3, 4, 5		40	Individual	Holistic	Extended Abstract

Description of Assessment Components (if applicable)

Continuous Assessment 1: Quiz 1

Multiple choice and short-answer questions

Continuous Assessment 2: Quiz 2

Multiple choice and short-answer questions

Continuous Assessment 3: Individual Written Report

Select a package failures observation and how you will approach as a failure analysis engineer to go ahead to gather information and apply various failure analysis techniques to collect evidences of the failure mechanism. You will need to propose solutions to improve the process yield or enhance the package failure.

Formative Feedback

- Grading and general feedback after each CA.
- You are encouraged to attend coordinator's consultation hours to clarify any doubts in the lecture and discuss any issues, if needed.

## NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Creative Thinking	Advanced
Curiosity	Intermediate
Problem Solving	Advanced
Transdisciplinarity	Advanced
Critical Thinking	Advanced



# Course Policy

## Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

## Policy (General)

You are expected to complete all assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

## Policy (Absenteeism)

In-class activities make up a significant portion of your course grade. Absence from class without a valid reason will affect your participation grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

## Policy (Others, if applicable)

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