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 2
Course Author * Faculty proposing/revising the course	Dr Alfred Tok
Course Author Email	CS-ALFRED.TOK@ntu.edu.sg
Course Title	Nanofabrication Engineering
Course Code	MS6002
Academic Units	2
Contact Hours	26
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

This course aims to provide students with a deep understanding of nanofabrication processes, including both top-down and bottom-up approaches. Students will learn to design, fabricate, and characterize nanomaterials and nanostructured devices using today's state-of-the-art techniques. It also aims to foster interdisciplinary thinking by integrating principles from physics, chemistry, materials science, and engineering. By gaining a holistic understanding of nanofabrication and its applications across various industries, paired with the cultivation of their research skills through literature research and research projects / presentations, students will be adequately prepared to meet the challenges of today's and tomorrow's industry. Innovation and entrepreneurship will also be encouraged by challenging students to develop new nanofabrication techniques and technologies in their projects.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Understand the structure and properties of nanomaterials and nanostructured devices.
ILO 2	Understand how different nanomaterials synthesis methods are applied to the synthesis of 0D, 1D, 2D and 3D nanostructured materials.
ILO 3	Identify current opportunities, limitations and common failures surrounding top-down and bottom-up approaches in nanofabrication.
ILO 4	Identify & Compare nanoscale characterisation techniques for specific nanofabrication processes.
ILO 5	Apply suitable nanofabrication techniques to different devices and structures.
ILO 6	Evaluate and Critique nanomaterials synthesis methods by nanofabrication processes.
ILO 7	Discuss the application of nanofabrication techniques and its opportunities to specific industries.

Course Content

- Introduction to Nanomaterials, Nanotechnology and Nanofabrication.
- Nanomaterials Synthesis. Synthesis and characterization of 0D, 1D, 2D and 3D nanomaterials (eg. quantum dots, nanoparticles, nanowires, thin films & 3D nanostructures). Synthesis techniques include chemical and physical synthesis like sol-gel, co-precipitation, self-assembly, physical vapour deposition, chemical vapour deposition, and atomic layer deposition etc.
- Device Nanofabrication. Introduction to more complex nanofabrication of nanoscale devices and structures using top-down and bottom-up approaches. Methods include photolithography, electron beam lithography, nanoimprint lithography, and self-assembly techniques etc.
- Nanoscale Characterization. Explores the latest techniques for characterizing nanomaterials and nanostructured devices, including scanning electron microscopy, atomic force microscopy, X-ray diffraction, and spectroscopic methods.
- Device Integration and Applications. Studies on the integration of nanoscale devices into larger systems and their applications in critical growth areas such as catalysis, photonics, sensing, defence and biotechnology.
- Research Project: Students are required to complete a mini research project that focus on understanding various nanofabrication techniques, application to specialized application areas as well as innovation of nanofabrication.

Reading and References (if applicable)

1. Nanofabrication: Principles and Applications. Christo Papadopoulos, Springer, 2016.
2. Nanostructures and Nanomaterials – Synthesis, Properties and Applications, 2nd edition, Cao, & Wang, World Scientific, 2011.
3. Nanocharacterization Techniques, Da Róz, Ferreira & Oliveira, Jr., Elsevier, 2017
4. Nanofabrication, Nanolithography Techniques and their Application, JMD Teresa, IOP Publishing 2020.
5. Journal Paper – Nanofabrication: Conventional and Non-Conventional Methods, Electrophoresis 22 (2001) 187-207.
6. Journal Paper – Advances in top-down and bottom–up surface nanofabrication: Techniques, applications & future prospects, Advances in Colloid and Interface Science 170 (2012) 2–27.
7. Journal Paper – Synthesis Methods of Carbon Nanotubes and Related Materials, Materials 3 (2010) 3092-3140.
8. Journal Paper – A comprehensive review of template-synthesized multi component nano wires: From interfacial design to sensing and actuation applications, Sensors and Actuators Reports 3 (2021) 100029.
9. Journal Paper – Thin Film Deposition and Nanoscale Characterisation Techniques, Nanostructured Materials & Their Applications, Springer (2011)
10. Journal Paper – TiO2 inverse-opal electrode fabricated by atomic layer deposition for dye-sensitized solar cell applications, Energy & Environmental Science, 4 (2011) 209.
11. Journal Paper – TiO2–WO3 core-shell inverse opal structure with enhanced electrochromic performance in NIR region, Journal of Materials Chemistry C, 6 (2018) 8488.

Note: The above listing comprises the foundational readings for the course and more up-to-date relevant readings will be provided when they become available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to Nanomaterials, Nanotechnology and Nanofabrication (2h)	1-3	1, 2, 6, 7	Online	Prerecorded lecture
2	Nanofabrication of 0D Nanomaterials Part 1 (2h)	1-3	1, 2	Online	Prerecorded lecture
3	Nanofabrication of 0D Nanomaterials Part 2 (2h)	1-3	1, 2	Online	Prerecorded lecture
4	Consultation + CA1 & CA2 Briefing (2h)	1-3	N/A	Online	Online Zoom class (live)
5	Nanofabrication of 1D Nanomaterials Part 1 (2h)	1-3	1, 2, 7, 8	Online	Prerecorded lecture
6	Nanofabrication of 1D Nanomaterials Part 2 (2h)	4-5	1, 2, 7, 8	Online	Prerecorded lecture
7	Consultation (2h)	4-5	N/A	Online	Online Zoom class (live)
8	Nanofabrication of 2D Nanomaterials Part 1 (2h)	4-5	9	Online	Prerecorded lecture
9	Nanofabrication of 2D Nanomaterials Part 2 + CA3 Briefing (2h)	4-5	9	Online	Prerecorded lecture

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
10	Nanofabrication of 3D Nanomaterials (2h)	4-5	10, 11	Online	Prerecorded lecture
11	Consultation (2h)	6-7	N/A	Online	Online Zoom class (live)
12	Guest Lecture 1: Nanoscale Characterization: “Practical Applications of Scanning Electron Microscopy in Nanofabrication” (Industry Speaker Carl Zeiss) (1h)	6-7	3	Online	Prerecorded lecture
13	Guest Lecture 2: Device Integration & Industrial Applications: “Applications of Nanomaterials & Nanostructured Devices in Batteries” (Industry Speaker IMRE) (1h) + Consultation (2h)	6-7	N/A	Online	Prerecorded lecture

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Blended learning with active use of multi-media resources (TEL)	This will permit flexibility of access to learning materials, activities and assessments and can help you develop independent learning and critical thinking skills.
Showing real-world applications	Most of the concepts that are dealt in the course have real-world implications and applications. Therefore, they are used as examples while discussing the related concepts.
Regular consultation	Regular consultation hours will be available to encourage discussions that will reinforce students' understanding on various concepts and applications. Instead of providing answers directly to students' queries, they will be guided to think and make intelligent guesses based on sound principles. This approach will cultivate critical thinking.

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): Report/Case study(Continuous Assessment 1 (CA1): Individual Written Report)	1-4	N/A	30	Individual	Holistic	Multistructural
2	Continuous Assessment (CA): Presentation(Continuous Assessment 2 (CA2): Individual Oral Presentation)	1-4	N/A	30	Individual	Holistic	Relational
3	Continuous Assessment (CA): Report/Case study(Continuous Assessment 3 (CA3): Group Written Report)	5-7	N/A	40	Team	Holistic	Extended Abstract

Description of Assessment Components (if applicable)

Continuous Assessment 1 (CA1): Individual Written Report
Individual written report on nanomaterials and nanofabrication concepts

Continuous Assessment 2 (CA2): Individual Oral Presentation
Individual oral presentation on nanomaterials and nanofabrication concepts

Continuous Assessment 3 (CA3): Group Written Report
Group written report on Nanofabrication Solution to Novel Application

Formative Feedback

- In-video tutorial classes and discussions / feedback during group presentations
- Grading and general feedback after each CA.
- You are encouraged to drop by coordinator's office during the consultation hours to browse through your papers 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
Adaptability	Intermediate
Collaboration	Intermediate
Creative Thinking	Basic
Transdisciplinarity	Intermediate
Design Thinking	Intermediate

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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