Academic Year	AY20/21	**Semester**	1
Course Coordinator	Ling Xing Yi		
Course Code	CM4063		
Course Title	Nanoscience and Nanotechnology		
Pre-requisites	CM3011 or by permission		
Mutually Exclusive	CM4014[1]		
No of AUs	3 AUs		
Contact Hours	3 hours per week		

Course Aims

This course provides a platform to understand small systems, in particular, materials at the nanometer length (10^{-9} m). In the last few decades, we have witnessed the progress and rise of Nano Age. Upon completing this course, you will understand the foundation and principles of this multidisplinary field, which is the convergence of chemistry, materials, physics, biology and etc. You will also study how nanoscience and nanotechnology help solving global challenges faced by mankind.

Intended Learning Outcomes (ILO)

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

1. explain the principle, and foundation of the multi-disciplinary field of nanoscience and nanotechnology,
2. describe the historical background on the development of nanoscience and nanotechnology,
3. explain how nanoscience and nanotechnology are related to your daily life, describe what are the existing products in the market that utilize nanotechnology,

Nanoscale phenomena

4. describe the advantages of miniaturization,
5. explain what happens at nanoscale, describe what are the expected properties change at nanoscale from the perspectives of surface-to-volume ratio, strength-to-weight ratio, mechanics, electricity, fluids, biology and etc,

Nanotools

6. describe the nanotools available to characterize, image, and examine nanomaterials,
7. describe the principle of conventional optical microscopy, and explain their advantages and limitations,
8. describe the latest state-of-the-art super-resolution optical imaging technique that allows imaging of single molecule,
9. describe the principle of scanning probe microscopy,
10. explain different types of scanning probe microscopy and their working principles, and describe their advantages and limitations in nanomaterial imaging,
11. describe the principle of electron microscopy,
12. explain different types of electron microscopy and their working principles, and describe their advantages and limitations in nanomaterial imaging,
13. distinguish the various advantages and limitations of the nanomaterial imaging tools, and decide which is the best imaging technique to characterize certain nanostructures,

[1] Replaced course

Metal nanomaterials

14. explain metal nanoparticle formation mechanism,
15. describe various methods to synthesize metal nanoparticles,
16. explain the size-dependent catalytic, optical and photothermal properties of metal nanomaterials, and explain how these unique properties can be used for real-life applications,

Carbon nanomaterials

17. describe various types of carbon nanomaterials, and describe their synthesis or fabrication methods,
18. explain the unique structural, chemical, electrical, electronic, mechanical, and optical properties of carbon nanomaterials, and explain how these unique properties can be used for real-life applications,

Nanochemistry

19. describe various bottom-up nanochemistry approaches to synthesize and self-assemble (solution-based) nanomaterials,
20. explain the principle and applications of vapor-liquid-solid approach to grow one-dimensional nanowires,
21. explain the mechanism and applications of self-assembled monolayer,
22. explain the principle and applications of supramolecular chemistry,
23. explain the principle and applications of DNA-based self-assembly,
24. explain the mechanism of self-assembly of various nanomaterials and describe their potential applications,

Nanofabrication – Top-down techniques

25. describe various top-down nanofabrication approaches to fabricate substrate-based nanomaterials,
26. describe the patterning process of photolithography and various photoresists that can be used to achieve the desired nanostructures, explain the current applications of photolithography and their limitations,
27. describe the working principle of electron-beam lithography and the nanostructures that can be fabricated, explain the advantages and limitations of electron-beam lithography,
28. describe the working principle of focused ion beam lithography and describe the nanostructures that can be fabricated, explain the advantages and limitations of focused ion beam lithography,
29. describe the patterning process of nanoimprint lithography and describe the nanostructures that can be fabricated,
30. describe the working principles of various additive and subtractive processing techniques,
31. distinguish the advantages and limitations of the top-down lithographic approaches and decide which is the best technique to make a pre-defined nanostructure.

Course Content

1. Chapter 1 – Introduction
2. Chapter 2 – Nanoscale phenomena
3. Chapter 3 – Nanotools
4. Chapter 4 – Metal nanomaterials
5. Chapter 5 – Carbon nanomaterials
6. Chapter 6 – Nanochemistry
7. Chapter 7 – Nanofabrication – Top-down techniques

Formative feedback

You will be given feedback in three ways:

1. by posting your feedback on the course discussion board.
2. through face-to-face discussion during the collection of your mid-term paper.
3. an examiner report will be provided to you after the final exam, as a way to allow you to reflect on the areas for improvement and allow you to achieve intended learning outcomes 1 – 30.

Assessment (includes both continuous and summative assessment)

This is a graded course. There is a checklist of ALL the components of the assessments.

Component	**Course LO Tested**	**Related Programme LO or Graduate Attributes**	**Weighting**	**Team/ Individual**	**Assessment rubrics**
CA1: Assignment	1 – 31	Competence	10%	Individual	See Appendix 1
CA2: Responseware & LAMS	1 – 31	Communication, Competence, Creativity	10%	Individual	See Appendix 1
CA3: Mid-term Test	1 – 16	Competence, Civic-mindedness	25%	Individual	See Appendix 1
CA4: Oral Presentation	1 – 31	Communication, Competence, Creativity	10%	Team	See Appendix 1
Final Examination	1 – 31	Competence, Civic-mindedness	45%	Individual	See Appendix 1
Total			100%		

Learning and Teaching approach

Approach	**How does this approach support students in achieving the learning outcomes?**
Lectures	Face to face lectures will be employed for ILO 1 – 16. This is to allow you to interact directly with the instructor.
Technology-enhanced learning & LAMS	The ILO 17 – 31 will be delivered online. This allows (a) extensive use of animations and laboratory videos and (b) use of interactive questions so that you may immediately you're your learning. This approach is an online technology that can free you from the classroom and allows you to address the questions at your convenient and comfortable locations. Moreover, there will be LAMS questions at the end of reach chapters, it will you to review the knowledge point right after the delivery and to master the knowledge in-depth.
ResponseWare	Allow instructor to challenge you during lecture and to achieve instant feedback. It also allows you to review the knowledge point right after the delivery and to master the knowledge in-depth.

Reading and References

1. Nanotechnology – Understanding Small Systems, by Ben Rogers, Jesse Adams, Sumita Pennathur, CRC Press, 2007, ISBN-10: 0849382076.
2. Introduction to Nanoscience, by Gabor L. Hornyak, Joydeep Dutta, H.F. Tibbals , Anil Rao, CRC Press, 2008, ISBN-10: 1420048058.

Course Policies and Student Responsibilities

(1) General

You are expected to complete all online activities in good time.

(2) Absenteeism

If you miss a lecture, you are expected to make up for the lost learning activities. If you are sick and unable to attend your class, you have to:

1. send an email to the instructor regarding the absence
2. submit the original Medical Certificate‖ to the administrator. (‖ the medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.)

If you miss the mid-term exam with approval, you will be graded based upon the final.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructor

Instructor	Office Location	Phone	Email
Ling Xing Yi	SPMS-CBC-04-05	6513 2740	xyling@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Introduction	1 – 3	Lecture, Responseware, Assignment
2	Nanoscale phenomena	4 – 5	Lecture, Responseware, Assignment
3	Nanotools	6 – 8	Lecture, Responseware
4	Nanotools	9 – 10	Lecture, Responseware
5	Nanotools	11 – 13	Lecture, Responseware, Assignment
6	Metal nanomaterials	14 – 15	Lecture, Responseware
7	Metal nanomaterials	16	Lecture, Responseware, Assignment
8	Midterm		Assessment
9	Carbon nanomaterials	17 – 18	Online interactive content, LAMS
10	Nanochemistry	19 – 24	Online interactive content, LAMS
11	Nanofabrication – Top-down techniques	25 – 28	Online interactive content, LAMS
12	Nanofabrication – Top-down techniques	29 - 31	Online interactive content, LAMS
13	Review on course contents	1 – 31	Lecture

The above schedule is for illustrative purposes and is subject to the exigencies of the calendar

Appendix 1:

Rubric for Assignment (10%)

For the assignments, you will be expected to show your competency to understand the principle nanoscience and nanotechnology, and explain how various nanomaterials can be used to further improve current real life applications in catalysis, medicine, electronic components, and etc, You are expected to apply the knowledge you learn to solve scientific problems. Marks will be scaled to 10% of the course.

0-3 marks	4-7 marks	8-10 marks
Shows little to no understanding of the theoretical and practical principles	Shows moderate to good understanding of the theoretical and practical principles covered in the	Shows a comprehensive or near comprehensive understanding of the theoretical and practical principles covered in the

Rubric for Responseware and LAMS questions (10%)

For the Responseware and LAMS questions, you will be expected to show your competency to understand the principle nanoscience and nanotechnology, and explain how various nanomaterials can be used to further improve current real life applications in catalysis, medicine, electronic components, and etc, You are expected to apply the knowledge you learn to solve scientific problems. Moreover, the Responseware and LAMS questions are open for discussion with your course mates. It is desgined as an avenue to demonstrate your communication skills, where you can openly discuss your thought and thinking with your peers, and work as a small group to answer the Responseware and LAMS questions. Marks will be scaled to 10% of the course.

0-3 marks	4-7 marks	8-10 marks
Shows little to no understanding of the theoretical and practical principles covered in the lectures	Shows moderate to good understanding of the theoretical and practical principles covered in the lectures	Shows a comprehensive or near comprehensive understanding of the theoretical and practical principles covered in the lectures

Rubric for Presentation (10%)

Performance Level	Criteria
Excellent (9 – 10 marks)	Demonstrates complete achievement of the learning outcomes 1 – 31. Able to organize the team to present the assigned topic and answer the comments/questions after the oral presentation. Show good communication ability to lead the team and peer tutor the team members.
Good (7 – 8 marks)	Demonstrates complete achievement of the learning outcomes 1 – 31. Able to present the scientific topic and have good communication with the team members.
Satisfactory (5 – 6 marks)	Demonstrates partial achievement of the learning outcomes 1 – 31. Able to present the scientific topic but may not be precise or concise enough.

Unsatisfactory (3 – 4 marks)	Demonstrates minimal achievement of the learning outcomes 1 – 31. Not able to present the scientific topic well or have difficulty to maintain good communication with the team member.
Poor (<3 marks)	Do not possess sufficient understanding on the learning outcomes 1 – 31. Not able to complete presentation and not able to answer questions.

Grading criteria for the Course

The following guideline describes the criteria expected of the different levels of performance in this course.

Standards	**Criteria**
A+ (Exceptional) A (Excellent)	Actively participate and answer Responseware and LAMS questions correctly in and out of class. Complete assignment punctually and correctly. Able to apply the knowledge learned very well with referenced to the learning outcomes (LO) 1 to 31 in order to answer the questions in written exams.
A- (Very good) B+ (Good)	Actively participate in Responseware and LAMS questions in and out of class. Complete assignment punctually and be correct on majority of the questions. Able to apply the knowledge learned with referenced to the LO 1 to 31 to answer most of the questions in written exams.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Participate in Responseware and LAMS questions in and out of class. Complete homework with average marks. Partially able to apply the knowledge learned with referenced to the LO 1 to 31 to answer some of the questions in written exams.
C (Bordering unsatisfactory) C- (Unsatisfactory)	Seldom participate in Responseware and LAMS questions in and out of class. Not able to complete homework on time or achieve average marks. Not able to apply the knowledge learned with referenced to the LO 1 to 31 to answer some of the questions in written exams.
D, F (Deeply unsatisfactory)	Does not participate in Responseware and LAMS questions in and out of class. Not able to complete homework. Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.

CBC Programme Learning Outcome

The Division of Chemistry and Biological Chemistry (CBC) offers an undergraduate degree major in Chemistry that satisfies the American Chemical Society (ACS) curricular guidelines and equips students with knowledge relevant to the industry. Graduates of the Division of Chemistry and Biological Chemistry should have the following key attributes:

1. Competence

Graduates should be well-versed in the foundational and advanced concepts of chemical science, be able to evaluate chemistry-related information critically and independently, and be able to use complex reasoning to solve emergent chemical problems.

2. Creativity

Graduates should be able to synthesize and integrate multiple ideas across the curriculum, and propose innovative solutions to emergent chemistry-related problems based on their training in chemistry.

3. Communication

Graduates should be able to demonstrate clarity of thought, independent thinking, and sound scientific analysis and reasoning through written and oral reports to audiences with varying technical backgrounds. They should also be able to effectively engage other professional chemists in collaborative endeavours.

4. Character

Graduates should be able to act in responsible ways and uphold the high ethical standards that the society expects of professional chemists.

5. Civic-mindedness

Graduates should be aware of the impact of chemistry on society, and how chemistry can be applied to benefit mankind. They should also be aware of and uphold the best chemical safety practices.