Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2021/22	**Semester**	1
Course Coordinator	Professor Lew Wen Siang		
Course Code	PH3601		
Course Title	Fabrication of Micro- and Nano-electronic Devices		
Pre-requisites	PH2102 Electromagnetism		
No of AUs	4 AU		
Contact Hours	Lectures: 39, Tutorials and Lab Demonstration: 12		
Proposal Date	17 September 2020		

Course Aims

This course aims to provide comprehensive introduction to student on the fabrication technologies of micro- and nano-structured electronics devices. The fabrication techniques discussed in the course are relevant for micro- and nano-devices in the fields of semiconductor, magnetics, optoelectronics, micro- and nano-electro-mechanical systems (MEMS/NEMS), and biomedical. This course covers essential topics including principles, fabrications and applications. The working principles of each fabrication technique will be explained in detail, and the combination of these techniques as a complete process flow for making different microdevices will be discussed. Specifically, it is also the aim of this course to familiarise student with the semiconductor processing techniques employed in the advanced manufacturing industry so that the student can acquire direct applied knowledge before embarking their engineering career in the semiconductor industry.

Intended Learning Outcomes (ILO)

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

1. identify and describe the basic building block of semiconductor devices
2. present a general view of the trend of semiconductor technologies development and its technological ecosystem.
3. explain the importance of contamination control and apply the relevant approach in semiconductor processing.
4. design the doping concentration in bulk wafer fabrication.
5. describe the techniques of optical lithography, wet and dry etching and apply the process conditions to achieve lithography minimum feature size.
6. identify the properties of non-optical lithography techniques
7. apply the lithography process in building microfluidics device
8. explain the physics of doping and able to apply the diffusion or ion implantation conditions.
9. explain vacuum technology and able to design a desired vacuum condition by selecting suitable pump and gauges.
10. describe metallic and dielectrics film deposition processes and able to apply suitable tools to grow films.
11. use appropriate metallic layers for interconnect metallisation process
12. design probing configuration for device electrical measurement and use optical microscopy techniques
13. describe device packaging process and apply suitable model for manufacturing yield calculation.
14. design an integrated process to complete CMOS transistor fabrication.
15. search relevant references and review technical topics.
16. write a technical review technical reports and give a technical presentation on the surveyed topics.

Course Content

Lecture 1: An Overview of Semiconductor Technology

Lecture 2: Contamination Control
Lecture 3: Semiconductor Wafer and Growth Techniques
Lecture 4: Photolithography
Lecture 5: Etching and Pattern Transfer
Lecture 6: Advanced Lithography Techniques
Lecture 7: Impurity Doping
Lecture 8: Thermal Oxidation and Silicon-on-Insulator Technology
Lecture 9: Vacuum Science and Technology
Lecture 10: Physical Vapour Deposition
Lecture 11: Chemical Vapour Deposition
Lecture 12: Metallisation
Lecture 13: Metrology Techniques
Lecture 14: Device Packaging and Yield Models
Lecture 15: Device Fabrication

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	Competency (1,3,4,5,6)	60%	Individual	Point-based marking (not rubric-based)
2. CA1: Assignment Report and Presentation	All	Communication (1,2,3) Creativity (1,2) Character (1,2,3) Competency (2,6)	20%	Individual	Rubric marking – Appendices 1 and 2
3. CA2: Midterm Test 1	Lectures 1 - 6	Competency (1,3,4,5,6)	10%	Individual	Point-based marking (not rubric-based)
4. CA3: Midterm Test 2	Lectures 7 - 15	Competency (1,3,4,5,6)	10%	Individual	Point-based marking (not rubric-based)
Total			100%		

Formative feedback

You will receive formative feedback through discussion within tutorial lessons.

You will receive both written and/or oral feedback on your report and presentation.

Feedback is also given after each term test on the common mistakes and level of difficulty of the problems. Past exam questions and content of previous examiner's report will be discussed in lecture

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lectures	In the lecture, student will be first motivated with the relevant technology and processing techniques of electronic devices, followed by lectures that further explains the working principles and physics. Wrap up questions will also be provided.
Tutorials	Discussion on tutorial questions will help to improve the understanding of the main concepts learned in lectures.
Lab Demonstration	Lab demonstration session will be held at the SPMS/PAP Microfabrication Cleanroom Laboratory and student will have the opportunity to firsthand experience of the device microfabrication processes. Demonstration of fabrication techniques, such as photolithography, physical vapour deposition, etching, will be conducted, and student will be encouraged to ask questions so that the field work experience can help to better understand the lecture taught.

Reading and References

1. Fabrication Engineering at Micro- and Nanoscale, The Oxford Series in Electrical and Computer Engineering, 4th edition, Stephen A Campbell, Oxford University Press, USA, 978-0195320176, 2012.

2. Fundamentals of Microfabrication and Nanotechnology, Three-Volume Set: Manufacturing Techniques for Microfabrication and Nanotechnology, 3rd edition, Marc J. Madou, CRC, 978-1420055191, 2011

3. Semiconductor Devices - Physics and Technology, 3rd edition, Simon M. Sze and Ming-Kwei Lee, Wiley, 978-0470537947, 2012.

4. Introduction to Microfabrication, 2nd edition, Sami Franssila, Wiley, 978-0470749838, 2010.

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class (particularly the mid-terms), you must:
1. Send an email to the instructor regarding the absence.
2. Submit the original Medical Certificate* to administrator.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

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 Instructors

Instructor	Office Location	Phone	Email
Lew Wen Siang	SPMS-PAP 03 04	63162963	WenSiang@ntu.edu.sg

Planned Weekly Schedule

Week	Topics (refer to the above listed lecture)	Course ILO	Readings/ Activities
1	Course Introduction and Lecture 1	ILO 1-2	Lecture note 1
2	Lectures 1 and 2	ILO 1-3	Lecture notes 1and 2
3	Lecture 3	ILO 4	Lecture note 3
4	Lecture 4	ILO 5	Lecture note 4
5	Lectures 4 and 5	ILO 5	Lecture notes 4 and 5
6	Lectures 5 and 6	ILO 5-6	Lecture notes 5 and 6
7	Lectures 6 and midterm test 1	ILO 6-7	Lecture notes 6
8	Lectures 7 and 8	ILO 8, 10	Lecture notes 7 and 8
9	Lecture 9	ILO 9	Lecture note 9
10	Lecture 10 and 11	ILO 10	Lecture notes 10 and 11
11	Lectures 12 and 13	ILO 11-12	Lecture notes 12 and 13
12	Lectures 14 and midterm test 2	ILO 13	Lecture note 14
13	Lecture 15 and assignment presentation	ILO 14-16	Lecture note 15

Appendix 1: Assessment Rubrics for Assignment Report

Criteria Description	**Assessment**				**Score**
	Poor (0)	**Adequate (1)**	**Good (2)**	**Excellent (3)**	
REPORT STRUCTURE & ORGANISATION Consider the layout of the report - a clear and concise abstract followed by logical sequences on the written chapters, and good finishing in conclusion and suggestion of prospective development in the topic surveyed.	Report is poorly organised	Report is adequately organised	Report is well organised	Report is excellently organised	Max 3
QUALITY OF REPORT CONTENT Consider the level of work presented in the report, particularly the quality of the technical content in the abstract and written chapters. Write-up is in good English with minimal grammatical errors and spellings.	Quality of work presented is poor	Quality of work presented is marginally acceptable	Good quality of work presented	Excellent quality of work presented	Max 3
INFORMATION GATHERING & LITERATURE REVIEW Consider the degree of preparation on the information gathering related to the work. Literature review with extensive use of relevant references.	Poor information gathering	Only minimal effort of information gathering is shown	Good effort of information gathering is shown	Excellent information gathering is presented	Max 3
RESULTS & DISCUSSIONS Consider if interpretation and discussion of results are put into context, main points picked for discussion, understanding of underlying assumptions and limitation while being rationale to various approaches.	Poor or no discussion	Only minimal discussion is presented	Good discussion and in-depth analysis in presented	Excellent discussion and new ideas is presented	Max 3
				Total	Max 12

Appendix 2: Assessment Rubrics for Assignment Presentation

Criteria Description	**Assessment**				**Score**
	Poor (0)	**Adequate (1)**	**Good (2)**	**Excellent (3)**	
FUNDAMENTAL UNDERSTANDING Consider the student's ability to explain the technical knowledge learnt, specifically from physics viewpoint. Also consider the coherence between the presentation and the contents of the report submitted.	Fails to demonstrate the relevant technical understanding.	Able to demonstrate the relevant technical understanding.	Demonstrate good understanding of the technical knowledge	Demonstrate excellent understanding and strong command of the technical knowledge	Max 3
PRESENTATION, ORGANISATION AND MATERIALS Consider the degree of preparation of the presentation materials – informative, and appropriateness on the topics discussed; consider the clarity and context of the slides.	Ideas were poorly presented and visuals were not helpful to audience.	Ideas were vaguely presented and visuals were marginally helpful to audience.	Ideas were presented clearly and visuals were helpful to audience.	Exceptional presentation skills with highly informative materials.	Max 3
CLARITY, LANGUAGE USE AND ACCURACY Consider the student's ability to give a clear and concise presentation – appropriate choice of words, understandable, minimal stoppage, proper pace and good timing.	Poor verbal and communication skills	Able to communicate ideas and relates to others.	Communicates and explains ideas clearly and concisely.	Communicates in a highly convincing and persuasive manner.	Max 3
QUESTIONS AND ANSWERS Consider the student's ability to explain his/her work in the Q&A session – able to provide unambiguous and logical answers confidently.	Unable to answer any questions asked.	Limited capability in answering questions	Able to answer most queries raised.	Confidently respond to all queries raised and able to provide new ideas	Max 3
				Total	Max 12

Graduate Attributes

What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY and PHMA programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics [PHMA only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.