Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2020/21	**Semester**	2
Course Coordinator	Professor Lew Wen Siang		
Course Code	PH4601		
Course Title	Physics of Semiconductor and Spintronics Devices		
Pre-requisites	PH3102 Condensed Matter Physics I		
No of AUs	4 AU		
Contact Hours	Lectures: 39, Tutorials and Lab Demonstration: 12		
Proposal Date	14 September 2020		

Course Aims

This course aims to provide comprehensive introduction to student on the physics of semiconductor and spin-electronics (spintronics) devices. It covers essential topics including principles and design, in order to provide foundation knowledge of the functionality and applications of the devices. You will be taught to design experiment that uses these devices, and linking theory and practice so that concept learned in the course can be implemented. Widely used semiconductor devices, be it logic, such as diode and transistor, or memory, such as, SRAM, DRAM, NAND Flash, and magnetic devices, such as MRAM, will be explained in detail. It is also the aim of this course to familiarise student with the common semiconductor devices in advanced manufacturing industry so that the student can have relevant background before embarking their engineering career in semiconductor industry.

Intended Learning Outcomes (ILO)

Upon successful completion of this course, you should be able to:

<u>Semiconductor (SC)</u>

1. explain the fundamentals of semiconductor physics
2. use extrinsic semiconductor concepts to analyse carrier concentrations in semiconductor device.
3. explain the carrier transport phenomena in semiconductor, such as Hall effect, and apply the relevant concept in experimental measurement to calculate the transport properties, such as, carrier type and concentration, mobility, conductivity and total current density in semiconductor device.
4. unpack the concepts of generation and recombination of excess carriers in non-equilibrium state of semiconductor, and apply the concept of ambipolar transport model to determine the excess carrier dynamics behaviour when device is under external stimuli.
5. decipher the working principles of pn junction diode, and use the concept to design device current-voltage characteristics.
6. decipher the working principles of metal-semiconductor-oxide field effect transistor (MOSFET), and use the concept to design device current-voltage characteristics.
7. describe and explain the engineering approach in making transistor advancement, such as FinFET.
8. explain the concepts of semiconductor memory devices, such as SRAM, DRAM and NAND Flash.
9. explain the concepts of metal-semiconductor device, such as Schottky device, and use the concept to design device current-voltage characteristics.
10. explain he concepts of microwave semiconductor devices, such as MESFET, HEMT and resonant tunnel device.

<u>Magnetism (MG)</u>

1. explain the fundamental of magnetism and magnetic materials.
2. describe and differentiate the techniques of magnetic properties measurement.

3. explain and illustrate the concepts of magnetic domains and magnetisation dynamics properties, and how they can be used for magnetic memory applications.
4. explain the phenomena shown in multi-layered magnetic thin films structures and how such spin-electronics devices can be used as magnetic sensors and solid state memory devices.
5. search relevant references and review technical topics.
6. write a technical review technical reports and give a technical presentation on the surveyed topics.

Course Content

Lecture 1: Introduction to Semiconductors
Lecture 2: Carrier Transport Phenomena in Semiconductors
Lecture 3: Non-Equilibrium Excess Carriers in Semiconductors
Lecture 4: The pn Junction Diodes
Lecture 5: The Metal-Oxide-Semiconductor Field-Effect Transistors
Lecture 6: Other Semiconductor Devices
Lecture 7: Introduction to Magnetism
Lecture 8: Magnetic Domain
Lecture 9: Electronic Transport in Magnetic Materials

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, you 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.

Reading and References

1. Semiconductor Physics and Devices: Basic Principles, 4th edition, Donald A. Neamen, McGraw-Hill, 978-0073529585, 2011.
2. Physics of Semiconductor Devices, 3rd edition, Simon M. Sze and Kwok K. Ng, Wiley-Interscience, 978-0471143239, 2007.
3. Fundamentals of Semiconductor Devices, Betty L. Anderson and Richard L. Anderson, McGraw-Hill College, 978-0072369779, 2004.
4. Modern Semiconductor Devices for Integrated Circuits, Chenming Calvin Hu, 978-0137006687, 2009.
5. Introduction to Magnetism and Magnetic Materials, 3rd Edition, David Jiles, CRC Press, 9781482238877, 2015.
6. Modern Magnetic Materials: Principles and Applications 1st Edition, Robert C. O'Handley, 978-0471155669, 1999.
7. Introduction to Magnetic Materials, 2nd Edition, B. D. Cullity and C. D. Graham, 978-0471477419, 2008.
8. Magnetism and Magnetic Materials, 1st Edition, J. M. D. Coey, 978-0521816144, 2010.
9. Magnetism: Basics and Applications, 1st Edition, Carmen-Gabriela Stefanita, 978-3642229763, 2012.

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 lectures)	Course ILO	Readings/ Activities
1	Course Introduction and Lecture 1	SC 1-2	Lecture note 1
2	Lecture 1	SC 1-2	Lecture note 1
3	Lecture 2	SC 3	Lecture note 2
4	Lecture 3	SC 4	Lecture note 3
5	Lectures 3 and 4	SC 3-4	Lecture notes 3 and 4
6	Lectures 4 and 5	SC 5-6	Lecture notes 4 and 5
7	Lectures 5 and midterm test 1	SC 7	Lecture note 5
8	Lecture 5 and 6	SC 8-9	Lecture notes 5 and 6
9	Lecture 6	SC 9-10	Lecture note 6
10	Lecture 7	MG 1-2	Lecture note 7
11	Lecture 8	MG 3	Lecture note 8
12	Lectures 9 and midterm test 2	MG 4	Lecture note 9
13	Lecture 9 and assignment presentation	MG 4-6	Lecture note 9

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.