Academic Year	AY2020-21	**Semester**	2
Course Coordinator	Asst/Prof Xiao WANG		
Course Code	PH4403		
Course Title	Surfaces and Interfaces		
Pre-requisites	PH3102 Condensed Matter Physics I		
No of AUs	4 AU		
Contact Hours	Lectures: 39 hours, Tutorials: 12 hours Face to face: 4 hours a week (~3h lecture and 1h tutorials each week)		
Proposal Date	30 September 2020		

Course Aims

This course is targeted at physics students in their fourth year. It aims at introducing key concepts in surface and interface science, with a focus on electronics structures. The course will provide an overview of interfacial phenomena and relevant applications, introduce their underlying physical principles, and aims to build the analytical skills to describe these phenomena mathematically. Topics include the thermodynamics of surface phenomena, Schottky barriers and band offsets in semiconductors, band engineering, and analytical techniques such as photoemission. This course thus will equip you with the relevant concepts of modern science and technology that will prepare you to follow or initiate research in the field or to work in industry jobs related to applied nanoscience and technology.

Intended Learning Outcomes (ILO)

History of Nanoscience and Technology (HIS)

1. Provide an overview of modern surface and interface science and have a good grasp of their key milestones

Basics of concepts (BC)

1. Use basic formalism, such as Young's equation and surface tension, to determine surface contact angle and equilibrium crystal shape.
2. Explain the dynamics of thin-film growth.
3. Determine and express the surface geometry using basic notations, such as Wood's notation and Matrix notation.
4. Describe crystal structure in terms of lattice vectors and reciprocal space in terms of reciprocal for different crystal structures.
5. Explain the concept of electron inelastic scattering from surfaces.
6. Explain surface plasmons the dispersion relationship of the plasmon, and the coupling between light and plasmon
7. Explain the bulk electronic structures and surface/2D electronic structures.
8. Explain the metal work function and the factors affecting the metal work function.
9. Explain the basic carrier properties of semiconductors and the formation of the space charge layer.
10. Describe different types of band bending.
11. Analyse quantitatively two different cases of barriers
12. Explain the concept of semiconductor heterostructures.

Introduction to surface techniques (IT)

1. List and explain the key thin film growth techniques.
2. Discuss the characterisation techniques for growth.
3. Describe the technique of Low-energy Electron Diffraction (LEED).
4. Analyse the LEED patterns.
5. Describe the mechanism of electron energy loss spectroscopy.
6. Describe the working principle of high-resolution electron energy loss.
7. Describe the approaches to measure metal work function
8. Explain the different techniques of photoemission spectroscopy.
9. Explain the mechanism of techniques used in photoemission spectroscopy.
10. Describe the strength and weaknesses of different techniques.

Relevant applications (RA)

1. Explain the metal-semiconductor contact.
2. Analyse quantitatively the current-voltage relationship.
3. Explain the complications of the real metal-semiconductor contact.
4. Describe the applications of the metal-semiconductor contact.
5. Describe the applications of semiconductor heterostructures

Course Content

Basics of nanoscale science (BAS)	Review of basic conceptions of surface energy: surface contact angle, equilibrium crystal shape, the dynamics of thin-film growth, surface geometry using basic notations. Review of crystal structure: crystal structure in terms of lattice vectors and reciprocal space in terms of reciprocal for different crystal structures. Review of surface quasi-particle: surface phonons and plasmons wave vector, elastic scattering, inelastic scattering, surface plasmon the dispersion relationship of the plasmon, and the coupling between light and plasmon. Review of semiconductor physics: semiconductors based on band structure, work function, space charge layer, band bending, and semiconductor heterostructures.
Introduction to surface techniques (IT)	Key thin film growth techniques, characterisation techniques for growth, Low-energy Electron Diffraction (LEED), electron energy loss spectroscopy (EELS); Photoemission spectroscopy.
Relevant applications (RA)	Metal-semiconductor contact, current-voltage relationship, the real metal-semiconductor contact, applications of the metal-semiconductor contact, and the applications of semiconductor heterostructures

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)	60%	Individual	Point-based marking (not rubric-based)
2. Continuous Assessment 1 (CA1): Reading Project "Topics in Surface and Interface Physics" (report and presentation)	Depending on individual project topic (ILO BAS to EM)	Competency (1,4,5), Communication (1,2,3), Character (1,2,3)	20%	Team (1 – 3 students, depending on class size)	Rubrics based marking (see appendix)
3. CA2: Midterm test I	All	Competency (1,3,4)	10%	Individual	Point-based marking
4. CA3: Midterm test II	All	Competency (1,3,4)	10%	Individual	Point-based marking
Total			100%		

Formative feedback

Describe how you would be giving feedback to students on how they are learning in this course.

Formative feedback is given weekly through assignments marking and tutorial lessons. A weekly TA meeting discusses the progress, pace, and difficulty level of lectures. Formative feedback on the midterm exam is given as a midterm check of students' understanding of learned contents, including feedback on common mistakes. Past exam questions and examiner's report are made available for students. Finally, your lecturer will try and make himself available for fast turnaround feedback on a one-on-one basis, through email or personal discussions after the lecture, tutorials, or during the consultation.

1. Through the online assignment, I will regularly monitor and let you know your progress in learning

2. In the tutorial, I will give questions to test your understanding and give you feedback.

3. I will also observe how you perform in mid-term test and give you feedback. 4. In addition, I will go through your presentations, assess your presentation and give you feedback about your understanding. 5. Moreover, I will give regular feedback during classes.

Learning and Teaching approach

Approach	How does this approach support student in achieving the learning outcomes?
Lecture	Content and derivations, examples of problem solving and discussion of conceptual understanding.
Tutorial	Review and discussion of key concepts from lectures, by working through problems.
Homework	Homework comprises standard textbook practice questions that are covered during tutorials allowing for formative assessment and feedback
Project	Team-based reading project based on group work (1-3 students based on class size). You will research a specific topic chosen by the lecturer, and you will communicate your research to your peers in writing (report) and group presentation. The presentations will be held towards the end of the course during lecture/tutorial hours.

Reading and References

1. Solid Surfaces, Interface and Thin Films, 5th ed, Hans Lüth, Springer, 978-3642135910, 2010
2. Surface and Interfaces of Electronic Materials, 1st ed, Leonard J. Brillson, Wiley-IEEE Press, 978-3527409150, 2010

Course Policies and Student Responsibilities

Students are expected to participate in project discussions and activities.

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms, you have to: 1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms. 2. Submit the original Medical Certificate* or official letter of excuse to the administrator. 3. Attend the assigned replacement class (subject to availability) and make-up mid-terms.

* 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 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.

Collaboration is encouraged for your homework because peer-to-peer learning helps you understand the subject better and working in a team trains you to better communicate with others. As part of academic integrity, crediting others for their contribution to your work promotes the ethical practice.
You must write up your solutions by yourself and understand anything that you hand in.
If you do collaborate, you must write on your solution sheet the names of the students you worked with. If you did not collaborate with anyone, please explicitly write, “No collaborators." Failure to do so constitutes plagiarism.

Use of materials outside the course is strongly discouraged. If you use an outside source, you must reference it in your solution.

Course Instructors

Instructor	Office Location	Phone	Email
Asst/Prof Xiao WANG	SPMS-PAP-05-02	6513 7418	renshaw@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Lecture 1 (2h): An overview Lecture 2 (2h): Surface energy and equilibrium crystal shape	HIS BC 1	Textbook
2	Lecture 3 (2h): Thin-film growth Tutorial 1 (2h): Surface energy	BC 2 IT 1 - 2	Textbook
3	Lecture 4 (2h): Surface geometrical structure Lecture 5 (2h): LEED	BC 3 - 4 IT 3 - 4	Textbook
4	Tutorial 2 (2h): Surface geometry Lecture 6 (2h): Electron inelastic scattering from surfaces-EELS	BC 5 IT 5 - 6	Textbook/tutoiral
5	Lecture 7 (2h): Surface plasmons wave Tutorial 3 (2h): Electron inelastic scattering	BC 6	Textbook/tutoiral
6	Tutorial 4 (2h): Surface plasmon Lecture 8 (2h): Surface electronic structures	BC 7	Textbook/tutoiral
7	Tutorial 5 (2h): Surface electronic structure Lecture 9 (2h): Metal work function	BC 8 IT 7	Textbook/tutoiral
8	Tutorial 6 (2h): Metal work function Mid Term exam I (2h)	RA 1 - 2	Exam/tutoiral
9	Lecture 10 and 11 (3h): Photoemission spectroscopy	BC 8	Textbook

	Lecture 12 (1h): Space charge layer of semiconductors	IT 8 - 9	
10	Tutorial 7 (2h): Space charge layer Lecture 13 (2h): metal-semiconductor interface	BC 9 - 10 RA 3	Textbook/tutoiral
11	Tutorial 8 (2h): metal-semiconductor interface Lecture 14 (2h): Semiconductor heterostructures	BC 11 - 12 IT 10	Textbook
12	Tutorial 9 (2h): Semiconductor heterostructure Mid Term II (2h)	BC 11 - 12 RA 5	Exam/tutoiral
13	Lecture 15 (1h): Final review Project (3h)	All	

Appendix 1: Assessment Criteria for Rubrics

1. Mid-Term test will be a mixture of MCQ and long-answer questions. The student will be tested on magnetism and magnetic recording. The student must be able to provide clear and correct answers.

2. The following is the criteria for the project.

Project Report (Adapted from https://www.cte.cornell.edu/documents/Science%20Rubrics.pdf), adapted to include ideas of SOLO taxonomy)

Please note that by default you would receive the same score as your team. However, your score may vary should there be evidence that you had not contributed to your team.

Criteria	**Does not meet the standard (0 - 2) (Prestructural)**	**Nearly Meets Standard (3 – 4) (Unistructural)**	**Meets Standard (5 - 6) (Multistructural)**	**Exceeds Standard (7 - 8) (Relational)**	**Far Exceeds Standard (9 - 10) (Extended Abstract)**
Problem or Research Statement	Unclear and inaccurate or illogical statement.	Somewhat unclear or unable to accurately portray the problem.	Mostly clear and accurately communicated for the focused reader.	Clearly and accurately communicated, and gives most background or context and motivation.	Comprehensive description and overview of the topic, satisfactory to the expert reader.
Correctness and appropriate description of the physics	Incorrect or inappropriate use of physics in most areas.	Mostly correct and appropriate use of physics. But flawed in parts.	Correct and appropriate use of physics, with some clarity on assumptions, approximations, experimental techniques, and derivations.	Correct and appropriate use of physics, with assumptions, approximations, experimental techniques, and derivations that are accurate and detailed.	Correct and appropriate use of physics, with assumptions, approximations, experimental techniques, and derivations that are accurate and detailed. With further details of their limitation and how these could be improved.

Development of Ideas	Does not clearly introduce the topic. Does not establish or maintain focus on the topic.	Introduces the topic. Somewhat maintains focus on the topic, but lost in some parts. Developme nt of some of the ideas.	Introduces the topic clearly. Maintains focus on the topic. Development of and/or connection between ideas are clear and correct.	Introduces the topic clearly and creatively. Maintains clear focus on the topic throughout. Development of and connection between ideas are clear and correct.	Introduces the topic clearly and creatively. Maintains clear focus on the topic throughout. Development of and connection between ideas are clear and correct. Gives detailed outlook on how ideas could be further developed in the future.
Use of secondary material (references and citations)	Improper and unclear citations and attribution of others' work in most part, and with major errors.	Partly proper and clear citations and attribution of others' work, with some errors.	Proper, accurate and clear citations and attribution of others' work in most parts.	Proper, accurate and clear citations and attribution of others' work throughout.	Proper, accurate and *complete* referencing and attribution of others' work in the field.

Project Presentation

Criteria	Does not meet standard (0 - 2) (Prestructural)	Nearly Meets Standard (3 – 4) (Unistructural)	Meets Standard (5 - 6) (Multi-structural)	Exceeds Standard (7 - 8) (Relational)	Far Exceeds Standard (9 - 10) (Extended Abstract)
Organization and structure	No clear structure apparent to the presentation. Ideas appear scattered and incoherent. No clear distinction between introduction of background concepts, presentation of main results, and conclusions.	Somewhat structured presentation. Distinct sections such as introduction, results, conclusions, etc. exist, but sections are incomplete and their content scattered / unstructured.	Structured presentation. Distinct sections such as introduction, results, conclusions, etc. exist, and their content is mostly organized. Key conclusions are only apparent after reading the conclusions slide.	Well-structured presentation. Distinct sections such as introduction, results, conclusions, etc. exist, their content is well-organized throughout the presentation, and the key conclusions are clear throughout.	Above standard structured presentation. Content of introduction, results, conclusions, etc. are well organized throughout the entire presentation, presenting content not only comprehen-sively, but efficiently.
Visual presentation (e.g. design of presentation slides)	Ineffective or no use of presentation technology (e.g. PowerPoint) at all.	Somewhat effective use of presentation technology (e.g. PowerPoint slides). Technology is used but content presented is mostly illegible and disorganized	Effective use of technology (e.g. PowerPoint slides). Information legible and well- organized throughout most of the presentation.	Effective use of technology (e.g. PowerPoint slides). Information legible and well- organized throughout the entire presentation.	Effective and creative use of technology (e.g. PowerPoint slides). Information is not legible but also well-structured. Additional technology / applets (e.g. PPT animations are being used to further illustrate complex concepts.

Effectiveness of oral presentation and Q&A	Does not communicate ideas effectively. Uses pace, tone and style ineffectively (monotonous style) and hence loses attention of audience through most of the presentation.	Communicates ideas somewhat effectively. Ideas are are mostly comprehensiblea nd communicated somewhat effectively by use of pace, tone and style. Maintains attention of audience in some parts of the presentation.	Communicates ideas in an effective and understandable manner. Uses pace, tone and style effectively, most of the time. Catches the interest of the audience through most of the presentation	Communicates difficult or complex ideas in an effective and understandable way. Uses pace, tone and style effectively all the time, and catches the interest of the audience, or engages the audience throughout	Far exceeds expectations of a fourth year student in communicating complex scientific concepts. Uses pace, tone and style not only effectively but also creatively. Never loses interest and engagement of the audience
Individual Contribution	Little to no effective contribution in the presentation and Q&A portions, displays little knowledge in the chosen topic.	Contribution in the presentation and Q&A portions reflect only one aspect the chosen topic. Limited insights.	Contribution in the presentation and Q&A portions reflect more than one aspect of the chosen topic, but does not connect them as a coherent whole. Insights may be unoriginal.	Contribution in the presentation and Q&A portions reflect depth of knowledge not only in an individual segment, but in the whole topic. Insights are thoughtful and analytical.	Contribution in the presentation and Q&A portions reflect coherence, fluency, and depth of knowledge in the whole topic. Comes across as an integral part of the team. Insights are critical and offer new or unique perspectives on the topic.

The main presentation should include:

- a ***presentation*** of the appropriate ***concepts, theories, principles and possible applications***
- an ***explanation*** of the ***observed phenomena***
- an ***application*** of ***appropriate mathematics***
- reasonable **experimental technique** to ***gather*** and ***record data*** (or ***demonstrate*** the ***phenomena*** if appropriate)
- linking of ***theoretical*** and ***experimental findings*** to draw ***suitable conclusions***
- an attempt to communicate ***difficult*** or ***complex*** ideas in an ***effective*** and ***understandable*** manner

Student participation:
All students in the team need to participate in the presentation or Q&A.

Duration: Presentation (10-15 min) + Q&A (5 min) = Total of 20 min.

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 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.