UNSW SYDNEY Australia's Global University

Course Outline

MATS6104

Physical Properties of Materials

Materials Science and Engineering

Science

T1, 2021

1. Staff

Position	Name	Email	Consultation times and locations	Contact Details
Course Convenor	Dr. Pankaj Sharma	pankaj.sharma@unsw.edu.au	Level 3, School of Materials Science and Engineering (Building E10), by appointment	
Lecturer	Prof. Dewei Chu	d.chu@unsw.edu.au	Room 244, School of Materials Science and Engineering (Building E10), by appointment	9385 5090

2. Course information

Units of credit: 6

Pre-requisite(s): None

Timetabling website: TBA

Teaching times:

MATS6104

Part 1 – Prof. Dewei Chu

Week #	Monday	Wednesday	Friday
	3-5 pm	*2-4 pm*	*2-4 pm*
1	Lecture	Lecture	Lecture
2		Lecture	Lecture
3	Lecture	Lecture	Lecture
4		Lecture	Lecture
5	Lecture	Lecture	Lecture
6			
7	Mid-exam		

Part 2 - Dr Pankaj Sharma

Week #	Tuesday		Wednesday
	12-2 pm	*1-3 pm*	*11-1 pm*
7		Lecture	Lecture
8	Lecture		Lecture
9	Lecture		Lecture
10	Lecture		Lecture

2.1 Course aim and description

Aim: This course aims to provide students with a detailed understanding of a range of physical properties of materials including electrical, thermal, magnetic, dielectric and defect chemistry and related properties. Diverse material types such as metals, semiconductors, dielectrics, ferroelectrics, ferromagnetic materials will be introduced in the context of the various material properties. These are a rapidly emerging class of materials that exhibit novel physical properties and find applications in a wide range of fields such as electronic devices, actuators, and sensors.

Description: Students will investigate physical properties and applications of a range of advanced materials. You will explore microscopic underpinnings of these physical properties and how material properties can be tuned through careful introduction of defects and synthesis conditions. You will gain knowledge needed to design and tune material properties for targeted specific applications from the viewpoint of Materials Science and Engineering.

Teaching Strategies and Rationale

Key teaching/learning activities in the course include online lectures. Lectures will cover core concepts, theories, and approaches, which will then be contextualised and consolidated through assignments. Teaching material will utilise real-world key studies in the development of these materials to provide students with an opportunity to identify, evaluate and reflect on the innovative solutions these materials provide worldwide and locally. Where applicable, the course will use additional online learning technologies (e.g. videos or animations) to consolidate, support and extend student learning.

Course Learning Outcomes

1. Compare the key structural elements of sub-classes of different materials that control their physical properties and behaviour.
2. Apply an understanding of different physical properties of materials for the design of new materials with novel properties and for targeted specific applications.
3. Examine the inter-relationships between properties of materials, impurities, defects, synthesis conditions, composition, and microstructure.
4. Critique how variations in, size, defect concentration, and composition can lead to the tuning of properties for specific applications.

2.2 Assessment

Assessment task	Description	Weight	Due date
Assignments:	You will be required to undertake calculations involving the application of modern electron theory to topics covered throughout the course including -The wave nature of electrons -Electrical conduction in metals, semiconductors and insulators	20%	Assignment 1: Week 3 Assignment 2: Week 5
Mid-session exam:	The aim of this exam is to assess students' skills in solving problems concerning introductory aspects of electron theory and its application to materials science and engineering (PART I). It will consist of a combination of multiple choice and/or essay-style questions involving some calculations. Any derivations will assume knowledge of the material rather than memorizing equations with relevant background equations provided.	30%	Week 7
Assignment 3	A short written question-and-answer type assignment covering relevant course materials covered in the PART 2.	10%	Week 8

Final Exam	This exam is devoted to all parts of the course (from PART 2 of course) consisting of lectures, nominated reading material and assignments and will include, where appropriate, relevant equations. It will consist of a combination of essay-style answers, multiple-choice questions, and calculations. (2hrs)	40%	Exam Week

2.3 Course schedule and structure

Week	Topics	Activity
1-2	**PART I- Fundamentals of electron theory**	
1	• Introduction to the course • Short comings of classical physics • Particle and wave nature of matter • Introduction to the Schrödinger equation • The Schrödinger equation- model of the hydrogen atom • Quantum description of the atom	
2	• The Schrödinger equation • Handling multiple electrons in a crystal • Methods of describing electron energy levels in crystals	
3	• Electrical conduction in solids • Breakdown of the classical theory of conduction • Quantum model of electrical conduction • Intrinsic semiconducting elements • Electrical conduction of intrinsic semiconductors	Assignment 1
4	• The combined role of the band gap and temperature on conductivity • Simple intrinsic semiconductor devices • Extrinsic semiconductors • Introduction to band-gap engineering	
5	• Physics of the p-n junction • Basic semiconducting devices • Summary of Parts I and II	Assignment 2
7	• Mid-session Quiz	Mid-term Exam
7-10	**PART 2- Electrical, Thermal, Dielectric and Magnetic Properties of Materials**	
7	• Electrical properties of materials – metals, insulators, semiconductors (intrinsic and extrinsic), electrical resistance, electrical resistivity/conductivity, concept of energy bands, impact of impurity and temperature on electrical conductivity of semiconductors. • Defects chemistry and transport phenomena – defects, point defects, ionic solids, Frenkel and Schottky defects, Defect representation,	

	Kröger-Vink notation, electronic and ionic compensation, defect reaction, constructing defect diagrams, and applications.	
8	• Thermal properties of materials – heat capacity, specific and molar heat capacity, classical and quantum theory of heat capacity, Debye model, thermal conductivity, thermal conduction - classical and quantum consideration, thermal resistance and stresses, Seebeck effect, Peltier effect and applications, Thomson effect, thermoelectric materials, and figure of merit.	Assignment 3
9	• Dielectric, capacitance, and ferroelectric materials – capacitors, Gauss's law, capacitance calculation for simple geometries, capacitors in electrical circuits, dielectrics, electrical dipole moment, polarization, ferroelectricity, response of ferroelectrics in external fields, and applications of the ferroelectric materials. • Magnetic phenomena – permanent magnets, circular current carrying wire, magnetic dipole, magnetic dipole moment, magnetisation, magnetic force on moving charges, Lorentz force equation, Biot-Savart's Law, magnetic field determination, paramagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic materials, applications of magnetism, and magnetic materials.	
10	• Revision of some topics covered in part 2, and practice problems	

2.2 Expectations of students

- Students must read through lecture notes and lab sheets.
- During class, students are expected to engage actively in class discussions.
- Students should read through the relevant chapters of the prescribed textbook.
- Students should complete all assessment tasks and submit them on time.
- Students are expected to participate in online discussions through the Moodle page.

2.3. Feedback on assessment

- Unless otherwise specified in the task criteria, all assignments must be handed in to the lecturer prior to or on the due date for submission.
- Assignments submitted after the due date for submission will receive a 10% of maximum grade penalty for every day late, or part thereof.
- Students unable to submit assignments on time or attend the mid-term or final exams on health grounds should make a request for special consideration. Information on this process can be found here: https://student.unsw.edu.au/special-consideration. Medical certificates or other appropriate documents must be included. Students should also advise the lecturer of the situation.
- Students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course coordinator prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equity and Diversity Unit: https://student.unsw.edu.au/disability. Early notification is essential to enable any necessary adjustments to be made.
- Students who fail to achieve a score of at least 40% for either the mid-session quiz and/or final exam but achieve a final mark >50% for the course, may still be awarded a UF (Unsatisfactory Fail) for the course.
- Please refer to the UNSW guide to grades: https://my.unsw.edu.au/student/academiclife/assessment/GuideToUNSWGrades.html

- Rules governing conduct during exams are given at: https://student.unsw.edu.au/exam-rules

2.4. Feedback on assessment

Assignments: Feedback will be given after submission of the assignment and take the form of the marked assignment, comments on how the class performed, and any common areas that were not answered correctly. Additionally, personal feedback and how each student performed may be given. A solution sheet for each assignment, showing the worked answers and relevant comments, will be uploaded onto Moodle after their submission.

Final exam: Students will receive their final mark.

2.5. Literature and resources

Suggested books for various topics covered in the course:

- Materials for Semiconductor Devices, *C. R. M. Grosvenor, Institute of Metals, 1987.*
- The Science and Engineering of Materials (Sixth Edition), *Donald R. Askeland, Pradeep P. Fulay, Wendelin J. Wright, Cengage Learning, 2010.*
- Processing of Semiconductors, *ed. K.A. Jackson et al. VCH, 1996.*
- The Science and Engineering of Microelectronic Fabrication*, S. A. Campbell, OUP, 1996.*
- Dopants and Defects in Semiconductors, *M. D. McCluskey, E. E. Haller, CRC Press, 2013*
- Semiconductor Devices, *N.M. Morris, McMillan, 1976.*
- Nanoelectronics and Information Technology-Advanced Electronic Materials and Novel Devices, *Edited By Rainer Waser, Wiley-VCH, 2003.*
- The Defect Chemistry of Metal Oxides, *D. M. Smyth, Oxford University Press, 2000*
- Thermal Properties Measurement of Materials, *Yves Jannot Alain Degiovanni, 2018*
- Ferroelectric Materials for Energy Applications (1st edition), edited by Haitao Huang and James F. Scott. © 2018 Wiley-VCH Verlag GmbH & Co. KGaA.
- Introduction to Electrodynamics, *David J. Griffiths, Cambridge University Press, 2017.*

2.5. Administrative matters

School Office: Room 137, Building E10 School of Materials Science and Engineering
School Website: http://www.materials.unsw.edu.au/
Faculty Office: Robert Webster Building, Room 128
Faculty Website: http://www.science.unsw.edu.au/

2.5. Additional support for students

- The Current Students Gateway: https://student.unsw.edu.au/
- Academic Skills and Support: https://student.unsw.edu.au/academic-skills
- Student Wellbeing, Health and Safety: https://student.unsw.edu.au/wellbeing
- Disability Support Services: https://student.unsw.edu.au/disability-services
- UNSW IT Service Centre: https://www.it.unsw.edu.au/students/index.html