Course Outline

NANO3001

Advanced Nanomaterials

Materials Science and Engineering

Science

T1, 2020

1. Staff

Position	Name	Email	Consultation times and locations	Contact Details
Course Convenor	Prof. Jan Seidel	jan.seidel@unsw.edu.au	Room 340, School of Materials Science and Engineering (Building E10), by appointment	Phone: 9385 4442
Lecturer	Dr Claduio Cazorla Silva	c.cazorla@unsw.edu.au	Room 302 Materials Science and Engineering (Bldg E10) by appointment	Phone: 9385 5918

2. Course information

Units of credit: 6

Pre-requisite(s): None

Timetabling website: http://timetable.unsw.edu.au/2019/NANO3001.html#S1-11013

Teaching times and locations:

Part 1:	**Lecture**	**Lecture**	**Lecture**
Day	Tuesday	Wednesday	Thursday
Location	Webster Theatre B	Webster Theatre B	Mathews Theatre B
Time	09:00-11:00	13:00-15:00	15:00-17:00
Weeks	1-6	1-6	1-4

Part 2:	**Lecture**	**Lecture**	**Lecture**
Day	Tuesday	Wednesday	Thursday
Location	Science & Engineering G02	Science & Engineering G02	Macauley Theatre
Time	09:00-11:00	13:00-15:00	15:00-17:00
Weeks	7-9	7-10	7-9

2.1 Course summary

-Modern atomic theory: shortfall of classical physics and an introduction to wave mechanics; many-electron atoms and the Pauli exclusion principle; zone and band theories.
-Electrical properties: classification of metals, semiconductors and insulators.
-Thermal properties: heat capacity, thermal expansion, thermal conductivity and thermoelectricity.

-Magnetic properties: diamagnetism, paramagnetism, antiferromagnetism, ferrimagnetism and ferromagnetism; magnetic anisotropy and magnetostriction; magnetic materials and devices.
-Superconductivity and superconducting materials.
-Optical properties.

Introduction to nanotechnology: definitions and background, a brief history, scales and sizes, size effects, elegant examples from nature and materials science, nanotechnology as business - jobs and products.

Nanomaterials applications: 2D, 1D, and 0D - Thin films and interfaces, nanotubes, nanowires and nanoparticles, bio-nanotechnology and medical applications, surface coatings, sensors, energy applications - batteries, supercapacitors, water splitting, fuel cells, H2 storage, catalysis, nano-optics - near field optics, plasmonics; nanoelectronics - dimensionality, Coulomb blockade, resonant tunnelling, electron localisation.

Nanomaterials characterization: Spectroscopy (UV-VIS-IR, THz, Raman, XRD, XAS, XPS/UPS, EPR/ESR/NMR, RBS, SIMS), Microscopy (SPM, TEM, SEM,…).

Nanomaterials synthesis: a brief history of human history and materials, energy and matter - units and terminology, Fabrication techniques: nanolithography/imprint, MBE, PLD, ALD, VLS, sputtering, thermal/e-beam evaporation, CVD, arc synthesis, liquid based synthesis, self-assembly, Langmuir-Blodgett technique.

Nanotechnology - Environmental, health and safety: pollutant classifications, nanoparticle hazards, environmental and health impact.

2.2 Course aims

To generate a sound understanding of the state-of-the-art of advanced nanomaterials in order to understand various important physical phenomena including mechanical, electrical, magnetic and optical properties of materials and to show how such properties influence the design and operation of engineering components and devices used in nanotechnology.

2.3 Course learning outcomes (CLO)

At the successful completion of this course you (the student) should be able to:

1. Enhanced critical thinking, analytical and problem-solving skills in materials science and engineering
2. A basic understanding of nanomaterials concepts and their application to a broad range of materials
3. An understanding of the modern physical principles underlying fabrication and characterisation of nanomaterials
4. An appreciation of a "materials" contributions and importance in electronic systems

2.4 Relationship between course and program learning outcomes and assessments

Course Learning Outcome (CLO)	LO Statement	Program Learning Outcome (PLO)	Related Tasks & Assessment
CLO 1	Enhanced critical thinking, analytical and problem-solving skills in materials science and engineering	1, 2, 3 4, 5 & 7	all
CLO 2	A basic understanding of nanomaterials concepts and their application to a broad range of materials	1, 2, 3 4, 5 & 7	all
CLO 3	An understanding of the modern physical principles underlying fabrication and characterisation of nanomaterials	1, 2, 3 4, 5 & 7	all
CLO 4	An appreciation of a "materials" contributions and importance in electronic systems	1, 2, 3 4, 5 & 7	all

3. Strategies and approaches to learning

3.1 Learning and teaching activities

(based on UNSW Learning Guidelines)

- *Students are actively engaged in the learning process.*

  It is expected that, in addition to attending classes, students read, write, discuss, and are engaged in solving problems on the electronic properties of materials, and in analysis and evaluation of materials' electron-related properties in the context of modern theories of physics. Advanced nanomaterials concepts will be discussed in class discussions.

- *Effective learning is supported by a climate of inquiry where students feel appropriately challenged.*

  Problems involving electron theory are challenging; students will be given assignments that will motivate deep analysis of various physical phenomena in materials science and engineering. Assignments include tasks where students need to do some literature search regarding nanomaterials.

- *Learning is more effective when students' prior experience and knowledge are recognised and built on.*

This course is built on prior courses in mathematics, physics and chemistry.

- *Students become more engaged in the learning process if they can see the relevance of their studies to professional and disciplinary contexts*

Students will be asked to analyse the role of electron theory in understanding various physical phenomena in materials science and how properties such as electrical conduction and magnetism influence the science and engineering of existing and new devices and components. Industry and job relevance of nanomaterials will be discussed, participation in nanotech competitions will be encouraged

3.2 Expectations of students

- Students must attend at least 80% of all classes with the expectation that students only miss classes due to illness or unforeseen circumstances
- Students must read through lecture notes and lab sheets prior to class
- During class, students are expected to engage actively in class discussions
- Students should work through lecture, tutorial and textbook questions
- 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

4. Course schedule and structure

This course consists of 52 hours of class contact hours. You are expected to take an additional 98 hours of non-class contact hours to complete assessments, readings and exam preparation.

Week	Topics	Activity
1-2	**PART I- Fundamentals of electron theory**	
1	• Introduction to the course • Shortcomings 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	
3-5	**PART II- Electrical properties of materials**	
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 Part 1 Due
4	• The combined role of the band gap and temperature on conductivity • Simple intrinsic semiconductor devices • Extrinsic semiconductors • Introduction to band-gap engineering	
5-6	• Physics of the p-n junction • Basic semiconducting devices • Summary of Parts I and II	Assignment 1 Part 2
6	• Mid-session Quiz	Mid-term exam
7-10	**PART III- PART VII**	
7	Part III- Introduction to nanotechnology • Definitions and background, a brief history • Scales and sizes, size effects • Elegant examples from nature and materials science • Nanotechnology as business - jobs and products Part IV- Nanomaterials applications • 2D, 1D, and 0D - thin films and interfaces, nanotubes, nanowires	

	and nanoparticles • Bio-nanotechnology and medical applications • Surface coatings	
8	Part IV- Nanomaterials applications • Energy applications - batteries, supercapacitors, water splitting, fuel cells, H2 storage, catalysis • Nano-optics - near field optics, plasmonics • Nanoelectronics - dimensionality, Coulomb blockade, resonant tunneling, electron localization Part V- Nanomaterials characterization • Spectroscopy (UV-VIS-IR, THz, Raman, XRD, XAS, XPS/UPS, EPR/ESR/NMR, RBS, SIMS) • Microscopy (SPM, TEM, SEM, …)	
9	Part VI- Nanomaterials synthesis • A brief history of human history and materials • Energy and matter - units and terminology • Fabrication techniques: nanolithography/imprint, MBE, PLD, ALD, VLS, sputtering, thermal/electron-beam evaporation, CVD, arc synthesis, liquid based synthesis, self-assembly, Langmuir-Blodgett technique Part VII- Nanomaterials- Environmental, health and safety • Pollutant classifications	
10	Part VII- Nanomaterials- Environmental, health and safety • Nanoparticle hazards • Environmental and health impacts	Assignment 2 due

5. Assessment

5.1 Assessment tasks

Assessment task	Description	Weight	Due date
Assignment 1:	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%	Part 1: Week 3 Part 2: Week 5
Mid-term 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 (Parts I & II). It will consist of a combination of multiple choice and 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 6
Assignment 2:	You will be required to undertake essay writing and calculations involving the application of modern advanced materials topics covered throughout the course. This assignment will enable you to achieve the desired learning outcomes and develop graduate attributes.	20%	Week 10
Final exam:	This exam is devoted to all parts of the 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 and calculations. (2hrs)	30%	Final exam period

Further information

UNSW grading system: https://student.unsw.edu.au/grades

UNSW assessment policy: https://student.unsw.edu.au/assessment

5.2 Assessment criteria and standards

Assignment 1 and the mid-term: Each assignment and exam question will be graded on a rating scale of (1)-(5), where the highest rating (1) denotes: (i) a correct mathematical solution to the problem together with a logical 2-5 line written explanation of the meaning of the result, or (ii) a thorough written explanation of the question if it is an essay-type one (full marks), through to (5), which indicates that no attempt was made to answer the question (no marks). This rating is converted to the value of the mark for each question.
All assessment criteria and standards are available on the course Moodle page.

Assessment criteria and standards for each assessment tasks are available on the course Moodle page.

5.3 Submission of assessment tasks

- UNSW operates under a Fit to Sit/ Submit rule for all assessments. If a student wishes to submit an application for special consideration for an exam or assessment, the application must be submitted prior to the start of the exam or before an assessment is submitted. If a student sits the exam/ submits an assignment, they are declaring themselves well enough to do so. 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.
- Unless otherwise specified in the task criteria, all assignments must be uploaded via Moodle prior to the due date for submission.
- Assignments/lab reports submitted after the due date for submission will receive a 10% of maximum grade penalty for every day late, or part thereof.
- 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.
- All assignments must contain a completed student declaration sheet and will be due on the dates specified above. Assignments submitted after the deadline will receive a 10% of maximum grade penalty for every day late, or part thereof.
- 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

5.4. Feedback on assessment

Assignments: Feedback will be given two weeks 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 two weeks after their submission.

Mid-term exam: As the mid-term exam is the formal exam for Part 1 of the course, with the content not examinable in Part 2, students will receive their final mark.

Final exam: Students will receive their final mark.

6. Academic integrity, referencing and plagiarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism. If you compare a calculated result in an assignment with an experimental value taken from the literature, please reference the source: Authors, publication & date.

Further information about referencing styles can be located at https://student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits**:** honesty, trust, fairness, respect, responsibility and courage.[1] At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

Further information about academic integrity and **plagiarism** can be located at:

- The *Current Students* site https://student.unsw.edu.au/plagiarism**,** and
- The *ELISE* training site http://subjectguides.library.unsw.edu.au/elise/presenting

The *Conduct and Integrity Unit* provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct.

7. Readings and resources

Preferred textbooks:

- Electronic Properties of Materials, Hummel, Rolf E. 4th ed. Springer. ISBN: 978-1441981639
- Gateway to Nanotechnology, Sanghera, Paul Infonential, ISBN: 978-1-4392308-7-9

Other suitable books at elementary level:

- The Structure and Properties of Materials: Volume IV – Electronic Properties: R.M. Rose, L.A. Shepard and J. Wulff, John Wiley and Sons, 1966.
- Lectures on the Electrical Properties of Materials: L. Soymar and D. Walsh, Oxford, 1988.
- An Introduction to the Electron Theory of Solids: J. Stringer, Pergamon, 1967.
- Introduction to the Modern Theory of Metals: A. Cottrell, Institute of Metals, London, 1988.
- Physics of Solids: C.A. Wert and R.M. Thompson, McGraw-Hill, 1964.
- Introduction to solid State Physics: C. Kittel, John Wiley and Sons, 1986.
- Electronic Properties of Crystalline Solids: R.H. Bube, Academic Press, New York, 1974.
- Solid State Theory in Metallurgy: P. Wilkes, Cambridge University Press, 1973.
- Solid State Electronic Devices: B.G. Streetman, Prentice-Hall, 1980.
- Magnetic Materials: R.S. Tebble and D.J. Craik, Wiley Interscience, 1969.

- *Introduction to Nanoscience*: S. M. Lindsay, Oxford University Press, 2010.
- *Nanophysics and Nanotechnology*: E. L. Wolf, Wiley-VCH,2004.
- *Nanoscale Multifunctional Materials*: S. M. Mukhopadhyay, Wiley, 2012.
- *Nanostructures &Nanomaterials*: G. Cao, Imperial College Press, 2004.
- *Nanotechnology – A Crash Course*: R. J. Martin-Palma and A. Lakhtakia, SPIE Press, 2010.
- *Optical Properties and Spectroscopy of Nanomaterials*: J. Z. Zhang, World Scientific, 2009.
- *Functional Metal Oxide Nanostructures*: J. Wu, J. Cao, W.-Q. Han, A. Janotti, and H.-C. Kim, Springer, 2010.

[1] International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013.

8. 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/

9. 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
- Assessment Implementation Procedure: https://www.gs.unsw.edu.au/policy/documents/assessmentimplementationprocedure.pdf