Winter 2025
Course Outline

Materials 792
Nanoscale Semiconductor Materials and Applications
3 units

CALENDAR/COURSE DESCRIPTION

Nanoscale semiconductor materials and devices including quantum confinement, quantum dots, dipole radiation, quantum radiation physics, molecular and bulk excitons, advanced molecular electronics, tight-binding modelling, and emerging nanoscale devices

PRE-REQUISITES AND ANTI-REQUISITES

It is assumed that students have a background in quantum mechanics and solid state physics. Electronic Materials 760 that was offered in Fall 2024 is good preparation for graduate students new to these topics, however alternative preparation is also acceptable. See instructor if you are unsure about your readiness for this course.

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Adrian Kitai kitaia@mcmaster.ca
ABB140

Office Hours:

By appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

http://avenue.mcmaster.ca/

COURSE INTENDED LEARNING OUTCOMES

By the end of this course, students should have a firm grasp of the following topics

- Carrier inversion in semiconductors
- Electronic properties of semiconductor surfaces and interfaces
- Debye length and Debye screening
- Modified work functions
- Semiconductor surface carrier mobility models
- Thermionic emission in semiconductors
- Fowler-Nordheim carrier transport
- Flash memory physics
- The MOS capacitor
- The MOS transistor
- Sub-10nm Finfets and advanced MOS design
- Quantum dots
- Quantum dot bandgap modelling
- Vibrational quantum states
- Vibronic transitions
- Frank Condon principle
- Stokes shift
- Quantum description of radiation theory
- Dipole radiation matrix elements
- Selection rules
- Excitons
- Molecular electron transport
- Sigma and pi bonds
- Pi bands
- Singlet and triplet states
- Molecular excitons
- Homo and lumo states
- Scanning tunnelling microscopy and homo and lumo state imaging
- Dexter and Forster energy transfer
- Phosphorescent molecules and spin-orbit coupling
- Thermally stimulated delayed fluorescence
- OLED devices
- Graphene, Dirac point, Photon-like carrier transport
- Transition metal dichalcogenide (TMD) two dimensional semiconductors
- Surface reconstruction
- Image potential states at metal surfaces
- TMD coulomb scattering

- Tight binding models and the density functional theory approach

MATERIALS AND FEES

Recommended Text:

1) Fundamentals of Semiconductor Materials and Devices, Adrian Kitai, Wiley 2023, ISBN9781119891406

Supplementary References:
To be specified during course

Calculator:
Any non-networked calculator is acceptable.

COURSE FORMAT AND EXPECTATIONS

COURSE SCHEDULE

3 one hour lectures per week:

Monday 5:30 pm – 6:20 pm
Wednesday 5:30 pm – 6:20 pm
Thursday 5:30 pm - 6:20pm

Location: T13 Room 106

ASSESSMENT

Component	Weight
Assignments	12.5%
Midterm	12.5%
Class Participation	12.5%
Research Project	50%
Final Exam	12.5%
Total	100%

Class participation includes 2 short (5 minutes or less) Powerpoint presentations. The presentations will be based on homework problem solutions. You will be assigned a homework problem to present at least one week ahead of your scheduled presentation date.