Optical Materials
Fall 2014
Course No. 14:635:433
Department of Materials Science and Engineering
Rutgers, The State University of New Jersey

Time: 3.20 - 4.40 pm, Tues & Thur
Location: SEC 204, Busch Campus
Instructor: Deirdre O'Carroll, CCR 218
Office Hours: Thur. 12 - 2 pm
Contact: ocarroll@rutgers.edu

Description:

This course will describe the properties of important passive and active optical materials including glasses, crystals, polymers, semiconductors and metals. The first part of the course will introduce the fundamental issues such as optical transmission and reflection, the interaction of light and optical materials, and the materials chemistry and physics necessary to be able to interpret the basic optical properties of materials. Next, experimental measurement and theoretical simulation approaches used to determine optical properties of materials followed by sections on unique characteristics of individual classes of optical materials will be covered. Materials of interest will be crystalline, semiconducting, and glassy solids including passive optical polymers, oxide and fluoride glasses, inorganic semiconductor like Si, Ge and GaAs, organic optically active semiconductors, non-linear optical materials and new optical materials such as metamaterials and optical composites. For each material, there will be brief discussions on fabrication techniques and applications of the materials such as optical fiber communications, microscopy, display and lighting and optical sensing.

Objective:

The primary objective of the course is to provide an understanding of the origins and uses of the optical properties of materials. The student will be exposed to a quantitative interpretation of the fundamentals of the interaction of light with passive and active optical materials as well as general information on the applications of optical materials in optical engineering. A major objective of the course is to for students to learn how to apply course knowledge to solve real-world problems in a variety of optical engineering applications. The students should be prepared by the end of the course to work in industries employing enabling optical technologies or to continue in graduate school in more advanced optical materials research and development.

Prerequisites: none

Reference Texts (not required):

- Photonics by Amnon Yariv & Pochi Yeh, Oxford University Press, 6th Edition, New York, 2007.
- Introduction to Modern Optics by Grant R. Fowles, Dover Publications, 2nd Edition, New York 1989.
- Materials Chemistry by Bradley D. Fahlman, Springer, 2nd Edition, New York, 2011.

Course Materials:

Class lecture slides, summary sheets, reading materials and homework questions including relevant equations and diagrams will be posted on Sakai in conjunction with syllabus topics. The course instructor retains copyright to all lecture slides, summary sheets and homework questions posted on Sakai and these materials are not to be distributed by students to persons not registered for this course or to other media or websites without written permission from the course instructor.

Topics Covered:

Introduction to Light-Matter Interactions:

- Introduction; passive & active optical materials
- Electromagnetic radiation; Maxwell's Equations; quantum nature of light
- Origin of the dielectric constant: molecular orbital theory; band structure
- Optical constants; dispersion relations
- Absorption, transmission, reflection (Fresnel Equations), refraction, diffraction, emission, scattering (phonons, elastic, Raman, Brillouin), polarization
- Measurement and simulation of the optical properties of materials

Passive Optical Materials:

- *Glasses:* silicates, fluoride, chalcogenides, origin of color in glasses
- *Polymers:* optical constants, specialty optical applications, polarization
- *Crystals:* polarization, birefringence, waveplates, liquid crystals
- *Metals:* physical origin of the dielectric constant, reflectance, surface plasmons
- *Passive optical components*: lenses; optical coatings; mirrors; gratings
- *Optical waveguides*: thin films (slab); optical fibers; mode equations and profiles, mode cutoff

Active Optical Materials:

- *Semiconductors*: interband absorption; direct, indirect bandgap; Si, III-V; II-V
- *Semiconductors*: nanoscale phenomena, excitons, quantum confinement
- *Semiconductors:* organic semiconductors; small molecules; conjugated polymers
- *Applications of active semiconductor optical materials:* photodetectors, amplifiers (lasers), lighting, displays.
- *Nonlinear optical materials:* Nonlinear optical properties; gain materials; upconversion; harmonic generation, electrooptic materials
- *Plasmonics, metamaterials and photonic crystals:* optical frequency magnetic permeability, optical composites.

Important Dates, Exams, Homework and Grading:

Assessment Type	***Date***	***Information***	***Duration***	***% of Total Course Grade***
Homework	Exact due date for each homework assignment will be specified upon assignment.	5 homework assignments will be given. One homework assignment will involve an optical simulation problem.	Throughout the course.	35 %
Exam 1	Oct. 7th	Will cover all preceding lectures.	45 min.	15 %
Exam 2	Nov. 13th	Will cover all lectures not covered by Exam 1.	45 min.	15 %
Final Exam	December	Will cover all lectures given during the entire semester.	90 mins.	30 %
Attendance	All semester	Attendance will be taken in each class and the attendance grade will be calculated based on your percentage attendance.	-	5 %

Tentative Class Schedule:

Sept. 2rd 2014	Introduction; syllabus, prior knowledge quiz, passive and active optical materials
Sept. 4th 2014	**Homework 1 assigned.** Electromagnetic radiation; Maxwells equations; quantum nature of light.
Sept. 9th 2014	Origin of the dielectric constant: Molecular orbital theory; band structure
Sept. 11th 2014	Optical constants; dispersion relations; absorption, transmission
Sept. 16th 2014	**Homework 1 due. Homework 2 assigned.** Reflection (Fresnel Equations), refraction, diffraction, emission, scattering, polarization
Sept. 18th 2014	Measurement of the optical properties of materials
Sept. 23rd 2014	Simulation of the optical properties of materials
Sept. 25th 2014	Glasses
Sept. 30th 2014	**Homework 2 due.** Polymers
Oct. 2nd 2014	Review
Oct. 7th 2014	**Exam 1: Covers all lectures to date**
Oct. 9th 2014	**Homework 3 assigned.** Crystals
Oct. 14th 20140	Metals

Oct. 16th 2014	Application of passive optical components
Oct. 21st 2014	Optical waveguides
Oct. 23rd 2014	**Homework 3 due. Homework 4 assigned.** Inorganic semiconductors
Oct. 28th 2014	Semiconductors: Nanoscale pheonmena
Oct. 30th 2014	Organic semiconductors
Nov. 4th 2014	Applications of active semiconductor optical materials
Nov. 6th 2014	**Homework 4 due.** Applications of active semiconductor optical materials
Nov. 11th 2014	Review
Nov. 13th 2014	**Exam 2: Covers all lectures not covered by Exam 1.**
Nov. 18th 2014	**Homework 5 assigned.** Nonlinear optical materials
Nov. 20th 2014	Plasmonics, metamaterials
Nov. 25th 2014	Metamaterials and photonic crystals
Nov. 27th 2014	**Thanksgiving recess**
Dec. 2nd 2014	**MRS Fall**
Dec. 4th 2014	**Homework 5 due.** **MRS Fall**
Dec. 9th 2014	**Review class**
~Dec 15th (to be confirmed)	**Final Exam: Covers all lectures**