PHY-928, Spectroscopy of Nanomaterials

Credit Hours: 3-0

Prerequisite: None

Objectives and Goals: To introduce the students with the optical properties of nanomaterials and the techniques needed to characterize these properties. To impart students an overview of electron theory of nanomaterials, band theory, electrical behavior of metals, semiconductors and dielectrics, theory of optical behavior and applications.

Core Contents: Optical Processes, optical materials, modes of optical modes and their detection, application of optical properties of nanomaterials

Detailed Course Contents: Classification of optical processes, optical coefficients, the complex refractive index and dielectric constant, optical materials including metals, semiconductors and dielectrics, characteristic optical physics in solid state; electronic bands, vibronic bands, density of states, microscopic models, interband transitions, transition rate, band edge absorption in direct bandgap materials, interband absorption above the band edge, measurement of absorption spectra, excitons, free excitons in fields, interband luminescence, photoluminescence, free electrons, plasma reflectivity and conductivity, free electrons in metals and doped semiconductors, plasmons, UV-visible absorption spectroscopy, photoluminescence, infrared and Raman vibrational spectroscopy, time-resolved optical spectroscopy, single molecule spectroscopy, dynamic light scattering, optical properties of semiconductor nanomaterials, energy levels and density of states in reduced dimension systems, optical properties of metal oxide and metal nanomaterials, surface plasmon resonance, surface enhanced Raman scattering, applications of optical properties of nanomaterials

Course Outcomes: Students will be able to mimic well defined optical nanomaterials that can be used later for optoelectronic device miniaturization.

Textbook:

1. Jin Zhang Zhang, Optical properties and spectroscopy of Nanomaterials, 2^{nd} ed. World Scientific Publishing Co. Pte. Ltd. 2008. (referred as JZ)

2. Mark Fox, Optical properties of Solids, Oxford University Press Inc., New York 2001. (referred as MF)

Reference books: Neil W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt College Publishers 1976.

Publishers 1976.

Weekly Breakdown		
Week	***Section***	***Topics***
1	MF 1.1-1.6	Classification of optical processes, optical coefficients, the complex refractive index and dielectric constant, optical materials such as metals, semiconductors and dielectrics, electronic bands, vibronic bands, the density of states, microscopic models
2	MF 3.1-3.6	Interband transitions and transition rate for direct absorption, frequency dependence, interband absorption above band edge
3	MF 4.1-4.3, 5.1, 5.3	Excitons, free excitons, binding energy and radius, free excitons in external fields, luminescence, light emission in solids, photoluminescence, degeneracy
4	MF 7.1-7.5	Plasma reflectivity, free carrier conductivity, doped semiconductors, the Drude model, interband transition in metals, impurity absorption, plasmons
5	JZ 2.1-2.3	UV-Vis absorption spectroscopy, Beer-Lambert's law, spectrum and interpretation, spectroflurometer, spectrum and interpretation
6	JZ 2.3.1, 2.3.2, handouts	Infrared (IR) and Raman vibrational spectroscopy
7	JZ 2.4-2.7	Time-resolved spectroscopy, non-linear optical spectroscopy, harmonic generation and up-conversion, single molecule spectroscopy, dynamic light scattering (DLS)
8	JZ 5.1.1-5.2.3	Basics concepts of semiconductors, density of states in reduced dimension systems, density of states in nanomaterials, size dependence of absorption coefficient, exciton lifetime
9	JZ 5.3-5.4	Electronic structure of nanomaterials, electron-phonon interaction, direct and indirect bandgap transitions, photoluminescence and
10	JZ 5.5	Raman scattering, interaction between nanoparticles, shape dependent optical properties

11	JZ 6.1-6.5	Optical properties of metal oxide nanomaterials, optical absorption, optical emission, other optical properties: doped and sensitized metal oxides, nonlinear optical properties, luminescence up-conversion (LUC)
12	JZ 7.1-7.3.4	Optical properties of metal nanoparticles, surface plasmon resonance (SPR), correlation between structure and SPR, effect of size, surface, substrate and particle-particle interaction on SPR.
13	JZ 7.4.1-7.4.6	Surface enhanced Raman scattering (SERS), background and mechanism of SERS, distance dependence of SERS, location and orientation of SERS, single molecule SERS
14	JZ 10.1, 10.2	Chemical and biomedical detection, imaging and therapy, luminescence-based detection, surface plasmon resonance detection, SERS for detection, chemical and biochemical sensing
15	JZ 10.4, 10.5	Photovoltaic solar cells, photoelectrochemical cells, lasers, optical detectors and filters, photonic bandgap materials and crystals