3.23 Electrical, Optical, and Magnetic Properties of Materials
Fall 2007

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LAST LECTURE!

Exam

- Monday 17, 9am-12noon
- 2 questions on electronics, 1 on optics, 1 on magnetic

PEN(S), CALCULATOR (THAT WORKS), 1 SHEET

BAND STRUCTURE (Si, Ge, GaAs)
Syllabus

• From particles to waves: the Schrödinger equation
• The mechanics of quantum mechanics: operators, expectation values
• Measurements and probabilities. The harmonic oscillator.
• The hydrogen atom and the periodic table
• Periodicity and phonons
  • Electrons in a lattice: Bloch’s theorem
  • The nearly-free electron model
  • The tight-binding model. Band structures
• Metals, semiconductors and insulators
• Intrinsic and extrinsic semiconductors
• Transport of heat and electricity
• The p-n diode

Syllabus

• Electromagnetism in dielectric media
• Classic propagation of waves
• Optical materials and refractive index
• Interband absorption
• Excitons and luminescence
• Fundamental of ferromagnetic materials
• Hysteresis loop and driving energies
• Hard materials and permanent magnets
• Soft materials: thin films and nanoparticles. Spintronics and GMR
• Spin valves, spin switches, and spin tunneling
Last time

- Fermi’s golden rule, joint density of states
- Perturbing Hamiltonian, selection rules
- Frequency-dependence of band adsorption in direct or indirect band gap SC. Absorption above the band edge
- Excitons and exciton absorption
- Luminescence: low-carrier density; degeneracy.

Study

- Fox, Optical Properties of Solids, Chap. 7.5, 9.4, 10.4
Photoluminescence spectroscopy

Please see: Fig. 5.9 in Fox, Mark. *Optical Properties of Solids*. Oxford, England: Oxford University Press, 2001.

Electroluminescence: LED

Diode laser: resonant longitudinal modes

\[ \lambda = \frac{n}{m} \]
\[ L = \frac{\lambda'}{2} \text{ INTEGER} \]
\[ V = \int \frac{c}{2 \pi l} \]
\[ dI = \gamma \nu \, dm \, I(n) \]
\[ I(n) = I_0 e^{-kn} \]

Injection current, threshold gain, slope efficiency

\[ R_1 \, R_2 \, e^{2 \alpha B \cdot L} \cdot e^{-2 \alpha B \cdot L} = 1 \]
\[ \gamma_{th} = e \left( \frac{1}{2 \theta} \right) \ln \left( \frac{R_1}{R_2} \right) \]

\[ P_{out} = \eta \frac{hv}{e} \left( I_{th} - I_{inj} \right) \]
Electroluminescence: diode laser

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Solid state lasers

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Plasmons

\[ N \underbrace{\frac{\partial \varepsilon}{\partial \varepsilon}} = \frac{N e u}{\varepsilon_0} \]

\[ N m \frac{d^2 u}{dt^2} = -\frac{N e \varepsilon}{1 + \left( \frac{N^2 e^2}{\varepsilon_0} \right) u} \]

\[ \omega_p = \left( \frac{N e^2}{\varepsilon_0 m} \right)^{\frac{1}{2}} \]

Plasmonics

Polarons

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Electron Transfer

- Electron transfer mediated by polar solvent fluctuations.
- Tunneling can occur when reactant and product are degenerate

$\varepsilon = \varepsilon_{\text{product}} - \varepsilon_{\text{reactant}}$ is the energy gap or reaction coordinate

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Please see Fig. 2 in Sit, P. H.-L., et al. "Realistic, Quantitative Descriptions of Electron-transfer Reactions: Diabatic Free-energy Surfaces from First-principles Molecular Dynamics." arXiv:cond-mat/0606310v1 [cond-mat.mtrl-sci], 2006.
Ferrous-ferric self-exchange

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- $\Delta G$ is the free-energy barrier of the reaction
- $\lambda$ (reorganization energy) is the difference in free energy between product and reactant in the optimum atomic configuration for the reactant

The colour of gems

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Inelastic light scattering

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