Course Approval Form
(Saved)

Coll./Schl./Div.: College of Engineering
Dept./Comm./Prog.: Electrical Engineering
Action: CHANGE
Course Level: Graduate Course
Course Type: Standard Course
Effective: Winter 2018
Offered once only: No
Offered summer sessions only: No
Quarter(s) Offered: Winter, Spring
(Previously Fall, Winter, Spring)
Last Approved Form Effective: Fall 2010 (Submitted: 02/25/2010)

<table>
<thead>
<tr>
<th>Previously Approved</th>
<th>Proposed</th>
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<tbody>
<tr>
<td><strong>Course Number:</strong> EE 208</td>
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<tr>
<td><strong>Course Title:</strong> Semiconductor Electron, Phonon, and Optical Properties</td>
<td><strong>Semiconductor Electronic and Optical Properties</strong></td>
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<td><strong>Justification:</strong> Title: Title more accurately reflects topics covered.</td>
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<td><strong>E-Z Segment Title:</strong></td>
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<td><strong>Units:</strong></td>
<td>4</td>
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<tr>
<td><strong>Activity(ies):</strong></td>
<td>Lecture, 3 hours per week (group activity)</td>
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<td></td>
<td>Discussion, 1 hour per week (group activity)</td>
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<tr>
<td><strong>Prerequisite(s):</strong></td>
<td>EE 202/MSE 217</td>
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<td></td>
<td><strong>Corequisite:</strong> EE 202/MSE 217 or PHSY 221B</td>
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|                           | **Justification:** The prerequisite EE202/MSE217 is changed to a corequisite. Experience has shown that this is sufficient preparation. New alternative prerequisites and corequisites are also now given. PHYS 221B is also an acceptable corequisite.
**Description:**
Topics include semiconductor electronic band structure theory and methods; phonon dispersion theory and methods; defects in semiconductors; and optical properties of semiconductors.

**EE 208 Semiconductor Electronic and Optical Properties (4)**
Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 202/MSE 217 or PHYS 221B (may be taken concurrently). Introduction to electronic bandstructure. Topics include electronic structure of semiconductors, graphene, localized orbital models, k dot p models, spin-orbit coupling, and optical generation of spin.

**Grading**

<table>
<thead>
<tr>
<th>Type</th>
<th>Letter Grade or petition for Satisfactory/No Credit (S/NC)</th>
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<tbody>
<tr>
<td>In Progress Statement</td>
<td>No</td>
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<tr>
<td>Statement</td>
<td>May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor</td>
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</table>

**Repeatable:** No

**Maximum Units:**

| Statement              | No |

**Cross-listed With:**

| MSE 2XX                  |

**Credit Statement:**

MSE 2XX
Justification: This will be a 200 level course in the 'computational' category of the graduate MSE curriculum.

**If repeatable, may be taken more than once per quarter:** No (previously No)

**Breadth Statement:**

**Instructor(s):** Professor Roger Lake

**Justification:**
Catalog Description: A long overdue update that more succinctly describes the topics covered. The prerequisite EE202/MSE217 is changed to a corequisite. Experience has shown that this is sufficient preparation. New alternative prerequisites and corequisites are also now given. PHYS 221B is also an acceptable corequisite.

Cross-listing: Cross listing with MSE. The number is to be determined. This will be a 200 level course in the 'computational' category of the graduate MSE curriculum.
Title: Title more accurately reflects topics covered.

Correspondence:

Overlaps/Duplicates Other Courses: No
Affects Programs: No
Affects Prerequisites/Descriptions: No

Syllabus:
EE 208: Semiconductor Electronic and Optical Properties

Course Objective: The objective of this course is to introduce the students to a basic understanding of semiconductor band-structure theory and methods.

Corequisites: EE 202/MSE 217 or PHYS 221B.

Instructor: Roger Lake (WCH 437; phone: 827-2122; e-mail: rlake@ece.ucr.edu).
Office Hours: TBD
Lecture: MW 5:10-6:30pm
Discussion: F 3:10 - 4pm

References
Supriyo Datta, "Modular Series on Solid State Devices v. VIII, Quantum Phenomena" (Addison-Wesley).
Supriyo Datta, "Quantum Transport Atom to Transistor" (Cambridge University Press, 2005).
All necessary material is posted on ilearn.

Topics Covered: Electronic structure of semiconductors, graphene, localized orbital models, k dot p models, spin-orbit coupling, and optical generation/recombination.

Grading: Homework assignments 80%, Attendance 20%

Attendance: Mandatory. There is no required text for this course. All material is covered in the lectures.

Topics by Week:
1. Review of bras, kets, and basis functions. Matrix formulation of Schrödinger's equation. 2-state problem. 2x2 Hamiltonian matrix. Bonding (symmetric) and anti-bonding (anti-symmetric) states. HOMO (highest occupied molecular orbital) and LUMO (Lowest unoccupied molecular orbital).

3. Two band model. Chain of alternating anions and cations. Nearest neighbor tight-binding model. Form Bloch sums of the s orbitals |s,k> and the pz orbitals |pz,k>. Construct the 2x2 Hamiltonian matrix H(k). Solve for the eigenvalues E(k) by solving |H(k) - E| = 0. At the band edges at k=0 (Gamma), the valence band wavefunction sits on the anion and the conduction band wavefunction sits on the cation. At k=pi/a (X), the wavefunction is approximately an equal mix of s and p. The envelope changes sign every unit cell.

4. Two band model continued. Band gap, effective mass, and dispersion. Low-energy (ka <<1) limit of the 2-band model dispersion. Corrections to the density of states. The density of states (DOS) starts off like the parabolic DOS, and then increases faster going from a sqrt(E) dependence to a E^2 dependence for large E >> Eg. This is critical for narrow bandgap materials. Imaginary k in the bandgap. Within the bandgap, the imaginary k in the 2-band model wraps around from the conduction band edge to valence band edge. Imaginary k governs the tunneling, T ~ exp(-2kd).

5. Sigma bonds and pi bonds. Definition of px, py, and pz orbitals. Four non-zero matrix elements. Calculation of the matrix elements between the A & B atom in the primitive cell of a diamond or zinc-blende lattice. Elements in the Slater-Koster Table.

6. Construct the sp3 Bloch sum basis. Calculate the k-dependent Hamiltonian matrix elements for the diamond or zinc-blende lattice. Determine the orbital composition and energies of the states at Gamma. Determine orbital composition of the states at X.


8. Finish spin-orbit coupling. Determine the eigenstates and eigenergies of the states at Gamma including spin-orbit coupling. Total angular momentum eigenstates at k=0. Breaking of 6-fold degeneracy in-to 4-fold and 2-fold degeneracies.


Topics covered in tutorial homework assignments and discussion sessions: (1) 2-level systems. (2) Derivation, calculation, and analysis of the dimerization induced bandgap. (3) pi-bond model of graphene. Derivation and analysis of the graphene bandstructure. (4) Derivation and analysis of the low-energy model of graphene. (5) Calculation of the 8-band and 16-band bandstructure (without and with SOC) of Si and GaAs using literature tight-binding parameters.
Executive Committee
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College of Natural and Agricultural Sciences:
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Graduate School of Education:
Graduate School of Management:
University Honors Program:

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Graduate Council:

Committee on Courses: