LEDs and Solar Cells

ECE 498 CB, Spring 2017

Instructor: Prof. Can Bayram | cbayram@illinois.edu | MNTL 3264 | (217)300-0978

Lecture 2:00-2:50 pm MWF | Lab: TBD (2 hr per week per section – either on W or R)

Office hours: By appointment

Location/Time: TBD

Catalog Description: This course explores the energy conversion devices from fundamentals to system-level issues. The modern devices to be explored include light emitting diodes and solar cells. Topics include energy transfer between photons and electron-hole pairs, light emission and capture, emission and absorption engineering via device simulation/design, radiative and non-radiative processes in devices, electrical and optical characteristics, carrier diffusion and mobility, and light extraction and trapping for high efficiency devices.

Purpose: This is an advanced course in energy conversion physics, devices, and design technology. The course will cover fundamentals as well as modern research topics, and will accommodate a broad range of backgrounds and interests from Electrical Engineering, Physics, Material Science, and Chemistry. If you are unsure of your individual preparation for this class, please check with the instructor. A solid knowledge of solid-state physics, semiconductors, and familiarity with a numerical computing software (e.g. Matlab, Python) is recommended.

Timeline: There are 42 lectures and ~12 labs spread over 14 weeks during the Spring of 2017.

Homeworks: Due approximately every week, and some will contain open-ended "research" problems. That is, not all necessary information will be provided up front, you may have to look up constants, material properties, and make reasonable approximations. Some homeworks will involve computational work with Matlab or freeware software available on campus, including numerical integrals, straightforward finite difference problems, and simple device simulation. You may work in groups on the homeworks, although separate write-ups must be submitted.

Projects: The class involves a final project. This will be an open-ended research project of your choice, written as an NSF-style format. You are encouraged to work in pairs, and to think of topics as the course progresses. There will be a one-page abstract, and short in-class pitch due on the week of the Midterm. Final conference-style presentations (8 minute talk with a 2 minute Q&A) will occur in the week before the final.

(Computer) Lab Work: Crosslight software is used in the computer labs for the design and simulation of quantum structures, light emitting diodes, and solar cells. There will be a formal report for each lab set. The formal report will be considered part of the HW assignment in its due week. The computer lab and fab lab are used in alternating weeks and for 2 hours per week. The select topics of computer lab include: (1) Quantum simulation of active layers in semiconductor devices; (2) Simulation of a red light emitting diode; (3) Simulation of a silicon solar cell.

(NanoFab) Cleanroom Work: Fab Lab cleanroom located in the ECE Building is used for the cleanroom activities related to the characterization of light emitting diodes and solar cells. There will be a formal report for each lab set. The formal report will be considered part of the HW assignment in its due week. The computer lab and fab lab are used in alternating weeks and for 2 hours per week. The select topics of NanoFab lab include: (1) Investigation of P-I-V curves of blue and green LEDs; (2) Identification of leakage paths and loss mechanisms in a solar cells; (3) Effects of temperature on LED and Solar Cell performance.

Reading: No single textbook covers all topics. We will rely on handouts, slides, PDFs, and sections from several books including "Light Emitting Diodes" by E. Fred Schubert (Cambridge, 2003) (Lectures III-V) [http://www.amazon.com/Light-Emitting-Diodes-E-Fred-Schubert/dp/0521865387], and "The Physics of Solar Cells" by J. Nelson (Imperial College Press, 2003) (Lectures VI-VIII) [http://www.amazon.com/Physics-Solar-Properties-Semiconductor-Materials/dp/1860943497].

Grading: Homeworks/Lab Reports (25%). Midterm (25%). Project (25%). Final Exam (25%).

Pre-reqs: ECE 340

Lecture Topics:	**Approximate Hours:**	
I. Introduction to Semiconductors and Quantum Devices	**2**	
II. Technology of Compound Semiconductors	**2**	
III. Introduction to Light Emitting Diodes	**3**	
a) Brief History and Evolution		1.5
b) Human Vision and Light		1.5
IV. Fundamentals of Light Emitting Diodes	**8**	
a) Radiative and Non-radiative Recombination		1.5
b) Electrical Properties		2
c) High Internal Efficiency Designs		1.5
d) High Extraction Efficiency Designs		1.5
V. Spectral Engineering of Light Emitting Diodes	**4.5**	
a) Ultraviolet LEDs		1.5
b) Visible LEDs		1.5
c) Optical Communication LEDs		1.5
VI. Introduction to Solar Cells	**2**	
a) Brief History and Evolution		1
b) Sun Spectrum and Photovoltaic Effect		1
VII. Principles of Solar Cells	**7.5**	
a) Photocurrent and Quantum Efficiency		1
b) Dark Current and Open Circuit Voltage		1
c) High Internal Efficiency Designs		2
d) Light Management/Confinement/Recycling		1
e) Concentration and Its Effects		1
VIII. Strategies for High Efficiency Solar Cells	**6**	
a) Thermodynamic Limits		1
b) Engineering the Bandgap		1
c) Tandem Cells		2
d) Intermediate Band and Multiple Band Cells		1
e) “Hot” Carrier Cells		1
IX. Project In-Class Presentations	**6**	
X. Review	**1**	
	Total: 42	