TO: The Faculty of the College of Engineering

FROM: School of Electrical and Computer Engineering of the College of Engineering

RE: New Graduate Course, ECE 50616 Physics and Manufacturing of Solar Cells

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 50616 Physics and Manufacturing of Solar Cells
Sem. 1, Lecture 3, Cr. 3.

Prerequisite: Graduate standing or one of the following: ECE305, MSE370, ME315, ME363, CHE378, PHY330, and CHM370; or consent of instructor

Description: This course introduces the electronic, optical and material properties and the manufacturing of photovoltaic devices. Topics include electronic charge separation, transportation and recombincation; optical concentration, trapping and confinement; material preparations in photovoltaic systems; bulk crystal, thin-film and organic photovoltaic device configurations; energy storage; as well as emerging concepts in photovoltaics. Discussions also involve the process and equipment for the manufacturing of various photovoltaic modules, with special emphasis on driving down the cost of photovoltaic systems.

Reason: The basic operation of solar cells can be understood with the background equivalent to ECE 305. However, new device configurations such as tandem cells with or without optical concentration, thin-film cells with various optical trapping schemes, as well as the manufacturing processes for photovoltaic cells, require advanced interdisciplinary knowledge beyond those covered in undergraduate ECE curriculum.

Michael R Melloch

Michael R. Melloch, Associate Head
School of Electrical and Computer Engineering

Approved for the faculty of the Schools of Engineering by the Engineering Curriculum Committee
ECC Minutes 14 Date 3-1-16
Chairman ECC

Supporting Document to the Form 40G
for a New Graduate Course

To: Purdue University Graduate Council

From: Faculty Member: Minghao Qi

Department: Electrical and Computer Engineering

Campus: West Lafayette

Date:

Subject: Proposal for New Graduate Course

Contact for information if questions arise:
Name: Matt Golden
Phone: 494-3374
Email: goldenm@purdue.edu
Address: EE Building, Room 135

Course Subject Abbreviation and Number: ECE 50616

Course Title: Physics and Manufacturing of Solar Cells

Course Description:

This course introduces the electronic, optical and material properties and the manufacturing of photovoltaic devices. Topics include electronic charge separation, transportation and recombincation; optical concentration, trapping and confinement; material preparations in photovoltaic systems; bulk crystal, thin-film and organic photovoltaic device configurations; energy storage; as well as emerging concepts in photovoltaics. Discussions also involve the process and equipment for the manufacturing of various photovoltaic modules, with special emphasis on driving down the cost of photovoltaic systems.

Semesters Offered:

For the benefit of graduate student plan of study development, how frequently will this prototype be offered? Which semesters?
Fall Odd Years

A. Justification for the Course:

Provide a complete and detailed explanation of the need for the course (e. g., in the preparation of students, in providing new knowledge/training in one or more topics, in meeting degree requirements, etc.), how the course contributes to existing majors and/or concentrations, and how the course relates to other graduate courses offered by the department, other departments, or interdisciplinary programs.

Justify the level of the proposed graduate course (500- or 600-level) including statements on, but not limited to: (1) the target audience, including the anticipated number of undergraduate and graduate students who will enroll in the course; and (2) the rigor of the course.

- The basic operation of solar cells can be understood with the background equivalent to ECE 305. However, new device configurations such as tandem cells with or without optical concentration, thin-film cells with various optical trapping schemes, as well as the manufacturing processes for photovoltaic cells, require advanced interdisciplinary knowledge beyond those covered in undergraduate ECE curriculum.

Use the following criteria:
Graduate Council policy requires that courses at the 50000 level in the Purdue system should be taught at the graduate level and meet four criteria: a) the use of primary literature in conjunction with advanced secondary sources (i.e., advanced textbooks); b) assessments that demonstrate synthesis of concepts and ideas by students; c) demonstrations that topics are current, and; d) components that emphasize research approaches/methods or discovery efforts in the course content area (reading the research, critiquing articles, proposing research, performing research). Such courses should be taught so that undergraduate students are expected to rise to the level of graduate work and be assessed in the same manner as the graduate students.

- Anticipated enrollment
  - Undergraduate 2-5
  - Graduate 15-20

B. Learning Outcomes and Method of Evaluation or Assessment:

ECE Graduate Learning Outcomes:

a. Knowledge and Scholarship (thesis/non-thesis)
b. Communication (thesis/non-thesis)

c. Critical Thinking (thesis/non-thesis)
d. Ethical and Responsible Research (thesis) or Professional and Ethical Responsibility (non-thesis)

- List Learning Objectives for this course and map each Learning Objective to one or more of the ECE Learning Outcomes (a-d, listed above):

1)uderstanding of different market segments for photovoltaics and their key requirements. (a, b, c)
2) understanding ofp-njunction, chift and diffusion of charges, LUMO and HOMO. (a)
3) capability of extracting efficiency from i-v characteristics ofphotovoltaic cells. (a)
4) understanding the effect of optical trapping on short-circuit currents. (a)
5) capability of design manufacturing process flow for bulk and thin-film photovoltaic devices. (c, d)
6) ability to estimate the manufacturing cost of photovoltaic systems. (c, d)

- Methods of Instruction
    - Lecture
- Will/can this course be offered via Distance Learning?
    - No
- Grading Criteria

  Grading criteria (select from checklist); include a statement describing the criteria that will be used to assess students and how the final grade will be determined. Add and delete rows as needed.

    - exams and/or quizzes
    - papers and/or projects
    - homework

  ▶ Describe the criteria that will be used to assess students and how the final grade will be determined:
  HWs, 20%, One Midterm, 30%, Final Project, 50%

C. Prerequisite(s):

List prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence. Add bullets as needed.

- Graduate standing or one of the following: ECE305, MSE370, ME315,

ME363, CHE378, PHY330, and CHM370; or consent of instructor
- Prerequisite by Topic: Semiconductor physics

D. Course Instructor(s):

Provide the name, rank, and department/program affiliation of the instructor(s). Is the instructor currently a member of the Graduate Faculty? (If the answer is no, indicate when it is expected that a request will be submitted.) Add rows as needed.

Name	Rank	Dept.	Graduate Faculty or expected date
Minghao Qi	Associate Professor	ECEN	Yes

E. Course Outline:

Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory of field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For special topics courses, include a sample outline of a course that would be offered under the proposed course. **(This information must be listed and may be copied from syllabus).**

Lectures	*Principal Topics*
1	Overview of global energy requirements and sources.
1	Basic principles and device configurations of photovoltaic cells
1	Review of electrons and holes in semiconductors
2	Photo-induced charge-separation, including molecular-based separations
2	Charge transportation and recombination with presence of structural defects
4	Optics for photovoltaic systems, including antireflective coating, light trapping, concentration and photon recycling.
4	Materials for photovoltaic systems, including silicon, III-V, CdTe, CuinGaSe, dye-sensitized, and organic materials.
2	Modeling and simulation of photovoltaic devices
1	Testing and reliability of photovoltaic devices

1	Solar cell design and optimization, including thin-fim and tandem cells.
1	Secondary batteries and other energy storage devices
2	Overall efficiency and cost of an installed photovoltaic system for residential, grid-level, and portable applications
4	Processes and equipment in photovoltaic system manufacturing
2	Cost reductions in manufacturing
2	Student project presentations

This assumes 2 lectures per week, each is 75 minutes in duration.

F. Reading List (including course text):

A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not be a compilation of general reference material.

A secondary reading list or bibliography should include material students may use as background information.

- Primary Reading List
    - The Physics of Solar Cells, by Jenny Nelson, Imperial College Press, 2003
- Secondary Reading List
    - Research papers that cover recent advances.

G. Library Resources

Describe any library resources that are currently available or the resources needed to support this proposed course.

- The course text book will be on reserve at the library. All additional assigned readings will be made available to the students electronically through Blackboard or other means.

H. Course Syllabus

(While not a necessary component of this supporting document, an example of a course syllabus is available, for information, by clicking on the link below, which goes to the *Graduate School's Policies and Procedures Manual for Administering Graduate Student Program.*
See Appendix K.
http://www.purdue.edu/gradschool/faculty/documents/Graduate_School_Policies_and_Procedures_Manual.pdf

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE
(50000-60000 LEVEL)

DEPARTMENT: Electrical and Computer Engineering EFFECTIVE SESSION: Spring 2016

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:		EXISTING:	
Subject Abbreviation	ECE	Subject Abbreviation	
Course Number	50616	Course Number	
Long Title	Physics and Manufacturing of Solar Cells		
Short Title	Phys & Manufact of Solar Cells		

Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

TERMS OFFERED (Check All That Apply): [x] Fall [ ] Spring [ ] Summer

CAMPUS(ES) INVOLVED: [ ] Calumet [ ] N. Central [ ] Cont Ed [ ] Tech Statewide [ ] Ft. Wayne [x] W. Lafayette [ ] Indianapolis

CREDIT TYPE

1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range: Minimum Cr. Hrs ____ (Check One) To [ ] Or [ ] Maximum Cr. Hrs ____
3. Equivalent Credit: Yes [ ] No [x]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply

1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ] Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request — Include comment to explain fee
6. Registration Approval Type: Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	3	50	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

This course introduces the electronic, optical and material properties and the manufacturing of photovoltaic devices. Topics include electronic charge separation, transportation and recombincation; optical concentration, trapping and confinement; material preparations in photovoltaic systems; bulk crystal, thin-film and organic photovoltaic device configurations; energy storage; as well as emerging concepts in photovoltaics.

*COURSE LEARNING OUTCOMES:

1)uderstanding of different market segments for photovoltaics and their key requirements. (a, b, c)
2) understanding ofp-njunction, chift and diffusion of charges, LUMO and HOMO. (a)
3) capability of extracting efficiency from i-v characteristics ofphotovoltaic cells. (a)

Calumet Department Head	Date	Calumet School Dean	Date	Calumet Director of Graduate Studies	Date
Fort Wayne Department Head	Date	Fort Wayne School Dean	Date	Fort Wayne Director of Graduate Studies	Date
Indianapolis Department Head	Date	Indianapolis School Dean	Date	IUPUI Associate Dean for Graduate Education	Date
North Central Department Head	Date	North Central School Dean	Date	North Central Director of Graduate Studies	Date
West Lafayette Department Head	11/20/15	West Lafayette College/School Dean	3/1/16	Date Approved by Graduate Council	Date
Graduate Area Committee Convener	Date	Graduate Dean	Date	Graduate Council Secretary	Date
				West Lafayette Registrar	Date

OFFICE OF THE REGISTRAR