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 60614 Reliability Physics of Nanoelectronic Transistors

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 60614 Reliability Physics of Nanoelectronic Transistors

Sem. 2, Lecture 3, Cr. 3.
Prerequisite: ECE 60600

Description: This course will focus on the physics of reliability of small semiconductor devices. In traditional courses on device physics, the students learn how to compute current throgh a device in response to applied voltage. However, as transistors are turned on and off trillions of times during the years of operation, gradually defects accumulate within the device so that at some point the transistor does not work anymore. The course will explore the physics and mathematics regarding how and when things break—a topic of great interest to semiconductor device engineers.

Reason: Modern integrated circuits are made possible by billions of impossibly small transistors. Every microelectronic and nanotechnology program teaches its students the physics of transistor performance (e.g. ECE606, ECE612). Equally important (and no less astonishing) is the fact that these nanoscale transistors survive trillions of switching operation under an electric field a thousand times larger than the high voltage power-lines that crisscross the country. At universities, reliability physics of transistors is taught as an afterthought -- and yet, industry would ask their employees to learn this fundamentally important topic from the very first day of their job. This course fills the essential gap, and does so with a deep appreciation of the physics involved and the practical aspect of transistor design. This unique course will broaden/deepen the understanding of transistor physics of every student, and make our students uniquely qualified. This course requires a reasonably good understanding of semiconductor device physics.

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 8 Date 11/20/15
Chairman ECC [signature]

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 2017

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:
Subject Abbreviation: ECE
Course Number: 60614
Long Title: Reliability Physics of Nanoelectronic Transistors
Short Title: Reliab Phys Nanoelectr Trans
Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

EXISTING:
Subject Abbreviation:
Course Number:

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

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

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	50	3	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 will focus on the physics of reliability of small semiconductor devices. In traditional courses on device physics, the students learn how to compute current throgh a device in response to applied voltage. However, as transistors are turned on and off trillions of times during the years of operation, gradually defects accumulate within the device so that at some point the transistor does not work anymore. The course will explore the physics and mathematics

*COURSE LEARNING OUTCOMES:
i. The students will have deep understanding regarding a topic of broad interest to academic community and to the industry.
ii. The class quizzes, homework, and exams will involve critical thinking related to broad range of topics involving various aspects of reliability physics.

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

[signature] 10/8/15
West Lafayette Department Head — Date
[signature] 11/20/15
West Lafayette College/School Dean — Date
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

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

To: Purdue University Graduate Council

From: Faculty Member: Ashraf Alam

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 60614

Course Title: Reliability Physics of Nanoelectronic Transistors

Course Description:

This course will focus on the physics of reliability of small semiconductor devices. In traditional courses on device physics, the students learn how to compute current throgh a device in response to applied voltage. However, as transistors are turned on and off trillions of times during the years of operation, gradually defects accumulate within the device so that at some point the transistor does not work anymore. The course will explore the physics and mathematics regarding how and when things break—a topic of great interest to semiconductor device engineers.

Semesters Offered:

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

- Modern integrated circuits are made possible by billions of impossibly small transistors. Every microelectronic and nanotechnology program teaches its students the physics of transistor performance (e.g. ECE606, ECE612). Equally important (and no less astonishing) is the fact that these nanoscale transistors survive trillions of switching operation under an electric field a thousand times larger than the high voltage power-lines that crisscross the country. At universities, reliability physics of transistors is taught as an afterthought -- and yet, industry would ask their employees to learn this fundamentally important topic from the very first day of their job. This course fills the essential gap, and does so with a deep appreciation of the physics involved and the practical aspect of transistor design. This unique course will broaden/deepen the understanding of transistor physics of every students, and make our students uniquely qualified. This course requires a reasonably good understanding of semiconductor device physics.

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 0
  - Graduate 20-25

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):

    i. The students will have deep understanding regarding a topic of broad interest to academic community and to the industry. (a,)
    ii. The class quizzes, homework, and exams will involve critical thinking related to broad range of topics involving various aspects of reliability physics. (c)

- 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:
    A combination of scores from exams, quizzes, homework, and projects.

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.

- EE606 required; EE612, EE658 are good to have, but not essential

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
Ashraf Alam	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
3	Reliability Physics -- Broad Introduction
3	Spatial Randomness and Nature of Defects
6	Interface Reliability of Semiconductor Devices: NBTI Degradation
4	Interface Reliability of Semiconductor Devices: Hot Carrier Degradation
7	Time-Dependent Dielectric Breakdown
2	Breakdown in Thick Dielectrics
5	Radiation Damage in Semiconductor Devices
4	Statistics of Reliability
4	Theory and Practice of Defect Characterization
2	Concluding Remarks

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
    - None
- Secondary Reading List
    - Lecture Notes from 2013 (https://nanohub.org/resources/16560)
    - Lecture Notes from 2013 (https://sites.google.com/site/teachingreliabilityclassnotes/2010-word-documents)
    - Fundamentals of Modern VLSI Devices Yuan Taur and Tak H. Ning, Cambridge University Press, 1998 ISBN: 0 521 55056 4 (hardback) or 0 521 55959 6 (paperback)
    - Advanced Semiconductor Fundamentals, 2nd Edition R.F. Pierret, Prentice Hall, ISBN 0-13-061792-X
    - Semiconductor Material and Device Characterization, D. K. Schroeder, John Wiley and Sons, ISBN: 0-471-73906-5

G. Library Resources

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

- None.

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