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 60645 High-speed Semiconductor Devices

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 60645 High-speed Semiconductor Devices
Sem. 2, Lecture 3, Cr. 3.

Prerequisite: ECE 60600 or taking ECE 60600 at the same time

Prerequisite by Topic: ECE 25500 and ECE 30500 level of semiconductor physics and devices

Description: As semiconductor device geometry miniaturizes, the device becomes faster and some devices move into the quantum-effect region. These high-speed devices are the key components for future electronic systems in communications, computers, control, and consumer applications. This course covers the physics and operational principles of these devices to meet the needs of microelectronics in the 21th century. This course emphasizes the integration of the state-of-the-art technologies such as high-k dielectrics, SiGe, SiC and GaN devices. This course is intended for graduate students in science and engineering who are either i) interested in pursuing research in semiconductor materials, structures or devices, or ii) seeking the broad device background on the state-of-the-art technologies for a future R&D career in the microelectronic industry.

Reason: This is the course above ECE 60600 and is used for graduate students to broad their knowledge on modern semiconductor devices. We expect the students having the knowledge on fundamentals of semiconductor materials and the basic concepts of field-effect transistors and bipolar junction transistors.

Michael R. Melloch

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

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:		EXISTING:	
Subject Abbreviation	ECE	Subject Abbreviation	
Course Number	60645	Course Number	
Long Title	High-speed Semiconductor Devices		
Short Title	High-speed Semiconductr Devics		

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

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	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):

As semiconductor device geometry miniaturizes, the device becomes faster and some devices move into the quantum-effect region. These high-speed devices are the key components for future electronic systems in communications, computers, control, and consumer applications. This course covers the physics and operational principles of these devices to meet the needs of microelectronics in the 21th century. This course emphasizes the integration of the state-of-the-art technologies such as high-k dielectrics, SiGe, SiC and GaN devices. This course is intended for graduate students in science and engineering who are either i) interested in pursuing research in semiconductor materials, structures or devices, or ii) seeking the broad device background on the state-of-the-art technologies for a future

*COURSE LEARNING OUTCOMES:

attached

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
M. R. McCuen	11/15/17				
West Lafayette Department Head	Date	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

Course Description—ECE 60645

As semiconductor device geometry miniaturizes, the device becomes faster and some devices move into the quantum-effect region. These high-speed devices are the key components for future electronic systems in communications, computers, control, and consumer applications. This course covers the physics and operational principles of these devices to meet the needs of microelectronics in the 21th century. This course emphasizes the integration of the state-of-the-art technologies such as high-k dielectrics, SiGe, SiC and GaN devices. This course is intended for graduate students in science and engineering who are either i) interested in pursuing research in semiconductor materials, structures or devices, or ii) seeking the broad device background on the state-of-the-art technologies for a future R&D career in the microelectronic industry.

Learning Outcomes—ECE 60645

a. Knowledge and Scholarship: This course is intended for graduate students in MN and related areas who are either i) interested in pursuing research in semiconductor materials, structures or devices, or ii) seeking the broad device background on the-state-of-the-art technologies for a future R&D career in the microelectronic industry. The students are required to understand the III-V compound semiconductor epitaxy technologies, dielectric technologies, III-V HEMTs and HBTs in depth about fabrication, process and device physics, scaled CMOS devices and also microwave, photonic and power devices. We have mid-term and final exams to test these basic concepts. We also have regular homework assignments.

b. Communication: We have the discussion to do research and presentation to strengthen the students' communication skill and critical thinking. For example, we research on f_T and fmax high-speed matrix on GaAs HEMTs, InP HEMTs, GaN HEMTs, graphene FETs and MoS_2 FETs.
c. Critical Thinking: The students are required to search and study the state-of-the-art device work published at IEDM, VLSI, EDL or IEEE TED. They choose some interesting topics and organize the materials into a 15-20 minutes presentation. They will discuss the pros and cons of the new technologies compared to the existing technologies. In this way, their critical thinking skill is enhanced.
d. Ethical and Responsible Research or Professional and Ethical Responsibility: The discussion sessions are independent topics which assesses the professional and ethical responsibility. The presentation is similar to the formal conference presentation. I ask the students have to cite other people's work professionally. They can learn the professional and ethical responsibility during this training.

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

To: Purdue University Graduate Council

From: Faculty Member: Peide Ye

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 60645

Course Title: High-speed Semiconductor Devices

Course Description:

As semiconductor device geometry miniaturizes, the device becomes faster and some devices move into the quantum-effect region. These high-speed devices are the key components for future electronic systems in communications, computers, control, and consumer applications. This course covers the physics and operational principles of these devices to meet the needs of microelectronics in the 21th century. This course emphasizes the integration of the state-of-the-art technologies such as high-k dielectrics, SiGe, SiC and GaN devices. This course is intended for graduate students in science and engineering who are either i) interested in pursuing research in semiconductor materials, structures or devices, or ii) seeking the broad device background on the state-of-the-art technologies for a future R&D career in the microelectronic industry.

Semesters Offered:

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

- This is the course above ECE 606 and is used for graduate students to broad their knowledge on modern semiconductor devices. We expect the students having the knowledge on fundamentals of semiconductor materials and the basic concepts of field-effect transistors and bipolar junction transistors.

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 15 (More students want to be registered in spring semester 2017)

B. Learning Outcomes and Method of Evaluation or Assessment:

ECE Graduate Learning Outcomes:

a. Knowledge and Scholarship: This course is intended for graduate students in MN and related areas who are either i) interested in pursuing research in

semiconductor materials, structures or devices, or ii) seeking the broad device background on the-state-of-the-art technologies for a future R&D career in the microelectronic industry. The students are required to understand the III-V compound semiconductor epitaxy technologies, dielectric technologies, III-V HEMTs and HBTs in depth about fabrication, process and device physics, scaled CMOS devices and also microwave, photonic and power devices. We have mid-term and final exams to test these basic concepts. We also have regular homework assignments.

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d. Ethical and Responsible Research or Professional and Ethical Responsibility: The discussion sessions are independent topics which assesses the professional and ethical responsibility. The presentation is similar to the formal conference presentation. I ask the students have to cite other people's work professionally. They can learn the professional and ethical responsibility during this training.

- Methods of Instruction
    - Lecture
- Will/can this course be offered via Distance Learning?

    No plan at this moment

- 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.

- 2 exams including mid-term and final one.
- Discussion session with the presentations by the students after doing research on active research topics
- Homework weekly

- We don't have resource to do lab exercises at cleanroom at Birck. However, we will have a cleanroom tour and introduce the equipment functions and operations to the students
- Attendance/participation is strongly required and checked.

- Mid-term exam 40%, Final Exam 40%, Presentation/Research 10%, Homework 10%

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.

- ECE 606 or taking ECE 606 at the same time
- Prerequisite by Topic: ECE 255 and ECE 305 level of semiconductor physics and devices

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
Peide Ye	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).**

Weeks	Principal Topics
1	Overview of Modern Semiconductor Devices
	Semiconductor Epitaxial Growth (MBE and MOCVD)

1	Chemical Vapor Deposition (CVD) Atomic Layer Deposition (ALD); High-k dielectrics for ultimate CMOS
1	Homogeneous Field-Effect Transistors (III-V MESFET) Homogeneous Field-Effect Transistors (III-V MESFET and JFET)
1	Heterostructure Field-Effect Transistors (III-V HFET) Heterostructure Field-Effect Transistors (III-V HEMT)
1	Discussion on III-V MOSFET Research Discussion on GaN HEMT Research
1	Bipolar Transistor Operation, Silon Bipolar Transistor Heterojunction Bipolar Transistor (III-V HBT)
1	Scaled MOSFETs, CMOS/Bi CMOS Strain-Si and SiGe based MOSFETs
1	Discussion on Ge MOSFET Research Discussion on CNTFET Research
1	Power MOSFET, Si LDMOSFET
1	SiC Power Devices, GaN Power Devices
1	Quantum-Effect Devices (Resonant-Tunneling Diodes and RTBTs) Hot-Electron Devices
1	Discussion on Single-Dlectron-Transistors (SET) and Quantum Dots Research Active Micowave Devices
1	Discussion on THz transistor Research (i.e. UIUC work) High-Speed Photonic Devices (LED, Pin Photodetector, Avalanche Photodetector)
1	High-Speed Photonic Devices (Laser) Discussion on VCSEL Research
1	Review

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

- Class Notes
- Secondary Reading List

  S.M.Sze,"High-speed Semiconductor Devices"

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

ECE 695V High-Speed Semiconductor Devices—Spring 2019 Schedule

Time: Tuesday and Thursday 9:00-10:20 am Credit:3 Location:EE226

Data	Topics
1/8 T	Overview of Modern Semiconductor Devices
1/10 Th	Semiconductor Epitaxial Growth (MBE and MOCVD)
1/15 T	Chemical Vapor Deposition (CVD)
1/17 Th	Atomic Layer Deposition (ALD); High-k dielectrics for ultimate CMOS
1/22 T	Homogeneous Field-Effect Transistors (III-V MESFET)
1/24 Th	Homogeneous Field-Effect Transistors (III-V MESFET and JFET)
1/29 T	Heterostructure Field-Effect Transistors (III-V HFET)
1/31 Th	Heterostructure Field-Effect Transistors (III-V HEMT)
2/5 T	Discussion on III-V MOSFET Research
2/7 Th	Discussion on GaN HEMT Research
2/12 T	Bipolar Transistor Operation, Silon Bipolar Transistor
2/14 Th	Heterojunction Bipolar Transistor (III-V HBT)
2/19 T	Scaled MOSFETs, CMOS/Bi CMOS
2/21 Th	Strain-Si and SiGe based MOSFETs

2/26 T	Discussion on Ge MOSFET Research
2/28 Th	Discussion on CNTFET Research
3/5 T	Power MOSFET
3/7 Th	Si LDMOSFET
3/12 T	SiC Power Devices
3/14 Th	GaN Power Devices
3/19 T	Quantum-Effect Devices (Resonant-Tunneling Diodes and RTBTs)
3/21 Th	Hot-Electron Devices
3/26 T	Discussion on Single-Electron-Transistors (SET) and Quantum Dots Research
3/28 Th	Active Micowave Devices
4/2 T	Discussion on THz transistor Research (i.e. UIUC work)
4/4 Th	High-Speed Photonic Devices (LED, Pin Photodetector, Avalanche Photodetector)
4/9 T	High-Speed Photonic Devices (Laser)
4/11 Th	Discussion on VCSEL Research
4/16 T	RF Measurements
4/18 Th	State-of-the-Art CMOS (FinFETs and GAAFETs)
4/23 T	2D Materials and Devices
4/25 Th	Review Session
4/30 T	Final Exam

Course Outcomes:

1. Produce homework and presentations at the course that use appropriate formats, knowledge of electronic materials and devices, and documentation styles while controlling the right technical terms, writing skill including grammar and spelling.

2. Demonstrate an understanding of technical contents of the course and writing reports as a process that includes multiple drafts, collaboration, feedback, and reflection.

3. Examine critically, summarize, apply, analyze, and synthesize information as the basis for developing original ideas and claims.

4. Demonstrate proficiency in identifying, reading, evaluating, analyzing, and using reliable sources of technical contents of this course.

Grading:

We make the assignment weightings and mappings from scores to letter grades as following. We assign 40% weight on mid-term exam, 40% weight on final exam and 20% for homework, lecture attendance and discussion session presentation. The letter grade A refers to 90/100 or above; the letter grade B refers to 80/100 or above but less than 90/100; the letter grade C refers to 70/100 or above but less than 80/100; the letter grade D refers to 60/100 or above but less than 70/100; the letter grade F (fail) refers to less than 60/100. Any academic dishonest behavior will lead to the letter grade F.

Offering History: Spring 2021 – 10, Spring 2019 - 8