NEW COURSE PROPOSAL

College: [Engineering &Computer Science] **Department: [ECE]**

Note: Use this form to request a single course that can be offered independently of any other course, lab or activity.

1. **Course information for Catalog Entry**
   Subject Abbreviation and Number: **[ECE 645]**
   Course Title: **[Microelectronics Device Fabrication Principles]**
   Units: **[3]** units
   Course Prerequisites: **[ECE 545]** *(if any)*
   Course Corequisites: **[ ]** *(if any)*
   Recommended Preparatory Courses: **[ ]** *(if any)*

2. **Course Description for Printed Catalog:** *Notes:* If grading is NC/CR only, please state in course description. If a course numbered less than 500 is available for graduate credit, please state "Available for graduate credit in the catalog description."

   [Prerequisites: ECE 545. Introduction of fabrication and characterization process equipment and tools with fabrication process physics for device fabrication. This course is focused on semiconductor device fabrication dealing with diffusion, ion implantation and epitaxy processes for the doping of the active areas of semiconductor devices; contact formation, contact patterning and window opening for selective doping and mask design: thin film deposition, photolithographic processes and etching processes; device yield management: device failure analysis and yield analysis, fabrication process induced defects and radiation effects on semiconductor devices: process modeling and device modeling for device fabrication process and device structure optimizations.**]**

3. **Date of Proposed Implementation: (Semester/Year): [Spring] / [2017]** *Comments*

4. **Course Level**
   []Undergraduate Only **[X]**Graduate Only **[]**Graduate/Undergraduate

5. **Course Abbreviation "Short title" (maximum of 17 characters and spaces)**
   Short Title: **[D•E•V•I•C•E•F•A•B•R•I•C•A•T•I•O•N]**

6. **Basis of Grading:**
   []Credit/No Credit Only **[X]Letter Grade Only** **[]CR/NC or Letter Grade**

7. **Number of times a course may be taken:**
   [X] May be taken for credit for a total of **[1]** times, or for a maximum of **[3]** units
   [ ] Multiple enrollments are allowed within a semester

8. **C-Classification:** *(e.g., Lecture-discussion (C-4).)*
   [3] units @ **[C] [4]**

9. **Replaces Current Experimental Course?**
   [X] YES **[ ]** NO
   Replaces Course Number/Suffix:**[ECE 695DFP]**

Previously offered **[2]** times.

10. **Proposed Course Uses:** *(Check all that apply)*
    [X]Own Program: **[ ]**Major **[ ]**Minor **[X]**Masters **[ ]**Credential **[ ]**Other
    [ ] Requirement or Elective in another Program
    [ ] General Elective
    [ ] General Education, Section **[ ]**
    [ ] Meets GE Information Competence (IC) Requirement
    [ ] Meets GE Writing Intensive (WI) Requirement
    [ ] Community Service Learning (CS)
    [ ] Cross-listed with: *(List courses)* **[ ]**

11. **Justification for Request**: *Course use in program, level, use in General Education, Credential, or other. Include information on overlap/duplication of courses within and outside of department or program. (Attach)*

12. **Estimate of Impact on Resources within the Department, for other Departments and the University.** *(Attach)*

(See Resource List)

13. **Course Outline and Syllabus** *(Attach) Include methods of evaluation, suggested texts, and selected bibliography.* Describe the difference in expectations of graduates and undergraduates for all 400 level courses that are offered to both.

14. **Indicate which of the PROGRAM'S measurable Student Learning Outcomes are addressed in this course.** *(Attach)*

15. **Assessment of COURSE objectives** *(Attach)*
    A. Identify each of the course objectives and describe how the student performance will be assessed

(For numbers 14 and 15, see Course Alignment Matrix and the Course Objectives Chart)

16. **If this is a General Education course, indicate how the General Education Measurable Student Learning Outcomes (from the appropriate section) are addressed in this course.** *(Attach)*

17. **Methods of Assessment for Measurable Student Learning Outcomes** *(Attach)*
    A. Assessment tools
    B. Describe the procedure dept/program will use to ensure the faculty teaching the course will be involved in the assessment process (refer to the university's policy on assessment.)

18. Record of Consultation: Professor Ali Amini, Chair, Department of Electrical and Computer Engineering

(Normally all consultation should be with a department chair or program coordinator.) If more space is needed attach statement and supporting memoranda.

Date:	Dept/College:	Department Chair/ Program Coordinator	Concur (Y/N)
[1/26/15]	[ECE]	[Chair]	[Y]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

Consultation with the Oviatt Library is needed to ensure the availability of appropriate resources to support proposed course curriculum.

Collection Development Coordinator	Date
Please send an email to: collection.development@csun.edu	[ ]

19. Approvals:

Department Chair/Program Coordinator:	Date:	[ ]
College (Dean or Associate Dean):	Date:	[ ]
Educational Policies Committee:	Date:	[ ]
Graduate Studies Committee:	Date:	[ ]
Provost:	Date:	[ ]

Attachments

11. Justification for Request:

Physics of device fabrication process and detailed characterizations will support a conceptual and practical understanding supporting material ECE 445 and ECE545. This course covers how to design the semiconductor devices on the basis of analysis of electrical and fabrication parameters as well as understanding of the principle of fabrication process, system operation of fabrication equipment and characterization tools. This course will train the students to work at the microelectronics laboratory and greatly support the students' building of a conceptual understanding of solid state device physics and device applications.

12. Estimate of Impact on Resources within the Department, for other Departments and the University:

This course requires the use of MATLAB and SRIM which are already available. The fabrication process modeling and its impact in the device modeling based on device physics and materials' properties is one of the most vital parts of the Electrical and Computer Engineering Curriculum. The in-house laboratory facility for this course is available in the microelectronics laboratory (JD1101) and all resources for necessary device fabrication are available in the microelectronics laboratory.

13a. Course Outline and Syllabus:

- **Crystal growth and wafer preparation**,
- **Epitaxy**: vapor-phase epitaxy, molecular beam epitaxy, liquid phase epitaxy, SOI and epitaxial evaluation,
- **Oxidation:** oxidation techniques and systems, oxide properties, oxidation-induced defects,
- **Lithography:** optical lithography, electron lithography, X-ray lithography, ion lithography,
- **Diffusion:** models of diffusion, atomic diffusion mechanisms, impurity behavior in silicon and gallium arsenide, diffusion in SiO_2,
- **Ion Implantation:** Range theory, implantation equipment, annealing, shallow junctions, high energy implantation, implantation damage,
- **Metallization:** metallization application and patterning, electron beam evaporation, sputtering unit, physical vapor deposition,
- **Etching and Cleaning:** wet chemical etching, dry physical etching, dry chemical etching, reactive ion etching, etching induced damage, cleaning,
- **Process Simulation:** Ion Implantation, diffusion, epitaxy, lithography, etching and deposition,
- **Device and Circuit fabrication:** silicon based p-n junction diode, MOS-based silicon microcircuits, BJT-based silicon microcircuits, gallium arsenide based microcircuits,
- **Yield and Reliability management** and
- **Device and process failure analysis.**

(SYLLABUS ATTACHED)

13b. Methods of Evaluation for Measurable Student Learning Outcomes:

Assessment will be made on the basis of quizzes, two mid-term exams, one comprehensive final examination and weekly assigned homework problems. Homework problems include analytical as well as those using MATLAB and SRIM.

13c. Suggested Text:

- VLSI Technology, Simon M. Sze, 2nd Edition, McGraw Hill, ISBN-0-07-062735-5.

13d. Selected Bibliography:

- Fabrication Engineering at the Micro-and Nanoscale, Stephen A. Campbell, Oxford University Press 2008, 3rd Edition, ISBN 978-0-19-532017-6
- Fundamentals of Semiconductor Fabrication, Gary S. May and Simon M. Sze, John Wiley & Sons Inc., 2004, ISBN 0-471-23279-3
- Introduction to Microelectronic Fabrication, Richard C. Jager, 2nd Edition, Prentice Hall, ISBN: 0-201-44494-1
- VLSI Fabrication Principles silicon and GaAs, Sorab K. Ghandi, John Wiley & Sons Inc., 2nd Edition, ISBN 0-471-58005-8

13e. Grade Replacement Policy:

- No make-up examination is allowed and no late homework is accepted.

14. Indicate which of the Program's Measurable Student Learning Objectives are addressed in this course.

The table below shows applicability of the objectives of this course against those of the program.

COURSE ALIGNMENT MATRIX

Directions: Assess the how well ECE695 (course) contributes to the program's student learning outcomes by rating each course objective for that course with an I, P or D.

I=introduced (basic level of proficiency is expected)

P=practiced (proficient/intermediate level of proficiency is expected)

D=demonstrated (highest level/most advanced level of proficiency is expected)

Course Objectives	A. Ability to apply knowledge of advanced principles to the analysis of electrical and computer engineering problems.	B. Ability to apply knowledge of advanced techniques to the design of electrical and computer engineering systems.	C. Ability to apply the appropriate industry practices, emerging technologies, state-of-the-art design techniques, software tools, and research methods for solving electrical and computer engineering problems.	D. Ability to use the appropriate state-of-the-art engineering references and resources, including IEEE research journals and industry publications, needed to find the best solutions to electrical and computer engineering problems.	E. Ability to communicate clearly and use the appropriate medium, including written, oral, and electronic methods.	F. Ability to maintain life-long learning and continue to be motivated to learn new subjects.	G. Ability to learn new subjects that are required to solve problems in the industry without being dependent on a classroom environment.	H. Ability to be competitive in the engineering job market and/ or be admited to an excellent Ph.D . program.
1. Gaining the conceptual understanding of the cutting edge technology for semiconductor device manufacturing and semiconductor materials for different semiconductor device applications.			**P**	**P**	**P**			**I**
2. Become familiar different fabrication process to understand the front-end wafer processing and fabrication process parameters		**I**	**I**	**P**	**I**			
3. Modeling of fabrication process based on the fabrication process physics and device physics.	**P**	**I**	**I**	**P**	**I**		**I**	**I**
4. Understand the front-end wafer doping process by solving the mathematical problem using special function and probability function	**P**	**I**	**I**	**P**	**P**		**I**	

5. Learn about key aspects of the microelectronics industry, from device design, to processing, to photolithography, to manufacturing and packaging. Learn the core processes of ion implantation, diffusion, oxidation, deposition, etching, including the fundamental physical mechanisms, and the necessary understanding for using these processes in a manufacturing environment.			**I**	**I**	**P**		**P**	**I**
6. Learn about the "design for manufacturability" issues that are key in microelectronics	**I**				**I**			
7. Become familiar with a wide range of both conventional & novel semiconductor devices.				**I**	**I**		**P**	
8. Learn the chemical engineering, metallurgical engineering, material science, applied physics in order to understand the wafer processing	**I**	**I**	**I**		**I**		**P**	**I**
9. Apply numerical and application of software such as MATLAB and SRIM in solving of fabrication process technology.	**P**	**P**	**P**		**I**			**I**
10. Learn the electrical and analytical characterization of the semiconductor devices in wafer level and apply the electrical circuit to test semiconductor devices.	**I**	**I**	**I**	**I**	**I**			
11. Learn in detail many of the core problems involved with MOSFET, MESFET, HBT and HEMT technology, and the technology problems encountered in the continuing push on scaling and miniaturization.				**P**	**I**		**I**	**I**
12. Learn the device yield management, device failure analysis, and engineering management for semiconductor industries.	**I**	**I**			**I**			**I**
13. Study some important business case studies in microelectronics, that strongly depended on the rapidly changing technology in this area, merged with the business climate that these cases studies occurred in. Learn about most of the economic and business drivers of the microelectronics industry. Embracing solid manufacturing practices will be essential for these new and exciting technologies to reach their full potential in the rapidly changing technology business market					**I**	**I**	**I**	**I**

15. Assessment for Course Objectives:

Homework assignments, examinations, and a written report submitted at the end of the semester showing the proficiency of use of MATLAB and SRIM in developing the analytical model for fabrication process development will be used to evaluate and measure students learning outcomes.

Due to MSEE program requirements; this course will be evaluated in detail in terms of Measuring Students Outcomes using appropriate tables, feedback and consultation with appropriate groups such as Industrial Advisory Committee.

Course Objectives	Assessments of Student Performance
1. Gaining the conceptual understanding of the cutting edge technology for semiconductor device manufacturing and semiconductor materials for different semiconductor device applications.	Homework, Exams, and Use of MATLAB/SRIM.
2. Become familiar different fabrication process to understand the front-end wafer processing and fabrication process parameters.	Homework, Exams, and Use of MATLAB/ SRIM.
3. Modeling of fabrication process based on the fabrication process physics and device physics.	Homework, Exams, and Use of MATLAB/ SRIM.
4. Understand the front-end wafer doping process by solving the mathematical problem using special function and probability function.	Homework, Exams, and Use of MATLAB/ SRIM.
5. Learn about key aspects of the microelectronics industry, from device design, to processing, to photolithography, to manufacturing and packaging. Learn the core processes of ion implantation, diffusion, oxidation, deposition, etching, including the fundamental physical mechanisms, and the necessary understanding for using these processes in a manufacturing environment.	Homework, Exams, and Use of MATLAB/ SRIM.
6. Learn about the “design for manufacturability” issues that are key in microelectronics.	Assigned Project and Use of MATLA/ SRIM
7. Become familiar with a wide range of both conventional & novel semiconductor devices.	Homework, Exams, and Use of MATLAB/ SRIM.
. 8. Learn the chemical engineering, metallurgical engineering, material science, applied physics in order to understand the wafer processing	Homework, Exams, and Use of MATLAB/ SRIM.
9. Apply numerical and application of software such as MATLAB and SRIM in solving of fabrication process technology.	Homework and Use of MATLAB/ SRIM.
10. Learn the electrical and analytical characterization of the semiconductor devices in wafer level and apply the electrical circuit to test semiconductor devices.	Homework, Exams, and Use of MATLAB/ SRIM.

11. Learn in detail many of the core problems involved with MOSFET, MESFET, HBT and HEMT technology, and the technology problems encountered in the continuing push on scaling and miniaturization.	Homework, Exams, and Use of MATLAB/ SRIM.
12. Learn the device yield management, device failure analysis, and engineering management for semiconductor industries.	Homework and Use of MATLAB/Mathematica.
13. Study some important business case studies in microelectronics, that strongly depended on the rapidly changing technology in this area, merged with the business climate that these cases studies occurred in. Learn about most of the economic and business drivers of the microelectronics industry. Embracing solid manufacturing practices will be essential for these new and exciting technologies to reach their full potential in the rapidly changing technology business market	Homework, Exams, and Use of MATLAB/ SRIM.

17. Methods of Assessment for Measurable Student Learning Outcomes:

Due to MSEE program review, all the ECE graduate courses and their corresponding Student Learning Outcomes are assessed and evaluated periodically. This is based on examination questions, quizzes, homework, project reports, etc.

California State University, Northridge - Spring 2017
College of Engineering & Computer Science
Department of Electrical & Computer Engineering

ECE645 Microelctronics Device Fabrication Principles
Course Units: 3.00
Design Units: 00

Professor:	Dr. Somnath Chattopadhyay
Office:	JD 3327
Office Phone:	(818) 677-7197
ECE Fax:	(818) 677-7062
EMAIL:	somnath.chattopadhyay@csun.edu
Class Schedule:	Friday 4:00PM – 6:45PM
Class Location:	Jacaranda 1553
Office Hours:	Tuesday/Thursday: 7:00PM -8:30PM

I - COURSE DESCRIPTION

Prerequisites: ECE 545. Introduction of fabrication and characterization process equipment and tools with fabrication process physics for device fabrication. This course is focused on semiconductor device fabrication dealing with diffusion, ion implantation and epitaxy processes for the doping of the active areas of semiconductor devices; contact formation, contact patterning and window opening for selective doping and mask design: thin film deposition, photolithographic processes and etching processes; device yield management: device failure analysis and yield analysis, fabrication process induced defects and radiation effects on semiconductor devices: process modeling and device modeling for device fabrication process and device structure optimizations.

II - TEXTBOOK (Recommended)

Recommended Text:
VLSI Technology, 2nd Edition, McGraw Hill, ISBN-0-07-062735-5.

Additional Reference:

- Fabrication Engineering at the Micro-and Nanoscale, Stephen A. Campbell, Oxford University Press 2008, 3rd Edition, ISBN 978-0-19-532017-6
- Fundamentals of Semiconductor Fabrication, Gary S. May and Simon M. Sze, John Wiley & Sons Inc., 2004, ISBN 0-471-23279-3
- Introduction to Microelectronic Fabrication, Richard C. Jager, 2nd Edition, Prentice Hall, ISBN: 0-201-44494-1
- VLSI Fabrication Principles silicon and GaAs, Sorab K. Ghandi, John Wiley & Sons Inc., 2nd Edition, ISBN 0-471-58005-8

III –SOFTWARE

MATLAB AND SRIM
Internet Resources:
http://hpme12.me.edu/matlab/hml/
http://www.srim.org/

IV– PREREQUISITE

Prerequisite: ECE545 or an equivalent course.

V - GRADING POLICY

Homework	10%	+ / - Grading is used in this course
Quiz	10%	
Midterm Exam1	20%	
Midterm Exam 2	20%	
Final Examination	40%	

VI – CLASS POLICIES AND PROCEDURES

Attendance:

Each student is required to attend every lecture. Students are responsible for arriving before class begins, and remaining for the duration of the course meeting. If a student misses a class, it is his or her responsibility to find out what was discussed in class, any homework assigned or exam scheduled.

Grade Replacement Policy (Make-Up Exam and Homework):

No late homework is accepted, and no make-up examination is allowed.

Homework:

Homework will be assigned on a regular basis and it will be due one week after it is assigned. Homework must be turned in on 8.5"X11" paper written on one side with the necessary information such as ID#, Course #, Homework # and date on top left hand corner of the first page.

Examinations:

Midterm I will be administered during week 5 or 6.

Midterm II will be administered during week 10 or 11.

Final Examination /Midterm III Examination

All Exams are closed book and closed notes.

Academic Integrity:

Ideas and learning form the core of the academic community. In all centers of education, learning is valued and honored. No learning institution can thrive if its members counterfeit their achievement and seek to establish an unfair advantage over their fellow students. The Academic Integrity is designed to foster a fair and impartial set of standards. All students are required to adhere to these standards. Any dishonest act such as copying, plagiarism, lying, unauthorized collaboration, alteration of records, bribery, and misrepresentation for the purpose of enhancing one’s academic standing results in a failing grade for the entire course and will be reported to the College as well as the Dean of Students.

VII - COURSE MATERIAL

Week	Material
1.0 week	**Crystal Growth and wafer preparation**

- Growth Materials
- Consideration for proper crystal growth
- Doping in the melt
- Semi-insulating Gallium Arsenide
- Properties of melt-grown crystals

2.0 weeks **Epitaxy**

- Molecular beam epitaxy
- Vapor phase epitaxy (VPE)
- Liquid phase epitaxy
- VPE for silicon and gallium arsenide
- Evaluation of epitaxial layers

1.0 week **Oxidation**

- Oxidation processes
- Oxide properties
- Oxide –induced defects

1.0 weeks **Lithography**

- Optical lithography
- Electron lithography
- X-ray lithography
- Ion lithography
- Pattern generation and mask making
- Pattern transfer

1.0 weeks **Etching and Cleaning**

- Wet chemical etching
- Dry physical etching
- Dry chemical etching
- Reactive ion etching
- Etching induced damage

1.5 weeks **Diffusion Process**

- Models of diffusion
- Atomic diffusion mechanisms
- Diffusion in a concentration gradient
- Impurity behavior in silicon and gallium arsenide,
- Diffusion in SiO_2,

2.0 weeks **Ion Implantation process**

- Range theory
- Implantation equipment
- Annealing
- Shallow junctions
- High energy implantation
- Implantation damage

1.5 weeks **Metallization Process**

- Metallization application and patterning
- Electron beam evaporation
- Sputtering unit
- Physical vapor deposition

1.0 week **Process Simulation**

- Ion Implantation
- Diffusion
- Epitaxy
- Lithography
- Etching
- Deposition

1.0 week **Device and Circuit fabrication**

- Silicon based p-n junction diode
- MOS-based silicon microcircuits
- BJT-based silicon microcircuits
- Gallium arsenide based microcircuits

1.0 week **Yield and Reliability Management**

1.0 week **Device and process failure analysis.**

Note: The Content of the Course Syllabus is subject to Change with Appropriate Notice to the Students