Online Master of Engineering Program in Microelectronics Manufacturing Engineering: A Valuable Resource for Engineers in Semiconductor Industry

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***Abstract* - The worldwide semiconductor industry is advancing at an astounding pace that requires a specially educated workforce and opportunities for further learning while on job. The master of engineering in microelectronics manufacturing engineering program offered by the Rochester Institute of Technology (RIT) provides a broad based education in current and developing semiconductor processing to students with a bachelor's degree in traditional engineering or science disciplines working for the semiconductor industry. The program consists of one transition course, seven core courses, two elective courses and a minimum of 5 credits of internship. The core courses are microelectronics processing, microelectronics manufacturing and microlithography. The elective courses are graduate-level courses in microelectronics or a related field. The courses are delivered via a variety of formats – streamed video, PowerPoint Breeze narratives and are powered by a versatile course management system supported by the online learning at RIT. Students take typically one course per quarter that enables them to complete the program within three years.**

Index Terms – Distance learning, Microelectronics online education, Online masters program, Semiconductor online resource

INTRODUCTION

The worldwide semiconductor industry is expected to double, growing from $150 billion to $300 billion over the next five years. The integrated circuit technology makes use of many diverse fields of science and engineering. The optical lithography tools, which print microscopic patterns on wafers, represent one of the most advanced applications of the principles of Fourier optics. Plasma etching involves some of the most complex chemistries used in manufacturing today. Ion implantation draws upon understanding from research in high-energy physics and ion solid interactions. Thin films on semiconductor surfaces exhibit complex mechanical and electrical behavior that stretches our understanding of basic materials properties. Computing skills are necessary to design, model, simulate and predict processes and device behavior, extremely vital to manufacturing. Statistics is required to manipulate data and process control. Manufacturing concepts are extremely important in maintaining high yields and cost effectiveness. One of the great challenges in integrated circuit manufacturing is the need to draw on scientific principles and engineering developments from such an extraordinary wide range of disciplines not adequately provided by traditional engineering or science programs. Scientists and engineers, who work in this field, need broad understanding and the ability to seek out, integrate and use ideas from many fields. Acceptance of online education as a major and viable component of higher education has grown dramatically. Studying engineering online from anywhere and at anytime has become possible in recent years. In the field of engineering, advancements are taking place at an unprecedented pace that demand continued education and training of engineering work force while on job. The RIT master of engineering program in Microelectronics Manufacturing Engineering has been designed for the purpose of educating engineers with baccalaureate degrees in science and engineering with the state of the art education in semiconductor processing [1]. This program became available through distance learning in 1998. Currently, distance learning students enrolled in the Microelectronic Manufacturing Engineering program are distributed nationwide and even international. These students are working in the semiconductor industry and have bachelor degrees in disciplines such as chemical engineering, electrical engineering, mechanical engineering, physics, and chemistry.

[1] Online Learning , Rochester Institute of Technology, http://online.rit.edu/

PROGRAM

The master of engineering degree is awarded upon successful completion of an approved graduate program consisting of a minimum of 45 credit hours [2]. The program consists of one transition course, seven core courses, two elective courses and a minimum of 5 credits of internship (professional work experience in the semiconductor industry). Under certain circumstances, a student may be required to complete more than the minimum number of credits. The transition course is in an area other than that in which the BS degree was earned. The core courses are microelectronics (processing) I, II, and III, microelectronics (manufacturing) I, II, and microlithography materials and processes and microlithography systems. The two elective courses are graduate-level courses in microelectronics or a related field. Elective courses may be selected from a list that includes courses such as defect reduction and yield enhancement, semiconductor process and device modeling, and nanoscale CMOS.

The courses delivered on campus have strong laboratory components. The laboratories teach basic principles involved in each of the core courses and most of the elective courses. As our targeted online audience comes from the semiconductor industry, almost all students have access to the *cleanroom* fabrication/manufacturing environment in their respective companies. They primarily need fundamental understanding of the principles involved in engineering and do not need the base level laboratory instruction. The laboratory component is substituted with a self study paper or a research report under the faculty guidance.

CURRICULUM

- **Microelectronics (Processing)**
  Microelectronics I, II, III sequence covers major aspects of integrated circuit manufacturing technology such as oxidation, diffusion, ion implantation, chemical vapor deposition, metallization, plasma etching, etc. These courses emphasize modeling and simulation techniques as well as hands-on laboratory verification of these processes. Students use special software tools for these processes. In the laboratory students design and fabricate silicon MOS and bipolar integrated circuits. They learn how to utilize most of the semiconductor processing equipment and how to develop and create a process, manufacture and test their own integrated circuits.
- **Microelectronics (Manufacturing)**
  The manufacturing courses include topics such as scheduling, work-in-progress tracking, costing, inventory control, capital budgeting, productivity measures and personnel management. Concepts of quality and statistical process control are introduced to the students. The laboratory for this course is the student-run factory functioning in the department. Important issues that include measurement of yield, defect density, wafer mapping, control charts and other manufacturing measurement tools are introduced to the students in the lecture and laboratory. Computer integrated manufacturing is also studied in detail. Process modeling, simulation, direct control, computer networking, database systems, linking application programs, facility monitoring, expert systems applications for diagnosis and training and robotics are all introduced and supported by laboratory experiences in the integrated circuit factory at RIT.
- **Microlithography**
  The microlithography courses are advanced courses in the chemistry, physics and processing involved in microlithography. Optical lithography will be studied through diffraction, Fourier and image assessment techniques. Scalar diffraction models will be utilized to simulate aerial image formation and influences of imaging parameters. Positive and negative resist systems, as well as processes for IC application, will be studied. Advanced topics will include chemically amplified resists; multiple layer resist systems; phase shift masks, and electron beam, x-ray and deep UV lithography. Laboratory exercises include projection system design, resist materials characterization, process optimization, electron beam lithography and excimer laser lithography
- **Transition Course**
  An online transition course "Principles of Semiconductor Devices" is available for students coming from non electrical engineering backgrounds. The course is taught from the unique perspective of microelectronic engineering with a focus on device layout for fabrication.
- **Electives**
  The choice of electives provides students an opportunity to focus on their area of interest. The recommended electives courses currently offered online are:
  - Semiconductor process and device modeling
  - Nanoscale CMOS
  - Metrology and failure analysis
  - Statistical process control
- **Internship**
  The on-campus program requires a five quarter credit internship, which is equivalent to at least three months of full time successful employment in the semiconductor industry. The purpose of the internship is to provide a structured and supervised work experience that enables students to gain job-related skills that will assist them in achieving their desired career goals. Students with prior related engineering job experience may request “credit by experience.” Students already employed in the semiconductor industry may qualify for the internship credits after submission of a report or presentation. If the students are not employed in the semiconductor industry and would like to enroll in the online program, the laboratory experience can be made available through intensive laboratory short courses on campus.

Table I lists the titles of the distance learning courses and quarters they are offered.

TABLE I
ONLINE COURSES OFFERED IN THE PROGRAM

Course	Course Title	Quarter Offered
Transition	Principles of semiconductor devices	Summer, Fall
Core	Microelectronics I	Fall
Core	Microelectronics II	Winter
Core	Microelectronics III	Summer
Core	Microlithography materials and Processes	Fall
Core	Microlithography systems	Spring
Core	Microelectronics manufacturing I	Winter
Core	Microelectronics manufacturing II	Spring
Elective	Semiconductor process and device modeling	Spring
Elective	Nanoscale CMOS	Winter
Elective	Metrology and failure analysis	Fall
Elective	Statistical process control	Winter

DELIVERY METHODS

Distance learning courses at RIT are continuously changing as new techniques and tools become available. For example, our new learning management system, Desire2learn [3], allows our faculty to explore variations in online exams as alternatives to proctored exams, streamlines how assignments are managed through drop boxes, provides timely feedback through grade books, and facilitates good online discussion in small groups and team projects. We have also seen continuous improvement in our approach to course media. In the early 1990's we recorded lectures in front of a live classroom and delivered them in subsequent quarters via VHS videotapes to distance learning students. Our distance learning students would typically receive 20 hours or more of VHS lectures along with the textbooks ordered from our bookstore. Since then, our course lecture material has moved onto CD's and now most of that is also available online through streaming media, offering students an even greater degree of flexibility. And now Breeze Presenter enables RIT Faculty to produce their own high-quality voice annotated lecture material from PowerPoint directly on their own personal computer and publish it to the Breeze server where students can access it immediately. Instructors are no longer tied to a videotaped classroom or studio where materials have to be created weeks and months in advance of a course offering. The improvements in our course management tools have increased faculty ability to interact with students, and now with Breeze Presenter our faculty can create up to date content appropriate for the current course offering.

RESULTS

The program started by delivering a few courses with VHS tapes to students in the semiconductor industry on demand basis. Subsequently, the entire on-campus ME program was made available by the year 1998. In the year 2001, RIT produced its first graduate of the online Master of Engineering in Microelectronics Manufacturing Engineering. The total number of graduates is 12 by the year 2006. Currently, 20 students are enrolled in the program despite the fact that the program is not aggressively advertised. Table II lists the companies that are represented in our online program.

TABLE II
SEMICONDUCTOR COMPANY AFFILIATIONS OF ONLINE ME STUDENTS

Company Names	Location
ASML	Phoenix, AZ
Agilent Technologies	Colorado Springs, CO
Cypress Semiconductor	Minneapolis, MN
Eastman Kodak	Rochester, NY
Fairchild Semiconductor	Portland, ME
Fairchild Semiconductor	Mountaintop, PA
IBM	Burlington, VT
Intel	Rio Rancho, NM
National Semiconductor Corporation	Portland, ME
Texas Instruments	Dallas, TX
Tokyo Electronics	Nagasaki, Japan
Xerox	Rochester, NY

In most cases, the industry provides tuition support to their employees for taking these courses. Their engineers get to gain academic knowledge without compromising their productivity but in fact motivating them to learn. The program has brought a great value to the faculty by being in direct contact with the educational needs of the semiconductor industry. Recently, international universities and companies are expressing interest in our online courses.

REFERENCES

[1] http://www.microe.rit.edu/me.php

[2] http://www.microe.rit.edu/onlinecourses.

[3] http://www.desire2learn.com/