Educational Activities

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Microelectronics Fabrication Technology (6.152J)

Technical Instructor

Bill Teynor and Octavio Hurtado

This combination laboratory and lecture course is offered (and taught) jointly by the Department of Electrical Engineering and Computer Science and Materials Science and Engineering Department. The course includes weekly lectures on all aspects of microfabrication technology, and includes design problems to teach process design. Additionally, the course includes 10 four-hour laboratory sessions conducted in the MTL. During these sessions, each student fabricates a wafer of poly-silicon gate MOS devices and test structures. The devices and structures are tested at the end of the semester. A final report correlating the test results with theoretical expectations culminates the education experience. The course is offered every semester, and a laboratory-only version of the course is offered 3-4 times/year. Last year, approximatley 100 students were educated in microfabrication technology through this course.

Microfabrication Project Laboratory (6.151)

Technical Instructor

Bill Teynor

This laboratory course is offered in the spring semester for students that have already completed 6.152J. The course is designed to teach experimental microfabrication process design. The students of this subject are given a broad process goal, namely to build a device, and they are challenged to design and develop a process sequence. Typically, the entire class (4-6 students) works on one device, and they partition the integrated process into a set of unit process sequences. Work proceeds first on the development of the unit processes, and then on the integrated process. In recent years, the students have succeeded in microfabricating micromachined contactors for integrated circuit testing, flexible electrode arrays for retinal implants, and microcantilevers for AFM applications.

continued

Technology Demonstration Systems Program

Professor Charles G. Sodini

I. Introduction

The Technology Demonstration Systems Program addresses the question "What else can we do with this new technology?" Technology innovation is happening at such a rapid rate that often novel applications of the technology in new products are missed. Examples of novel application of recent technology are:

- 900MHz cordless phones - uses cellular technology for this home application
- Low cost digital cameras - uses imagers based on digital CMOS technology
- Electronic Navigation - uses Global Positioning System (GPS) technology

In this program teams of two or three EECS students will develop their own Master's of Engineering thesis project. The project will involve the creation of a prototype electronic system based on recently reported integrated circuits and other microsystem technology designed at MIT. Examples of demonstration systems currently being designed include, a 256x256 pixel parallel processing system capable of performing real time low level machine vision, a video camera based on a brightness adaptive CMOS imager capable of acquiring images with a wide intensity dynamic range, and a battery powered high data rate 2.5 Mb/sec transmitter based on recent silicon RF integrated circuits. The functionality and scope of the demonstration system is only limited by the students' creativity and the requirement for successful implementation of the system within the time constraints of a Masters of Engineering thesis. In addition, the system must be easily transportable such that it can be demonstrated at industrial participant's sites.

II. Program Description

To enter the program, students take a two semester course starting in the Fall of their senior year. This course sequence will introduce recent MIT designed integrated circuits and other microsystem technology that will be used by student teams to create and design their own system demonstrating the microsystem technology. Previous and on-going demonstration systems will be described along with ideas for new systems based on mature research technology. At the end of the first semester, an oral and written presentation of a functional description of the proposed demonstration system will be made by teams of two or three students. Students selected to continue in the program will refine their project plans, execute any required feasibility studies and develop a schedule and budget during the second semester of this course. Near the end of the second semester, a formal proposal will be presented to a board of industry representatives, faculty and senior graduate students contributing state-of-the-art components to the program. Project funding during the following summer and graduate year to design and fabricate the proposed demonstration system, including possible research assistantships will be determined by this board. The system design, fabrication, and testing will take place during the summer and first graduate semester. During the second semester of the graduate year, the system should be demonstrated to the board. It is expected that industrial participants will invite students to visit their companies to demonstrate their prototype system.
The Masters of Engineering thesis will have two components. The team written component will give an overview of the prototype system, describe the research technology demonstrated, and give a global specification of the system such that others can make use of the work for future systems. The individually written component will outline the specific issues relating to the individual responsibilities of each student on the project.

III. Educational Components

It is expected that students who successfully complete this program will have increased their breadth of knowledge through the prototype fabrication coupled with understanding the operation of state-of-the-art components. They will have a chance to exercise creativity by generating innovative ideas for demonstrating the state-of-the-art technology. They will learn the importance of succinct communication of their ideas through their presentations of the proposal, project reviews, and demonstration of their system. In addition, they will be exposed to the importance of project planning in order that they successfully complete the implementation of their demonstration system on a timely basis. Finally, the team approach of this Masters thesis experience will help them understand the dynamics of team-based engineering. In summary, the students will "learn by doing."

IV. Research Technology

At the beginning of this program the majority of the research technology which will be demonstrated will be a vast array of silicon integrated circuits designed by researchers in the Microsystems Technology Laboratories (MTL). However, we will be seeking other mature research technologies such as micromechanical devices, displays, and a variety of sensors and actuators from other researchers in MTL and other MIT labs. We will invite researchers to contribute their technology to the program along with sufficient funding to have student participants design and build a demonstration system based on the research technology. The researchers contributing the technology will have a chance during the proposal phase of the program to decide whether the proposed demonstration system of their technology warrants funding. It is believed that this entrepreneurial approach will help the students in the program develop the best possible demonstration system proposals, as well as understand the technical aspects of venture funding.

V. Industrial Participation

The program is seeking several electronics industries to become members. The industrial participants will be invited to participate in the evaluation of project proposals, project reviews and the presentation of the demonstration systems. It is also expected that some industrial members may want to invite students to bring their demonstration to the company. In some cases, the participating industries may also contribute research technology to the program for possible incorporation into a demonstration system. The benefits to the participating companies are:

- An overview of state-of-the-art integrated circuits and other research technology designed at MIT.
- A first hand look at the creative application in a prototype system of the research technology.
- Closer interaction with EECS Masters of Engineering students.

MIT Microelectronics WebLab: a Web-enabled Microelectronics Test Station

Personnel

L. Brooks and C. McLean (J. del Alamo)

Sponsorship

MIT Class of '51 Fund for Excellence in Undergraduate Education, MIT Class of '55 Fund in Teaching,
MIT Class of '72 Fund for Educational Innovation, Hewlett Packard, Agilent Technologies, Microsoft, and Intel

The teaching of microelectronics device physics rarely involves actual hands-on testing of the devices being studied. This is because of the substantial cost, space, and training associated with the required testing station. Actual device characterization, however, can substantially enhance the educational experience. Students can compare their measured data with theoretical expectations and think about discrepancies, limitations, and design criteria. In addition, close contact with the real world is a powerful motivator, and students learn better.

Over the last two years, we have developed an Internet-based microelectronics device characterization test station that overcomes all these difficulties. This system allows many students with little specialized training to access remotely limited and expensive equipment. A single test setup can be used by an entire class in a nearly simultaneous way with minimum safety and security concerns. Students can use the station to run tests, collect data, and analyze it via the Internet from a location and at a time of their choosing.

Fig. 1: MIT Microelectronics WebLab portal. To learn more, go to:
http://www-mtl.mit.edu/~alamo/weblab/index.html

The testing station is built using an Hewlett Packard HP4155B Semiconductor Parameter Analyzer which is connected to a web server via a GP-IB connection. The web server downloads a Java applet to the client computer. The Java applet runs on any regular Java-enabled web brower on any platform. Through this applet, the user can perform actual device characterization measurements. The Java applet looks in many ways just like the actual front panel of the HP4155B. The user sets up the test parameters in the applet, and the applet then passes these parameters to the web server via the Internet, which in turn transfers them to the HP4155B. The HP4155B runs the measurement, collects the data, and returns it to the server. The server passes the data back to the Java applet where it is displayed graphically. The user can then choose to download the raw data to the client machine for further manipulation.

This project was designed specifically to implement lab opportunities in device physics courses at MIT. In the Fall semesters of 1998 and 1999, the Microelectronics WebLab was utilized to carry out two labs in a graduate-level device physics course involving about thirty students. Students took measurements on both diodes and NMOS transistors. In the Spring semester of 1999, the WebLab was used in a Junior level subject on microelectronics devices and circuits involving about 90 students. Students carried out a detailed characterization and parameter extraction of p-n diodes and MOSFETs. In these three field trials, students praised the WebLab for motivating them to study device physics and for helping them to better understand device operation.

We are currently in the process of introducing a switching matrix to the system to allow the user to select one among several devices that are made available for testing. This will build redundancy against device blow up. It will also enable students to compare the characteristics of different devices and study, for example, the impact of gate length in MOSFET figures of merit.

We are also in the process of carrying out an experiment in the context of the Singapore-MIT Alliance. Students from Singapore are performing a detailed characterization of a MOSFET that sits at MIT. If successful, the system will be deployed in a SMA subject in the Fall of 2000.

Finally, we have just recently installed a WebLab at the site of a major microelectronics industrial lab. This will be used in experimental basis by MIT students taking a graduate-level subject in device physics in the Fall of 2000. Through this WebLab, students will characterize state-of-the-art CMOS hardware that is “too hot” to leave the plant.

I-Lab: a new framework for hands-on science and engineering education

Personnel

J. del Alamo, C. Cesnik (A&A), C. Colton (ChemE), K. Amaratunga (CEE), S. Teller (EECS), F. Ulm (CEE), and J. Ying (ChemE)

Sponsorship

Microsoft

I-Lab is a new framework for hands-on science and engineering education. I-Lab integrates remote web-enabled laboratories coupled with simulation tools all immersed in a collaborative user environment that allows semiautomatic rapid feedback and evaluation.

Many subjects in science and engineering education do not include a laboratory experience. This is because of equipment, space, training, safety and staffing constraints that become nearly insurmountable the moment there are more than a dozen students in the class. Laboratory experiences, however, can substantially enhance educational effectiveness. Students get to use the "real thing", poke at it and make observations on its actual behavior. Students can also compare measured characteristics with theoretical predictions and reflect on discrepancies, limitations, and design criteria. In addition, a hands-on interaction with a physical system allows curiosity-driven exploration and becomes a powerful motivator for students. As a result of all this, students learn better.

I-Lab is a new initiative about to be launched at MIT that will address the dearth of laboratory experiences in science and engineering education. Based in MTL, I-Lab will harness new communications and software technology to bring remote access to students to *real* laboratories in a 24x7 mode (24 hours a day, 7 days a week). This is what we call a WebLab, for web-enabled laboratory. While a WebLab is not completely equivalent to an actual lab, with proper thought a WebLab can be designed to be a very effective proxy for the real thing if it is not available. A WebLab also complements a real existing laboratory. WebLabs can be used in well-structure laboratory exercises. In addition, WebLabs can be used to run live demos in lectures, to carry out homework, and to let students explore a physical system at their leisure. In this way, they complement physical labs. Some of these benefits have been demonstrated over the last two years at MIT by Prof. del Alamo with his Microelectronics WebLab (http://www-mtl.mit.edu/~alamo/weblab/index.html). In a sense, microelectronics device characterization is a natural candidate for remote access: the devices are small, they can be measured very quickly and the results of the experiments are of an electrical nature.

The I-Lab initiative wants to explore to what extent the WebLab concept can be extended to other engineering disciplines. To investigate the compliance of this concept, we have selected very different disciplines in the broad areas of aeronautics and astronautics (a set up to examine static and dynamic behavior of mechanical structures), chemical engineering (a heat exchanger and a chemical reactor) and civil engineering (an instrumentalized flag pole for vibration studies). The variables of interest in these systems are for the most part not of an electrical nature. Additionally, the time constants of these experiments are very different. At one extreme, is microelectronics device characterization where a few seconds is all it takes to carry out a complete experiment. At the other end is probably a chemical reactor with a time constant on the order of hours. How these experiments can be used in a remote 24x7 fashion is a great challenge to figure out and is a central goal of this initiative.

The I-Lab project, however, goes far beyond demonstrating the viability of remote-accessible laboratories in multiple engineering disciplines. We believe that a WebLab is a powerful educational platform on top of which one can integrate a set of simulation tools and a software framework for novel and rich human interactions with unprecedented educational pay-off.

The integration of experiments and simulations is a powerful way to learn about a given physical system. In the experiments, one can see the response of the physical system to various stimuli, and by comparing them with the result of simulations, a great deal of understanding about the system can be attained. Seamless coupling of a WebLab with state-of-the-art modeling tools will facilitate improved understanding of when the related idealized models are applicable through direct comparison with the experimental results. The simulation environment additionally allows one to explore the operation of a system in regimes that might not be accessible experimentally or that are unsafe, for example, a voltage condition that leads to transistor breakdown. The integrated simulation environment, then, allows a more comprehensive view of the nature of a given system.

Our initiative additionally pursues the demonstration of a software framework that allows new human interactions to take place around this integrated laboratory/ simulation environment. This framework is constructed based on Prof. Teller's Fusion project (http://edufuse.lcs.mit.edu/) which pursues the study of interactive algorithm development through the Web. In this initiative, we will incorporate concepts developed by Prof. Teller of peer-to-peer and peer-to-instructor interactions through the Web so that experiments can be carried out in a collaborative way with the various players in different locations. This will allow scheduled as well as spontaneous human interactions around specific experiments with great educational pay off. An additional element of Seth Teller's Fusion project that we will explore is a rapid and semiautomatic evaluation/ feedback environment. Errors in the conduct of experiments or simulations could be diagnosed and binned according to a database of previous errors and a rapid suggestion can be produced to overcome the problem. This should result in less "dead" time and frustration for the students. The student-system, student-student and student-staff interaction would be mediated by the Fusion system, and interesting (as yet unseen) examples of qualitative behaviors would be stored for future reference and use.