

INTERACTIVE MULTIMEDIA COURSEWARE FOR INTEGRATED CIRCUIT FABRICATION COURSES

Muhammad A. Khaliq¹

Abstract - *The Integrated Circuit manufacturing no longer belongs to industry, but is a flourishing area in academics. The complicated process of integrated circuit fabrication requires many steps where visualization is essential to understand the concept. Interactive multimedia modules were developed to present fundamental concepts using animation and playback features. The modules developed served as good learning tools to complement classroom and laboratory instructions. This paper describes the development of interactive multimedia modules created with Macromedia Director and implemented on the standard web browser with Macromedia's Shock Wave plug-in as the interface. The Interactive Modules and online laboratory manual were implemented in undergraduate senior and graduate classes. The impact of these modules and online laboratory manual was assessed from a survey and interview with the students. Almost all students unanimously preferred modules that incorporated animation and interactivity to traditional static images and diagrams. Online laboratory manual and virtual laboratory tour showed a positive impact on student learning.*

Index Term - *Computer based teaching, Interactive multimedia modules, online learning*

INTRODUCTION

Over the past decade, the development of modern advanced technologies combining computation and communication has offered exciting opportunities to the educators. There has been interest in engineering education to develop interactive multimedia based learning tools to transmit knowledge to the students. New models for engineering education are being explored, which are using the increasing capability of computing, information technology, and the rapidly developing Internet (World Wide Web - WWW) [1]-[3]. Those who have used new technologies in their classroom teaching have experienced more classroom discussions, and more interest in the subject matter. The overall response from the students has also been very positive and encouraging [4]-[5].

The engineering educators are challenged to reach a visually motivated generation brought up on music, videos, and computer games. The traditional pedagogy for engineering education has not changed over the last several

decades despite the rapid change in technology. It seems that sometimes the blackboard, overhead projector, teacher's handouts, and verbal explanation does not convey the theme to a significant number of students. Numerous studies have shown that majority of the students are visual learners. Information conveyed to students through interactive multimedia learning material helps to enhance their performance [5]-[6]. In order to satisfy the student's need, visual and interactive learning material should be incorporated in classroom instruction.

Many researchers in colleges and universities have created multimedia interactive course materials, which they are using inside and outside the classroom. It has proven to be a useful tool for enhancing the critical discussion in the classroom and enhancing the level of understanding of key concepts [4]-[5]. The objectives of the work presented in this paper is to describe the development, implementation and dissemination of interactive multimedia material for Integrated Circuit (IC) Fabrication courses offered at Minnesota State University, Mankato (MSUM). Also presented is the evaluation data collected from the students to measure student learning and to assess the strengths and weaknesses of the interactive multimedia material.

Integrated Circuit Fabrication courses are offered as a senior elective in Electrical Engineering (EE) and Electronic Engineering Technology (EET) programs at MSUM. This is one of the major areas of specialization offered to our undergraduate and graduate students. The courses reviewed for the work reported in this paper are:

- EE 475 - Integrated Circuit Engineering
- EE 480 - Integrated Circuit Fabrication Laboratory
- EET 492 - Integrated Circuit Technology

The "EE 475 - Integrated Circuit Engineering" course covers the fabrication theory of Integrated Circuits and the processing models for very large scale integration (VLSI). The students are required to simulate the basic fabrication steps, and finally design and simulate process schedule for bipolar junction transistor (BJT), and complementary metal-oxide semiconductor (CMOS) transistor. In addition, the students should know the fabrication sequence for bipolar complementary metal-oxide-semiconductor (BiCMOS) devices. The students are encouraged to take IC Fabrication Laboratory along with IC Engineering course.

In the "EE 480 - Integrated Circuit Fabrication Laboratory", the students have to fabricate their own IC chip

¹ Professor, Department of Electrical and Computer Engineering and Technology, 137 Trafton Science Center South, Minnesota State University, Mankato, MN 56001, e-mail: muhammad.khaliq@mankato.msus.edu

starting from a virgin wafer. The chip is fabricated with a mask set that contains diodes, BJTs, MOSFETs, resistors, capacitors, and test structures for process evaluation. Emphasis in the IC fabrication Laboratory is to fabricate metal gate n-channel MOSFET and complete the electrical testing.

The "EET 492 - Integrated Circuit Technology" course is offered in EET program, which covers basic fabrication steps and their integration, safety requirements in IC fabrication area, and hazard material management. The associated laboratory experiments are related to basic fabrication steps and their evaluation using analytical tools.

MOTIVATION

Teaching of IC Fabrication courses is quite frustrating when using only chalkboard to describe complex concepts such as changes in concentration of doping level in transistors, diffusion and ion implantation techniques, cross-sectional diagrams of ICs, different levels of fabrication steps and keeping a track of the sequence of IC fabrication steps, etc. The IC fabrication steps often involve an order of hundred processing steps. It is practically impossible to draw a sketch of each step on the blackboard, or use textbook figures or static images to convey all the involved processing steps in a clear manner. Students have a difficult time in understanding these concepts and sequences of masking level used in IC fabrication. These concepts require a scientific visualization to aid student understanding, and a simple animation can illustrate essential physical phenomenon. Moreover, in engineering courses, a single animation is inadequate because the behavior of a physical phenomenon will change with changing parameters. We have developed interactive multimedia modules for fabrication sequence of devices for a simple diode to BiCMOS. By viewing these modules, students will be able to keep track of the complex processing steps and its interactive playback feature, thereby, enhancing the understanding of the underlying concepts. These modules will complement the classroom lectures and the student can view it anywhere at his/her convenience. The dynamic nature of these modules will pick up where most of the textbooks leave off.

IC fabrication laboratory was another area where we felt the students should be prepared before coming to the laboratory. The students should have a feel of the sequence of steps, precautionary measures for each step, the purpose of the steps, and most importantly the sequence of operating procedure for the complex equipment used in IC fabrication laboratory. The manual for laboratory experiments with static images of processing steps, and operating procedure of the equipment are linked to the modules. By this, hopefully the students will view the modules and laboratory manual before performing laboratory experiments. This will allow more efficient use of laboratory time, and the students will understand the purpose of each step. They will come prepared with the visual picture of operating the equipment

in IC Fabrication Laboratory. It will be engaging and fun for the students. Note that these modules will complement the class work and lab work but cannot replace the laboratory experience. The students will be able to view new concepts, review previous concepts, and synthesize this information with lecture notes and laboratory experience. This practice will reinforce concepts, and prepare the student for the much needed skills required for today's semiconductor industry.

DEVELOPMENT OF INTERACTIVE MULTIMEDIA MODULES

The basic requirements for developing interactive multimedia modules consist of selection of a software package, which can combine animation, interactivity, playback feature, textual explanation, platform independence, and easy to learn. Also, the time required to learn how to use the developed modules should be negligible. The modules are intended to be stand-alone, self-learning units that maximize the use of information technologies to engage the learner. There are many software packages on the market, and the software packages reviewed for this work were Macromedia Authorware, Macromedia Director, and SUN Microsystems Java [7]. Merits and demerits of these packages were reported in references [5]-[8]. All multimedia software packages have steep learning curves to utilize the power of these programs. For this work Macromedia Director was selected, whose learning curve is quite steep, but the advantages of enhanced functionality far outweigh the extra learning time required. Many of the functions developed for these modules require innovative use of the software package resulting in spending of more time in creating those functions.

The Modules were developed with Macromedia Director, which can be deployed using standard Web browser with Macromedia Shock-wave plug-in as the interface. The Modules design involve more than twenty steps with static images which illustrates various stages of device fabrication starting from a bare silicon wafer to a final, completed device. In between these static images, an animated process flow with description of typical processing parameters is incorporated, leading to the next processing step. The static images with interactive dynamics can be viewed as a slide show by using start, previous, next and last buttons. Planar view of the semiconductor device under process at different stages of its fabrication can be viewed during interactive animation. Finally, the circuit diagrams, planar view of the fabricated semiconductor device are compared to show relation between the two. The time used to develop the first few modules was quite long, but later on the time spent for creating new modules decreased. Twenty five modules for devices ranging from a simple diode to BiCMOS have been developed, which are available at the author's web page. These Modules have been used as a learning tool since fall 1999 for Electrical Engineering

senior/graduate courses on IC Engineering and IC Fabrication Laboratory, and for Electronic Engineering Technology senior course on Integrated Circuit Technology and its associated laboratory.

Microelectronics Fabrication Laboratory virtual tour, safety precautions, process sequence demonstration, instruction manual for IC chip fabrication, operating instructions for equipment in the laboratory were placed on the Web and linked to the modules. The laboratory manual and virtual tour is further enhanced by still pictures of different IC processing sequences. The Web site also contains updated course information, laboratory report format, and instructions for maintaining laboratory notebook.

IMPLEMENTATION OF INTERACTIVE MULTIMEDIA MODULES

The modules were used after a new topic was introduced in the traditional manner during lecture. Perhaps, this was the most effective approach, because the students can visually see what is going on. The other approach to use the module was to show the module in class before starting a new topic to give an overall picture and to stimulate student's attention before starting actual discussion. Sometimes the combination of the above two approaches was used in the lecture. The students can also view these modules anytime at their convenience as a self study material.

The students are expected to prepare for the experiment before starting their work in the IC fabrication laboratory. A short discussion session was started to clarify questions relating to the concepts, design calculations, purpose of certain sequence steps for device fabrication, operation of equipment, and the safety precautions. Students were excited and satisfied by this approach compared to traditional style, because it reduced the total time spent in the laboratory, resulting in sufficient time available at the end of the semester to perform electrical testing of the fabricated chip. This approach also helped students to understand the objectives of the experiments from the data collected during the laboratory session.

EVALUATION OF INTERACTIVE MULTIMEDIA MODULES

As described above, the Modules were first implemented in the classroom and the laboratory in the fall of 1999. A survey form was created, which contains short questions relating to: i) accessibility of modules, ii) effectiveness of the modules and online laboratory manual, iii) its help in clarifying difficult concepts, iv) stimulate student interest in class and laboratory, v) organization of the modules, and at the end of the survey form students can express their opinions without the help of any crafted question. The questions were answered on a scale of zero to ten. The

participation in the survey was voluntary and anonymity of the students was maintained to gain an unbiased opinion. Students were also interviewed after graduation to ascertain their opinion about interactive multimedia modules and online laboratory manual. Since, the modules were available on the web, comments were received from students and teachers from other universities. Results of the survey form and comments received about the modules and online laboratory manual are given below.

Figure 1 shows the evaluation of IC Modules. The percentage of students response to the following survey questions are plotted: No.1- Good tool of Education, No.4- Clear understanding of different processing steps, No. 8 - Helped me to understand complex topics.

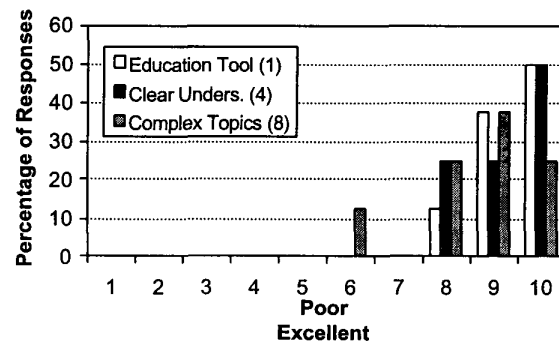


FIGURE 1 STUDENTS RESPONSE TO SURVEY QUESTIONS RELATING TO IC MODULES

Figure 2 shows the evaluation of online laboratory manual. The percentage of student responses to the following survey questions are plotted: No. 1- Accessibility of Laboratory Manual, No. 2 - Clear and understandable, No. 3 - Provides sequential laboratory experiments, and No. 4 - Notebook and lab. report format instructions are useful.

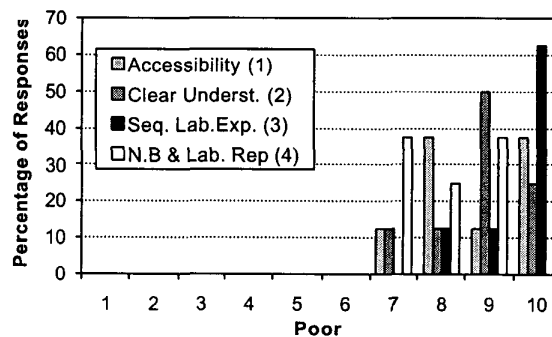


FIGURE 2 EVALUATION OF ONLINE LABORATORY MANUAL

Figure 3 shows the general evaluation of the interactive multimedia modules and the online laboratory manual. The percentage of student responses to the following questions are plotted: No.1 - Accessibility of syllabus, No.3 - Convenient and appropriate for students, No.6 - Illustration of modules helped in lectures, and No.8 - Laboratory manual in general.

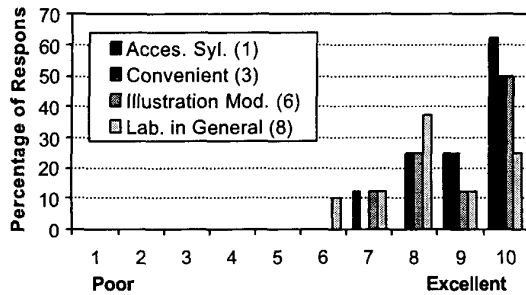


FIGURE 3
GENERAL EVALUATION OF INTERACTIVE MULTIMEDIA
MODULES AND ONLINE LABORATORY

Following are the excerpts of the students feedback collected from comments section of the survey form and comments received from the web.

"Helped me a lot. The modules are better than static images because it showed sequence of process. Most IC modules helped with concepts more than problem solving."

"Very helpful in introducing me to some of the methods and concepts involved with IC fabrication."

"The lab. portion complemented the course nicely and I think that everyone taking the course should have to be in the lab."

"The modules that were presented to us were good and helpful."

"Placing the labs on the web allowed us to printout and read before class. The lab print out was very thorough and easy to understand."

"I found the modules on internet to be very helpful in understanding the more complicated processes. Plus it can be accessed at any time."

"Guidelines for lab. notebook and report format was helpful."

The data presented in Figure 1-3 and students comments show an increasing interest of the students to the subject, clarifying the multiple fabrication steps, more interest in the laboratory and earlier completion of experiments resulting in sufficient time at the end of the semester to test their fabricated IC chip and extract electrical parameters of the devices. Also noticed was a significant increase in classroom discussion. Overall, the responses from the students have been very positive and encouraging.

SUMMARY

The aim of this research was to develop and implement interactive multimedia teaching tools for IC fabrication courses. Student's feedback through evaluation survey was obtained to determine the impact of the interactive multimedia modules on student learning and to improve teaching of the courses.

A major part of the work has been completed to develop and implement courseware for IC fabrication courses and laboratory. The modules and online laboratory manual was tested in senior/graduate EE courses and senior EET course. The student feedback shows a significant positive impact on their studies. Students greeted the technology with enthusiasm, and overwhelmingly considered multimedia component of the courses as helpful in understanding of difficult concepts. Online material enables students to access the information at their own time and pace (i.e. asynchronously) outside the classroom and laboratory. The next effort will be to further refine the modules and add additional modules with more features and details.

ACKNOWLEDGMENTS

This work was partially supported from the President's Teaching Scholar Fellowship awarded to the author in the Summer 1999.

REFERENCES

- [1] Penfield, Paul, "Education via Advanced Technologies", *IEEE Transactions on Education*, Vol. 39, No. 3, August 1996, pp. 436 - 443.
- [2] Oakley II, B., "The Virtual Classroom: At the Cutting Edge of Higher Education", presented at the *ASEE/IEEE Frontiers in Education Conference*, Salt Lake City, Utah, November 1996.
- [3] Pullen, J., Mark, and Benson, Michael, "Class Wise: Synchronous Internet Desktop Education", *IEEE Transactions on Education*, Vol. 42, No. 4, November 1999, p. 370.
- [4] Wic, R., C., "Educational Java Applets in Solid State Materials", *IEEE Transactions on Education*, Vol. 41, No. 4, November 1998, p. 354.
- [5] Iskander, Magdy, F., Catten, J., Corey, Jones, Jameson, Rex, and Balcells, Albert, "Interactive Multimedia Lessons for Education", presented at the *ASEE/IEEE Frontiers in Education Conference*, November 1995.
- [6] Zywno, Malgorwno, S., and Kennedy, Diane, C., "Integrating the Internet, Multimedia Components, and Hands-on Experimentation into Problem-Based Control Education", presented at the *ASEE/IEEE Frontiers in Education Conference*, Kansas City, Kansas, October 2000, Session T2D.
- [7] SUN Microsystems, Inc., "The Java Development Kit JDK 1.2" available for download from www.java.sun.com
- [8] Chirico, M., Giudici, F., Sappia, A., and Scapolla, A., M., "The Real Experiment execution Approach to Networking Courseware", *IEEE Transactions on Education*, Vol. 40, No. 4, November 1997, p. 297.