Work in Progress - Integrating Semiconductor and Nanotechnology Fundamentals into a High School Science Curriculum Module

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Abstract - **The Microelectronic Engineering Faculty at Rochester Institute of Technology have been engaged in two day K-12 Teacher forums addressing the engineering and fabrication of semiconductor devices for 12 years. A common theme that has emerged is the difficulty teachers have introducing new topics, such as those presented at the above-mentioned forums, to their students. It has become apparent to the Microelectronic Engineering faculty that a pre-developed curriculum requiring only teacher training would have the best chance of making a major impact. This paper reports on work in progress on a five week module designed to introduce semiconductor and nanotechnology fundamentals to AP physics students during the time after their AP exam in May and graduation in June. A major benefit of such a program would be introducing STEM students to exciting career opportunities.**

Index Terms – K-12 Outreach, STEM education, H. S. Physics, Microelectronics, Research Experience for Teachers (RET)

INTRODUCTION

The Microelectronic Engineering Faculty at Rochester Institute of Technology have developed and delivered a variety of two day workshop on Microelectronics for K-12 STEM teachers for the past 12 years. Originally funded with a grant from Advanced Micro Devices (AMD), nine workshops for 68 attendees were held during the 1998 – 2001 time frame. Teachers from New York made up the majority of attendees, but Alabama, Arizona, California, Ohio, and Texas were also represented. At this time the focus was on informing teachers of the rapid advances in Microelectronic Engineering and integrated circuit (IC) processing. In 2005, the Department secured a Department Level Reform (DLR) grant (EEC-530575) from the NSF to conduct a thorough self-evaluation of the curriculum in light of the emergence of new fields such as nanotechnology. A major component of the DLR grant was the establishment of an outreach office.

The Microelectronic Outreach Office consists of a faculty member who serves as the Outreach Director, and an Outreach Coordinator. Both positions are part-time. Based on the curricular developments resulting from the DLR grant, which are covered in detail elsewhere, the two-day workshop for K-12 teachers was resurrected and revamped to reflect the emerging technologies [1]. To date, nearly 100 teachers from New York State have attended the seven forums offered.

I. K-12 Teachers Forum

The two day workshop is focused on introducing teachers to the existing field of Microelectronic Engineering and emerging technologies such as Nanotechnology. Once an overview is given, the teachers are taken through the basic device physics of resistors and diodes. Attendees embark on a sequence of lectures and labs illustrating how the physics is put into practice. These modules cover the basics of IC processing including oxidation, doping, photolithography, metallization, and the vacuum systems needed to control the processing environment. Current-voltage device testing is introduced to enable the teachers to evaluate device performance. The presentations are conceptual in nature, focus on a qualitative understanding of the phenomenon, and are on par with some basic electronic technology courses that are offered in many high schools. Table I shows the workshop agenda in more detail.

TABLE I
K-12 TEACHERS FORUM ON MICROELECTRONICS AND NANOTECHNOLOGY [1]

Day 1	Day 2
Origins of Nanoelectronics	Snapshot of Today's High-Tech Marketplace
Overview of Emerging Technologies	Lithography and Microscopy Laboratory / Material Science of Nanofabrication
Fundamentals of Semiconductor Devices	How and where to include New Material into Existing Curricula
Silicon Run Lite' DVD; by Silicon Run Fabrication	Electronics Lab II/ Test
Overview (Cleanroom Tour)/ Electronics Lab 1	Focused Discussion: Preparing Today's Students for Careers in the High-Tech Industry. Snapshot of the Programs /Current Research in the Microelectronic Engineering Department at RIT.
Vacuum Systems	Bringing it all together/ K-12 Connections/ Commencement

In the final segment of the workshop, entitled “Bringing it All Together / K-12 Connections”, RIT faculty and teachers brainstorm ideas to introduce the newly presented topics into the K-12 classroom. While the teachers do receive materials such as videos, electronics kits, and course notes to use in their courses, there has been no major development of high school curricular experiences by the attendees. Introducing the knowledge acquired in the workshop to the high school student remains a challenge.

II. The Challenge

A common theme expressed by teachers attending our workshops is the difficulty in introducing new material into existing curricula. With school districts placing an emphasis on meeting standardized testing, many curricula are focused on preparing students for the exams. In addition, current teaching loads may not permit individuals to innovate at a significant level. Finally, given the broad educational backgrounds possessed by the teachers attending our forums, some type of organized teacher training is probably required to introduce new topics into the K-12 classroom

One attendee, an alumnus of the Microelectronic Engineering program who practiced engineering for several years before returning to NYS to pursue a career as a high school Physics teacher, received NSF “Research Experience for Teachers (RET)” supplement grant in the summer of 2009. He proposed to evolve the workshop into a curriculum module for his physics students. Current high school physics curricula in NYS, including the Advanced Placement (AP) Physics, do not include any material on solid state electronics. While the integrated circuit, developed and evolved since 1947, has achieved a ubiquitous status in our daily lives, our current high school graduates often remain uninformed as to its basic principles and applications. The emergence of nanotechnology further exacerbates this absence of recent advancements in physics and chemistry from the high school experience. With AP exams scheduled in early May, and graduation in mid-June, NYS AP physics teachers have a five week period for instruction with no set curriculum. This is a perfect opportunity to develop a module on recent advances in Microelectronics and Nanofabrication.

III. Opportunity: Module on Semiconductor Fundamentals

Development of a curricular prototype is currently underway, with a targeted goal for delivery in May 2010. The program will consist of five modules designed around five, 45-minute periods per week. One or two of the periods will be dedicated to hands-on work. Each unit begins with an introductory lecture which includes a general outline and goal for the week. Students will be divided into two groups to explore the unit through a variety of resources and activities. Flexibility is designed into each module to enable to instructor some options.

Course objectives include:

- Introduction of basic engineering principles
- Introduction to science and engineering careers
- Development of deeper understanding of science concepts through analysis of application
- Development of vocabulary needed in semiconductor and nanotechnology fields
- Development of skills needed to explore high-tech concepts independently
- Development of skills needed to work as part of a team

Curricular modules to be delivered include:

- Introduction to IC’s and the Engineering fields of Microelectronics and Nanotechnology
- Fundamental physics of resistors and diodes
- Transistors; a combination of two diodes
- Processing: the materials science of building an IC
- Device fabrication and tour of cleanroom facility.

The modules to be discussed in this presentation will have a slant toward physics given the teacher and co-author’s background. The vision is to modify the curriculum to focus on the chemical processing aspects of Microelectronic and Nanofabrication to make the developed materials useful to a wider range of teachers, starting with AP chemistry teachers. Once these materials are developed, the role of mathematics in statistical process control and device simulation may be used to attract the math teachers to incorporate this material. The RIT Outreach Office hopes to secure funding to provide a week long summer training event for teachers interested in adopting these materials.

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REFERENCES

[1] Kurinec, S., Jackson, M., Mariotti, D., Gupta, S., et.al., “*Microelectronic Engineering Education for Emerging Technologies*”, 40th ASEE/IEEE Frontiers in Education Conference, Washington, D.C., Oct. 27-30, 2010

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