AC 2009-187: TECHNICIAN EDUCATION MATERIALS IN PLASMA TECHNOLOGY: A TEMPLATE

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TEMPlaTe: Technician Education Materials in Plasma-Aided Manufacturing

Abstract

Normandale Community College (NCC) in Bloomington, MN, has developed technician-level, educational resources in plasma-aided manufacturing. These resources include instructional modules, laboratory exercises and demonstrations, and faculty-enhancement workshops. The instructional modules range from an introduction to plasma physics to RF power delivery to sputtering materials onto a substrate. Laboratory exercises range from low-cost transmission line experiments to capstone laboratory activities using a table-top sputtering system. Faculty-enhancement workshops include both basic and advanced workshops related to RF plasma processing and measurement.

The project, funded through a grant from the Advanced Technological Education program at the National Science Foundation (NSF # 0603175), is an extension of work performed at Portland Community College (NSF # 0101533). This project increases the robustness of the instructional modules, expands the number and scope of the laboratory exercises, and provides basic and advanced faculty-enhancement workshops for college and university faculty.

This paper provides an overview of the instructional modules, the laboratory exercises, and a brief description of the faculty workshops.

Introduction

Plasma processing is critical to the manufacture of a myriad of consumer products that enhance our quality of life. These products range from the coatings on our eyeglass lenses to the integrated circuits in our computers, cell phones, and other electronic products. Plasma processing steps include surface cleaning, deposition of materials, patterning/etching surface layers, and sputtering metals and non-metals on substrates. Plasma technology enabled manufacturers to make features smaller and smaller, now in the nanometer regime.[1,2]

Few community colleges currently teach this important enabling technology due to a lack of technician-level educational materials, teaching laboratories, and faculty expertise. This project, funded through a grant from the National Science Foundation, addresses these barriers to providing training in plasma-aided manufacturing for students at our nation's community colleges. To date this project has developed eight instructional modules ranging in topics from an introduction to plasma physics, to RF power delivery, to plasma-based manufacturing processes, e.g. sputtering of metals and non-metals. In addition, the project has enabled Normandale Community College (NCC) to implement a plasma-aided manufacturing teaching laboratory. This laboratory is not only be used by NCC students, but is also being used to train community college faculty in basic and advanced topics in plasma-aided manufacturing.

Context

In Portland Community College's (PCC) Microelectronics Technology Program, their plasma-aided manufacturing course was placed in the fifth term of a six-term associate of applied science program. It was so positioned in the curriculum because the study of plasma-aided manufacturing requires a foundation in chemistry and physics along with concepts from electronics, vacuum technology, and mathematics. The course also serves as a prerequisite for a capstone "Process Equipment" course in PCC's curriculum. Table 1 lists the courses required for PCC's associate of applied science degree in Microelectronics Technology.

Table 1. Associate of Applied Science Degree Program
In Microelectronics Technology at Portland Community College[3]

Term/Course Numbers	Course Title	Credits
First Term		
MT 101	Introduction to Semiconductor Mfg.	1
MT 102	Introduction to Semiconductor Devices	1
MT 103	Introduction to Micro and Nano Processing	1
MT 111	Electronic Circuits & Devices I	4
MTH 95	Intermediate Algebra	4
WR 121	English Composition	3-4
Second Term		
MT 112	Electronic Circuits & Devices II	4
MT 121	Digital Systems I	3
MTH 111C	College Algebra for Math, Science, & Eng.	5
CH 221	General Chemistry	5
Third Term		
MT 113	Electronic Circuits & Devices III	4
MT 122	Digital Systems II	3
MTH 243	Statistics I	4
WR 227	Technical Writing I	3-4
CH 222	General Chemistry	5
Fourth Term		
MT 223	Vacuum Technology	3
MT 224	Process Equipment I	3
PHY 201	General Physics	4
SP 130	Business and Professional Speech Comm.	3-4
	General Education	3-4

Fifth Term		
MT 240	RF Plasma Systems	3
MT 227	Process Equipment II	4
PHY 202	General Physics	4
SP 215	Small Group Communication	3
Sixth Term		
MT 200	Semiconductor Processing	3
MT 222	Quality Control Methods in Manufacturing	3
MT 228	Process Equipment III	4
PHY 203	General Physics	4
	General Education	4

PCC's plasma-aided manufacturing course is MT 240 RF Plasma Systems. The PCC Catalog describes this course as follows:

> "MT 240 RF Systems 3.00 (credits): Covers the theory and practice of RF plasma systems used in semiconductor manufacturing. Includes plasma physics, RF power subsystems, and plasma-aided manufacturing. Prerequisites: MT 223, MT 224, CH 222 and WR 227." [3]

From 1990 to 1995, the MT 240 RF Systems requirement was satisfied by Intel University's RF Plasma Systems course. This worked because the students in the associate degree program were all Intel employees and had access to Intel University courses. The Intel course covered the appropriate topics, but the delivery was very condensed, not allowing for homework assignments between class sessions. The course did not have a laboratory component, and academic rigor was lacking.

In 1995, the associate degree program was moved from the Intel campus back to Portland Community College. This allowed non-Intel employees to enroll in the program. However, non-Intel employees were not allowed to take Intel University courses and this required that on-campus, credit course be created. For several years, Intel employees were allowed to use Intel University's course to satisfy this course requirement, creating a dichotomy between Intel and non-Intel students. This dichotomy was eliminated in 1998 and all students from that point forward would have to take the on-campus, credit MT 240 course.

At this point in time, lacking a RF technology, teaching laboratory, MT 240 was implemented in a 3 quarter-credit, 3 lecture-hour/week format. The academic rigor for the course was set at a level consistent with other microelectronics courses in the associate degree program in Microelectronics. Although students performed adequately on written exams, the faculty felt that student understanding was at a theoretical level, not a practical level of understanding of plasma-aided manufacturing.

Several barriers were identified that kept students from developing a practical understanding of this important technology. One barrier was the lack of consistency in presentation. Instructors used their own class materials. Although some may argue that is not necessarily a negative, there were differences in content and level from term to term. Another barrier was that the material still remained at the "theoretical" level in the minds of our students. To bring the material down to a "practical" level, students needed laboratory experiences similar to that received in other technical courses in the program.

Educational Materials Development

A search for a textbook turned up no suitable, technician-level textbooks in RF plasma technology or plasma-aided manufacturing. Hence, we set about the task of creating our own text materials. The Intel University course was used as a starting point with the realization that there might be some aspects of the course that might be "proprietary" to Intel and the material could not be used in a course that included non-Intel employees.[4]

A modular format was used in developing the instructional modules. The faculty felt that this format would best support adaptation of the modules by other faculty at other community college as they customized the instructional modules for their courses.

The seven instructional modules include:

Module 1: An Introduction to Plasma Physics
Module 2: Plasma Sources
Module 3: Transmission Line Fundamentals
Module 4: RF Power Delivery
Module 5: Microwave Power Delivery
Module 6: Sputtering
Module 7: Safety

Each module includes text material that provides a fundamental treatment of each topic along with demonstrations and laboratory exercises that would enable students to develop a practical understanding of the technology. End-of-chapter problems are included as is common in most technician-level teaching materials. To illustrate the composition of a module, the content of Module 4: RF Power Delivery is shown in Table 2.

Table 2
Table of Contents for Module 4

Laboratory Implementation

Consider the following analogy taken from a digital circuits course in a traditional, electronics technology program at a community college. In the lecture portion of the course, students are taught about digital components, e.g. gates, flip-flops, and MSI/LSI components. They are shown how these components are connected to form circuits that perform a specific function. But if the course stops there, does the student really understand how to implement, i.e. build and test, a digital circuit? My years of teaching have shown that taking a project from design to functioning circuit must be experienced in the lab, or other venue, for it to become "real."

Likewise, students can learn to describe plasma processes, list appropriate safety precautions, and identify industry practices. But can the student operate, troubleshoot, and successfully execute a manufacturing process? Most students cannot. Hence, the teaching laboratory becomes an important complement to the classroom experience.

Creating a teaching laboratory for a plasma technology course for technicians is not a trivial pursuit. There are three barriers to implementing a teaching laboratory in plasma technology: (1) commercially-available training equipment, (2) funding, and (3) faculty expertise and technician support. This NSF project addresses all three barriers.

Our strategy for laboratory improvement was to develop a variety of laboratory exercises to support all of the instructional modules. Our goal was to have a logical sequence of learning activities that would methodically build the student's expertise in plasma technology and their sophistication with equipment. Hence, beginning experiments are fundamental in nature and these basic exercises gradually build to a capstone experience running an actual manufacturing process. The cost of implementing these experiments would range from inexpensive to costly, requiring outside funding.

Two pieces of equipment are critical to implementing the breadth of laboratory experiences. The first instrument, the MFJ-259B SWR analyzer shown in Figure 1, is a low-cost meter used by ham radio enthusiasts to troubleshoot and maintain their equipment. It has the capability of measuring impedances in both rectangular form (R and X) and polar form (Z, and θ). In addition, it also measures the standing wave ratio and reflection coefficient. The MFJ-259B SWR analyzer can be used to support a variety of transmission line and impedance matching experiments.

Figure 1. MFJ-259B SWR Analyzer.

The other major piece of equipment is a tabletop, plasma-processing training system capable of sputtering metal, either aluminum or copper, onto a substrate. The tabletop plasma processing training system can be assembled from components, or purchased as complete systems from MKS, Inc., or Manitou Systems, Inc. The training system consists of a 6-inch cross that serves as the process chamber. The electrode is a magnetron electrode that is powered by a 300-watt, 13.56 MHz RF generator and manual matching unit. The vacuum subsystem consists of a small turbomolecular pump backed with a scroll pump, and the gas delivery system delivers both nitrogen for purging as well as argon as the process gas. The cost of the complete system is approximately $35,000.

Appendix A provides a list of the laboratory exercises and illustrates the breadth of activities that can be included in the laboratory portion of a plasma technology course. Rather than describe each exercise, two exercises will be discussed in detail.

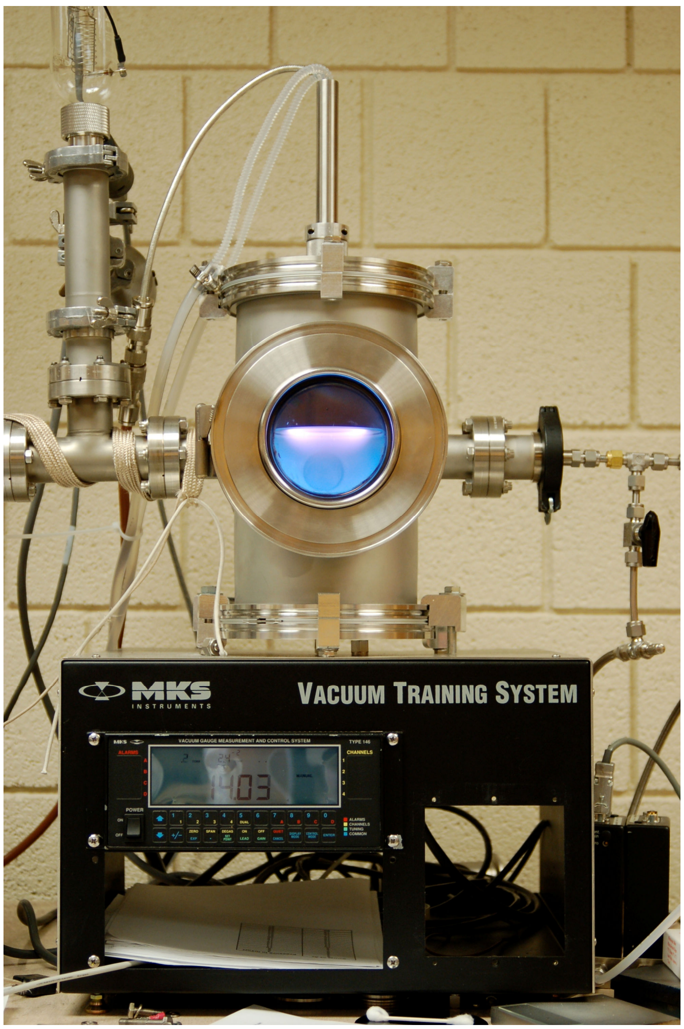

Figure 2. PPTS training system from MKS, Inc.

Funding a teaching laboratory takes more resources than is commonly available in more department equipment budgets. Grants from the Advanced Technological Education (ATE) Program funded by the National Science Foundation (NSF) can provide up to $150,000 to purchase equipment for a teaching laboratory. Other sources of funding include grants from local and state economic development funds and from contributions for local companies that employ your graduates.

Portland Community College implemented a six-student station RF Plasma Laboratory at the Rock Creek Campus. Each student station includes MFJ SWR Analyzers and a PPTS Plasma Processing Training System. Normandale Community College is replicating PCC's teaching laboratory and currently has three teaching stations that include the MFJ SWR Analyzers and PPTS Plasma Processing Training Systems.

Revised MT 240 RF Systems Course

With the new teaching laboratory, PCC's RF Systems course was reconfigured as a 3 credit, 2 lecture-hours/week, 3 laboratory-hours/week, 11 week course. This laboratory has supported the range of laboratory experiments listed in Appendix A.

Instructor evaluations of the course have indicated that students now have a practical understanding of plasma processing and plasma processing systems. Feedback from students employed in industry indicate that this knowledge of plasma processing systems has enabled them to adapt more quickly to their work environment. An indicator of this is their ability to test out of in-house training in basic RF systems.

Since 2001, 178 students at Portland Community College have taken MT 240 RF Systems course.[5] Many are now working in the local semiconductor industry and applying their RF knowledge the manufacture of integrated circuits and other silicon-based products.

Normandale Community College has created a new course entitled NANO 2295 Advanced Plasma Processing. This course was first offered during Spring semester of 2008 and had an enrollment of 8 students. The course was modeled after PCC's MT 240 RF Plasma Systems course.

Faculty Enhancement

Finally, this project will provide faculty training in plasma technology and plasma-aided manufacturing. Three faculty enhancement workshops for community college faculty will be held during 2008 and 2009. A two-day basic plasma technology workshops, which focuses on basic plasma physics and RF power delivery, were hosted by Normandale Community College on August 12-

13, 2008, and March 19-20, 2009, and were attended by eight college faculty and 9 college faculty, respectively.

The two-day advanced plasma workshops are being developed. These workshops will build on the basic workshop material and laboratory exercises and will add material and laboratory exercises in measuring plasma parameters using a Langmuir probe, determining operating parameters using a V/I probe, and advanced processing experiments using the tabletop, plasma-processing training system. The first workshop will be offered in May of 2009 and will focus on the use of Advanced Energy's Z-Scan Probe and Tomco's T-1000 Impedance Analyzer.

Summary

This paper describes a National Science Foundation funded project at Portland Community College and Normandale Community College that aim to create educational resources for a technician-level course in plasma-aided manufacturing. Major components of the NSF project include the development of technician-level instructional modules and the implementation of a teaching laboratory for plasma technology along with faculty enhancement opportunities for community college faculty.

References:

(1) Xiao, Hong. Introduction to Semiconductor Manufacturing Technology, Prentice-Hall, Inc., 2001.
(2) Wolf, S. and Tauber, R. N. Silicon Processing for the VLSI Era: Volume 1 – Process Technology, Lattice Press. 1986.
(3) www.pcc.edu, Portland Community College Catalog, Microelectronics Technology
(4) Intel Corporation. "RF Plasma Systems" Course, Rev. 07/91.
(5) E-mail communication with Eric Kirchner, Department Chair, Microelectronics Technology Program at Portland Community College on March 2, 2009.
(6)

Appendix A.

List of laboratory exercises for a plasma-aided manufacturing course.

Exercise 1.1 Experimental Determination of the Spectral Emission of Selected Gases
Exercise 1.2 NE-2 Lamp Experiments
Exercise 1.3 Structure of a DC Glow Discharge in a Long Tube
Exercise 2.1 RF Power Measurement and Testing
Exercise 3.1 Velocity of Propagation
Exercise 3.2 Reflection Coefficient and Standing Wave Ratio
Exercise 3.3 Coaxial Cables as Impedance Transformers
Exercise 4.1 Impedance Matching
Exercise 6.1 Sputtering Metal onto a Substrate