Vacuum Systems Laboratory Development: Teaching More About Making Less

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Abstract

The implementation of new associate degree programs in semiconductor manufacturing at community colleges across the nation has created a critical need for vacuum technology courses and supporting laboratories. Unfortunately, few resources have been available to support technology-level courses in vacuum systems. This paper describes the results of a two-year project to develop a vacuum technology course, implement a vacuum systems laboratory, and provide faculty enhancement activities.

Introduction

Vacuum systems are used in virtually every functional area of a wafer fab to create the proper processing environments for semiconductor manufacturing processes. Because of the pervasive of vacuum technology in the wafer fab, most two-year, associate degree curricula require at least one course in vacuum technology. Unfortunately, support for technology level courses in this area are lacking in terms of textbooks, vacuum training systems, and laboratory manuals.

In 1995, Portland Community College, with funding from the National Science Foundation, began development of a generic vacuum technology course and supporting laboratory.[1] A team of community college faculty and industry experts was formed and the team was charged with the task of developing a vacuum technology course, complete with laboratory.

The course content was delineated without much difficulty. Using available resource materials,[2,3] the development team recommended that the course begin with a review of gas laws from chemistry and then progress from rough vacuum to high and ultra-high vacuum regimes, examining the underlying gas dynamics, pumping methods, and pressure measurement techniques. The team also recommended that advanced topics, such as leak detection and gas analysis using RGA's, complete the course of study.

The more difficult issue was definition of the laboratory portion of the course. Research had shown that community college that had developed their own vacuum technology courses supported these courses with custom-built training systems, assembled out of donated and salvaged vacuum components. This development was usually the result of the work of one "expert" faculty member. The development team rejected this approach since most community colleges would not have a similar level of expertise to build their own custom systems nor may they have a source for donated vacuum components. Rather, the team sought an off-the-shelf approach whereby community colleges could purchase a commercially-available vacuum trainer.

Leon Hammer of Intel Corporation and David Abercrombie of Varian Vacuum Products took the charge to design a vacuum training system. They took Varian's mini-pumping station design and added a baseplate/bell jar chamber, roughing line, and additional gauges.

Varian Vacuum Products, at their expense, built a prototype of the vacuum training systems and made it available to the development team. Ten experiments were then written for the Varian Trainer.

In 1996, Portland Community College received an Instrumentation and Laboratory Improvement (ILI) Grant to equip a five-station vacuum systems laboratory.[4] The laboratory was implemented and supported vacuum technology courses during the Spring quarter of 1997 and again during the Fall quarter of 1997.

In addition, Portland Community College and the Maricopa Advanced Technology Center (MATEC) are co-sponsoring three-day faculty enhancement workshops in vacuum technology. These workshops provide high school and community faculty not only with laboratory experience with the Varian vacuum trainer, but also an excellent opportunity to collaborate with their fellow teachers on the design of new experiments and demonstrations.

Vacuum Training System

The Varian vacuum trainer, shown in Figure 1, is a high vacuum pumping system. The trainer has two pumps: a Turbo-V70LP turbomolecular pump backed by a MDP 30 mechanical diaphraphm pump. A roughing line connected the MDP 30 to the baseplate/bell jar chamber and includes a hand-operated block valve (rough valve). The parallel path to the bell jar consists of a foreline with hand operated block valve that connects the mechanical pump to the Turbo-V70LP and a butterfly valve and linear gate valve between the turbo pump and the bell jar.

Vacuum gauging on the trainer includes three thermocouple gauges--one in the roughing line, one in the foreline, and one attached to the chamber--and one Bayard-Alpert Ionization Gauge. The trainer uses a Multi-Gauge Instrument Controller to operate all four gauges and to provide an RS-232 serial link to a PC.

The trainer also has two vent valves--a hand-operated vent valve for the chamber and an automatic vent valve for the turbo pump. The base plate has fittings for a gas feedthrough, rf feedthrough, and two additional ports.

The trainer has an ultimate base pressure in the rough vacuum regime of approximately 0.5 torr, the rating of the MDP 30 mechanical pump. Ultimate pressure in the high vacuum regime varies from system to system and ranges from 1 x 10^{-5} torr to 5 x 10^{-6} torr. The ultimate pressure in the high vacuum regime is limited by the outgassing of the glass bell jar and the stainless steel components in the high vacumm portion of the trainer.

Several problems in the initial design were addressed. These problems resulted from incompatibility of the Multi-Gauge firmware and having both thermocouple and Convectorr control boards in the system. This caused problems in reading gauge pressures and in communicating via the RS-232 link to the PC. These problems were resolved by updating the Multi-Gauge firmware and removing the redundant Convectorr gauging from the system.

Use over two academic quarters has shown the systems to be relatively reliable. Maintenance has been minimal. This is due to leaving the systems essentially intact during the course.

Vacuum Experiments

The development team authored nine experiments that could be performed using the basic Varian vacuum trainer.[5] The experiments ranged from simple pumpdowns to surface area outgassing and leak detection experiments. The nine experiments include:

- Experiment 1: Rough Pumpdown from Atmospheric Pressure: Air Environment
- Experiment 2: Rough Pumpdown from Atmospheric Pressure: Nitrogen Environment
- Experiment 3: High Vacuum Pumpdown from Atmospheric Pressure: Air Environment
- Experiment 4: High Vacuum Pumpdown from Atmospheric Pressure: Nitrogen Environment
- Experiment 5: Heated Chamber Pumpdown
- Experiment 6: Liquid Nitrogen-Assist, High Vacuum Pumpdown
- Experiment 7: Rate-of-Rise Experiment Following High Vacuum Pumpdown
- Experiment 8: Surface Area Experiment: Outgassing
- Experiment 9: Conductance and It's Effect on Pumpdowns

Residual Gas Analyzer

To enhance the capability of the Varian vacuum trainer, a Stanford Research Systems residual gas analyzer was added to the trainer. The RGA-100 is a 100 atomic mass unit residual gas analyzer. In the analog mode, the RGA produces a graph of partial pressure versus amu.

From an instructional point-of-view, it is a significant advantage to be able to analyze the gas being evacuated from the chamber. For example, with an RGA the student can measure the amount of water being outgassed during the initial stages of pumpdown as opposed to the later stages of pumpdown. Students can view the relative partial pressures of other gases such as nitrogen, oxygen, and carbon dioxide.

Another use of the RGA is for leak detection. The RGA can be configured to monitor the partial pressure of helium and a helium gas bottle can be used as a source for leak checking the vacuum system.

Addition of the RGA required moving the Bayard-Alpert Ionization Gauge to the port on the baseplate originally assigned to the rf feedthrough. This permitted the RGA to be installed at the back of the trainer.

The two additional experiments can be added to the list of experiments performed on the Varian trainer.

Experiment 10: Residual Gas Analyzer: Air Pumpdown
Experiment 11: Residual Gas Analyzer: Unknown Gas Mixture

Faculty Enhancement

Four faculty enhancement, vacuum technology workshops were held during the 1997-98 academic year: September, 1997; December, 1997; March, 1998; and June, 1998. The workshops were sponsored by the Maricopa Advanced Technology Education Center (MATEC). MATEC provided lodging and meals and paid for the cost of the workshop. Participants paid for their travel to Portland, Oregon, and paid a $125 workshop registration fee. Portland Community College hosted the three-day workshops at the CAPITAL Center.

The three-day format provided participants with ample opportunity to answer the questions “What do I teach in a vacuum technology course?” and “How do I teach the material?” The workshops are envisioned as dialogues between teachers who teach vacuum technology courses at the high school and community college levels.
One community college teacher had just received their Varian vacuum trainer just before coming to the vacuum technology workshop. For him, the workshop provided an excellent opportunity to work with the Varian trainer before returning to his home institution to unpack his own trainer.

The workshop also gives participants sources for information. For example, part of the first lab session is spent on the Internet looking at several sources for information, vacuum principles demonstrations, and products.

Future Enhancements

Future enhancements to the Varian Vacuum Trainer include the addition of rf generation, mass flow control, and a redesigned chamber to add rf plasma generation capability. By so doing, the basic vacuum trainer can also be used to support a rf plasma systems course in a two-year semiconductor manufacturing technology curriculum.

Conclusion

The development of a vacuum technology course and laboratory taught us more than just what equipment to purchase. The close collaboration between Intel Corporation, one of our premier semiconductor companies, Varian Vacuum Products, a major supplier to the semiconductor industry, and community colleges set an important precedent for future projects. The collaboration between community colleges, in itself, was a direct result of a National Science Foundation Advanced Technological Education grant that has supported activities to encourage partnerships and networking between community colleges across the country.

The five student station laboratory has not only served students in the Microelectronics Technology Program at Portland Community College, but has also supported faculty enhancement workshops sponsored by the Maricopa Advanced Technology Education Center, helping high school and community college faculty update their understanding of vacuum technology. Over thirty faculty will attend MATEC-sponsored vacuum technology workshops at Portland Community College during the 1997-98 academic year.

References:

1. National Science Foundation, Advanced Technological Education Grant, DUE 9454589.

2. SEMATECH Technician Training Task Force, “Final Report: Technician Training Curriculum Task Force,” January, 1995.

3. O’Hanlon, John, A User’s Guide to Vacuum Technology, Second Edition, John Wiley & Sons, Inc., 1989.

4. National Science Foundation, Instrumentation and Laboratory Improvement Grant, DUE 9650916.

5. - - - , “Vacuum Technology for Semiconductor Manufacturing,” Committee Report, February, 1997.

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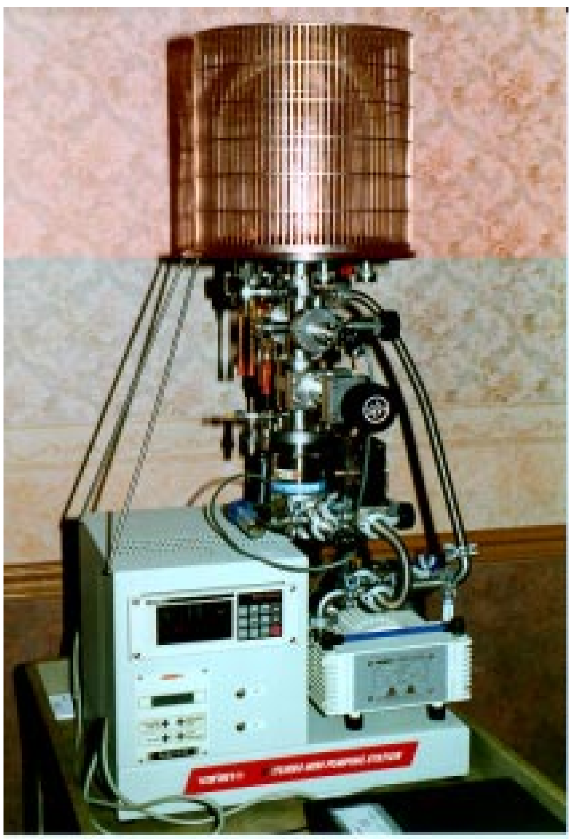

Figure 1. Varian Vacuum Training System.