AVS Short Course Catalog Index

Courses that are most commonly requested during the year are noted below.

Alternatively, many AVS courses can be customized through our Onsite Short Courses program and taught at your facility.

Don't see what you are looking for on our current schedule then use our Courses By Request form to make a request.

Vacuum and Equipment Technology

Topics related to vacuum and processing equipment design, operation, and maintenance

Materials and Interface Characterization

Topics covering chemical, physical, and electrical characterization of films, surfaces, particles, and interfaces

Materials Processing

Topics covering materials processing, modification, and integration

Process and Equipment Technology

Process and Materials Integration

An Overview of Applied Vacuum Technology

Course Objectives

- Be introduced to the fundamental concepts of vacuum technology.
- Learn about common vacuum system hardware and instrumentation, including pumps, gauges, flanges, valves, and feedthroughs.
- Understand applications and processes involving vacuum technology.
- Benefit from a "just right" two-day course (when you don't have the time or the need to attend a four- or five-day introductory course).

Course Description

The course begins with a definition of vacuum and a description of the physical conditions existing in a vacuum environment. Following this introduction will be a discussion of gases at low pressures and the interactions between gases and solids. The phenomena of gas flow through vacuum systems will then be examined. The primary components of vacuum systems, with an emphasis on pumps and gauges, will be described.

Requirements for materials compatible with the vacuum environment will be discussed. Various sealing techniques will be described, including coverage of all demountable flange systems in common use today. Common vacuum system configurations and operational procedures will be outlined. The course will finish with a description of vacuum leak detection methods and the far-reaching applications of vacuum technology today.

Ample time for questions and discussion will be scheduled. A comprehensive list of references will be provided for those wishing to learn more detailed information about specific areas. The emphasis of the course will be to provide practical information for individuals with minimal training in vacuum technology.

Who Should Attend?

Managers, technicians, engineers, and scientists who desire an introduction to the concepts, hardware, and instrumentation used in applied vacuum technology today. Those interested in a short review of vacuum basics will also find this course valuable.

Days: Two

Instructor: Woody Weed, Technical Staff Member, Sandia National Laboratories [Mike Benapfl, Engineering Technical Associate, Mechanical Engineering Department, Lawrence Livermore National Laboratory; Bob Childs, Senior Scientist, Massachusetts Institute of Technology; Tim Gessert, Senior Scientist, NREL; Paul Holloway, Professor of Materials Science and Engineering, University of Florida, and Director of MICROFABRITECH; Howard Patton, Project Engineer, Lawrence Livermore National Laboratory; Jack Singleton, Consultant

Course Materials: Course Notes and "High-Vacuum Technology" by Mars Hablanian, 1997 [Tompkins uses Course Notes and "A User's Guide to Vacuum Technology" by O'Hanlon, 1989]

Cost: $950

Fundamentals of Vacuum Technology

Course Objectives

- Understand vacuum fundamentals essential to operating, maintaining, designing, or using vacuum systems.
- Know the working principles and limitations of pumps, gauges, and other vacuum system components.
- Understand the procedures for operating and performing preventive maintenance on vacuum systems, including analyzing and troubleshooting malfunctioning vacuum systems and leak detection.
- Learn the design concepts involved in matching equipment and instrumentation to applications.

Course Description

This extensive [four- or five-day] course provides a working knowledge of vacuum equipment and the technology associated with its use. It includes enough theory to provide a basis for the material covered; however, the major emphasis is on practical applications.

The working principles of the pumps and gauges used on vacuum systems are discussed, followed by a description of the characteristics of pumps and gauges in current use. Characteristics required of components such as valves, connecting lines, flanges, and seals that connect pumps to process chambers are described next, especially with regard to the application (i.e., medium-, high-, or ultrahigh vacuum conditions). The materials normally used for vacuum systems are discussed, with particular attention to handling, fabrication, and cleaning procedures.

Procedures for system operation, preventive maintenance, and leak detection are covered, with emphasis on practical applications. In addition, techniques used to troubleshoot systems operating at less than optimum levels are provided. System design concepts for matching equipment and instrumentation to the intended application are also covered.

Who Should Attend?

Those entering the field of vacuum technology or fields using vacuum technology who need a detailed working knowledge of vacuum equipment and practice will benefit from this comprehensive introduction. Those interested in a review of vacuum basics will also find this course valuable.

Days: Four or Five

Instructor: Michael Benapfl, Engineering Technical Associate, Mechanical Engineering Department, LLNL; Peter Biltoft, Materials Scientist, LLNL; Bob Childs, Senior Scientist, Massachusetts Institute of Technology; Tim Gessert, Senior Scientist, NREL; Paul Holloway, Professor of Materials Science and Engineering, University of Florida, and Director of MICROFABRITECH; Ronald Outlaw, Research Professor, College of William and Mary; Howard Patton, Project Engineer, LLNL; Neil Peacock, Development Engineer for HPS Division, MKS Instruments, Inc.; Jack Singleton, Consultant

Course Materials: Course Notes and "High-Vacuum Technology" by Mars Hablanian, 1997

Cost: $1,495

Recent Advances in Vacuum Technology

Course Objectives

- Learn about advances in vacuum technology that have emerged or matured since 1990.
- Gain insight into computer-aided design and engineering (CAD/CAE) techniques now being used to construct vacuum systems.
- Define topics in vacuum science and technology that are currently being investigated.

Course Description

Vacuum technology continues to evolve, driven by the requirements of the semiconductor, thin-film, space, surface, physics, and industrial communities. Many recent advances are the direct result of user communities defining needed technology and the equipment manufacturers responding. Vacuum science is focused on a more complete understanding of gas-solid phase interactions at the atomic and macroscopic scale.

This course will discuss advances in vacuum hardware, instrumentation, and computer-aided design and engineering that have emerged or matured since 1990. Devices such as dry pumps, “water” pumps, turbodrag pumps, enhanced and miniaturized total and partial pressure gauges, *in situ* particle monitors, and leak detectors will be described. The application of workstation and PC-based 3-D solid modeling software to the mechanical design of systems will be illustrated. Software used to model gas flow and predict the performance of vacuum systems will be demonstrated. Additionally, the topics of material outgassing, rapid evacuation, automation, control, and cleaning will be discussed.

Time will be reserved to discuss vacuum technology issues of specific interest to the students. Attendees are encouraged to bring problems and case studies from their workplace.

Who Should Attend?

Technicians and engineers who have completed the AVS four- or five-day vacuum technology course prior to 1990 and desire an update. Those with no formal training in vacuum technology, but who have 10 or more years of work experience in the field.

Days: One

Instructor: Woody Weed, Technical Staff Member, Sandia National Laboratories; and Peter Biltoft, Materials Scientist, LLNL

Course Materials: Course Notes

Cost: $575

Analysis of Residual Gas Analyzer Spectra

Course Objectives

- Learn how a residual gas analyzer (RGA) works
- Learn how to interpret RGA mass spectra

Course Description

This course provides the basics needed to analyze Residual Gas Analyzer (RGA) data. It begins at a very elementary level, first describing the atom, then proceeds to the atomic electronic structure, then on molecular bonds. The operation of an RGA is next described, especially phenomena that occur in the ion source. All this information is used in the discussion of RGA spectral interpretation. Typical RGA spectra are shown and analysis of the spectra is demonstrated. Relevant references, tables and graphs are presented.

Who Should Attend?

Scientists, engineers and technicians who use or plan to use residual gas analyzers in research and support of high vacuum processes.

Days: One

Instructor: Bob Langley, Oak Ridge Scientific Consultants

Course Materials: Course Notes and “Partial Pressure Analyzers and Analysis” from the AVS monograph series

Cost: $575

Mass Flow Controllers: Fundamentals, Techniques, and Applications

Course Objectives

- Understand current mass flow controllers (MFCs) technology.
- Learn calibration methods.
- Know practical considerations for optimal performance.
- Practice troubleshooting and diagnostics.

Course Description

Thermal MFCs are widely used for the precise delivery of materials into vacuum. These instruments are important in many processes in semiconductor fabrication, vacuum coating, and materials research.

This course presents a basic overview of thermal MFC technology, along with a discussion of calibration methods and practice. The course emphasizes practical topics, such as temperature effects, line pressure effects, attitude sensitivity, control stability, gas correction, materials, contamination, and electrical considerations. Procedures for troubleshooting MFCs are demonstrated, along with various diagnostic tools and *in situ* verification techniques.

Who Should Attend?

Scientists, engineers, technicians, and others who work with systems relying on repeatable, verifiable gas flow rates.

Days: One

Instructor: Luke Hinkle, Educator, Falmouth High School, Falmouth, Massachusetts

Course Materials: Course Notes

Cost: $575

Partial Pressure Analysis

Course Objectives

- Learn what a residual gas analyzer (RGA) is and how one works.
- Know how to troubleshoot vacuum systems using an RGA.
- Learn how to interpret mass spectra with an RGA.
- Understand applying RGAs to process monitoring of sputter deposition systems.

Course Description

This course begins with the basics—a review of the elements, isotopes, molecules, and compounds. The magnetic sector and the quadrupole, ion formation, double ionization, and "cracking patterns" are discussed. RGA sensitivity and resolution are covered and compared to using a leak detector with the self-contained helium mass spectrometer.

The discussion of leak detectors will focus on application to the support of process equipment such as sputter deposition tools, including post pm fingerprinting, trouble-shooting, and process monitoring.

Who Should Attend?

Process engineers, equipment engineers, and maintenance technicians who are using or plan to use partial pressure analyzers in support of high-vacuum systems, especially those designed for thin-film etch and deposition.

Days: One)

Instructor: Stanley Goldfarb, Founder, Exxus

Course Materials: Course Notes and "Partial Pressure Analyzers and Analysis" from the AVS monograph series

Cost: $575

Total Pressure Gauging Techniques

Course Objectives

- Understand the concepts and physical basis of commercially available gauging.
- Gain an understanding of the limitations of vacuum gauging.
- Learn the advantages and disadvantages of different gauging methods.
- Be able to select gauging appropriate for the application.
- Learn proper use and operation of gauging.
- Learn to make better and more reliable pressure measurements.

Course Description

All vacuum systems use one or more of the many available gauging methods to either monitor system conditions or to ensure control during a process. The aim of this course is to provide a firm understanding of available vacuum gauging methods. This will allow users to select the gauging technique that best fits their needs and applications. Additionally, users will gain knowledge in the correct use and operation of each gauge type.

Gauge types covered include the capacitance manometer, spinning rotor gauge (SRG), thermocouple gauge, Pirani gauge, and hot and cold cathode ionization gauges. The discussion of each type covers principles, useful pressure range, correct use, precautions to obtain reliable and accurate measurements, and good and bad applications. Accuracy/repeatability information drawn from the literature will also be reviewed for each type of gauge. Using a combination of the gauge types discussed, pressures from atmosphere to 10^{-11} Torr (10^{-9} Pa) can be measured.

Who Should Attend?

Vacuum system designers and engineers and technicians involved with selecting, installing/setting up, operating, or maintaining vacuum pressure measurement equipment. Process and quality engineers working with processes that have critical pressure requirements will also benefit.

Days: One)

Instructor: Neil Peacock, Development Engineer for HPS Division, MKS Instruments, Inc.

Course Materials: Course Notes

Cost: $575

UHV Design and Practices

Course Objectives

- Understand the pump factors that limit ultimate pressure.
- Know the degassing methods that minimize the total outgassing rate.
- Learn how to measure total and partial pressures in ultrahigh vacuum (UHV).
- Learn the operating methods necessary to maintain UHV.

Course Description

Ultrahigh vacuum is a required environment for many research areas, such as surface science (which requires the use of electron, ion, and neutral spectroscopies), as well as for many technological areas, such as thin-film growth of electronic and optical materials. In this course, the techniques involved in the production, measurement, and operation of such pressure levels are discussed.

In addition to kinetic theory, system design elements—such as methods of pumping, materials selection, materials processing, outgassing considerations, system degassing, instrument degassing, surface effects, pressure-limiting factors, methods to shorten pumpdown time, and sample transfer systems—are reviewed. Special emphasis is given to total and partial pressure measurement within UHV systems. Various applications requiring an operational UHV environment are also discussed.

The course concludes with an open forum to exchange new ideas and techniques.

Who Should Attend?

Scientists, technicians, and others with a fundamental understanding of basic vacuum technology wishing to learn the techniques necessary to achieve UHV.

Days: One

Instructor: Ronald Outlaw, Research Professor, College of William and Mary

Course Materials: Course Notes and “The Physical Basis of Ultra-High Vacuum” by P.A. Redhead, J.P. Hobson, and E.Z. Konelson, 1993

Cost: $675

Vacuum Sealing and Joining Techniques

Course Objectives

- Learn about elastomers used in O-rings and their behavior.
- Know the design of O-ring grooves.
- Learn about metal seals and metal sealing concepts.
- Learn about assembly by welding.
- Learn about elementary brazing.

Course Description

This course covers, from a practical viewpoint, demountable and permanent joining techniques used in the assembly of vacuum equipment.

Considerable time is allotted to a discussion of elastomer seals, including material selection, material properties, and the design of O-ring grooves. The portion on metal seals covers the importance of stored energy, its location in a seal component, seal metals, and surface finishes. The portion on permanent joining considers TIG welding, the design of weld preps, and weld problem analysis.

Topics covered in less detail include brazing, diffusion bonding, and seals, including materials such as glass, ceramics, and epoxies.

Who Should Attend?

Technicians and engineers concerned with the assembly of vacuum systems. Attendees should have a good working knowledge of vacuum techniques.

Days: One

Instructor: Neil Peacock, Development Engineer for HPS Division, MKS Instruments, Inc.

Course Materials: Course Notes

Cost: $575

Vacuum System Design

Course Objectives

- Learn how to select materials and fabricate vessels and components.
- Learn how to maintain a proper in-chamber environment.
- Understand the calculations and steps for vacuum-pumping system design.
- Learn about the design and fabrication of vacuum systems.

Course Description

This course deals with the principal aspects of system design, including materials selection, fabrication techniques, pump selection, sizing pumps and vacuum piping to a chamber, pumpdown time, leak rate specification, and surface preparation procedures. Methods for determining ultimate pressures are also discussed.

The course demonstrates that establishing the vacuum environment is the primary criterion for designing, constructing, and operating a vacuum system. A wide range of vacuum environments is discussed, from rough to ultrahigh vacuum, with emphasis on achieving a well-defined degree of vacuum.

The course compares calculated results from both hand calculations and commercially available computer software (not included with course material).

Who Should Attend?

Those familiar with the fundamentals of vacuum technology who are responsible for vacuum system design or fabrication and control of the in-chamber environment.

Days: One

Instructor: Howard Patton, Project Engineer, Lawrence Livermore National Laboratory

Course Materials: Course Notes and “Vacuum Technology” by Roth, 1990

Cost: $675

Vacuum Vessel Engineering

Course Objectives

- Identify your vessel performance requirements.
- Review standard and unconventional structural and mechanical design solutions.
- Understand the effects of vessel design on vacuum system pumpdown and ultimate pressure.
- Learn practical acquisition strategies, including vendor qualification, contract options, Statements of Work, and specifications.
- Add up-to-date vacuum-vessel resources to your toolbox.

Course Description

Vacuum vessels are basic infrastructure workhorses in a variety of applications and industries, including aerospace, microelectronics, lasers, and high-energy physics. A vacuum vessel can be a large capital investment that has a major impact on the cost, schedule, and technical performance of a system. Success in designing a vessel to meet aggressive requirements relies on a careful assessment of present and future operations and a graded approach to managing risk. Early decisions can have enormous leverage on the initial acquisition and the operations of the facility that it serves.

This course will review practical issues to consider when deploying vacuum vessels from bench scale to 100+ tons. The use and limitations of national standards, such as the ASME Boiler and Pressure Vessel code, will be presented. Sample calculations are presented for spherical, cylindrical, and rectangular shells. Numerous examples of real vessel designs are shown. Additional topics include fabrication, cleaning, and installation; safety margins; weld details; pressure relief; windows; and seal designs. The course offers guidance for choosing an appropriate acquisition strategy, including a review of specification options and when to use them. Resources provided include codes and standards references, sample procedures and forms, commercial components, vendor contacts, government agencies, and web links.

Attendees are encouraged to bring case studies from their workplace. Time will be reserved to discuss vacuum vessel issues of specific interest to course participants.

Who Should Attend?

The course will be helpful to project engineers, designers, or scientists responsible for specifying, designing, or procuring vacuum vessels.

Days: One

Instructor: Joel Bowers, Project Engineer, Lawrence Livermore National Laboratory

Course Materials: Course Notes

Cost: $575

Controlling Contamination in Vacuum Systems

Course Objectives

- Understand the three phases of vacuum chamber contamination: gases, films, and particulates.
- Learn the origins of vacuum chamber contaminants and methods for controlling or eliminating them.

Course Description

Various forms of contamination in a vacuum system affect the environment in which vacuum processes are conducted. Understanding and controlling these contaminants are important steps in producing the desired chamber conditions or products.

This course addresses three phases of in-chamber contamination: gases, films, and particulates. The origin of these contaminants and methods of eliminating them are discussed. The emphasis is on defining the level of control required and identifying the appropriate procedures necessary to establish that control. There will also be discussion on the environment that must be achieved in the chamber and how it is related to the vacuum system operating and maintenance procedures and the environment outside the chamber.

This course is presented in a semi-workshop, interactive format.

Who Should Attend?

Those responsible for the production of contaminant-free products and for the design, operation, and maintenance of vacuum systems producing these products. The course will also interest suppliers of components and products that either control or produce contamination in a vacuum environment.

Days: One

Instructor: Howard Patton, Project Engineer, Lawrence Livermore National Laboratory

Course Materials: Course Notes

Cost: $575

Cryopump Technology

Course Objectives

- Learn the principles of operation and maintenance of cryogenic vacuum pumps.
- Learn ways to optimize the use of cryopumps for a variety of vacuum processes.
- Understand the differences in performance of systems using cryopumps and those using diffusion, turbomolecular, or other types of vacuum pumps.

Course Description

Starting with a review of basic vacuum concepts, the operation of cryogenic pumps using closed-loop refrigeration systems will be covered in detail. The operation of helium refrigerator systems and maintenance requirements will be discussed. The creation of vacuum through gas condensation and adsorption on cryogenic surfaces will be explained, especially as it relates to processes such as sputter and evaporative deposition, ion implantation, ultrahigh vacuum research, and other applications. Part of this discussion will focus on gas handling and safety. The need for cryopump regeneration and various methods for accomplishing it are covered. Operation of multiple pumps on networked systems will be a subject of discussion.

In a discussion of applications, methods for selecting appropriate sizes of pumps, calculation of pump down times and base pressure, gas throughput, crossover from rough vacuum, and estimation of time between regenerations will be addressed. Specific applications of attendees will be covered as examples.

Who Should Attend?

This course is intended for process and equipment engineers, system operators, maintenance personnel, and others involved in the design, use, or servicing of cryopumped vacuum systems.

Days: One

Instructor: Gary Ash, Ph.D., President, Castle Brook Corporation

Course Materials: Course Notes and a reprint of the chapter "Cryogenic Vacuum Pumps" from the *Handbook of Vacuum Science and Technology*.

Cost: $575

Operation and Maintenance of Vacuum Pumping Systems

Course Objectives

- Learn to operate vacuum pumping systems efficiently with minimum downtime.
- Learn about preventive maintenance on pumps and pumping systems.
- Understand leak detection in operating vacuum systems.
- Learn to troubleshoot and test the performance of vacuum pumping systems.

Course Description

The major thrust of this course is to show how vacuum pumping systems can be operated most effectively to achieve maximum performance while holding downtime for maintenance to a minimum. Typical procedures used for systems that employ oil-sealed rotary, Roots, vapor diffusion, turbomolecular, sputter-ion, and cryogenic pumps are described. There are also discussions of possible variations in typical procedures that may be used in special cases.

Troubleshooting and performance-testing techniques are presented as well as methods of leak detection that are most effective for operating vacuum systems.

Who Should Attend?

Those who want to learn how to properly operate vacuum systems themselves or are responsible for people who operate them. Knowledge of operating limits and general characteristics of pumps, gauges, and other auxiliary equipment used in vacuum systems is needed.

Days: Two

Instructor: Paul Holloway, Professor of Materials Science and Engineering, University of Florida and Director of MICROFABRITECH [or Michael Benapfl, Engineering Technical Associate, Mechanical Engineering Department, LLNL; Howard Patton, Project Engineer, Lawrence Livermore National Laboratory; Jack Singleton, Consultant}

Course Materials: Course Notes and "A User's Guide to Vacuum Technology" by John F. O'Hanlon, 2003

Cost: $950

Process Specific Pumping Requirements and Design

Course Objectives

- Become competent in selecting pumps and pump systems used in semiconductor etching and deposition processes.
- Understand practical pumping requirements for specific processes.
- Know how to select foreline and exhaust components for maximum uptime and reduced maintenance.
- Know how to design an optimal pumping system for various processes.

Course Description

Vacuum processes frequently used in semiconductor device fabrication require specific pumping techniques, foreline components, pressure control, and maintenance regiments. This course provides a working knowledge to design a process specific pumping system. The general process categories emphasized in this course include epitaxial deposition (Epi), low-pressure chemical vapor deposition (LPCVD), plasma deposition, and plasma etching. The participants in this course will review the basic pumping objectives and challenges for each of these processes along with the strategies commonly implemented to achieve them. The participants will engage in practice examples of realistic scenarios to reinforce a ?how-to? understanding of pumping system design.

Significant portion of the course will focus on practical design and maintenance issues including:

1) An overview of available high vacuum pump technologies and their selection criteria for each process.

2) Suitable forepump technologies and sizing considerations for each process.

3) Design and selection of foreline and exhaust components such as valves, line heaters, filters, scrubbers, etc.

It is not the intent of this course to address safety issues or hazards.

Who Should Attend?

Engineers and technical personnel engaged in semiconductor system design, manufacturing improvement, and development.

Days: One

Instructor: Luke Hinkle, Consultant, Complex2Simple, Inc.

Course Materials: Course Notes

Cost: $575

Vacuum Leak Detection

Course Objectives

- Learn how to analyze vacuum systems and other closed systems for leaks during operation.
- Learn to use mass spectrometer leak detectors and residual gas analyzers to locate and measure leaks.
- Know the most effective ways to connect a mass spectrometer leak detector or residual gas analyzer to a vacuum system.

Course Description

This course is an introduction to the technology and practice of leak detection. It includes a discussion of the types of leaks that are to be expected in vacuum systems and how they affect the leakage rate. The principles of leak detection and the methods of putting these principles into practice are described. Practical techniques for detecting and locating leaks are provided, with special attention to making the most effective use of the mass spectrometer leak detector.

Also covered in detail are the various ways in which mass spectrometer leak detectors can be connected to systems and their effects on obtaining satisfactory results from the test procedures. A method of verifying the effectiveness of the leak-detection system before starting a test is described. The use of a residual gas analyzer (RGA), a partial pressure gauge, in detecting leaks and analyzing vacuum system difficulties is also discussed.

Who Should Attend?

Those involved in leak detection of vacuum and other closed systems and those who need to evaluate whether a given leak rate is acceptable or unacceptable. A working knowledge of vacuum equipment and instrumentation and familiarity with the basic equations for throughput, pumping speed, and conductance are helpful.

Days: One

Instructor: Michael Benapfl, Engineering Technical Associate, Mechanical Engineering Department, LLNL

Course Materials: Course Notes

Cost: $575

Vacuum Pumps

Course Objectives

- Learn about the types of commercially available vacuum pumps and their performance specifications.
- Learn how each pump works and what maintenance is required.
- Understand how to select a pump or pumps for a given application.

Course Description

This course provides a comprehensive description of all vacuum pumps currently used in industry, research and development. Roughing, high and ultrahigh vacuum pumps will be described. The two primary pumping mechanisms, throughput and capture, will be explained. Criteria for selecting pumps will be examined and performance specifications illustrated to assist the user in designing and operating pumping systems. A complete listing of commercially available pumps will be provided.

Who Should Attend?

Technicians, engineers, sales/marketing people, and scientists who desire a comprehensive, one day course on vacuum pumps.

Days: One

Instructor: Woody Weed, Technical Staff Member,
Sandia National Laboratories

Course Materials: Course Notes

Cost: $575

A Comprehensive Course on Surface Analysis: AES, SIMS, XPS, and Depth Profiling

Course Objectives

- Learn about the commonly used surface analysis techniques and depth profiling methods, including AES, XPS/ESCA, and SIMS.
- Know the advantages and limitations of each surface analysis technique.
- Know the advantages and limitations of destructive and nondestructive depth profiling.
- Learn about the latest developments in instrumentation.
- Learn the qualitative and quantitative analysis techniques, data interpretation, and potential artifacts with each technique

Course Description

This course is a combination of four one-day classes on AES, XPS, SIMS, and Depth Profiling, which are also being offered during this program. The combination is being offered at a significantly discounted rate compared to taking all four courses separately ($1,495 compared to $2,300). The course will provide attendees with a comprehensive treatment of the most commonly used surface analysis methods in industry and research.

The course emphasis will be on providing an in-depth understanding of the physical principles of each technique with insights into instrumentation, qualitative and quantitative analysis, and data interpretation. Examples of applications will be used to demonstrate the strengths of each technique. Additionally, important information about artifacts and the limitations of each method will be discussed.

Who Should Attend?

Scientists, engineers, and others who wish to obtain a comprehensive understanding of the most commonly used surface analysis techniques and depth profiling methods.

Days: Four

Instructors: Fred Stevie, Senior Researcher, North Carolina State University

Course Materials: Course Notes

Cost: $1,495

A Comprehensive Course on Surface Analysis: AES, SIMS and XPS/ESCA

Course Objectives

- Learn about the commonly used surface analysis techniques AES, SIMS, and XPS/ESCA.
- Know the advantages and limitations of each surface analysis technique.
- Know the various ways to do depth profiling.
- Learn about the latest developments in instrumentation.
- Learn the qualitative and quantitative analysis techniques, data interpretation, and potential artifacts with each technique.

Course Description

This course is a combination of the two 1-day classes on AES, and SIMS, and the 2-day class on XPS/ESCA which are also being offered separately during this program. The combination is being offered at a significantly discounted rate compared to taking all of these courses separately ($1,495 compared to $2,000). The course will provide attendees with a comprehensive treatment of the most commonly used surface analysis methods in industry and research.

The course emphasis will be on providing a detailed understanding of the physical principles of each technique with insights into instrumentation, qualitative and quantitative analysis, and data interpretation. Examples of applications will be used to demonstrate the strengths of each technique. Additionally, important information about artifacts and the limitations of each method will be discussed.

Days: Four

Instructors: Fred Stevie, Senior Researcher, North Carolina State University

Course Materials: Course Notes

Cost: $1,495

Secondary Ion Mass Spectrometry

Course Objectives

- Understand the principles of secondary ion mass spectrometry (SIMS).
- Become familiar with the different types of instrumentation.
- Learn how qualitative and quantitative analysis can be achieved despite mass interferences and artifacts.
- Know how SIMS can be applied to many different fields.

Course Description

A brief history of SIMS is followed by a comparison of SIMS with other commonly used analytical techniques (AES, XPS, RBS, and TEM).

The SIMS process is examined. Sputtering, sputtering yield, secondary ion yield, secondary ion energy distribution, and information depth are discussed. Static sputtering versus dynamic sputtering is addressed.

The instrumentation commonly used is discussed. The ion source, ion optics, mass analyzer, detector, and vacuum system are described with emphasis on the advantages and disadvantages of various approaches to mass separation (magnetic sector, quadrupole, and time-of-flight analyzers).

Analysis considerations include choice of primary ion species and energy, primary beam angle of incidence, secondary ion species monitored, mass resolution, and gating required to achieve the desired sensitivity, depth resolution, and lateral resolution.

The methods of converting qualitative SIMS data into quantitative results are discussed. Procedures for obtaining quantitative standards are presented. The impact of matrix effects and artifacts on the quantitative process is described.

Examples of the various types of SIMS data (mass spectra, ion images, depth profiles, and line scans) are given. Applications will be discussed for semiconductors, insulators, metals, minerals, and polymers.

Who Should Attend?

Scientists, engineers, technicians, and others who desire a practical, current understanding of the acquisition and interpretation of SIMS data.

Days: One

Instructor: Fred Stevie, Senior Researcher, North Carolina State University

Course Materials: Course Notes

Cost: $575

Atomic Force and Scanning Tunneling Microscopy

Course Objectives

- Understand the basic principles of scanning tunneling and atomic force microscopy (STM and AFM).
- Know the instrumentation required for STM and AFM, including hardware, software, samples, and tips.
- Learn an overview of STM and AFM applications with practical operational details.
- Be introduced to the growing number of STM-related scanning probe techniques.

Course Description

STM evolved rapidly in the 1980s from a unique physics experiment to become a widely applied and highly developed technique for the 1990s.

This course begins with a brief history of the events and technologies that led to the development of STM and AFM. All basic aspects of STM and AFM instrumentation are addressed, including tunneling, tip fabrication, piezoelectric scanner systems, and electronics (feedback control systems, data acquisition, and imaging systems).

The emphasis is on the interaction of the system components of a working imaging instrument. Applications of imaging—ranging from atomic-resolution surface structure determination to large-area, three-dimensional mapping of manufactured surfaces—are presented with an emphasis on the practical and instrumentation aspects of various imaging situations. Practical techniques, including tip selection, scanning speed, and current and voltage settings, are addressed for a variety of applications.

Related techniques, such as tunneling spectroscopy and other near-field scanned probes, are also covered.

Who Should Attend?

Scientists, engineers, technicians, and others who want a practical and applications-oriented introduction to STM and AFM and a brief introduction to related techniques.

Days: One

Instructor: Phillip Russell, Professor of Materials Science and Engineering and Director of the Analytical Instrumentation Facility, North Carolina State University

Course Materials: Course Notes

Cost: $575

Focused Ion Beams: Principles and Applications

Course Objectives

- Become familiar with the principles of the generation and control of focused ion beams (FIBs).
- Know the capabilities of current instrumentation.
- Learn the varied applications of FIB techniques in manufacturing and research.

Course Description

This one-day course begins with a discussion of the evolution and principles of operation of the liquid metal ion source (LMIS). The ion optics and features of the ion column are then presented, and then the way these components are incorporated into a FIB system is shown, along with a discussion of current FIB instrumentation.

The interaction of ions with matter is presented to the extent needed to understand the sputtering process. Sputtering yield as a function of sputtering ion parameters is investigated. Explanation is made of the ion beam assisted chemical vapor deposition (CVD) process and the gas source method that is used to improve etch rate.

The ability to sputter and deposit at less than 10 nm resolution makes possible a wide range of FIB applications. Applications discussed include the following:

- Imaging—grain size measurements.
- Ion implantation—few nm lateral resolution.
- Mask repair—modification and defect removal.
- Micro-machining—hard disk write heads, micro-mechanical systems (MEMS).
- Integrated circuit (IC) modification—cut-and-paste operations.
- Scanning electron microscopy (SEM) sample preparation—failure analysis techniques.
- Transmission electron microscopy (TEM) sample preparation—site-specific capability.
- Secondary ion mass spectrometry (SIMS)—description of SIMS process, lateral resolution, sensitivity.

Who Should Attend?

Scientists, engineers, analysts, and managers who want to understand the capabilities of FIB.

Days: One

Instructor: Jon Orloff, Professor, University of Maryland, and Fred Stevie, Senior Researcher, North Carolina State University

Course Materials: Course Notes

Cost: $575

High Resolution X-ray Reflection and Diffraction Methods for Thin Film Characterization

Course Objectives

- Define key concepts in X-ray scattering theory as they apply to the analysis of thin film materials.
- Learn about high resolution X-ray analytical techniques.
- Understand specific details regarding the application of high resolution X-ray diffractometry and X-ray reflectometry methods to problems that are of interest for thin film analysis.
- Examine the strengths and limitations of high resolution methods.

Course Description

X-ray methods with high angular resolution are becoming increasingly important for the physical characterization of thin film materials and structures. Vendors now market state-of-the-art X-ray tools (both hardware and software) for the routine analysis of parameters such as layer thickness, chemical composition, strain relaxation, and interfacial roughness. The recent integration of X-ray diffraction and reflectivity systems into fab-compatible process metrology tools suggests that the importance of these techniques will only increase with time.

Unfortunately, the users of X-ray analysis instruments (or the supervisors who are responsible for their use) often have had relatively little introduction to the theory that underpins their operation; they may not have an appreciation of quantity of information that can be gained from X-ray analyses or the deleterious effects that limitations in hardware, software, the sample, and the experimental technique can have.

In this short course, will discuss some basic principles of high resolution X-ray methods (notably double axis X-ray diffractometry and high resolution X-ray reflectometry) and will describe the capabilities and limitations of these tools for thin film materials analysis. Extensive reference will be made to "real-life" problems involving bulk and thin-film structures (ranging from amorphous dielectrics and polycrystalline metals to highly perfect epitaxial single crystal materials) to show both the utility and the shortcomings of high resolution X-ray methods.

Who Should Attend?

Scientists, engineers, and technicians who use (or wish to use) high resolution X-ray methods for characterizing thin film materials.

Days: One

Instructor: Richard Matyi, Professor, College of Nanoscale Science and Engineering and Senior Scientist, Albany NanoTech, SUNY – University at Albany

Course Materials: Course Notes

Cost: $575

Materials and Surface Microcharacterization and Analysis

Course Objectives

- Learn about a large number of widely used techniques for the practical characterization of surfaces, interfaces, and thin films (the emphasis is on semiconductor and storage technologies).
- Understand what information is required (composition, phase identification, structure, topography, etc.), over what physical region the information is needed (lateral and depth distances, small samples, big samples), and for what types of materials a technique is applicable.

Course Description

This course provides a working knowledge of current practical capabilities of characterization techniques without intending to turn attendees into analytical experts. The emphasis is on use for modern technological materials, particularly surface and near-surface analysis.

The techniques are grouped by either user information or instrumentation (e.g., imaging techniques, which include light microscopy, SEM, STM, and TEM). A simple description of the principle is given along with specific examples of practical use, followed by a comparison of the importance of each method, the information content, advantages and disadvantages, cost, availability, etc. A significant portion of time will be devoted to the four major techniques for surface and near-surface characterization: XPS (or ESCA), Auger, SIMS, and ion scattering (RBS and other methods). Though many of the techniques are surface sensitive, a number of traditionally bulk methods are included (e.g., XRD, neutron diffraction, and IR) and, since there is often very little material present at all, many trace microanalytical methods are included.

The course provides enough comparative information for choices to be made when faced with practical materials characterization problems. It is not a "hands-on" training in the operation of any particular technique.

Who Should Attend?

Process engineers, scientists, and students who are primarily materials users or managers who have responsibilities in these areas. Anyone who needs a practical working knowledge of the characterization of materials and particularly the surfaces of materials.

Days: Two

Instructor: C.R. Brundle, C.R. Brundle & Associates

Course Materials: Course Notes and "Encyclopedia of Materials Characterization," Ed. C.R. Brundle, C.A. Evans, and S. Wilson, 1992

Cost: $950

Scanning Electron Microscopy and X-ray Microanalysis

Course Objectives

- Understand the basics of electron guns, optics, and imaging concepts.
- Learn about the basic modes of secondary and backscattered electron imaging.
- Be introduced to the concepts of resolution, contrast, charging, etc.
- Learn about both qualitative and quantitative analysis.

Course Description

This course provides an overview of conventional and field emission scanning electron microscopy (SEM) and SEM-based x-ray microanalysis for engineers and physical scientists.

Starting with the basics of electron guns and optics, the course develops imaging concepts. Examination of the electron beam/sample interactions provides the tools to understanding the basic modes of secondary and backscattered electron imaging and issues such as resolution, contrast, charging, etc. Detectors for electrons as well as x-ray (EDS and WDS) are reviewed. Aspects of qualitative and quantitative analysis are then developed.

The course concludes with case studies, general guidelines, and practical aspects of SEM imaging and analysis.

Who Should Attend?

Technicians, process engineers, managers, and others who wish to gain a basic understanding of SEM microanalysis.

Days: One

Instructor: Phillip Russell, Professor of Materials Science and Engineering and Director of the Analytical Instrumentation Facility, North Carolina State University

Course Materials: Course Notes

Cost: $575

X-Ray Photoelectron Spectroscopy (XPS): The Basics and Advanced Approaches and Applications

Course Objectives:

The Basics

- Learn the physical principles of XPS (also known as ESCA, Electron Spectroscopy for Chemical Analysis)
- Understand the principles of its use for identification, qualitative, and quantitative analysis of the elemental and chemical species present in a sample
- Understand the surface sensitivity and microanalytical aspects of the technique and what types of materials and problems can be tackled by XPS

Advanced Approaches and Applications

- Learn about the more advanced aspects of the spectroscopy that are useful for analysis purposes.
- Understand Angle-Resolved XPS and other related approaches for obtaining depth resolved information
- Learn about the advanced applications being tackled by XPS, using case histories as examples
- Understand where XPS fits in compared to other analytical techniques

Course Description:

The first day covers all the basics needed to understand how XPS is used as a method to determine what atoms are present, and in what chemical state and relative proportions, for solid samples. The reasons for, and the extent of, its surface sensitivity, plus general sensitivity limits, and spatial resolution issues, are discussed. Ways to obtain depth profiles are introduced. The various types of instrumentation commercially available are introduced and compared. Examples of use for many types of material (bio to chemical industry to semiconductors) and different types of problems (eg surface contamination, corrosion, catalysis, failure analysis, metrology) are used to illustrate strengths and weaknesses.

The optional second day covers the usage of more complex aspects of the spectroscopy for chemical state determination, with illustrative examples. Quantification of surface analysis is treated in detail. Angle- Resolved XPS and related approaches to non-destructive depth profiling for ultra-thin films are fully covered, including Photoelectron Diffraction for structural information. Current industry usage of XPS and Angle Resolved XPS, for characterization and metrology of ultra-thin films are reviewed. Finally XPS is put in context with other surface sensitive and microanalytical techniques in general use to help the student decide which approach is suitable for which problem.

Who Should Attend?

Scientists, engineers, students, and technicians who would like a detailed understanding of the use of XPS/ESCA for surface analysis.

Days: Two Days

Instructor: C.R. Brundle, C.R. Brundle & Associates

Course Materials: Course Notes

Cost: $575 (Day One); $850 (Two days)

Full Wafer Particle and Defect Detection, Review, and Characterization

Course Objectives

- Learn how full wafer particle and defect detection, review, and characterization are done in the semiconductor processing and equipment industry.
- Understand the different techniques and how they relate to each other in the defect analysis approach (light scattering, optical imaging, SEM/EDX-based approaches, more advanced back-up approaches).
- Understand the differences between Survey, Review, and Characterization leading to a root cause and elimination of the defect problem, and where each of these fits in the industry.

Course Description

This course provides a working knowledge of the techniques and methodologies for defect metrology and characterization on full wafers (up to 300mm) in use in the semiconductor processing and equipment industries. The objective is to eliminate the particle/defect problem. This requires some combination of defect survey (detection), review, and characterization leading to a root cause. Definition of these terms is given, and the differences in the way individual tool defect issues and overall yield issues are approached are explained. The relative roles of optical imaging, light scattering, e-beam-based approaches (e.g., SEM/EDX) are discussed, together with their limitations and advantages. The differences between monitor/blanket wafer analysis and patterned wafer analysis, and where they fit in the industry are reviewed. Case histories are presented illustrating the connection between the results of defect analysis and identification of the hardware or process-related defect culprits. Examples are mostly concerned with blanket wafer situations. Current drives toward automatic defect review and automatic defect classification are presented, with a discussion of the situations when this is likely to be useful and when it is not. Advanced full-wafer techniques that are becoming available are briefly discussed (Auger, dual beam FIB, WDX).

Who Should Attend

Process and defect engineers, hardware designers, analytical engineers, yield engineers, failure analysis/materials characterization engineers with an interest in or responsibility for particle or defect problems.

Days: One

Instructor: C.R. Brundle, C.R. Brundle & Associates

Course Materials: Course Notes

Cost: $575

Fundamentals of Semiconductor Characterization: Electrical and Optical Techniques

Course Objectives

- Understand junction formation and capacitance.
- Learn to measure charge density in the depletion region.
- Understand the free-carrier Hall effect, deep levels, and the Shockley-Read-Hall model.
- Learn about recombination physics, minority-carrier lifetime measurement, and minority-carrier diffusion length measurements.
- Learn defect identification by photoluminescence spectroscopy.

Course Description

The measurement of semiconductor majority and minority carrier parameters is important in evaluating materials and making useful devices. Operating the measurement equipment is relatively simple for measurements of this type. The application of the appropriate physical models to the raw data is crucial to obtaining the real parameters. For example, what quantity does one really measure in a capacitance-voltage (C-V) measurement?

This course develops the device models needed to understand measurements and emphasizes measurement theory based on physical models of diagnostic devices. Techniques and hardware are described. The course begins with a brief review of elementary semiconductor device physics and junction formation. Measurement techniques include:

- Capacitance-voltage measurements.
- Resistivity and the Hall effect.
- Deep-level transient spectroscopy.
- Measurement of minority-carrier lifetime.
- Photoluminescence analysis of semiconductors.
- Measurement of diffusion length with surface photovoltage, electron beam, and laser-beam-induced currents (EBIC and LBIC).

Some in-class problem solving is included.

Who Should Attend?

Scientists, engineers, and technicians who use electrical and optical measurements for characterizing semiconducting materials. Some familiarity with elementary calculus and solid-state physics is recommended. (Please bring a calculator.)

Days: One

Instructor: Richard Ahrenkiel, Principal Scientist/Group Leader, NREL, and Adjunct Professor, University of Colorado at Boulder and Colorado School of Mines

Course Materials: Course Notes

Cost: $575

Surface Analysis, Interface, and Thin Film Analysis: The Major Methods

Course Objectives

- Learn the fundamentals and practical aspects of using the major surface, interface, and thin film analysis spectroscopic techniques.
- Understand and be able to interpret the data provided by each technique.
- Know the comparative usage and limitations of each technique.

Course Description

This course is for those wanting a good understanding of the practical usage of the major spectroscopic analytical methods used for determining atomic and chemical composition and, in some cases, structural information at the surfaces and interfaces of materials, and through thin films.

The major techniques covered are x-ray photoelectron spectroscopy (XPS, or electron spectroscopy for chemical analysis [ESCA]), Auger electron spectroscopy (AES, including scanning Auger microscopy [SAM]), secondary ion mass spectroscopy (SIMS), and Rutherford backscattering spectroscopy (RBS). The principles of each technique are given, followed by specific examples of practical applications (particularly to semiconductor, data storage, and thin-film material situations).

A comparison is made of the information content provided; the differences in surface sensitivity, spatial resolution, etc.; and the cost and ease of obtaining the information. If time allows, a few of the lesser used techniques will also be reviewed. The aim is to provide enough knowledge to be able to choose and use the techniques to answer surface, interface, and thin film analytical questions. It is not intended, however, to be an instrument operation training course.

Who Should Attend?

Anyone with a need to understand, in some depth, what information these analytical techniques can provide and how to get it. This would include scientists and students working in surface-related fields, process engineers and managers with responsibilities for surface- or interface-related technologies, and technicians working with these techniques.

Days: One

Instructor: C.R. Brundle, C.R. Brundle & Associates

Course Materials: Course Notes and "Encyclopedia of Materials Characterization," ed. C.R. Brundle, C.A. Evans, and S. Wilson, 1992

Cost: $675

Surface Characterization of Biomaterials

Course Objectives

- Understand the biological significance of surface analysis data.
- Learn what surface analysis techniques are available.
- Understand the information each technique provides.
- Learn the major techniques used.
- Learn how to interpret surface analysis data.
- Learn how to identify high-quality data.

Course Description

This one-day course on biomedical surface analysis uses examples from biomedical research and development studies to introduce and explain the surface analysis techniques. Attendees will learn the capabilities of surface analysis methods and how to review data from surface analysis laboratories. The course will address the following topics:

- Introduction to Surface Analysis
- Electron Spectroscopy for Chemical Analysis
- Static Secondary Ion Mass Spectrometry
- Multivariate Data Analysis
- Scanning Probe Microscopy
- Surface Plasmon Resonance
- Near Edge X-ray Absorption Fine Structure
- Contact Angle Measurements
- Surface Modification
- Biomedical Applications of Surface Analysis

Who Should Attend?

This course is for industrial and academic biomedical researchers who want to be introduced to the surface analysis techniques available for characterizing biomaterials and biomedical devices.

Days: One

Instructor: David Castner, Director, NESAC/BIO, Depts. of Chemical Engineering and Bioengineering, University of Washington

Course Materials: Course Notes

Cost: $575

Thin and Ultra-thin Film Analysis, Characterization, and Metrology for the Wafer Processing Industry

Course Objectives

- Become familiar with the materials being introduced, and their applications, as films get thinner.
- Understand which parameters need controlling and the different requirements for lab analysis/characterization and fab metrology.
- Learn the basics of the commercially available techniques for analysis/metrology of very thin films. Understand their limitations and learn about emerging commercially available tools for analysis of ultra-thin films.

Course Description

This course provides a working knowledge of the commercially available techniques used in the semiconductor industry for analyzing very thin to ultra-thin films (elemental and chemical composition, composition variation with depth, dopant distribution, surface and interface roughness, crystallinity/ amorphicity/ grain size, surface and interface contamination and reaction, surface and interface roughness, film hardness).

On the fab metrology side (meaning rapid, robust determination to a known precision on wafers, without expert intervention), the most common specification is thickness. Composition and electrical properties, such as junction depth for implant and equivalent oxide thickness (EOT) for dielectrics, may also be under spec. All these are discussed.

Films are getting thinner at each technology node. Currently gate oxide thickness is 20 to 30A in production and 12A in development. Back end films, are 100's A in production and sub 50A in development. Both analysis and precision in metrology, get difficult as the films get thinner. At the same time the artifacts of surface and interface reaction/contamination/roughness become more important. Many of the techniques/tools in standard use for analysis/metrology are running out of steam and new ones are being developed and introduced.

The course will include discussion on ellipsometry, XRR, XRF (and combination of these in commercial metrology tools), acoustic wave methods (such as the Rudolph Scientific MetaPulse tool), AFM, XPS (both standard and Angle Resolved), Low Energy X-Ray Emission (LEXES), electron microscopy cross-sectional methods, SIMS, and some non-contact electrical methods. Discussion will be largely limited to what is commercially available for semiconductor material support labs (where "engineering mode" usage provides more detailed characterization) and/or metrology in the fab in "operator mode."

Who Should Attend

Process/defect engineers, yield engineers, analytical engineers, failure analysis/material engineers, anyone with responsibility in film development and integration.

Days: One

Instructor: C.R. Brundle, C.R. Brundle & Associates

Course Materials: Course Notes

Cost: $575

Hard Coatings by PVD Methods

Course Objectives

- Learn the different hard-coating processes.
- Understand plasma processing fundamentals.
- Learn about hard-coating systems.
- Learn about characterization and testing of hard coatings.

Course Description

Today, hard coatings, such as titanium nitride, are produced by several different plasma-assisted PVD processes. The common link between all of the successful PVD hard-coating processes is the use of plasma-assisted deposition, which ensures a hard, fully dense, well-bonded coating.

This course reviews the fundamentals of the different PVD processes and describes the similarities and differences among them. The coatings produced by the different processes are discussed, and particular attention is given to the methods for coating characterization. The specific topics covered are as follows:

- Plasma process fundamentals.
- Advantages of PVD techniques.
- Evaporative and sputtering techniques.
- Commercial hard-coating systems.
- Process control.
- Potential process problems.
- Selection of coatings.
- New coatings such as (Ti, Al)N, diamond, and diamond-like coatings.
- Characterization and testing of hard coatings.
- Applications of hard coatings.

Who Should Attend?

Scientists, technicians, and technical managers who want to understand hard coatings: what they are, how they are produced, how they are characterized, and what their applications are.

Days: Two

Instructor: William Sproul, Consultant, Reactive Sputtering, Inc., and Allan Matthews, Director of the Research Center in Surface Engineering, Hull University, UK

Course Materials: Course Notes

Cost: $850 or $575 for one day

Low k and Other Interlevel Dielectrics

Course Objectives

- Learn about the impact of low k materials on IC performance.
- Find out about the alternate dielectric materials, their properties, and advantages.
- Understand the relationship between materials properties, deposition techniques and process integration issues.
- Learn the vendors and their products.

Course Description

A brief introduction of the trends in scaling of VLSI and ULSI circuits and the impact on interconnect performance and density will be given in order to relate the course contents to past and future trends in interconnect development and the Semiconductor Industry Association (SIA) technology roadmap. This will be followed by a discussion of new trends in interconnect technologies with copper and low dielectric constant material. The main part of the course will be devoted to thin film dielectrics used in multilevel metallization schemes. Both low dielectric constant organic polymers and inorganic dielectric materials will be reviewed. Materials properties and deposition and etching techniques will be presented. Materials compatibility, especially relative to aluminum and copper metallizations, and low temperature processing will be discussed. Processing technologies to produce high-density multilayered interconnect structures will be discussed. Planarization of dielectric materials using etch-back, damascene structures and chemical mechanical polishing will be reviewed. The interface between dielectrics and barrier layers in relation to adhesion and film properties will be described.

Who Should Attend

This course is intended for scientist, engineers, technicians, and managers who will be involved with or impacted by the transition to alternate dielectric materials in multilevel metallization schemes in advanced IC fabrication. The course will provide the basics for understanding the materials and process integration issues for low k materials as well the trends in the technology.

Days: One

Instructor: Gary McGuire, President, International Technology Center

Course Materials: Course Notes

Cost: $575

Thin Film Nucleation, Growth, and Microstructure Evolution

Course Objectives

- Understand the primary experimental variables and surface reaction paths controlling nucleation/growth kinetics and microstructural evolution during vapor-phase deposition.
- Develop an appreciation of the advantages/disadvantages of competing growth techniques.
- Learn how to better design film growth processes.

Course Description

Thin-film technology is pervasive in many applications, including microelectronics, optics, magnetics, hard and corrosion-resistant coatings, micromechanics, etc. Progress in each of these areas depends on the ability to selectively and controllably deposit thin films (thicknesses ranging from tens of angstroms to micrometers) with specified physical properties. This, in turn, requires control—often at the atomic level—of film microstructure and microchemistry.

Essential fundamental aspects, as well as the technology, of thin-film nucleation and growth from the vapor phase (evaporation, MBE, sputtering, and CVD) are discussed in detail and highlighted with "real" examples. The course begins with an introduction on substrate surfaces: structure, reconstruction, and adsorption/desorption kinetics. Nucleation processes are treated in detail using insights obtained from both *in situ* (RHEED, LEED, STM, AES, EELS, etc.) and post-deposition (TEM and AFM) analyses. The primary modes of nucleation include 2D (step flow, layer-by-layer, and 2D multilayer), 3D, and Stranski-Krastanov. The fundamental limits of epitaxy will be discussed.

Experimental results and simulations will be used to illustrate processes controlling 3D nucleation kinetics, island coalescence, clustering, secondary nucleation, column formation, preferred orientation, and microstructure evolution. The effects of low-energy ion-irradiation during deposition, as used in sputtering and plasma CVD, will be discussed with examples.

Who Should Attend?

Scientists and engineers involved in deposition characterization or manufacturing/marketing of deposition equipment.

Days: One

Instructor: Joe Greene, D.B. Willett Professor of Materials Science & Physics, and Head of Electronics Materials Division, University of Illinois

Course Materials: Course Notes and extensive reference lists

Cost: $575

Transparent Conducting Oxides: Their Science, Fabrication and Characterization

Course Objectives

- Understand the physics and chemistry of transparent conducting oxides (TCOs).
- Learn about some of the methods for fabrication of TCOs.
- Learn about the techniques used to characterize TCOs.

Course Description

TCOs play important roles in many large- and small-scale applications, some of them passive (e.g., selective window coatings in architecture) and others active (e.g., solar cells and flat-panel displays). They are important to scientists and engineers designing, fabricating, and using such devices.

Very few materials both high optical transmittance and electrical conductivity but these phenomena can be explained for TCOs using elementary physics and chemistry. This understanding of the fundamental science of TCOs will help professional scientists and engineers appreciate the key factors to be improved when depositing and using TCO thin films.

Some of the most important methods commonly used to deposit films of TCOs, are also discussed and the properties of the films are related to the deposition parameters. These methods, and the resultant films, are characterized using a wide variety of techniques, some of which are discussed. There is a strong overlap between the section dealing with deposition and that dealing with characterization, and both relate to the section dealing with fundamental science.

Who Should Attend?

Scientists, technicians, and others involved with TCOs who want to learn about their fabrication, properties, and applications.

Days: One

Instructor: Timothy J. Coutts, Research Fellow, National Renewable Energy Laboratory

Course Materials: Course notes and CD-ROM (PC and Macintosh compatible)

Cost: $575

An Introduction to Ion Beam Coating Deposition Techniques

Course Objectives

- Learn the effects of ion bombardment on substrates and coatings, and the applications of ion beam processes in thin film deposition.
- Understand plasma generation, and the behavior and operation of ion sources used in coating processes.
- Become familiar with coating processes including ion beam substrate precleaning, ion beam-assisted deposition, and ion beam sputtering deposition.
- Acquire a working knowledge of contamination control principles relating to use of ion beams in thin film processing.

Course Description

The course presents a broad, nonmathematical introduction to the technology of ion beam processes, and their applications in optics, electronics, communication, data storage, aerospace, protective coatings, biomedical engineering, photovoltaics, and displays. The effects of ion bombardment on surfaces are reviewed, so students can understand how these phenomena are employed in deposition and modification of thin films. Ion sources will be explained and demonstrated, focusing on the widely used Kaufman-type and end-Hall sources. The practical relationships between ion bombardment parameters and thin film microstructure and properties will be emphasized, for processes including ion beam cleaning, ion beam-assisted deposition, and ion beam sputter deposition. Guidelines for the optimization of coating yields and performance will be given. Contamination control procedures, both general to deposition and specific to ion beam processing, will be discussed in detail.

Who Should Attend

New and experienced coating process and design engineers, deposition technicians, and their managers, as well as technical marketing personnel from suppliers of deposition equipment, ion sources, materials, and coating services. End users of thin film coatings will especially benefit if they want to purchase new deposition equipment and/or bring a coating process "in-house." Suppliers of coatings will learn how to optimize and troubleshoot existing ion beam deposition processes.

Days: One

Instructor: Larry Stelmack, Independent Technical Consultant

Course Materials: Course Notes

Cost: $575

An Introduction to Ion Sources: Principles and Techniques

Course Objectives

- Learn about ion formation, ionization, and recombination collisions.
- Understand gaseous breakdown and plasma formation.
- Know the collective behavior of particles in electric and magnetic fields.
- Understand the operating principles of widely used ion sources.
- Learn about extraction and transport of the ion beam from ion sources.
- Know the design and fabrication of ion sources and materials limitations.
- Learn about applications of ion beams and sources in research and industry.

Course Description

This course includes elementary atomic collisions, rudimentary plasma physics, essentials of gaseous discharges, principles of ion sources, and the basics of ion beam formation. It also emphasizes the applications and operating characteristics of commonly used ion sources: microwave, RF, DC discharges, multiply charged, negative, and novel. In each case, an ion source is described by the method in which the ions are formed and extracted as ion beams. Materials used for constructing electrodes and chambers are also discussed.

Who Should Attend?

Technicians, engineers, scientists, and supervisory personnel involved in the design, fabrication, installation, and operation of commonly used ion sources.

Days: One

Instructor: Abe Ghanbari, Vice President of Engineering, Dielectric Systems, Inc.

Course Materials: Course Notes

Cost: $575

Application of Residual Gas Analysis in Thin Film Processes

Course Objectives

- Understand the basic operation of a quadrupole mass analyzer (QMA).
- Learn to interpret mass spectra.
- Know the difference between background analysis and process sampling.
- Find out what typical spectra for semiconductor processes look like.
- Gain insight into the relationship between spectra and typical process problems.
- Learn how to get a return on your investment by the proper use of a QMA.

Course Description

This course will provide an introduction to the QMA as a residual gas analyzer. It will address the important QMA specifications and discuss how spectra are formed. Open and closed ionization sources, sampling from UHV to atmospheric pressure, and interpreting background spectra will be explained. The emphasis will be on the specific applications of the attendees, and students are encouraged to bring examples.

Interpreting spectra for vacuum processes—evaporation, sputtering, chemical vapor deposition, plasma etching, and ion implantation—will be discussed as well as interpreting spectra for atmospheric pressure processes: silicon epitaxy, rapid thermal processing, and scrubber exhaust gas analysis.

Who Should Attend?

Engineers, technicians, and operators responsible for troubleshooting the semiconductor processes used for thin-film deposition, plasma etching, ion implantation, and rapid thermal processing. Also, semiconductor fab personnel who have acquired or plan to acquire a mass spectrometer residual gas analyzer and wish to get a return on their investment.

Days: One

Instructor: Robert Waits, Thin Film Technology Consultant & Technical Writer

Course Materials: Course Notes and "Partial Pressure Analyzers and Analysis" from the AVS monograph series

Cost: $575

Atomic Layer Deposition

Course Objectives

- Learn the fundamentals of ALD based on sequential self-limiting surface reactions.
- Understand the important advantages of ALD and comparison with CVD.
- Learn about ideal and non-ideal ALD and thermal and plasma-enhanced ALD.
- Understand how ALD surface chemistry and growth are studied using in situ probes.
- Learn how ALD can be utilized for thin film nanoengineering.
- Understand the many current and potential applications of ALD.

Course Description

This course develops an understanding of atomic layer deposition (ALD). Al2O3 ALD is first introduced as an ideal model system and then ALD is compared with CVD. Non-ideal ALD behavior is presented before discussing plasma and radical-enhanced ALD. Subsequently, novel surface chemistry is described for metal ALD.

The course reviews the important topic of nucleation and growth during ALD before introducing low temperature ALD. ALD on polymers and ALD on particles are then discussed to illustrate some potential new application areas for ALD.

ALD on porous substrates is reviewed to illustrate how ALD can deposit conformally on high aspect ratio structures. The ALD of nanolaminates and composites is then discussed to demonstrate the potential of ALD for thin film nanoengineering.

Who Should Attend?

Engineers and scientists who want an introduction to ALD or need to broaden or update their knowledge of this important field.

Days: One

Instructor: Steve George, Professor, Dept. of Chemistry & Biochemistry and Dept. of Chemical & Biological Engineering, University of Colorado at Boulder

Course Materials: Course Notes

Cost: $575

Atomic Layer Deposition: Fundamentals, Chemistry, and Applications

Course Objectives

- Learn the fundamentals of ALD: basic principles, advantages, and limitations.
- Understand where ALD may be used and why it is an increasingly important deposition technique for microelectronics.
- Learn the key aspects of ALD reactors.
- Learn why precursor chemistry is in a central role in ALD process design.
- Learn how ALD processes are characterized.
- Know the current trends in ALD process development and applications.

Course Description

This course develops an understanding of the atomic layer deposition (ALD) method by starting from the basics and proceeding to the state-of-the-art of this rapidly developing technique. It emphasizes the issues that differentiate ALD from the otherwise closely related CVD, that is, precursor chemistry and reactor design.

The current status of ALD is introduced by examining the processes and application areas. Challenges for future development are outlined as well.

Surface chemistry is in a central role in ALD processes, and therefore its thorough understanding is vital for both process control and design of new processes. The various approaches to analyzing ALD process chemistry are surveyed.

Who Should Attend?

Engineers and scientists who want an introduction to ALD or to broaden or update their knowledge of this increasingly important field.

Days: One

Instructor: Mikko Ritala, Academy Researcher, University of Helsinki, Finland

Course Materials: Course Notes (and a reprint of the chapter "Atomic Layer Deposition" from *Handbook of Thin Film Materials)*

Cost: $575

Basics of Radio Frequency Technology

Course Objectives

- Understand the radio frequency (RF) plasma system as an electronic circuit.
- Learn a systematic approach to viewing a RF plasma system.
- Know techniques for maintaining and troubleshooting RF systems.

Course Description

This introductory course provides maintenance and equipment engineers and technicians with a basic working knowledge of RF technology as it is applied to semiconductor processing equipment.

The role of RF in the various deposition processes, including sputter deposition and etching systems, is discussed. The characteristics and uses of various components that make up an RF system are described. The differences between resistive and reactive components are explained as well as the differences between series and parallel resonance.

Under reactive components, the course covers tuning circuits, filter circuits, and the plasma chamber itself. The use of inductive versus capacitive coupling of RF power into the plasma discharge is reviewed as well as methods for measuring target and substrate voltages and their relation to ion energies.

The course also includes discussions of the operation and use of RF power amplifiers, transmission lines, and matching networks.

Who Should Attend?

Engineers and equipment technicians who use RF power in vacuum systems and require a working knowledge of RF fundamentals.

Days: Two

Instructor: Steve Barber, Vice President, RF VII, Inc. or John Caughman, Research Staff, RF and Plasma Technology Group, Oak Ridge National Laboratory

Course Materials: Course Notes

Cost: $850

Chemical Mechanical Planarization for Microelectronics Manufacturing

Course Objectives

- Learn about the fundamental principles for chemical mechanical planarization (CMP).
- Get to know the state-of-the-art dielectric and metallic CMP processes and the advanced applications for CMP in manufacturing.
- Find out about the equipment and consumables utilized in CMP.
- Understand the current advantages and limitations of CMP and the present techniques for process control and characterization of CMP in a manufacturing environment.
- Know the multidisciplinary engineering approach to effective use of CMP.

Course Description

CMP is an enabling technology for the microelectronics industry. It has developed into an integral component of the design, development, and integration of process modules necessary to the manufacture and yield of cost-effective and/or leading-edge products.

This course will discuss the engineering science and fundamental principles necessary to effectively utilize CMP. Emphasis will be on the empirical nature of CMP and how it bridges many engineering fields for resolution of its numerous challenges. The evolution and revolution of CMP equipment and consumables will be presented. The merits of various characterization techniques for process development and control will be presented, and the advantages and limitations of CMP processes for advanced microelectronics applications will be analyzed.

Who Should Attend?

Scientists, engineers, technicians, and others who want an introduction to or refresher course on the fundamental principles and applications of CMP.

Days: One

Instructor: John Givens, Senior Consultant and President, Innovative Materials Group, Inc.

Course Materials: Course Notes

Cost: $575

Cleaning and Surface Conditioning Techniques for Integrated Circuit Manufacturing

Course Objectives:

- Obtain a basic knowledge of various surface conditioning and cleaning technologies used in the manufacture of ICs.
- Learn about the processes and equipment used for wet, plasma, and dry cleaning.
- Receive an overview and comparison of established surface conditioning and cleaning techniques and new technologies. In addition, this course will introduce new technologies such as supercritical fluid processing that may be used for future clean requirement.
- Find out information on specific surface conditioning techniques including critical cleaning, photoresist stripping, and post-CMP cleaning. Discuss techniques such as megasonics, dilute chemistries, and the use of ozone.
- Understand how the cleans affect low-k dielectrics and copper, including cleaning challenges for new materials.

Course Description

This two-day course provides a working knowledge of surface conditioning and cleaning techniques used in the manufacture of integrated circuits (IC). Fundamentals of the techniques used for cleaning the wafer surface will be discussed. Practical applications and methods for cleaning will be presented.

Upon completing this course particpants will have an understanding of all types of cleaning processes used in IC manufacturing; surface conditioning for pre-diffusion clean, in particular pre-gate oxide clean, post-etch and post-implant photoresist removal, particle removal, post-CMP clean. Participants will be able to understand the cleaning roadmaps and limitations of clean technologies as the node sizes decrease and should be able to make informed decisions on the surface conditioning and cleaning processes and techniques to utilize for IC manufacturing.

Who Should Attend?

The intended audience is any engineer or manager associated with using or supplying clean and contamination free technologies for IC manufacturing. In particular semiconductor manufacturing process engineers, process development engineers, and integration engineers, IC equipment application and process engineers, and IC clean chemical process engineers are the target audience.

Days: Two

Instructor: Karen Reinhardt, Principle Consultant, Cameo Consulting and Robert Small, Technology Consultant, RS Associates.

Course Materials: Course Notes and "Handbook of Semiconductor Wafer Cleaning Technology," ed., Werner Kern, Noyce Publications, New York. 1993

Cost: $950

CVD for Microelectronics

Course Objectives

- Understand chemical vapor deposition (CVD) for integrated-circuit applications.
- Know the characteristics and processes of various reactor types, including cold-wall and hot-wall CVD reactors.
- Learn about the properties of CVD layers and how they are affected by deposition processes.

Course Description

Following an introduction to the kinetics of CVD, including gas-phase and surface processes, the practical aspects of CVD are emphasized. The various reactors used for CVD are discussed with special emphasis on contrasting cold-wall and hot-wall reactors. A discussion of the methods for achieving uniformity in each of these reactors illustrates the differing importance of gas-phase and surface processes. Most of the remainder of the day is devoted to considering the properties of the layers important in IC applications and how they are influenced by the deposition process.

Epitaxial and polycrystalline silicon and deposited dielectrics are described. The concept of plasma-enhanced CVD is introduced, and materials deposited by PECVD are described. The day concludes with consideration of the CVD process and properties of CVD metals and refractory metal silicides. Copies of the visuals used in the course will be supplied to participants.

Who Should Attend?

Engineers and technologists who want an introduction to CVD or to broaden or update their knowledge of the increasingly important field of CVD for integrated-circuit applications.

Days: One

Instructor: John E. Crowell, Professor of Chemistry and Biochemistry, University of California, San Diego

Course Materials: Course Notes

Cost: $575

Ion Implantation: Fundamentals, Process Controls and Advanced Applications

Course Objectives

- Understand fundamental concepts of ion penetration and damage accumulation, implant system architecture and operation of key system components.
- Understand the operating principles and capabilities of key process control metrologies for dosimetry, profile analysis, damage and wafer charging.
- Understand the interaction of machine design and operation for such process effects as chip-level dose variations, ion profile purity problems, contamination from dopant, metallic and organic materials, particle masking and kinetic damage and charging.
- Review examples of the use of ion implantation techniques and process metrologies for formation of ultra-shallow junctions, fabrication of SOI and other heterogeneous wafer materials by direct implant and layer transfer and doping challenges for 3-D structures such as Fin-FETs.

Course Description

This course will contain discussions of: (1) fundamentals of ion stopping, damage formation and range profile characteristics, (2) fundamentals of ion implantation systems, including ion sources, ion mass selection, acceleration, beam scanning dosimetry and vacuum issues, (3) reviews of the process metrologies for ion dose, depth profile, damage and wafer charging, (4) process effects for chip-level dose variations, energy and charge state contamination, dopant, metallic and organic contaminants, particle masking and kinetic damage effects and wafer charging, (5) formation of SOI materials by direct implant and by implant-driven layer transfer and (6) doping challenges for ultra-shallow junctions and 3-D structures such as fin-FETs.

Who Should Attend?

This course is intended for engineers and scientists involved with transistor fabrication process development or design and operation of ion implantation techniques for doping and materials modification.

Days: One

Instructor: Michael Current, Director of Technical Marketing, Frontier Semiconductor

Course Materials: Course Notes

Cost: $575

Ion Implantation Processes

Course Objectives

- Impart a practical working knowledge of the implantation technique with discussion of industry best practices.
- Understand the main parameters of the implant process and how they affect the performance of devices being fabricated.
- Learn about process integration issues and interactions of implant with related processes.
- Become familiar with the various configurations of implanters.
- Understand the relationship of equipment capabilities to applications.
- Know the important trends in device fabrication and implant equipment.

Course Description

This introductory two day course covers the basic science and technology of the ion implantation technique and the various systems used in IC wafer fabrication. Following an introduction of the science and technology of ion implantation, the basic characteristics of implanted and redistributed dopant profiles are reviewed. The basic principles of operation of machines in medium current, high current and high-energy configurations are discussed along with their similarities and differences. The techniques for measuring implants and their use for statistical process control in production are presented. The sensitivity of sheet resistance and junction depth to process variations is emphasized.

The process implications and possible complications of each topic are stressed throughout, particularly as they affect the variability of results obtained in production applications. The operation of sub-systems such as ion sources, mass analyzers and end stations are discussed along with issues of proper safety, maintenance, and vacuum practice. Process considerations discussed include dose errors, charge exchange phenomena, contamination, particulates, wafer cooling, photoresist, and wafer charging. The instructor will share his industrial experience from a practical perspective, referring back to the basic doping requirements wherever possible. The course is conducted in seminar style with active participation encouraged throughout.

Who Should Attend?

This course is intended for engineers and technicians involved in ion implantation as well as device engineers using implantation processes. Maintenance personnel and supervisors who want to know more about implanters and the impact upon the processes being run in them could also benefit from taking this course. Those who are presently working for equipment suppliers will learn what is happening in this manufacturing process and its interaction with other process steps.

Days: Two

Instructor: T.C. Smith, Consultant, Ion Implantation Technology

Course Materials: Course Notes

Cost: $850

Optical Diagnostic Techniques for Plasma Processing

Course Objectives

- Learn about current optical and laser diagnostic techniques used in plasma processing.
- Understand the selection and use of optical emission spectroscopy (OES) and laser-induced fluorescence (LIF) equipment, including technique limitations, problems and pitfalls, and spectral identification guidelines.
- Know the applications of optical methods in process problems ranging from endpoint detection to chemical and particle contamination.
- Learn about newly developed optical techniques and equipment for the lab and the fabrication line.

Course Description

The proper use of optical diagnostic techniques provides a key advantage in plasma processing because these techniques are fast, nonintrusive, sensitive *in situ* monitors of process conditions.

This course covers the use of optical monitors in plasma processing from basic research to automated methods for process monitoring and production control. First, concepts needed for spectroscopic identification are briefly reviewed. Then, the proper use of OES is critically discussed with an emphasis on equipment selection and use, "tricks of the trade," and hidden pitfalls that trap scientists and engineers alike.

Laser characterization techniques are also discussed, including LIF, absorption spectroscopy, optogalvanic methods, laser light scattering (LLS), and laser interferometry. Special attention is paid to process quality issues such as endpoint determination, impurity detection, and direct surface monitoring.

Finally, some current topics in plasma research and development are discussed, including detection and control of plasma particle contamination. A videotape of particles inside various plasma tools during processing is shown.

Who Should Attend?

Scientists, engineers, and technologists working with plasma processing of semiconductor and packaging substrates and with optical characterization of plasma processes.

Days: One

Instructor: Gary Selwyn, Technical Staff in Plasma Physics, Los Alamos National Laboratory

Course Materials: Course Notes and "Optical Diagnostic Techniques for Plasma Processing" by Gary Selwyn from the AVS monograph series

Cost: $575

Photolithography Process in IC Production

Course Objectives

- Become familiar with the optical lithography process.
- Learn basic photo-resist and process chemistry.
- Understand a baseline lithography process, variables, and their effects.
- Learn the advantages and disadvantages of g-line, i-line, DUV, e-beam, and other alternative patterning techniques.
- Understand the relationship between resolution, focus, and wavelength used for exposure.

Course Description

The course begins with a brief overview and introduction of electronic devices, design rules, and the important role lithography plays in integrated-circuit fabrication. It then provides a detailed description of current photolithography practices for IC production. The emphasis is on a baseline process, taking a wafer through the lithographic sequence step by step. Variables and alternative methods are discussed in detail.

Exposure equipment is compared in terms of optics, resolution, focus, and throughput capabilities. Masks/reticles (binary and PSM) and pellicles are described and issues regarding them are presented. Other topics covered include light sources, alignment, interference effects (standing waves), mix-and-match, OPC, OAI, defects, and metrology.

Throughout the presentation, the history of each step is briefly included so attendees understand where we have come from, where we are now, and the direction the industry is headed.

Attendees will learn how the resist mask is used in subsequent etching, ion implantation, and additive processes and how the resist is finally removed without damage to delicate structures being fabricated.

Many of the process tips described will be immediately useful in understanding and improving an existing lithography process. To encourage postcourse learning, web addresses of lithography equipment and material suppliers are provided. Also included is a list of industry publications (some at no cost) and how to subscribe.

Who Should Attend?

Engineers, scientists, technicians, and others working in the semiconductor industry who want to understand the lithography process used to produce integrated circuits.

Days: One

Instructor: John Frankenthaler, Consultant, F&F Associates

Course Materials: Course Notes

Cost: $575

Physical and Chemical Vapor Deposition

Course Objectives

- Understand the fundamental physics, chemistry, and technology of thin-film physical vapor deposition (PVD—evaporation and sputtering) and chemical vapor deposition (CVD) processes.
- Learn the strengths and limitations of the various PVD and CVD methods and the criteria for suitability for a given application.

Course Description

This course covers two widely used techniques for the deposition of thin films—physical vapor deposition and chemical vapor deposition—with emphasis on the strengths and limitations of each method.

First, the basics of the vacuum and plasma environments are introduced, including methods of producing a plasma. Next, the physical processes of evaporation and sputtering are discussed along with reactive and ion-enhanced modifications of these techniques. Methods for *in situ* monitoring and control are surveyed.

The third part of the course covers chemical vapor deposition, both thermal—from atmospheric pressure to low pressure with an ultrahigh vacuum background—and low-pressure plasma-enhanced processes employing glow-discharge or high-density ion sources.

The last part of the course will discuss the growth, structure, and sources of stress in thin films.

Who Should Attend?

Those without a thin-film technology background who must decide what deposition process best suits their needs and those who wish to broaden their perspective on thin-film PVD and CVD technology.

Days: One

Instructor: Robert Waits, Thin Film Technology Consultant & Technical Writer

Course Materials: Course Notes and “Thin Film Deposition and Patterning” from the AVS monograph series

Cost: $575

Plasma and Ion Beam Diagnostics: Principles and Applications

Course Objectives

- Learn the basics of gas discharges.
- Learn the fundamentals of industrial plasmas.
- Learn how to use diagnostics to measure density, temperature, and energy of neutrals and charged particles in a plasma.
- Learn how to apply diagnostics to ion beams to measure current, current density, energy, energy spread, beam profile, and beam divergence.
- Learn how to measure electric and magnetic fields and how to use various mass analyzers.
- Know about the applications of several state-of-the-art plasma and ion beam diagnostics in research and industry.

Course Description

Low-temperature plasmas are widely used in research and industry. Plasma diagnostics are process specific, and process improvement requires understanding of the plasmas involved. Plasma diagnostics provide the information needed to analyze and improve the desired processes.

This course reviews the fundamentals of gas discharges and low-temperature plasmas. It presents commonly used plasma diagnostics, such as the use of neutral particle detectors, electric and magnetic probes, microwave interferometry, and optical diagnostics instrumentation to measure density, temperature, and kinetic energy of the plasma particles. In addition, ion-beam diagnostics relevant to the measurement of current density, kinetic energy, energy spread, and mass analysis will be discussed. For each diagnostic technique, the why, what, and how of the measurements will be presented and will be followed by practical examples and applications.

Who Should Attend?

Technicians, engineers, scientists, and supervisory personnel involved in the development, improvement, and applications of plasma and ion-beam technologies.

Days: One

Instructor: Abe Ghanbari, Vice President of Engineering, Dielectric Systems, Inc.

Course Materials: Course Notes

Cost: $575

Plasma-Enhanced CVD: Fundamentals, Techniques, and Applications

Course Objectives

- Learn how PECVD is used in a wide variety of commercial applications.
- Understand how the basic process parameters affect materials and device properties.
- Understand the basic principles of plasma equipment design.
- Know the important trends in current commercial equipment and fabrication processes.

Course Description

This course reviews the basics of processing plasmas. This knowledge is applied to understand the practical complications when plasmas are used to deposit thin films in demanding device applications. Every attempt is made to develop an understanding of the relationship between the process and film properties based on practical examples.

The deposition and properties of important materials such as silicon oxide, silicon nitride, silicon carbide, amorphous and polycrystalline silicon, diamond and diamond-like carbon are discussed in detail.

Much emphasis is placed on an up-to-date discussion of hardware and hardware considerations as these apply to process control and process safety.

Important trends in the design and operation of commercial equipment, particularly as it relates to microelectronics, are discussed in detail.

Who Should Attend?

Those who want to get a good understanding of plasma-based deposition techniques, materials, and devices both in commercial and laboratory applications.

Days: One

Instructor: Frank Jansen, Vice President of Technology and Engineering, BOC Edwards

Course Materials: Course Notes and “Plasma-Enhanced CVD: Fundamentals, Techniques, and Applications” from the AVS monograph series

Cost: $575

Plasma Etching and RIE: Fundamentals and Applications

Course Objectives

The Fundamentals

- Know the basic concepts of plasma etching.
- Understand the physics of RF glow discharges (both high and low density).
- Understand the surface science aspects of reactive ion etching (RIE).
- Learn about plasma-surface chemistry leading to etching.
- Recognize the factors that influence etching anisotropy.

Applied Aspects

- Know fluorocarbon plasma etching of Si and its compounds.
- Learn about etching of Al, organics, III-V compounds, etc.
- Understand selectivity, loading effects, ARDE, uniformity, damage, feature charging, particles, wall reactions, etc.
- Become familiar with plasma diagnostics.

Course Description

The first day of this course covers plasma-assisted etching phenomena and equipment in a manner that will assist the attendee in understanding and developing plasma etching and RIE processes. The emphasis will be on the fundamental physical and chemical processes that determine the consequences of a reactive gas plasma/surface interaction. The role of energetic ions as encountered in RIE systems and the factors that influence anisotropy of etching will be described. Many kinds of plasma-assisted etching equipment will be discussed, including capacitively coupled, inductively coupled, and wave-generated plasma sources.

The second day of this course covers the applied aspects of plasma-assisted etching. Emphasis will be on mechanistic understanding as opposed to specific processing issues, recipes, and problems. The etching of Si and its compounds will be covered in detail as well as the etching of other technology-related materials such as Al, organics, III-V compounds, etc. Topics such as selectivity, loading, ARDE, damage, and issues associated with high-density plasma RIE will be covered. A section on plasma diagnostics will focus on optical emission spectroscopy with actinometry, mass spectrometry, and laser-induced fluorescence.

Who Should Attend?

Scientists, technicians, and others working with or interested in the dry etching of materials in reactive gas glow discharges, particularly those who do not have extensive experience in the field.

Days: One or Two

Instructor: John Coburn, Research Associate, Department of Chemical Engineering, University of California at Berkeley; Randy Shul, Technical Staff, Sandia National Laboratories

Course Materials: Course Notes

Cost: $575 (6/3, Plasma Etching and RIE: Fundamentals);
$850 (6/3–4, Plasma Etching and RIE: Fundamentals and Applications)

Reactive Sputtering and Deposition

Course Objectives

- Understand reactive processes for doping films.
- Learn about deposition methods and applications.
- Know the methods for sputtering insulators: AC, RF, Pulsed DC, ion beams, etc.
- Understand process monitoring and control methods as well as process modeling.

Course Description

This course is intended for those who have taken the basic Sputter Deposition course or who have an equivalent background in sputtering. Familiarity with different sputtering methods (magnetrons, RF, etc.) and the parameters (pressure, energy, etc.) that affect film properties (stress, structure, etc.) is required. The course provides an understanding of the fundamental parameters and effects that are important in particular applications and helps attendees recognize from experimental results those that determine the film properties, whatever the film and the desired properties may be.

Because applications of reactive sputtering have expanded significantly in the last decade for optical coatings and optical waveguides, decorative coatings, hard coatings, magnetic films, etc., and because industrial-scale manufacturing has focused on the materials and methods of deposition, this course will cover these topics in detail. This course will also focus on the following:

- Gettering effects and hysteresis of pressure, target voltage, deposition rate; the effect of pumping speed.
- Target processes in sputtering compounds; ejected species.
- Partially reacted target methods for high rates; avoiding arcing and defects; activation of reactions.

Who Should Attend?

Scientists, technicians, and others who have taken the basic Sputter Deposition course or who have an equivalent background in sputtering and are looking for more information on reactive sputtering processes. Familiarity with different sputtering methods and the parameters that affect film properties is required.

Days: One

Instructor: William Westwood, Consultant, THINK Films

Course Materials: Course Notes

Cost: $575

Sputter Deposition

Course Objectives

- Understand target effects and sputtered atoms.
- Learn about magnetron, diode, triode, and ion-beam systems.
- Learn about DC and RF systems for targets and substrates.
- Understand reactive sputtering.
- Understand film properties and learn system parameters.

Course Description

Films are deposited by sputtering for their useful properties in microelectronics, surface protection, optics, and so on, by a variety of sputtering techniques. The film properties depend on the parameters of the sputtering system, such as pressure and substrate bias.

This course provides an understanding of the cause and effect of changes in sputtering parameters on the energetics of the sputtering and deposition processes and their relationship to film properties. The energy and distribution of species ejected from the target are discussed. The effect of the sputtering system on material transport to the substrate and subsequent film deposition will be discussed for films of metals, alloys, and compounds. The parameters of different sputtering systems (diode, triode, magnetron, and ion guns) with DC and RF power supplies are discussed with respect to film properties.

Who Should Attend?

Scientists, technicians, and others involved in the deposition of thin films by sputtering who want to understand the effects of operating parameters on the properties of metal, alloy, and dielectric films.

Days: One or Two

Instructor: William Westwood, Consultant, THINK Films [or Joe Greene, D.B. Willett Professor of Materials Science & Physics, and Head of Electronics Materials Division, University of Illinois OR Angus Rockett, Professor and Associate Head for the Department of Materials Science and Engineering at the University of Illinois OR William Sproul, Consultant, Reactive Sputtering, Inc.]

Course Materials: Course Notes and "Sputter Deposition,"
by William Westwood (text not used in Joseph Green's class)

Cost: $675 (One-day); $950 (Two-day) (less $100 w/ Joe Green)

Surface Preparation for Thin-Film Deposition

Course Objectives

- Understand the nature of surfaces (practical and technologically significant).
- Learn about surface preparation, sample handling, and contamination control.
- Develop insight into surface characterization and analysis.
- Learn about surface preparation and film nucleation during thin-film deposition.

Course Description

Substrate preparation is an integral part of any film deposition process. This includes removing unwanted impurities and residues as well as conditioning the surface to promote adhesion through activation of interfacial layers. The selection of the cleaning and surface preparation techniques is dependent on the nature of the surface and the deposition technique.

This course reviews surface cleaning and preparation techniques, condensation and nucleation of the deposited atoms, film-substrate interface formation, and the initial stages of film growth. Both wet and dry cleaning procedures will be discussed with an aim toward removal of ionic, metallic, and organic residues as well as particles. Emphasis will be placed on atomistic and reactive deposition utilizing evaporation, sputtering, and chemical vapor and molecular beam deposition. Film properties such as intrinsic stress, which may affect adhesion, will be reviewed. Techniques used to characterize the elemental composition, chemical state, and phase of material will be illustrated for both *in situ* and *ex situ* analysis.

Who Should Attend?

Scientists, engineers, technicians, supervisors, and others involved in the deposition of materials in vacuum or controlled ambients who want to learn about the effects of surface preparation and condition on the nucleation and growth of films and the subsequent interfacial adhesion and film properties. Knowledge of elemental physics and chemistry is helpful, but not essential.

Days: One

Instructor: Gary McGuire, President, International Technology Center

Course Materials: Course Notes

Cost: $575

Thin-Film Deposition by Evaporation

Course Objectives

- Understand the fundamental physics and chemistry of the deposition of thin films by vacuum evaporation.
- Know the applicability of the various evaporation processes to manufacturing.
- Learn the fundamental and practical advantages and limitations of the technology.

Course Description

Thermal evaporation is an important technology for the formation of decorative and functional coatings on a variety of materials. This course is an introduction to the fundamentals of deposition of thin films by thermal evaporation in a vacuum. Topics covered include: the vacuum environment, vaporization and vapor sources (resistance and electron-beam heated), vapor transport, film condensation and growth, control of thickness and uniformity, the effects of deposition conditions on film structure and stress, reactive and ionized evaporation processes, and the advantages and disadvantages of evaporation versus other film deposition processes.

Process examples from application areas familiar to the attendees are included. Class discussion of practical problems and solutions is encouraged.

Who Should Attend?

This course is intended for technicians, engineers, and supervisors who have had no previous experience with evaporation methods. A background in elementary physics and chemistry is helpful.

Days: One

Instructor: Robert Waits, Thin Film Technology Consultant & Technical Writer

Course Materials: Course Notes and "Thin Film Deposition and Patterning" from the AVS monograph series

Cost: $575

Thin Film Deposition by Sputter Processes

Course Objectives

- Learn about sputtering.
- Know the differences between magnetron, diode, and triode sputtering.
- Learn about DC and RF systems.
- Get an introduction to reactive sputtering.

Course Description

This course is a short, one-day version of the popular two-day AVS short course entitled *Sputter Deposition*. It is intended to provide an overview of sputtering and will prepare students for more advanced sputtering topics.

This course will also provide an understanding of how sputtering works by showing students the differences and similarities between the various sputtering methods, such as DC, RF, magnetron, diode, and triode sputtering. An overview of how process parameters affect the properties of the coatings and an introduction to reactive sputtering—which is being used more and more to deposit many different types of compound coatings such as nitrides, oxides, and carbides—will be provided.

Who Should Attend?

Scientists, managers, and technicians who want to learn more about sputtering.

Days: One

Instructor: William Sproul, Consulting, Reactive Sputtering, Inc.

Course Materials: Course Notes

Cost: $575

An Introduction to Nanomanufacturing and Nanotechnology

Course Objectives

- Understand nanotechnology and its societal impact through biomedical, electronic, and structural applications.
- Learn how to synthesize nano particles.
- Be introduced to a host of nanoassembly and nanomanufacturing techniques, their merits, limitations and selection criterion for different applications.
- Learn about nanoscale characterization.
- Understand future challenges.

Course Description

To understand the science at nanoscale, it requires merging of sciences from atomic levels (including physicist, chemists and biologists) to micro and macro level (engineers). Nanotechnology is the prominent example of being an interdisciplinary science, which is of great importance to scientific as well as industrial community.

This course will address the importance of nanotechnology: what and why? It will cover problems associated with nanomanufacturing and provide details of nanomaterials with specific examples. Various synthesis and consolidation techniques will be discussed, including sintering, plasma based techniques, laser based techniques, Sol-Gel based process, cold spray, and high rate deformation. State-of-the-art fabrication of devices and Nanoarchitecture including electron beam technique, focused ion beam (FIB), biotemplating and near net shape manufacturing/rapid prototyping are covered in this course. In addition, discussion will focus on detailed nano characterization techniques and issues for evaluation of nanomaterials. The course will conclude with some case studies and future insight. The course will be presented in a semi-workshop, interactive format.

Who Should Attend?

This course is designed to supplement the learning needs of engineers, technologists, managers, and technicians from all backgrounds to keep them update about the current advances in the field of nanomanufacturing. Graduate students and other budding professionals in the field will also benefit greatly from this course by honing their current skills.

Days: One

Instructor: Arvind Agarwal, Assistant Professor, Department of Mechanical and Materials Engineering, Florida International University, Miami; and Sudipta Seal, Associate Professor with AMPAC and Department of Mechanical, Materials, and Aerospace Engineering, University of Central Florida

Course Materials: Course Notes

Cost: $575

Copper Interconnect Technology

Course Objectives

- Learn about the materials science, fundamental principles and engineering technology necessary to effectively utilize copper (Cu) interconnects.
- Get to know the state-of-the-art equipment and process schemes necessary to produce advance Cu metallization in manufacturing.
- Find out the merits and challenges of various characterization techniques for process control and quality assurance.
- Understand the material properties, interactions, and processing challenges associated with the integration of Cu interconnects.
- Know the advantages and limitations of current Cu interconnect strategies.

Course Description

This course covers the materials science, fundamental principles, and engineering technology necessary to effectively use Cu as a conductor for integrated circuits. Emphasis will be on the material properties, interactions, and processing challenges associated with the integration of Cu interconnects.

The equipment and associated process schemes available to produce Cu metallization will be presented. Also, the merits and challenges of various characterization techniques for process control and quality assurance will be discussed. And, finally, the advantages and limitations of current Cu interconnect strategies will be analyzed.

Who Should Attend?

This course is intended for engineers, scientists, managers, and technicians who are or will be involved with or impacted by the implementation of Cu technology. The course will provide the basics for those unfamiliar with materials science and interconnect technology as well as the most recent advances in Cu metallization to keep practitioners on the leading edge. Discussion time will be included in the program.

Days: One

Instructor: John Givens, Cenior Consultant and President, Innovative Materials Group, Inc.

Course Materials: Course Notes

Cost: $575

Micro-electromechanical Systems

Course Objectives

- Learn various microfabrication technologies for MEMS.
- Understand unique requirements for MEMS fabrication.
- Learn process design and control.
- Learn about merging mechanical devices with circuits.
- Learn current trends and future technology direction for MEMS.

Course Description

In micro-electromechanical systems (MEMS), both electrical and mechanical devices are formed. Often, the mechanical devices consist of movable components that are partially separated from the substrate they are anchored to. In some cases, special films with unique properties for sensing mechanical movement are needed. Although the basic principles of the IC technologies used in Si can be applied, there are many unique requirements for MEMS fabrication. In this short course, various microfabrication technologies for MEMS will be introduced. Process design and factors for precise dimension control for MEMS will be covered. Issues related to integrating mechanical and electrical components will be discussed. Current technology trends for MEMS with examples in mechanical, optical, and chemical sensing and actuation will be given. New development of MEMS technology in the future will be addressed. The specific topics covered are:

- Patterning by optical, x-ray, and focused ion beam lithography.
- Selective wet-etching processes.
- Directional dry-etching processes.
- Thin-film deposition by evaporation, sputtering, electroplating, chemical vapor deposition, and laser-assisted deposition.
- Bonding and release of mechanical structures.
- MEMS technology for mechanical, optical, and chemical sensors.
- Future trends and development in MEMS technology.

Who Should Attend

Engineers, scientists, technologists, and technical managers with an interest in the development and implementation of microfabrication technology for micro-electromechanical systems.

Days: One

Instructor: Stella Pang, Professor, Department of Electrical Engineering and Computer Science, University of Michigan

Course Materials: Course Notes

Cost: $575

Nanotribology and Nanomechanics and Applications to MEMS/NEMS and BioMEMS/BioNEMS

Course Objectives

- Understand the principles of nanotribology and nanomechanics.
- Acquire knowledge about adhesion and stiction.
- Learn the applications to MEMS/NEMS and BioMEMS/BioNEMS.

Course Description

This course provides attendees with a basic working knowledge of nanotribology and nanomechanics and applications of MEMS/NEMS and BioMEMS/BioNEMS. The course concentrates on the recent research carried out using scanning probe microscopy.

Who Should Attend?

Scientists, engineers, and technicians/technologists who are involved in design, selection of materials/coatings and study of failure mechanisms of various mico/nanodevices, especially in magnetic storage devices, MEMS/NEMS and BioMEMS/NEMS applications.

Days: One

Instructor: Bharat Bhushan, Ohio Eminent Scholar and Howard D. Winbigler Professor, Director, Nanotribology Laboratory for Information Storage and MEMS/NEMS, Ohio State University

Course Materials: Course Notes and "Nanotribology and Nanomechanics – An Introduction" by B. Bhushan, Springer-Verlag, 2005

Cost: $675

Photovoltaics: The Engineering, Technology, and Application of Solar Cells

Course Objectives:

- Understand the basic operation of photovoltaics (solar cells)
- Gain an understanding of the state of the art and current primary research focuses in all common and emerging photovoltaic technologies.
- Learn how solar cell operation is modeled to diagnose and optimize devices
- Gain an overview of methods to produce solar cells and some of the problems and solutions in manufacturing the devices.
- Understand how photovoltaics fit in to future energy generation schemes.
- Learn the general aspects of how solar cell materials and devices are characterized

Course Description:

This course introduces the broad aspects of photoelectric solar cells, properly known as photovoltaics (or PV for short). A description of how PV power systems are designed and how they fit into the potential generating technologies are reviewed briefly with examples of actual installations given. A general introduction to the electrical and optical theory of the devices is provided including analysis of ideal and non-ideal device performance, reflection, transmission, carrier generation, and other aspects of the optical properties. Consideration will include issues related to transparent contacts, antireflection coatings, and tunnel junctions for connection in multilayer devices. Students will be introduced to the AMPS and SCAPS modeling tools and useful spreadsheet-based approaches to modeling the devices.

Concentrating and non-concentrating systems, single and multijunction devices, thin film (eg. amorphous Si, CdTe, and $CuInSe_2$) and bulk devices, thermophotovoltaics, and novel concepts such as photoelectrochemical cells, organic PV, and quantum dot structures will be considered. The current status of each of these technologies and potential limitations to them are discussed. Selected topics related to the manufacture of the devices will be presented including a review of detailed examples, as available. Process techniques discussed will include Czochralsky crystal growth, casting and other specialized bulk Si growth techniques, evaporation, closed-space sublimation, solid-phase reaction, sputtering, and others. Case studies in issues related to the manufacture of a-Si and $CuInSe_2$ thin film technologies, will be discussed as examples. Cost, market, materials availability, and yield issues will be considered. The microchemical, microstructural, optical, and electronic characterization of PV devices will be described.

Who should attend?

Students, scientists, and engineers with little or no experience in photovoltaics. Those with a history of work in the field will also profit from the descriptions of device modeling and the range of approaches used. The course is not currently designed to educate system installers. System installers may gain some useful background concerning the devices they are installing. Questions concerning practical installation of systems can be answered but students should not expect to come away prepared to install their own system.

Days: One

Instructor: Angus Rockett, Prof. of Materials Science and Engineering, Univ. of Illinois

Course Materials: Course Notes

Cost: $250

Semiconductor Contacts: Their Science, Fabrication, and Characterization

Course Objectives

- Understand the formation of potential barriers at metal/semiconductor interfaces.
- Learn about charge transfer processes that determine whether a contact is ohmic or rectifying.
- Learn about characterization of ohmic and rectifying contacts and experimental limitations.
- Know about the reliability of practical ohmic contacts and interconnects.

Course Description

Reliable contacts are needed to operate all electronic devices successfully. Metal/semiconductor contacts are often the limiting factor in device operation; however, they are often neglected in device technology.

This course reviews the basic concepts of potential barrier formation at metal/semiconductor interfaces and discusses charge transfer processes that determine whether a contact is ohmic. Methods for preparing contacts (i.e., sputtering, chemical vapor deposition, etc.) are also discussed, with particular emphasis on the effect of preparation techniques on fundamental properties. Contacts to a variety of materials, including Si, III-V, and II-VI semiconductors, are considered.

Characterization techniques are discussed in detail. These include barrier height measurements (i.e., current/voltage, capacitance/voltage, and photo response techniques) and specific contact resistance measurements (i.e., transmission line and Kelvin bridge methods).

The approach is to supplement a historical discussion of fundamentals with current research and development in the field of contact technology. This also includes information about the reliability of contacts and interconnects, which is of great significance to the electronics industry.

Who Should Attend?

Scientists, technicians, and others working with semiconductor materials and devices who want to understand contacts and their fabrication and characterization.

Days: Two

Instructor: Timothy Coutts, Leader of Device Development Group, National Renewable Energy Laboratory

Course Materials: Course Notes

Cost: $850

Semiconductor Device Manufacturing Overview

Course Objectives

- Gain a "big picture" understanding of the steps involved in making and packaging an integrated circuit.
- Learn the jargon associated with the microelectronics manufacturing industry.
- Learn the key concepts and process parameters of each process step.

Course Description

The intent of this course is to provide an integrated overview of the complete semiconductor manufacturing process. We start with how single-crystal substrates are made and end with a packaged part. The background science needed for the information presented will be provided.

The course begins with an overview of basic materials-related concepts used in microelectronics processing. This is followed by a description of process steps required to make an integrated circuit. Process steps such as photolithography, deposition (chemical vapor and sputtering), oxidation, implant, and etch along with current packaging technology will be covered, followed by a review of a simple process flow to emphasize how each step integrates with the others to create a working device.

Who Should Attend?

This course is intended for engineers, technicians, marketing and sales people, or anyone involved in the microelectronics industry who wants a greater understanding of the microelectronic manufacturing and packaging processes.

Days: One

Instructor: Bridget Rogers, Assistant Professor, Chemical Engineering Department, Vanderbilt University, and Tom Dory, Package Design Integration Engineer, Intel Corporation

Course Materials: Course Notes

Cost: $575

Technological Aspects of Metal/ Semiconductor Contacts

Course Objectives

- Understand contact behavior.
- Learn techniques for characterizing metal/semiconductor contacts.
- Become aware of characterization pitfalls.
- Learn methods for depositing contact metallizations.
- Understand the fabrication of high-quality contacts.
- Appreciate why contacts age and exhibit variations.
- Become familiar with state-of-the-art contact performance.

Course Description

This course emphasizes practical applications and is appropriate for those involved in the fabrication and characterization of metal/semiconductor contacts. It begins by outlining the basic nature of ohmic and rectifying contacts. This section provides the background for the following section on contact characterization.

The course continues by giving examples and details of the fabrication and performance of contacts to specific semiconductors, including Si, GaAs, InP (as well as ternary and quaternary alloys in the III-V family), CdTe, and other semiconductors of technological importance. Information will also be provided on the reliability and reproducibility of various contact systems as well as on some of the practical issues and difficulties in their characterization.

Who Should Attend?

Those involved in the fabrication and characterization of metal/semiconductor contacts. A practical understanding of thin-film deposition technology and a working knowledge of laboratory-based science would be valuable, although not essential.

Days: One

Instructor: Timothy Coutts, Leader of Device Development Group, National Renewable Energy Laboratory

Course Materials: Course Notes

Cost: $575

About the Instructors

Richard Ahrenkiel is a principal scientist and leader of the Electrooptical Characterization Team at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. He received a Ph.D. in physics from the University of Illinois, Urbana, and has worked at the Kodak Research Laboratories and the Los Alamos National Laboratory. He is an adjunct professor of electrical engineering at the University of Colorado, Boulder, and professor of physics at the Colorado School of Mines, Golden, Colorado. He has published more than 200 papers and co-authored several books on semiconductor properties. He is a Fellow of the AVS and OSA and a senior member of the IEEE.

Arvind Agarwal is an Assistant Professor in the Department of Mechanical and Materials Engineering at the Florida International University, Miami. He has more than 11 years of experience in the academic and industrial research environment. His current research interests include: near net shape processing and rapid prototyping using thermal spray techniques processing, bulk nanostructured materials processing, surface engineering, and ultrahigh temperature ceramic coatings and composites. He has published more than 55 research papers in peer reviewed journals and conference proceedings. He has also co-edited three books. He is a member of the International Board of Review for the *Journal of Materials Engineering and Performance* and *Materials and Metallurgical Transaction A.* He is also a member of several professional societies such as American Society for Materials, The Minerals, Metals & Materials Society, Materials Research Society, and Thermal Spray Society.

Gary Ash is President of Castle Brook Corporation, Dartmouth, Massachusetts. The company provides technical and management consulting services for the vacuum and cryogenics industry. He has had more than 35 years of experience in vacuum systems, pumps and other components, deposition processes ranging from evaporation to sputtering to molecular beam epitaxy. Engineering experience includes equipment and process design, manufacturing process development, materials and failure analysis, and applications support. In addition, he has had extensive experience in product strategy, development, and manufacturing planning for industrial products and services. He was previously employed by the CTI-Cryogenics division of Helix Technology Corporation, ASTeX, RIBER division of Instruments SA, Optical Coating Laboratory Inc., Spectrum Systems division of Barnes Engineering Co., AAI Corporation, and American Electronic Laboratories. He holds a B.S. and M.S. in electrical engineering from Cornell University and a Ph.D. in optical physics from Heriot-Watt University, Edinburgh, Scotland.

Steve Barber is the Vice President of RF VII, Inc., in Williamstown, New Jersey. He has more than 18 years of plasma system and radio frequency (RF) consulting experience. After five years of electronic and RF communications training, he joined Plasma-Therm Inc., where he helped RF-enhance plasma systems for semiconductor production. He also helped many other plasma corporations introduce RF into their sputter, deposition, and etching systems that at one time used only DC and low frequency. He also played a major role in ICP RF emission applications using various frequencies for chemical analysis with various types of mass spectrometers.

Michael Benapfl works with the Accelerator Technologies Engineering Group at Lawrence Livermore National Laboratory (LLNL). At LLNL, he has been involved with weapon research, vacuum system design and fabrication, thin-film coatings, material outgassing studies, and process development. He has been a consultant to other DOE facilities and is President of New Vector Engineering, a consulting firm that specializes in developing educational material in vacuum technology for industry. A teacher of vacuum technology at Las Positas College, he has been an active AVS member for 18 years.

Bharat Bhushan received a M.S. in mechanical engineering from the Massachusetts Institute of Technology in 1971, a M.S. in mechanics and a Ph.D. in mechanical engineering from the University of Colorado at Boulder in 1973 and 1976, respectively, an MBA from Rensselaer Polytechnic Institute at Troy, NY in 1980, Doctor Technicae from the University of Trondheim at Trondheim, Norway in 1990, a Doctor of Technical Sciences from the Warsaw University of Technology at Warsaw, Poland in 1996, and Doctor Honouris Causa from the Metal-Polymer Research Institute of National Academy of Sciences at Gomel, Belarus in 2000. He is presently an Ohio Eminent Scholar and The Howard D. Winbigler Professor in the Department of Mechanical Engineering as well as the Director of the Nanotribology Laboratory for Information Storage and MEMS/NEMS at the Ohio State University. He is an internationally recognized expert of tribology on the macro- to nanoscales, and is considered by some a pioneer of the tribology and mechanics of magnetic storage devices. He has authored five technical books, 36 handbook chapters, more than 400 technical papers in referred journals, and more than 60 technical reports, edited more than 25 books, and holds 10 U.S. patents. He is founding editor-in-chief of World Scientific Advances in Information Storage Systems Series, CRC Press Mechanics and Materials Science Series, and Journal of Information Storage and Processing Systems (from 2002, renamed as Microsystem Technologies: MEMS, Systems for Information Storage and Processing).

Peter Biltoft is a materials scientist at Lawrence Livermore National Laboratory (LLNL), currently working on the Plasma Electrode Pockels Cell Subsystem for the National Ignition Facility. He attended the Georgia Institute of Technology and holds a B.S. in chemistry and a M.S. in Metallurgy. During his tenure at LLNL, he has made multilayer thin-film coatings for X-ray optical applications, built a soft X-ray diffractometer that operates under vacuum, and has used atomic emission spectroscopic techniques to diagnose PVD processes. He is an instructor in Vacuum Technology at Las Positas College and has written a chapter on vacuum technology for the *CRC Handbook of Engineering.*

Joel Bowers, PE, PMP, has been associated with the design, fabrication, and deployment of over 40 vacuum vessels ranging in size from hand-held to 45 tons and has managed engineering teams of up to 500 people. He has a B.S. in mechanical engineering, M.S. in computer science from Rensselaer Polytechnic Institute, with broad application experience in fabrication, welding, machining, inspection, and rigging operations. Major projects have included vacuum applications in laser isotope separation, accelerator technologies, inertial confinement fusion, extreme ultraviolet lithography, and infra red spectroscopy. In addition to vacuum vessels, he has designed 500-ton magnets and record-scale optical bench structures. He is the developer of VacTran, commercial vacuum system design software used by engineers worldwide. He is currently a project engineer at Lawrence Livermore National Laboratory.

Christopher Richard (Dick) Brundle obtained his Ph.D. in physical chemistry (Imperial College, London, and Balliol College, Oxford) in 1967, working in the early development years of Photoelectron Spectroscopy. After a postdoc period at Bell Labs, he was a lecturer in physical chemistry at Bradford University, UK, from 1970 to 1975, where he developed and implemented the first UHV ESCA capability for surface studies. In 1975 he moved to IBM Research, San Jose, where he stayed until 1993, doing a mixture of basic research, applications, and technical management in surface and thin-film analytical methods. In 1993 he formed his own consulting company and in 1998 joined Applied Materials full time as Director of the Defect and Thin-Film Characterization Laboratory. Since then his work has been concentrated on methodology for root cause analysis for particle defects on full wafers. As of 2003 he is consulting. He has over 200 publications and recently retired as Editor of the *Journal of Electron Spectroscopy* after 25 years in that position.

David Castner is the Director of the National ESCA and Surface Analysis Center for Biomedical Problems (NESAC/Bio), an NIH-funded instrumentation center at the University of Washington. His research is directed at determining, in detail, the composition, structure, spatial distribution, and orientation of surface species on biomaterials, thereby advancing our understanding of the relationship between the surface properties of a biomaterial and the biological reactions occurring on that material. Professor Castner received a B.S. in chemistry from Oregon State University in 1975 and a Ph.D. in physical chemistry from the University of California at Berkeley in 1979. Prior to joining the University of Washington in 1986, he spent seven years as a Research Chemist at Chevron Research Company applying surface analysis techniques to catalyst characterization. He has been involved in surface science research for 30 years and is an AVS Fellow and Biomaterials Science & Engineering Fellow. He has published more than 125 refereed papers and given more than 100 invited talks on the surface modification and analysis of materials.

John Caughman is on the research staff at Oak Ridge National Laboratory in the RF and Plasma Technology Group. He received his doctorate in nuclear engineering from the University of Illinois in 1989. He has extensive experience in developing and implementing RF diagnostic techniques for fingerprinting the RF systems used in micro-electronics fabrication. Current areas of research include RF power deposition in process plasmas (capacitively and/or inductively coupled) and the use of high-density plasmas for plasma-enhanced chemical vapor deposition of a variety of materials.

Bob Childs...Coming soon!

Douglas Chrisey is currently the head of the Plasma Processing Section of the Surface Modification Branch at the Naval Research Laboratory (NRL). He received a B.S. in physics from the State University of New York at Binghamton in 1983, and a Ph.D. in Engineering Physics from the University of Virginia in 1987. He joined the Naval Research Laboratory (NRL) as an Office of Naval Technology postdoctoral fellow in 1987 investigating radiation effects in thin films of high-temperature superconductors, and he became a staff member in 1988. As a staff member his research at NRL has focused on the deposition of thin films of ceramics by pulsed laser deposition and their application in next-generation electronic devices and sensors. He has authored more than 130 scientific papers, has given 30 invited presentations, has written three book chapters, and has edited a handbook on the pulsed laser deposition of thin films. He is a member of the American Physical Society, the Materials Research Society, the Metallurgical Society, and the Society of Photo-Optical Instrumentation Engineers.

John Coburn is a Research Associate in the Department of Chemical Engineering of the University of California at Berkeley. From 1968 to 1993, he was a Research Staff Member and Manager at IBM Research Laboratory in San Jose, California. During 1993–94, he was an Alexander von Humboldt Senior Scientist at the Fraunhofer Institute for Applied Solid State Physics in Freiburg, Germany. His scientific interests are associated with the fundamental aspects of plasma processing, plasma etching in particular. He has been an AVS member since 1969 and has been active in the Society at the national, divisional, and chapter levels. He has been teaching the AVS course on Plasma Etching and RIE since 1980.

Timothy Coutts is leader of the Device Development Group at the National Renewable Energy Laboratory in Golden, Colorado. His interests relate to the development of both single- and polycrystalline solar cells and their optimization. His work includes the modeling and diagnosis of device performance and limitations. He is also involved in the fabrication and electro-optical analysis of materials. He has been involved with thin-film materials and devices for more than 20 years.

John E. Crowell is a Professor of Chemistry and Biochemistry at the University of California, San Diego. He received his B.S. in chemistry from the University of Illinois, Urbana, in 1979 and his Ph.D. in physical chemistry under the direction of G. A. Somorjai from the University of California at Berkeley in 1984. He joined the faculty at the University of California, San Diego, in 1986 after postdoctoral research with J. T. Yates, Jr., and D. M. Hercules at the University of Pittsburgh. His research program is primarily focused on surface processes that govern thin film formation, including the kinetics of chemical reactions at semiconductor surfaces, the mechanism of dielectric and semiconductor thin film growth, photo-assisted deposition and desorption processes, and biomolecule analysis using nanoporous Group IV materials. He has taught often in the areas of General Chemistry, Physical Chemistry, Surface Processes, and Spectroscopy.

Michael Current is the director of technical marketing at Frontier Semiconductor, San Jose, California, with a focus on front-end metrology tools for process controls of transistor doping. His career spans three decades with research, teaching, process engineering and technical marketing activities at Applied Materials, Xerox-PARC, Signetics and a number of start ups and universities. His core interest has been in the use of ion beam technologies for the analysis and fabrication of electronic materials and devices. He is the author of more than 150 papers and book chapters and is an active member of the AVS, MRS, the ITRS working groups for wafers and transistor formation and the Bomische Physical Society. He was the founding president of the Silicon Valley Implant Users Group in 1983, now part of the NCCAVS West Coast Junction Technology Group.

Tom Dory is a package design integration engineer at Intel Corporation in Chandler, Arizona. He has worked in many different aspects of semiconductor manufacturing including plasma deposition, RTP, and packaging technologies. He obtained his doctorate at the University of Oklahoma in inorganic chemistry. He was awarded four patents in the area of silane replacement chemicals and processes. He is a member of the American Chemical Society, Electrochemical Society, and AVS.

John Frankenthaler is a consultant with more than 25 years experience in lithographic processes, materials, and manufacturing equipment. As a Product Manager at Shipley Company, he was directly involved with all aspects of developing, manufacturing, marketing, and selling commercial lithographic products. As Corporate Technical Service Manager, he performed hands-on process development solving lithographic problems at customer locations. Before that he held engineering positions at IBM and later at Texas Instruments. He received a B.S. from Stevens Institute of Technology and a M.S. in chemistry from MIT. He is on the organizing committee of the IEEE Lithography Workshop and is an AVS member.

Steven George is a professor in the Department of Chemistry and Biochemistry and Department of Chemical and Biological Engineering at the University of Colorado at Boulder. He received his B.S. in chemistry from Yale University in 1977 and his Ph.D. in chemistry from the University of California at Berkeley in 1983. He has more than 200 peer-reviewed publications in the areas of surface science, thin film growth, and physical chemistry. He is a Fellow of AVS and the APS. His research interests are in the areas of surface chemistry, thin film growth and nanostructure engineering. He is currently directing an internationally recognized research effort focusing on atomic layer deposition (ALD). This ALD research is examining new ALD surface chemistry, measuring ALD thin film growth rates, characterizing the properties of ALD films and developing new flow reactors for rapid film growth using ALD techniques. He served as Chair of the first AVS Topical Conference on Atomic Layer Deposition held in 2001. He is co-founder of ALD NanoSolutions, Inc., a startup company that is working to commercialize ALD technology. He is very active in the AVS.

Timothy Gessert is a Senior Scientist and leader of the CdTe Research Team at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. He received degrees in physics from the University of Wisconsin–River Falls (B.S.), Colorado School of Mines (M.S.), and University of Wales–College of Cardiff (Ph.D.). His more than 15 years of research experience at NREL have involved development of vacuum and photolithographic processes for the fabrication of transparent-conducting oxides, photovoltaic absorber layers, and electrical contact. He is currently working toward development of environmentally stable contacting systems for thin-film CdTe-based photovoltaic devices. He has published more than 70 papers and currently serves on the board of the Rocky Mountain Chapter of the AVS.

Abe Ghanbari is Vice President of Engineering at Dielectric Systems, Inc. He received his B.S. degree in electrical engineering from the University of Illinois and a Ph.D. degree in experimental atomic/plasma physics from Cornell University. In the past 15 years, he has been involved in the development and management of plasma technologies for processing equipment in the semiconductor and magnetic media industries. He is author or co-author of more than 50 publications on plasma diagnostics and high-density ion sources. He is author of two monographs and holds six patents. He is a member of the AVS, APS, IEEE, and SPIE.

John Givens is currently located in San Antonio, Texas, as the Senior Consultant and President for Innovative Materials Group, Inc. He is a 1990 graduate of the Materials Science Department at the University of Illinois in Champaign-Urbana. He has focused his career on the innovation and development of materials and processes necessary to enable IC fabrication. His industrial experience includes Vice President of Engineering for Thomas West, Inc., with a focus on CMP pad material development and process implementation, and CMP Section Manager for VLSI Technology with the responsibilities of CMP manufacturability and process strategy. In addition to providing technology necessary for the manufacturing of ASIC's at VLSI, he has developed advanced multilevel interconnects for the production of high-density DRAM's at Micron Technology, Boise, Idaho, and advanced microprocessors at IBM in Burlington, Vermont. He has presented, authored and co-authored over 60 publications and holds 39 patents concerning advanced interconnect methodologies. He is a member of TMS, ASM, AcerS, ECS, MRS and IEEE. He is an active member of AVS for which he is an organizer of the International Conference on Microelectronics and Interfaces. He is also an editor for *JVST B* and *Thin Solid Films.*

Stanley Goldfarb received his B.S. in chemical engineering from CCNY. He has been an active member of the AVS since 1960. His experience at Veeco Instruments included Field Sales, Training Director, and the Applications Engineering Laboratory Manager. He moved to California in 1970 to join first Airco Temescal, then UTI as Sales and Marketing Manager. In 1977, he cofounded US, Inc., a sales and marketing organization serving the high-vacuum and thin-film markets, and manufactured a small planar magnetron sputter source designed for research and development. Stanley founded Exxus in 1985. He has taught courses in vacuum technology, leak detection, and total and partial pressure analysis for the AVS and many corporations.

Joe Greene is the D.B. Willett Professor of Materials Science and Physics at the University of Illinois and the Tage Erlander Professor of Materials Physics at Linköping University, Sweden. The focus of his research has been the development of an atomic-level understanding of adatom/surface interactions during the dynamic process of vapor-phase crystal growth in order to controllably manipulate nanochemistry, nanostructure, and, hence, physical properties. His work has involved nanotechnology and film growth by all forms of sputter deposition, solid and gas-source MBE, UHV-CVD, MOCVD, and ALE. Joe has published more than 500 papers and review articles, 22 book chapters, and co-edited 4 books in the general areas of crystal growth, thin-film physics, and surface science. He is currently Editor-in-Chief of *Thin Solid Films* and past Editor of *CRC Critical Reviews in Solid State and Materials Sciences*. Joe is active in the AVS where he has served on the Trustees, twice as a member of the Board of Directors, as President of the society in 1989, and is currently Secretary. Major awards include: the AVS John Thornton Award (1991), the Tage Erlander Award (1991) from the Swedish Natural Science Research Council, Fellow of the American Vacuum Society (1993), Technical Excellence Award from the Semiconductor Research Corporation (1994), 1996 DOE Award for Sustained Outstanding Research, 1998 David Adler Award in Materials Physics from the American Physical Society, 1998 Aristotle Award from SRC, Fellow of the American Physical Society (1998), AVS Distinguished Lecturer (1998-present), David Turnbull Award form the Materials Research Society (1999), 2001 International Scientist of the Year, Elected to the European Academy of Science in 2002, and Elected to the US National Academy of Engineering in 2003.

Mars Hablanian has had 37 years of research and product development experience in high-vacuum industry. He has written more than 80 papers, vacuum pump chapters in books, and a textbook on vacuum technology. He holds 15 patents associated with high and ultra-high vacuum systems, turbopumps, vapor-jet pumps, sputtering, and thermal applications of electron beams. He has received awards from the AVS, the Association of Vacuum Equipment Manufacturers, and the Society of Vacuum Coaters for his contributions to vacuum technology.

Luke Hinkle is a technical consultant at Complex2Simple, specializing in consulting and training in vacuum, pressure, and flow technology. For twelve years, he was the Technology Manager and Product Marketing Director for MKS Instruments. Other activities and responsibilities at MKS included the development and management of technology roadmaps, the invention and patent program, and technology workshops. In addition to general vacuum technology and process control, recent areas of research have included gas flow transition behavior, vacuum gauging, contamination control, process pressure measurement and control, and calibration standards and techniques for pressure and flow. From 2001 to 2006 he taught advanced science and math at Falmouth High School in Falmouth Massachusetts. In addition to these duties, he has served on the editorial board for the *Journal of Vacuum Science and Technology* and on various technical, marketing, and education committees for the AVS. He coauthors the monthly column "Vacuum Corner" in *Vacuum Technology and Coating* magazine. He received a B.S. in physics from Elmhurst College in 1984 and a Ph.D. in physics from Pennsylvania State University in 1989. He has authored over 18 technical publications and holds six patents.

Paul Holloway is Director of MICROFABRITECH and Professor of Materials Science and Engineering at the University of Florida. His research at MICROFABRITECH emphasizes the growth, processing, and characterization of large bandgap elemental and compound semiconductors for optoelectronic applications, while his research in materials science emphasizes deposition, properties, and characterization of thin films. He teaches graduate-level courses on vacuum science and technology and on surface science. He is co-editor of the CRC Critical Reviews in Solid State and Materials Sciences and is on the editorial board of Surface Science Spectra. He is a Past President of the AVS.

Frank Jansen is currently the Vice President of Technology and Engineering, USA of BOC Edwards in Santa Clara, California. He has worked on thin-film deposition processes and devices since 1970 in several different industries. Much of his effort has been spent on the development of plasma deposition processes for a wide variety of applications. He is the author of 60 publications and holds 20 U.S. patents in the area of thin-film vacuum deposition technology.

Allan Matthews is Director of the Research Center in Surface Engineering at Hull University, UK. He has authored or co-authored over 200 papers plus three books and five patents. His special area is ionization-assisted PVD coatings. He has been a Symposium Committee Member and Session Chair for ICMCTF and other international conferences as well as Editor of the Proceedings. He is also Co-editor of *Surface and Coatings Technology.*

Richard Matyi is a professor in the College of Nanoscale Science and Engineering at the University at Albany – SUNY and a senior scientist at Albany NanoTech. He received his degrees in materials science and engineering from Northwestern University (B.S., 1975; Ph.D., 1983) and MIT (S.M., 1976). From 1982 to 1988 he was at Texas Instruments where his research involved materials characterization by X-ray methods and materials growth by MBE. From 1988 to 2000 he was a professor in the Department of Materials Science and Engineering at the University of Wisconsin–Madison where his research focused on advanced X-ray methods for materials analysis. Before coming to Albany in 2004, he was the National Institute of Standards and Technology where his work included precision X-ray metrology and the application of X-ray reflectometry to semiconductor manufacturing. He is the author or co-author of over 130 publications and holds three U.S. patents.

Gary McGuire is president of the International Technology Center, a non-profit research center located in Research Triangle Park, NC. He was formerly Director of Electronic Materials and Device Technology at MCNC. His responsibilities include the development and characterization of new materials and processes for novel semiconductor devices. He has done extensive research utilizing surface characterization techniques to investigate thin films and metallization schemes used in the microelectronics industry. He is Editor of the *Journal of Vacuum Science and Technology B*, Series Editor for William-Andrews Publications, Materials Science and Process Technology series and Series Editor for Kluwer Academic Publishers, Optical and Photonic-based Materials and Devices series. He has served AVS as the Electronic Materials and Processing Division Chair, and has been on the Board of Directors, the Board of Trustees, the Long Range Planning Committee and served as President in 1997.

Jon Orloff, a Professor of Electrical Engineering at the University of Maryland, earned his B.S. in physics from MIT in 1964 and his Ph.D. in applied physics from Oregon Graduate Institute in 1977. His research focuses on high-brightness electron and ion sources and charged particle optics; focused ion and electron beams and their applications for micromachining, surface analysis, and microscopy; and focused-beam instrumentation development for the semiconductor industry.

Ron Outlaw is a Research Professor in Applied Science at the College of William and Mary in Williamsburg, Virginia, and was formerly a Senior Scientist at NASA, Langley Research Center. He received his doctorate in Materials Science at Virginia Tech and did post doctoral work at MIT. His early work was in UHV systems and gauge design, physical adsorption, metal hydride secondary standards, orbiting molecular shield concepts, space processing, thin film growth of semiconductor materials, hydrogen transport and UHV generation of atomic oxygen and hydrogen. Present work includes the development of advanced vacuum instrumentation and electron emission sources. He has published over 100 technical articles and holds six patents. He is a member of AVS.

Stella Pang is a Professor in the Electrical Engineering and Computer Science Department and the Associate Dean for Graduate Education in the College of Engineering at the University of Michigan. From 1981 to 1989, she was with Lincoln Laboratory, Massachusetts Institute of Technology, working on submicrometer technology for microelectronics applications. Her research interests include nanofabrication technology, dry etching and dry deposition for micro-electromechanical, microelectronic and optical devices. She received a Ph.D. in Electrical Engineering and Computer Science from Princeton University in 1981. Dr. Pang has served as conference organizer for the AVS, Electrochemical Society, Electronic Materials Conference, Institute of Electrical and Electronics Engineers, International Microprocesses and Nanotechnology Conference, International Symposium on Electron, Ion, and Photon Beam Technology and Nanofabrication, Material Research Society, and SPIE. She was the editor and author for 16 books, journals, and conference proceedings. Dr. Pang has taught over 18 short courses on microfabrication technology for microelectronic manufacturing and micro-electromechanical systems at AVS, CEI, and SPIE. She is a Fellow of IEEE, ECS, and AVS.

Howard Patton has been an engineer for more than 37 years at Lawrence Livermore National Laboratory. Now semi-retired, he divides his time among the Laboratory, teaching, and consulting. Before his retirement, he was a lead project engineer for the Beamlet and National Ignition Facility. In addition to designing large lasers and vacuum systems, he has been involved in a variety of vacuum processes, including microelectronics fabrication, optical coating, fusion research, vacuum joining, vacuum isotope separation, vacuum deposition, and space simulation. He is also a consultant to the U.S. Department of Energy National Laboratories in the fields of vacuum, contamination control, and laser engineering. He has taught vacuum courses in the United States, Canada, Mexico, South America, Europe, Asia, and Australia and has been an AVS instructor for more than 25 years. He is an Honorary Member of the AVS.

Neil Peacock is a Development Engineer for the HPS Division of MKS Instruments, Inc., in Boulder, Colorado. In over 10 years with HPS, his responsibilities have included the design, testing, characterization, and calibration of thermal conductivity gauges and ionization gauges. He has helped in the training of HPS employees in vacuum technology and has presented invited and contributed papers on vacuum gauging. He received a bachelor's degree in physics from the University of Colorado. He is currently a member of the Board of Directors of the AVS Vacuum Technology Division and is chair of the AVS Recommended Practices Subcommittee on Ionization Gauges.

Karen A. Reinhardt is Principle Consultant at Cameo Consulting in San Jose, California. Prior to forming a consulting company, Karen was employed at Novellus Systems in San Jose, California. In this role she was responsible for investigating and assessing new and unique cleaning technologies that will allow realization of the ITRS roadmap with respect to smaller geometries, new materials, and the environmental issues associated with current cleaning processes. She has published more than 30 technical papers ranging from plasma processing to damage characterization and cleaning technology assessment. She has been awarded six patents. She is currently leading the ITRS surface preparation technical working group.

Mikko Ritala received his M.Sc. in 1991 from University of Turku, and his Ph.D. in 1994 from University of Helsinki, both in inorganic chemistry. From 1995–2003 he worked at University of Helsinki, first as a postdoctoral researcher and then as an academy research fellow, both posts granted by Academy of Finland. In 2003, he was nominated as a professor of inorganic materials chemistry at University of Helsinki. His research activities are in the area of thin film growth by atomic layer deposition and electrodeposition for microelectronics and other application areas. Real time reaction mechanism studies form an important part of his research. He has published 150 papers and holds several patents.

Angus Rockett is Professor and Associate Head for for the Department of Materials Science and Engineering at the University of Illinois in Urbana-Champaign. He received his B.S. in physics at Brown University and his Ph.D. in metallurgy at the University of Illinois. His research involves sputter deposition of solar cell materials. He has also worked with reactive sputtering of nitrides and other materials. He is the author of more than 100 publications, holds two sputtering-related patents, has given more than 30 invited talks, and is an AVS Fellow. At the University of Illinois he teaches courses in electronic materials and processing in addition to general materials science courses. He has presented short courses and tutorials in sputtering (for AVS), materials microanalysis, and solar cells and solar cell materials for other organizations.

Bridget Rogers is an Assistant Professor in the Chemical Engineering Department at Vanderbilt University. She is teaching and performing research in the areas of thin-film processing, focussing on the nucleation of CVD thin films. Prior to joining the Vanderbilt faculty she was employed in Motorola's Semiconductor Products Sector for 14 years. Over the years she held positions in the areas of process engineering, process development, device engineering, and materials characterization. She received her Ph.D. and M.S. degrees in chemical engineering from Arizona State University and her B.S. degree, also in chemical engineering, from the University of Colorado, Boulder.

Phillip Russell received his doctorate in materials science and engineering from the University of Florida. He has held positions at the National Renewable Energy Laboratory and at JEOL, USA. At present, he is a Professor of Materials Science and Engineering and Director of the Analytical Instrumentation Facility at North Carolina State University. Russell's research interests are in the development and application of STM, AFM, and electron- and ion-beam techniques.

Sudipta Seal is a Professor in AMPAC and the Department of Mechanical, Materials, and Aerospace Engineering, at the University of Central Florida. He is also serving as a nanoinititaitve Coordinator for UCF. He received his Ph.D. in 1996 from the University of Wisconsin followed by an M.S. from University of Sheffield UK. In 1990 he finished his undergraduate from Indian Institute of Technology (IIT India) in Metallurgical & Materials Engineering. After his Ph.D. he joined Advanced Light Source, Lawrence Berkeley National Laboratory, University of California, Berkeley as a post doctoral fellow. He is on the editorial board of nanoscience and nanotechnology, Reviews in Advanced Materials, Chair of the Surface Engineering sector for JOM, on the Review Board of Metallurgical Transactions. He has years of teaching and research experience in the field of nanoscience and nanotechnology and almost ten years in the area of materials processing and surface engineering. His projects are funded by National Science Foundation (NSF), National Institute of Health, Office of Naval Research, NASA and many Industries. He has published more than 160 refereed research papers, books, and book chapters in the area of surface science and engineering and nanotechnology. He has also delivered more than 50 invited lectures and 210 research presentations in the U.S. and abroad. He is the recipient of the 2002 ONR Young Investigator Award and Distinguished ASM-IIM lecturer Award from ASM 2003, as well as a Japan Society of Promotion Science Fellow (2004); and an Alexander Von Humboldt Fellow (2005-2006). He is an active member of ASM, TMS, MRS, ECS, and AVS.

Gary Selwyn is a principal investigator and technical staff member in plasma physics at Los Alamos National Laboratory (LANL), and an Adjunct Professor of Chemical Engineering at UCLA, and runs his own, successful consulting business. He has been involved in diagnostics and troubleshooting of plasma processing for more than 17 years, as engineer at IBM's development laboratory in East Fishkill, New York, and later as a technical staff member and manager at IBM's Thomas J. Watson Jr. Research Center in Yorktown Heights, New York. He was the first to discover the formation, detection, and control of particulate contamination in plasma-etching processes. His videotapes on this subject have been seen worldwide, and his research has been the topic of numerous conferences, workshops, and trade journal articles. He has written more than 60 technical publications, including an AVS monograph, and holds more than 15 patents. He recently received an R&D 100 Award for his invention of a plasma/mechanical method for cleaning wafers, and his work on low-temperature, atmospheric plasma processes was reported in *Discover Magazine* and earned him a Distinguished Performance Award at LANL.

Randy Shul is currently a Principal Member of Technical Staff at Sandia National Laboratories in the Microdevice Technologies Department. His current interests include Si micromachining for MEMS, integrated microsystems, sensors, and advanced packaging technologies. He is also active in plasma etch process development for the wide-bandgap group-III nitrides and the development of high-density, low-damage plasma etch processes for advanced compound semiconductor devices. Previously, he worked at AT&T Bell Laboratories where he was responsible for plasma process development for the fabrication of GaAs digital integrated circuits. He earned a B.A. in chemistry in 1981 from Rutgers University and a Ph.D. in chemistry from the Pennsylvania State University in 1987. He is author of over 150 journal publications, eight book chapters, and has six patents. He has been a member of AVS since 1988. He served as NMAVS symposium chair in 1995, Vice Chair in 1996, Chair in 1997, and is currently chapter Secretary. He was also technical program vice chair for the AVS International Symposium in 2000.

Robert Small is currently the Technology Consultant for RS Associates. He previously held the positions of CMP Technical Director and also was the R&D Technical Director for the remover line of business at DuPont/EKC Technology. He was involved in developing new chemistries for post-CMP cleaning, CMP chemistries, and post-etch residue removal. He has a B.S. from Norwich University, a M.S. from Texas Tech University, and a Ph.D. in organic photochemistry from the University of Arizona. He holds more than twenty-five U.S. and foreign patents and currently has ten submitted U.S. patent applications. He has authored or co-authored more than 115 articles and presentations, including BEOL, post clean treatment, post CMP, and CMP processes.

T.C. Smith has been continuously involved in the development of ion implantation processes in pilot line environments for more than 25 years. He recently retired from Motorola's Semiconductor Products Sector where he was a Member of Technical Staff in the Advanced Custom Technologies department. Prior to that, he developed implant processes for CMOS in Motorola's Advanced Product Research and Development Laboratory. He received his M.S. degree in physics from the University of Notre Dame and has specialized in various aspects of ion implantation technology throughout his career. With more than 25 publications in this field, he has focused on problems involved with the use of photoresist masking in implantation and particulate contamination. He has facilitated an internal Motorola course on ion implantation technology for more than 20 years and has taught a graduate course on ion implantation as Adjunct Professor at Arizona State University. Since 1986, he has been on the faculty of the International Ion Implantation School. This school accompanies the International Conference on Ion Implantation Technology, which is held every two years. He has also taught a course on Ion Implantation Process Engineering for Semyzen in Singapore and SEMI in Taiwan. He has been a member of the Greater Silicon Valley Ion Implant Users Group since its formation and is a member of AVS and the Electrochemical Society. He is actively involved in ion implantation technology, developing and conducting seminars, and in-house training in ion implantation process engineering. He also serves as a consultant to both equipment manufacturers and implant users.

William Sproul is a consultant for thin film deposition processes specializing in sputtering and reactive sputtering. Prior to starting his own consulting company, he was a Senior Scientist at Advanced Energy Industries, Inc. Before that, his career included three years as President and Co-Owner of Reactive Sputtering, Inc.; General Manager, Magnetic Products at Sputtered Films, Inc.; Manager, Vapor Deposition Coatings Group at the Basic Industrial Research Laboratory at Northwestern University; Senior Research Engineer, Borg-Warner Corporation; and Research Engineer at American Can Corporation. He has been involved with reactive sputtering of oxide and nitride coatings, and he is the inventor of the high-rate reactive sputtering process. He is the author or co-author of over 135 publications, and he holds 11 U.S. patents. He is an AVS past president and has chaired the International Conference on Metallurgical Coatings and Thin Films three times. He is an AVS Fellow, and in 2003 he was awarded the AVS John A. Thornton Memorial Award and the Society of Vacuum Coaters Mentor Award. He is the Co-editor for *Surface and Coatings Technology,* and he serves on the editorial board for *Vacuum.* He received his Ph.D. degree in materials science engineering from Brown University. He has been a short course instructor for more than 15 years.

Larry Stelmack is currenlty an Independent Technical Consultant and has worked in thin-film deposition and surface engineering since 1973, for applications in optics, electronics, aerospace, communication, and biomedical engineering. He studied engineering, optics, and management at MIT, and has held technical positions with NASA, MIT, Litton, Acton Research, Commonwealth Scientific, Implant Sciences, and Epion Corporation. He has organized and taught courses on thin-film deposition, ion beam processing, and contamination control for the AVS, MIT, Northeastern University, and George Washington University since 1989, and conducts on-site technical training at a number of corporations. He serves as a consultant to industry and government on processes, equipment, specifications, and research proposals for several coating applications, including optical communication and extreme UV lithography. His interests include ion beam processing; optical coatings for visible, UV, infrared, soft X-ray, and neutron beam applications; diamondlike carbon and other durable coatings; substrate cleaning processes; and contamination control.

Fred Stevie is a Senior Researcher at the Analytical Instrumentation Facility in North Carolina State University and is responsible for SIMS and XPS analyses. His experience with materials characterization using ion beams and mass spectrometry spans more than 25 years, principally with Bell Laboratories at Murray Hill, New Jersey, Allentown, Pennsylvania, and Orlando, Florida. He has authored or co-authored more than 150 publications, including a book on SIMS. His contributions to the SIMS field cover a range of topics including quantification, surface roughening effects, interfacial contaminants, and insulator analysis. FIB interests include sample preparation for TEM, particularly using the lift-out method, and FIB-SIMS. He is also a Research Professor of Materials Science at the University of Central Florida. He is active in technical organizations, particularly AVS and the SIMS Workshop Series. He received a M.S. degree in physics from Vanderbilt University in 1970.

Robert Waits is a thin film technology consultant and technical writer in Sunnyvale, California. Since 1962 he has been involved in such areas as integrated circuit production engineering, thin-film technology development, plasma etching and metallization and interconnect process development. Mr. Waits has authored numerous papers, a book chapter, and an AVS Monograph and holds four U.S. patents. He has been a member of the AVS since 1960 and has taught AVS short courses in microcircuit thin-film technology, thin film processes, and residual gas analysis applications. He received a B.A. in chemistry and physics from Texas Christian University and a M.S. in physical chemistry from Stanford University. He has been responsible for thin film technology process development and manufacturing at Fairchild Semiconductor, Hewlett-Packard Co., Trilogy Technology, and Digital Equipment Corp. He also was a Senior Applications Specialist at UTI Instruments and MKS Instruments. Most recently he has been a part-time technical writer at Technical Marketing Programs in Sunnyvale, and is now a free-lance technical writer and consultant.

Woody Weed is a principal member of the technical staff at Sandia National Laboratories in Albuquerque, New Mexico. He is part of the Thin Film, Vacuum, and Multi-Chip Modules Department, where he is currently designing vacuum pumping systems for laser inertial confinement fusion systems. Other recent work includes process development and deposition of metal hydride thin films, optical coatings, electronic neutron tubes, and thin films for flat panel displays. He worked on similar programs from 1983–1990 at the Lawrence Livermore National Laboratory. He is also active in the areas of vacuum system design, leak detection, partial pressure analysis, and material outgassing studies. He is Past Chair of the Vacuum Technology Division of the AVS and teaches various courses in applied vacuum technology for the DOE National Labs and the AVS. He was previously an instructor at Las Positas College in Livermore, California.

Kimo Welch has been an active member of the AVS since 1958 and a short course instructor since 1965, teaching various courses including Total and Partial Pressure Gauging, Basic Vacuum Technology, and forms of Capture Pumping and Cryopumping. He earned his B.S. degree from the University of the Pacific and a M.S. degree in electrical engineering from Stanford University. Over the last 40 years he has worked as a technician, engineer, R&D manager, manufacturing operations manager, P&L manager, and General Manager in vacuum-related disciplines at General Electric, Raytheon, SLAC, Varian, Litton, Brookhaven National Laboratory, and Ebara, and is presently an independent consultant. He has authored three books—the most recent *Capture Pumping Technology, An Introduction* (1991)—more than 40 articles, and holds 14 patents.

William Westwood earned his B.S. and Ph.D. in physics from the University of Aberdeen in Scotland. Apart from three years teaching at Flinders University in Australia, he spent his career at a telecommunications research lab in Ottawa, Canada (formerly Bell Northern Research). In 1996, he retired and is now a consultant with THINK Films in Ottawa, Canada. During his career, he managed groups developing devices for telecommunications systems and introduced them into production. This involved optoelectronic devices and GaAs-integrated circuits for high-speed fiber communications. He started to use sputtering in 1963 for the deposition of films for telecommunications products and has been involved throughout his career in using sputtering for magnetic, semiconductor, and optical applications. He was awarded a D.Sc. in 1986 by the University of Aberdeen for his research on thin films and has published a number of papers on these topics as well as reviewed articles on sputtering and co-authored and edited books on thin films and sputtering. He has served on the AVS Board and was Program Chair for several conferences, including the AVS National Symposium and a sputtering symposium, and has been teaching courses on sputter deposition for more than 15 years.