# EdCon Microelectronics 2024

SVC™ Society of Vacuum Coaters

The SVC is a non-profit, international, professional organization primarily devoted to coating and surface finishing using vacuum processes. Our organization consists of industry, academia and members from national research laboratories; our industrial membership includes coating companies, materials suppliers, process designers, and equipment manufacturers. Our stakeholders apply coatings and treatments to a wide variety of consumer and industrial products in all business sectors and is global in perspective. These technologies are critically important to an ever-growing number of companies and applications.

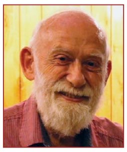
The SVC's education program is renowned as the broadest set of seminars that address thin film deposition and surface engineering technology. The SVC is delighted to provide a program tailored to the needs of our colleagues working in the microelectronics industry, taught by international subject matter experts. We are pleased to offer a week-long series of seminars that are offered virtually. Class sizes are limited, and the virtual format allows for direct interaction between the attendee and the instructor. The tutorials are a mixture of ½ day and full day tutorials. Full day tutorials are taught over a two day time period. A full set of downloadable course notes are provided for each tutorial. The pricing structure of the tutorial program has been designed to offer the most value to prospective students. Half-day tutorials are $150 USD/each, full-day tutorials are $250 USD/each and a "masterclass program" where all tutorials can be taken is priced at $500 USD. Come join us for a truly informative and valuable experience!


**WWW.SVC.ORG**

**Monday – Thursday**
**October 7-11, 2024**

*Morning sessions 08:30 AM–12:00 PM (Central Daylight Time, CDT);*
*Afternoon sessions 1:00–4:30 PM (Central Daylight Time, CDT).*
*Tutorials will either be ½ day events or full day events spread out over 2 sessions.*

## Monday, October 7, 2024


John O'Hanlon

**AM:** John O'Hanlon (Understanding and Operating Vacuum Systems); *½ day tutorial*

**PM:** John O'Hanlon (Ultraclean Vacuum Systems); *½ day tutorial*

## Tuesday , October 8, 2024


Dave Glocker

**AM:** Dave Glocker (Sputter Deposition for Microelectronic and Photonic Applications); Part 1, *full day tutorial*

**PM:** Dave Glocker (Sputter Deposition for Microelectronic and Photonic Applications); Part 2, *full day tutorial*

## Wednesday, October 9, 2024


Tim Gessert

**AM:** Tim Gessert (Contamination Control in Vacuum Systems); Part 1, *full day tutorial*

**PM:** Tim Gessert (Contamination Control in Vacuum Systems); Part 2, *full day tutorial*

## Thursday, October 10, 2024


Mike Miller

**AM:** Mike Miller (Troubleshooting for Thin Film Deposition Processes); Part 1, *full day tutorial*

**PM:** Mike Miller (Troubleshooting for Thin Film Deposition Processes); Part 2, *full day tutorial*

## Friday, October 11, 2024


Chris Muratore

**AM:** Chris Muratore (Introduction to Two-Dimensional Materials); *½ day tutorial*

**PM:** Chris Muratore (Flexible Electronics); *½ day tutorial*

**Scan the QR Code to Register for EdCon MicroElectronics 2024**

# Understanding and Operating Vacuum Systems

**John O'Hanlon**, *Emeritus Professor of Electrical and Computer Engineering, The University of Arizona*

This half-day-long short course is intended for those who wish to understand and operate high vacuum pumping systems used in semiconductor manufacturing. Mechanical pumps covered include rotary vane, lobe, claw, multistage lobe, dry piston, scroll, and screw. High vacuum pump and systems include turbo and cryogenic pumps.

This course also offers practical advice for operators, engineers, and maintenance personnel. It highlights useful and informative Best Practices for operating complex vacuum systems, e.g., guidance that would have been acquired historically through mentoring by experienced colleagues. However, rapid technical developments, and frequent career changes or added responsibilities, have left both experienced and new technologists in need of a reliable and concise information source. It is hoped that this material will help to replace the historic mentoring that is necessary to understand and operate modern vacuum systems.

1. Working in the Vacuum Environment
   - We begin by describing commonly used vacuum technology terms and concepts:
     i. Useful terms and definitions, and
     ii. Pump operating regions.
2. Mechanical Pumps
   - The construction, characteristics, operating principles, and applications of the several mechanical pumps are reviewed:
     i. Rotary vane,
     ii. Roots, claw, and multi-stage Roots,
     iii. Dry piston, scroll, and screw, and
     iv. Best Practices: Mechanical pumps
3. Turbo Pump Systems
   - The construction, characteristics, and operating principle of the turbo pump, and the operation of a typical turbo pump system are presented:
     i. Turbo pump construction & operating principles,
     ii. Turbo drag pumps,
     iii. Starting, cycling, and removing power, and
     iv. Best Practices: Turbo pump systems
4. Cryogenic Pump Systems
   - Construction, characteristics, and the operating principle of a helium-gas-refrigerated cryogenic pump, and operation of a typical cryopump system are described:
     i. Cryo pump construction and operation,
     ii. Cryo-condensation and cryo-sorption pumping,
     iii. Starting, cycling, and removing power,
     iv. Regeneration and maintenance, and
     v. Best Practices: Cryo pump systems.

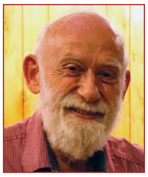
## Ultraclean Vacuum Systems

**John O'Hanlon**, *Emeritus Professor of Electrical and Computer Engineering, The University of Arizona*

This half-day-long short course describes pumps and pumping characteristics best used for ultraclean pumping. Process environments differ, and specific pump combinations are matched to suit the process environment. Choosing materials for use in ultraclean vacuum environments requires knowledge of their properties and how they are used in valves, seals, and feedthroughs. Water vapor is traditionally difficult to remove during the roughing cycle, and we provide methods for minimizing its effect on pumping time. Modern vacuum systems are designed for diverse applications, and one major distinction is their unique crossover pressure ranges in which pumping is switched from rough to high vacuum operation—a concept that is not well understood. We describe how to calculate the correct crossover pressure range for each major pump type.

This course offers practical advice for operators, engineers, and maintenance personnel. It highlights useful and informative Best Practices for operating complex vacuum systems, e.g., guidance that would have been acquired historically through mentoring by experienced colleagues.

1. Selecting Ultraclean Pumps
   - The specific pumping requirements of pumps and pump combinations needed for obtaining necessary vacuum levels and low particle concentrations for high yield manufacturing are reviewed:
     i. Mechanical,
     ii. Turbomolecular,
     iii. Cryogenic,
     iv. Sputter-Ion, and
     v. Getter and Titanium Sublimation (TSP).
2. Selecting Vacuum Materials
   - Materials are carefully chosen for their compatibility for use within an ultraclean vacuum environment. This section reviews properties and compatibility of materials used in chambers, valves, seals, and feedthroughs:
     i. Metals, glasses, and ceramics,
     ii. Elastomers for gaskets and seals,
     iii. Effects of outgassing and cleaning, and
     iv. Best Practices: Vacuum materials.
3. Rough Pumping Large Systems
   - Production systems are designed for specific applications; therefore, roughing systems no longer look like, or are operated like those described in historically dated books. This section describes roughing techniques for turbo- and cryopump systems that are designed for efficient pumping, prevention of pump overload and prevention of atmospheric aerosol-based contamination:
     i. Minimizing water vapor accumulation,
     ii. Preventing aerosol formation and deposition,
     iii. Best Practices: Reducing water vapor,
     iv. High vacuum pump crossover pressures for turbo, cryo, sputter-ion, and TSP systems, and
     v. Best Practices: Crossover pressure ranges
4. Ultraclean System Issues
   - Historically, ultrahigh vacuum was the domain of the researcher; however, it is necessary for ultra-clean manufacturing, even for processes that operate in the medium- or low-vacuum region. This places constraints on how systems are designed and operated, and how performance data are measured:
     i. Multi-chambered designs and load locs,
     ii. Cleaning chambers,
     iii. Metrology choices, and
     iv. Best Practices, Ultraclean Systems.



**John F. O'Hanlon** is Emeritus Professor of Electrical and Computer Engineering, The University of Arizona. He retired from IBM Research Division in 1987, where he was involved in thin-film deposition, vacuum processing, and display technology. He retired from UA in 2002, where he directed the NSF Ind./Univ. Center for Microcontamination Control. His research focused on particles in plasmas, cleanrooms, and ultra-pure water contamination. He and Tim Gessert are co-authors of "A Users Guide to Vacuum Technology", 4th Edition, John Wiley and Sons, 2023.

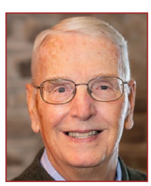
# Sputter Deposition for Microelectronic and Photonic Applications

**Dave Glocker**, *Isoflux (retired)*

This course covers topics of practical importance to those who presently use sputtering or who would benefit from an introduction to the technology. The emphasis is on developing an understanding of the underlying science and the factors that influence product throughput, coating quality and process robustness and reliability. Relationships between the sputtering conditions and important film properties - such as uniformity, microstructure, composition, stress, and adhesion - are discussed. Applications in the microelectronics and photonics industries are used to illustrate important features of the technology. The emphasis is on process and hardware considerations rather than device design or the detailed material properties of the coatings. No prior background in sputtering is needed.

### *Course Outline*

- Introduction and examples of sputtered coatings
- Coating nucleation and growth
- Overview of sputtering
- The vacuum environment
- Plasmas, plasma characteristics and magnetron sputtering
- Magnetron cathode designs
- Sputter yields and the distribution of sputtered atoms
- Collimated and ionized magnetron sputtering for high aspect ratio features
- Sputtering electrically insulating materials
  - RF sputtering
  - Ion beam sputtering
  - Reactive sputtering
- Stress in sputtered coatings
- Sputtering equipment for microelectronic and photonic applications



**David Glocker** has more than 40 years' experience in thin film research, development and manufacturing. He spent 15 years in the Eastman Kodak Research Labs, where he was the group leader of a team responsible for scaling vacuum coating and surface treatment processes from the laboratory into production. In 1993 he founded Isoflux Incorporated to design and manufacture inverted cylindrical magnetron cathodes and develop processes based on their unique features. Customers use the company's products in R&D and manufacturing for diverse applications such as medical devices, power transmission, sensors and many others. He's an inventor or co-inventor on 32 U.S. patents and has published a number of research papers in the areas of sputter source design, plasmas and plasma characteristics, sources of substrate heating in sputtering and the control of sputtering processes and sputtered film properties. He retired from Isoflux in 2015.

## SVC Student/Young Professional Travel Sponsorship Program

The SVC Student Sponsorship Program provides travel support and complimentary conference registration to selected full-time students to make an oral technical presentation at the SVC Annual Technical Conference. A limited number of sponsorships will be awarded to the best applicants. Applicants from academic, research, and technical institutions from the United States and around the world are encouraged to apply. The Student Sponsorship Committee evaluates applications from students and makes selections based on the quality and relevance of the student's project to the interests and mission of the SVC. It will also consider the quality of the application itself (completeness, quality, etc.), potential quality of the oral presentation, its relevance to the specific session, as well as the need for funding.

***Requirements for Participation:***

The student applicant must have a sponsor. The sponsor can be a faculty member at the student's institution or another academic, technical, or research institution. The sponsor must indicate that he or she understands the nature of the conference and what SVC technical programs are about. The student must commit to providing a manuscript based on the content of the oral presentation at the TechCon for subsequent publication by the SVC before any fiancial support is provided.

***Please visit the SVC website for more details on the 2025 Program.***

# Contamination Control in Vacuum Systems

**Tim Gessert**, *Gessert Consulting, LLC*

Contamination in a vacuum system affects the environment in which vacuum processes are conducted. Understanding and controlling these contaminants are important steps in producing the desired chamber conditions that result in high-quality and reproducible products. This course discusses typical in-chamber contamination including gases, films, and particulates. The origin of these contaminants, typical effects that these contaminants have on vacuum processes and products, and methods of limiting them are discussed. Emphasis is on defining how to control each contaminant, and identifying appropriate procedures to confirm that the established contamination control is effective. There will also be discussion on the how contamination control may be related to the vacuum system operating and maintenance procedures, as well as the environment outside the chamber.

This course is intended to offer practical advice for operators, engineers, maintenance personnel, and vacuum system/process designers. It highlights Best Practices for operating complex vacuum systems for processes requiring low contamination and high reproducibility, e.g., guidance that would have been acquired historically through mentoring by experienced colleagues.

1. Defining the Vacuum Environment: This section describes how contamination is defined and quantified. This includes both particle and vaporous contamination, in both volumes and on surfaces. It also presents the history and structure of various contamination Standards, including those related to ISO-14611 for contamination in volumes (Previously U.S. Federal Standard 209), and IEST Standard CC1246 (Previously U.S. Military Standard 1246).
2. Pumping and Related Contamination: This section reviews the types of contamination that can be expected from typical pumps used in various types vacuum technology. These pumps include wet and dry mechanical pumps, wet and dry high-vacuum pumps, and ultra-high vacuum pumps. Related discussion also included typical procedures and/or ancillary equipment that is often used to limit contamination from these various pumps.
3. Evacuating, Venting, and Condensation: This section reviews how the specific procedures used for venting, working within, and ultimately evacuating the chamber can have a profound effect on the type and amount of contamination potentially present during a vacuum process.
4. Mechanisms, Motors, Screws, and Bearings: This section reviews how the choice, preparation, location, and operation of typical vacuum-system components can result in various types of contamination. Components discussed include large components such as valves and mechanisms that impart movement to samples/products within the chamber, as well as much smaller components such as nuts, bolts, and pins used to fasten components.
5. Machining and Component Fabrication: This section describes how machining, welding, and post-fabrication procedures of the vacuum chamber and/or components can have a significant effect on in-chamber contamination. Procedures

to limit fabrication-related contamination of various typical vacuum materials are presented.

6. Process-Related Contamination: This section briefly reviews how most vacuum process produce contamination beyond those sources already discussed. Contamination related the leak detection, PVD sources, and source outgassing are provided as examples.
7. Lubrication-Related Contamination: This section briefly reviews how necessary low-friction "lubrication" can be provided within a vacuum chamber while still limiting contamination. The section reviews low-vapor-pressure fluid, grease, and solid-phase lubricants.
8. Vacuum System/Component Cleaning and The Clean-Room Environment: This section reviews some typical cleaning procedures used for vacuum chambers and components so that the vacuum environment produces minimal contamination. Similar typical cleaning procedures used for products/samples is also presented. The section concludes with a discussion of the design of clean room environments, and how these are typically designed for effective use and maintenance of vacuum-process equipment.

**Timothy Gessert** is the Principal and Managing Member of Gessert Consulting, LLC, and Adjunct Professor at University of Illinois at Chicago. Tim is also a retired Principal Scientist, formerly at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. He received degrees in physics from University of Wisconsin-River Falls (B.Sc.), Colorado School of Mines (M.Sc.), and University of Wales - College of Cardiff (Ph.D). His 30+ years of research at NREL included leading the Device Development and Fabrication Team, and the Thin-Film Photovoltaic Devices Research Group. Research activities have included development of vacuum and photolithographic processes, transparent-conducting oxides, photovoltaic absorber layers, and related electrical contacts. His present research is directed at understanding how choices in processes and device design affect the ultimate performance, stability, and other application aspects of polycrystalline and crystalline photovoltaic devices. Tim has more than 240 publications, more than 10 issued US Patents, and has authored two books on vacuum technology. Tim is a Fellow and former President of the American Vacuum Society, and serves as Editor-in-Chief for the journal *Thin Solid Films*. He is also co-author, along with John O'Hanlon, of "A Users Guide to Vacuum Technology", 4th Edition, John Wiley and Sons, 2023.

# Troubleshooting for Thin Film Deposition Processes

**Dr. Mike Miller**, *Director of Business Development at Angstrom Engineering Inc., Kitchener, Ontario, Canada*

The tutorial is designed for process engineers and technicians, quality control personnel, thin film designers, and maintenance staff.

Vacuum deposited thin films are used for optical coatings, electrically-conductive coatings, semiconductor wafer fabrication, and a wide variety of other uses. They may be deposited on glass, plastic, semiconductors, and other materials. Usually, a vacuum deposition process produces durable, adherant films of good quality. But what do you do when things go wrong? Not all films can be deposited on all substrate materials. Sometimes films peel off or crack. Other times they are cloudy, absorbing, scattering, or have other unacceptable properties.

This tutorial will teach you about techniques and tools that can be used to identify the source of the problems, correct the process, and get back into production. It will also help in learning how to develop new processes and products.

### *Topical Outline*

- Mechanical, electrical, and optical properties of thin films
- Process parameters that affect film properties
- Gauge and instrument calibration
- Properties of substrate surfaces
- Measurement of film stress
- Detection of contamination
- Introduction to surface analysis techniques (Auger, ESCA, SIMS, FTIR)
- Substrate preparation and cleaning

### *Course Details:*

Vacuum deposited thin films are used for optical coatings, electrically-conductive coatings, semiconductor wafer fabrication, and a wide variety of other uses. They may be deposited on glass, plastic, semiconductors, and other materials. Usually, a vacuum deposition process produces durable, adherent films of good quality. But what do you do when things go wrong? Not all films can be deposited on all substrate materials. Sometimes films peel off or crack. Other times they are cloudy, absorbing, scattering, or have other unacceptable properties.

This survey tutorial will teach you about techniques and tools that can be used identify the source of the problems, correct the process, and get back into production. It will also help in learning how to develop new processes and products. Many types of deposition processes will be discussed, although the focus is not on in-depth comparison of deposition processes. Techniques and tools are described for making a variety of measurements for quantifying the properties of thin films, both at the "cheap-and-quick" level and for precision analysis. By drawing on methods used in a variety of industries, examples are given that can introduce new approaches to solving problems. The tutorial is designed for process engineers and technicians, quality control personnel, thin film designers, and maintenance staff. Some of the topics to be covered:

- Mechanical, electrical, and optical properties of thin films
  - adhesion, abrasion, humidity, salt spray, hardness, bending
  - scratch and indenter tests
  - transmission, reflection, conductivity
  - index of refraction, absorption, scatter, haze
- Process parameters that affect film properties
  - temperature, rate, pressure, angle
  - effects of water vapor
  - stoichiometry control
- Gauge and instrument calibration
  - pressure (thermocouple, ion, capacitance manometer gauges)
  - mass flow (thermal, laminar flow, displacement types)
  - helium leak checking

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## Troubleshooting for Thin Film Deposition Processes (cont'd)

- Properties of substrate surfaces
  - smoothness, chemistry
  - results of polishing processes
- Measurement of film thickness and stress
  - use of thin optical flats for stress
  - thickness measurement devices
- Detection of contamination
  - UV light
  - water sheeting
  - residual gas analyzers, partial pressure measurements
  - contaminant "fingerprinting" using RGAs
- Introduction to surface analysis techniques
  - Auger, ESCA, SIMS, FTIR
  - RGA, GC/MS
  - Use of outside services and labs
  - Value vs. costs for capital equipment
  - Substrate preparation and cleaning
  - use of solvents and detergents
  - ultrasonic cleaning
  - contact angle measurements for detecting contaminants
  - glow discharge cleaning in vacuum
- Statistical Process Control (SPC)
  - Use of SPC
  - Run charts
  - Design of Experiments (DOE)
- Problem solving within organizational structures
  - Getting support
  - Finding resources
  - Identifying risks
  - Communicating clearly

**Dr. Mike Miller** is Director of Business Development at Angstrom Engineering Inc. in Kitchener, Ontario. He received his BSc in Chemistry from the University of Windsor in 2009 and his PhD in Chemistry from the University of Windsor in 2012. After graduation, Miller founded Substrata Thin Film Solutions Inc and began teaching Undergraduate Chemistry in 2014.

# Introduction to Two-Dimensional Materials

**Christopher Muratore**, *Ohio Research Scholars Endowed Chair Professor in the Chemical and Materials Engineering Department, University of Dayton - Dayton, OH*

Two dimensional (2D) materials are an expanding family of atomically thin materials with unique and unexpected optical and electronic properties that we continue discover each day. These materials are of particular interest because they offer the ultimate in layer-by-layer tailorablity to achieve the desired properties of materials. Moreover, electronic and optical devices produced from 2D materials demonstrate extreme mechanical flexibility, giving rise to new possibilities for technological developments with broad and impactful applications. This class will describe in detail the fundamental properties of this unique class of materials, typical approaches to making and characterizing them, and their applications.

### *Topical Outline*

*Properties:*

- Fundamentals of physics associated with 2D materials resulting in unique combinations of electronic, optical, and mechanical properties.
- Characteristics of two dimensional material families, including graphene, transition metal dichalcogenides, and group IV monochalcogenides.

*Processing:*

- Approaches for synthesis of 2D materials including mechanical and chemical exfoliation, chemical vapor deposition, physical vapor deposition, additive manufacturing, as well as the associated challenges of processing low dimensional materials
- Practical discussions on how to get started synthesizing new materials and fabricating 2D devices

*Characterization:*

- Common chemical and structural characterization approaches for two-dimensional materials including Raman, XPS, TEM
- Novel, in situ characterization techniques

*Applications:*

- Transistors
- Light sources
- Photodetectors
- Molecular sensors

# Flexible Electronics

**Christopher Muratore**, *Ohio Research Scholars Endowed Chair Professor in the Chemical and Materials Engineering Department, University of Dayton - Dayton, OH*

Revolutionary new capabilities for monitoring physical health of humans, machinery, and the processes governing the climate and condition of our entire planet are currently in development. Low cost flexible electronic devices play a critical role in these endeavors. This course will trace the evolution of reliable, large-area, flexible electronics and associated technologies, and will cover fabrication approaches such as chip attachment, thin-film devices, and nanoscale self-assembled and printed device based coatings. Additionally, fundamentals of state of the art fabrication techniques including vapor phase processing and direct fabrication approaches such as printing with aerosols and particle-based inks featuring advanced electronic materials to enable flexible electronic devices will be presented.

***Topical Outline:***

- Flexible electronics overview
- General concepts
- Applications
- Evolution of synthesis and fabrication methods optimized for flexible electronics
- Flexible Silicon
- Organic electronics
- Ultra-thin, or 2D materials
- Synthesis and processing methods for flexible electronics
- Substrate considerations and preparation
- Vapor phase processing
- Printing
- Photonic annealing
- Mechanical and electronic properties of flexible electronic devices
- Limitations on flex – performance vs. strain
- Lifetime dependence on strain
- Characterization and device integration
- State of the art approaches for flex characterization
- Challenges unique to flexible platforms
- The future of flex
- Performance potential
- Market/application projections

Christopher Muratore is the Ohio Research Scholars Endowed Chair Professor in the Chemical and Materials Engineering Department at the University of Dayton. Prior to joining the University, Professor Muratore spent 10 years as a staff member at the Air Force Research Laboratory and still works closely with multiple flexible electronics groups there. In 2013, he also founded m-nanotech Ltd., a consulting company specializing in thin film materials processing and characterization. Throughout his 20 year research career, Christopher's work has focused on developing an understanding of how to control structure and properties of thin films and surfaces for diverse applications, and their impact on properties and performance. His research group currently focuses on novel large-scale synthesis of materials for flexible, wearable electronic devices. He has 14 patents, published over 100 peer-reviewed articles and has served as guest editor for Surface and Coatings Technology and Thin Solid Films for five years.