Vacuum Technology Division
Room 203B - Session VT-TuA

IoT Session: Vacuum System Design and Automation & Flash Networking Session

Moderators: Julia Scherschligt, National Institute of Standards and Technology, Martin Wuest, Inficon

2:20pm **VT-TuA-1 The Importance of Vacuum Cleanliness in Semiconductor Process Control SEM Tools***, **Irit Ruach Nir,*** Applied Materials, Israel*; M Eilon, K Luria, G Eytan,* Applied Materials **INVITED**

In the semiconductor manufacturing process, integrated circuits are formed by many layers, and hundreds of process steps are required to produce a single wafer. If any problem occurs at any step of the production process, a huge amount of defective products will be produced. Therefore, inspecting the wafers during the production process is essential in order to discover any problem and solve it as early as possible.

Scanning electron microscopes are playing an important role in process control and yield management of the semiconductors process. Defect review (DR) SEMs are used for defect identification, review and classification, enabling the semiconductor fabrication plant (fab) yield management system to identify failures or problems at an early stage in the process flow and to point on possible root cause. The Critical Dimension (CD) SEM is used to measure critical dimensions of the fine patterns formed on the semiconductor wafer, enabling verification of process quality. Since the SEM tools are in-line tools it is essential that they will not affect the scanned wafer.

Organic contamination is one of the main challenges in vacuum systems and hence in e-beam based metrology systems. Organic molecules adsorbed on the wafer surface during SEM inspection may cause yield loss in the following process steps or affect the CD measurement. In addition, with decrease in design rules the processes become more and more sensitive to organic contamination and therefore the ability to control vacuum cleanliness is crucial. In this paper, we will specify some of the challenges involved in the design of clean SEM based metrology tools, possible contamination sources and possible effects of such contamination molecules on the wafer.

3:00pm **VT-TuA-3 Vacuum Chamber Design and Fabrication.***, **Steve Greuel,*** Nor-Cal Products **INVITED**

The Vacuum Chamber Design and Fabrication presentation will provide insights and considerations for those who are involved with the design and specifications of vacuum chambers. Proper vacuum chamber design, materials, machining, welding and other processing fundamentals will be discussed, as well common pitfalls to avoid during the design phase.

4:20pm **VT-TuA-7 Compact Ultra High Vacuum Systems for Applications of Cold Matter***, **Evan Salim,** S Hughes, M Perez, D Anderson,* ColdQuanta Inc. **INVITED**

Cold and ultracold states of matter offer tremendous potential to disruptively impact in the fields of timekeeping, inertial sensing, EM field sensing, and information science. Currently, however, the complexity of high-performing cold atom systems constrain them to laboratory environments. As the enabling technology matures these states of matter are beginning to make the transition from pure science to becoming critical engineering tools. For that transition to be successful, it is necessary for the building blocks of cold atom systems be simplified, stabilized, and ultimately commercialized. At the heart of all of these cold atom systems lies an ultra-high vacuum (UHV) package. In this talk we present on the progress towards miniaturized UHV technologies that support the specific requirements of atomic systems, such as high-quality optical access, non-magnetic structures, and exquisite control of local electromagnetic fields. Our approach takes advantage of compatible material systems, such as glass and silicon, to produce monolithic chambers that eliminate the need for flanges and similarly bulky components. We will also present on how these novel vacuum systems will enable future applications, including clocks and quantum computers, and will help to define a standard set of integrated UHV platforms for cold atoms.

5:00pm **VT-TuA-9 Plasma Window as Vacuum Atmosphere Interface for Various Applications***, **Ady Hershcovitch,*** Brookhaven National Laboratory **INVITED**

The Plasma Window is a novel apparatus that utilizes a stabilized plasma arc as an interface between vacuum and atmosphere or pressurized targets without solid material. In addition to sustaining a vacuum atmosphere interface, the plasma has a lensing effect on charged particles. The plasma current generates an azimuthal magnetic field, which exerts a radial Lorentz force on charged particles moving parallel to the current channel. With proper orientation of the current direction, the Lorentz force is radially inward. This feature can be used to focus in beams to a very small spot size, and to overcome beam dispersion due to scattering by atmospheric atoms and molecules

The best results to date have been the following:

1. Vacuum (pressure of ~ 10^{-6} Torr) was successfully separated from atmosphere and from a gas target pressurized up to 9 bar.

2. A 2 MeV proton beam was propagated from vacuum through the plasma window into atmospheric pressure with no measurable energy loss or beam degradation.

3. A 175 KeV electron beam was transmitted from vacuum through the plasma window to atmospheric pressure.

4. Successful transmission of X-rays from a light source to atmosphere.

5. Compatibility tests for transmission of electromagnetic radiation indicated that the plasma window does not generate electromagnetic interference, and that X-rays (away from resonance) are transmitted with negligible attenuation.

6. Electron beam welding in atmosphere (by an electron beam passing from vacuum through a plasma window) was accomplished with electron beams of unprecedented low power. Weld quality for the non-vacuum plasma window electron beam welding matched the quality of in-vacuum electron beam welding.

7. Internal gas stripper of ½ atmosphere helium confined by 2 plasma windows in accelerator vacuum.

Many industrial processes like electron beam welding and melting, as well as, ion material modification have low production rates due to required pumping time, and limits on the size of target objects. Utilization of the plasma arc as a window for targets removes these limitations and increases production rates. Other applications that can greatly benefit from plasma windows are those involving transmission of intense radiation or particle beams like high power lasers or deep ultraviolet photolithography sources, internal gas targets and beam dumpds. Plasma windows are practically completely transparent to high-energy particles and radiation, and unlike conventional windows, plasma windows are completely impervious to thermal damage.

5:40pm **VT-TuA-11 Applications of IoT in Vacuum Technology***, **Jacob Ricker,** J Hendricks,* NIST

Automation has become a necessary tool for scientists as they are expected to do more with less time and money. NIST is currently utilizing IoT (internet of things) in several applications to evaluate and control processes that benefit from continuous monitoring while simultaneously freeing up staff time. The presentation will feature two examples to highlight how IoT is changing how we monitor sensors and process data for real-time automation of vacuum technology. First, NIST's utilization of IoT to automatically protect and monitor primary pressure standards, and second, the use of IoT to monitor encasements holding historical documents such as a draft of the emancipation proclamation in Lincoln's handwriting.

Primary pressure standards require continuous pumping and must be monitored as failures can cause water vapor to contaminate the ultra-pure vacuum systems and monometer fluids. Additionally, it can cause damage to expensive vacuum pumps and cause significant down time of the system. Microcontrollers and circuits were designed and constructed to monitor pressure in the system, rotation of the pump, and to control shutoff valves if necessary. Additional controllers monitor for cooling water failures to protect diffusion pumps from overheating and for compressed air failure which would disable the automated valves. All these systems work simultaneously and report issues back to the operator.

In collaboration with the Smithsonian, Library of Congress, National Archives, and other agencies around the country, NIST has worked to fabricate encasements that protect historical documents such as the Declaration of Independence, US Bill of Rights, and Emancipation

Proclamation. All these encasements have featured sensors to monitor gas quality/stability; however recently IoT has enabled real-time monitoring of these readings to prevent operators from having to make manual readings of these sensors. The latest version of the encasement monitors Temperature, Humidity, O2 content, encasement pressure, and barometric pressure which are all reported and processed on cloud data storage. IoT has enabled instantaneous feedback and ensured these documents are preserved for future generations.

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