Tuesday Morning, October 20, 2015

Vacuum Technology
Room: 230B - Session VT-TuM

Vacuum Suitcases and Particulate Control
Moderator: James Fedchak, NIST, Marcelo Ferreira, European Spallation Source

8:00am **VT-TuM1 Applications for Mobile Vacuum Environments in Semiconductor Manufacturing**, ***Daniel Babbs***, Brooks Automation **INVITED**

The majority of processes found in semiconductor manufacturing occur within a vacuum environment. A vacuum environment provides a stable operating regime which permits precise process control which is highly repeatable. However, after a semiconductor wafer is processed it is removed from the vacuum environment, placed into an atmospheric transport container and subsequently delivered to the next process tool. Transitioning the semiconductor wafer between atmospheric and vacuum environments has been the traditional process method in the industry but recent advancements in device structures below the 22nm technology node are challenging the effectiveness of this method. Specifically, management of the semiconductor wafer exposure limits to oxygen and moisture at all times is now becoming standard practice to achieve desirable production yields.

The application of a mobile vacuum carrier to transport and store semiconductor wafers provides a contiguous vacuum environment between process platforms. The vacuum carrier utilizes a standard mechanical interface, or vacuum port, for docking to the process platform and is compatible with current factory automation systems. The vacuum port provides automatic loading/unloading of the vacuum carrier which includes dynamic pressure equalization between source and target environments. Typically, a vacuum carrier load/unload on the vacuum port is completed in <60 seconds on average. Preliminary experiments have demonstrated acceptable vacuum performance sustained in the carrier over prolonged durations (after 72 hours <3 Torr). Over the same period, exposure limits of oxygen and moisture within the vacuum carrier are within part-per-million ranges (66ppm and 349ppm, respectively). The reduction in exposure to environmental contaminants removes variability thus improving process quality and yield. In addition, a mobile vacuum environment can be used to connect discrete process platforms and create customized process flows without the semiconductor wafers ever leaving vacuum. This capability presents opportunities to develop new equipment architectures and unique semiconductor processes.

In summary, as device dimensions continue to shrink, wafer sensitivity to environmental contamination increases. This in turn drives the necessity for improved environmental control throughout the entire semiconductor process including transport and storage of the semiconductor wafers. For semiconductor manufacturers, the mobile vacuum environment provides the capability for endpoint-to-endpoint control of the wafer environment not only within critical process chambers but also while transferring them between process platforms.

8:40am **VT-TuM3 Experience of UHV Transportation of Critical Components**, ***Paolo Michelato***, Italian National Institute for Nuclear Physics (INFN), Italy **INVITED**

High quantum efficiency semiconductor photocathodes, as alkali telluride and antimonides, are used as high brightness electron sources in laser triggered radio frequency and high voltage guns. These materials are quite sensitive to gas contamination and UHV conditions must be guaranteed during preparation, storage and handling. Their photo emissive characteristics, as the quantum efficiency, are strongly affected by the exposition to reactive gases as oxygen, carbon dioxide and water vapor.

Photocathodes are commonly prepared and fully characterized in the preparation laboratory and then moved to the point of use, usually inside the tunnel of the accelerator facility. Different laboratories built custom designed UHV suitcases, which will be described and analyzed in this paper, for the transportation and manipulation of these sensitive materials.

INFN Milano – LASA produces, handles and transports Cesium Telluride photocathodes to different laboratories since 1990. Our suitcases are successfully used for transferring photocathode between production sites (INFN Milano, DESY-HH, Fermilab) to the accelerator facilities at DESY Hamburg (FLASH, XFEL), DESY Zeuthen, FERMILAB and LBNL. Up to now, seven suitcases transfer photocathodes between laboratories for preparation procedure, use in the gun, diagnostic and post-mortem investigation.

The transportation of other critical and delicate components might benefit from a similar suitcase design.

Generally, a sputter ion pump maintains the photocathodes in UHV during their transfer. This type of pump is heavy, and needs a HV power supply for continuous operation. These characteristics pose serious limitations for cathode air freight transportation due to present safety regulation. To overcome these limitations, we adopt a different strategy coupling a NEG pump with sputter ion pump. With this approach the NEG pump can preserve photocathode characteristics for a long time, even with the sputter ion pump switched off.

At present, we are testing a SAES Getters NEXTorr® pump that combines, in a synergic design, sintered NEG and sputter ion pump technologies. This would provide a more compact and lightweight system, with less residual magnetic fringe field, and an integrated pressure reading. The paper will discuss the results so far obtained, in terms of suitcase performances and reliability as well as photocathode properties preservation.

9:20am **VT-TuM5 Particle Behavior in Vacuum Systems: Protection Schemes for EUVL Critical Surfaces, Speed Controlled Particle Injection, Prevention of Particle Formation during Pump Down**, *D. Pui*, ***Shawn Chen***, University of Minnesota **INVITED**

Extreme Ultraviolet Lithography (EUVL) is a leading lithography technology for the next generation semiconductor chips. Photomasks, in a mask carrier or inside a vacuum scanner, need to be protected from nanoparticle contamination down to below 20 nm diameter, the minimum feature size expected from this technology. We have developed models and performed experiments in vacuum tools down to 20 mTorr. Nanoparticles between 60 nm and 250 nm were injected into the vacuum chamber with controlled speed and concentration to validate the analytical and numerical models. Also, methods and models were developed to evaluate nanoparticle generation, transport and deposition on photomasks in carriers. Various protection schemes have been developed and evaluated using these experimental and modeling tools. Inside the vacuum chamber, nanoparticles could be formed during rapid vacuum pump down and/or by conversion of outgassing materials by soft x-ray. The detection and control of these nanoparticle contaminants will also be addressed in this presentation.

11:40am **VT-TuM12 Differentially Pumped Interface to Transfer Environmentally Sensitive Materials Designed with Built-in figures of Merit**, ***Hugo Celio***, University of Texas at Austin

An interface designed to transfer air sensitive samples (e.g., battery materials) from an argon filled glove box (1 part-per-million of O_2 and H_20) into an ultra-high vacuum (UHV) chamber for surface analysis is described. This interface (referred as interface for pressure-to-vacuum environmental sample transfer or IP-VEST) is equipped with a differentially pumped load lock, a buffer chamber, a detachable vacuum suitcase (referred to as a capsule), pump chamber, and a set of pressure gauges. Differential pumping minimizes back-flow from the mechanical pump that backs the turbomolecular pump (TMP) of the pump chamber. In the glove box, where argon pressure is 800-900 Torr, samples are loaded into the capsule and remain under this pressure during their transport to the load lock of the IP-VEST. An automatic sequence of pneumatic valves control differential pumping gas flow from the capsule to the pump chamber during the transition from atmospheric pressure (viscous flow) to high vacuum (molecular flow). During this pressure transition, the IP-VEST is also designed to generate a pressure spike in the buffer chamber that is a six order in magnitude, crossing over from the molecular flow to the viscous flow, and returning to molecular flow. This pressure spike is tunable with respect to pressure and time, and it is used as reference peak, allowing a comparison between pump down curves acquired during different sample transfer events. This pressure spike, combined with pump down curve, is referred to as a viscous-to-molecular flow curve (or spiked flow curve). The high repeatability of the spiked flow curves allows a user to develop a method, e.g., figures of merit, to evaluate sample transfer reliability during the entire transfer process that includes gaseous contents of an argon filled glove box and pumping efficiency of the IP-VEST. As a comparison, spiked flow curves were measured after filling the capsule near standard pressure from two sources of argon gas: (1) A high pressure cylinder bottle and (2) a commercial glove box. Both argon sources have intrinsic levels of $_2$ and H_2O at 1 ppm. In addition, silicon and tin were separately exposed to these two sources of argon in order to evaluate the amount of oxidation of these materials due to intrinsic and extrinsic (e.g., leaks and back-flow) factors. These samples were transferred using the IP-VEST that is coupled to a port of a UHV chamber which is equipped with an X-ray photoelectron spectroscopy (XPS). XPS confirms that the IP-VEST does not contribute to the oxidation of these materials due to extrinsic factors.

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