Vacuum Technology
Room 121 - Session VT1-TuM

Vacuum Technology for Semiconductor

Moderators: Sol Omolayo, Lawrence Berkeley National Laboratory, **Jacob Ricker**, NIST

8:00am **VT1-TuM-1 Optimizing Electron Emitter Module Geometry for Improved Lifetime through Test-Particle Monte Carlo (TPMC) Simulation***, **Naga Chennuri**, N. Petrone, L. Muray,* KLA Corporation

Thermal field emitters (TFEs) are the most common electron sources used in scanning electron microscopes (SEMs) due to their stable emission and long lifetime (>10,000 hrs). To maintain long lifetime, TFE’s must operate at pressures less than ≤5x10-9 Torr, in ultra�high vacuum (UHV). The TFE’s consist of a cylindrical suppressor cap which is mounted a few hundred microns above the SEM lens stack. This narrow gap between the emitter and the top of lens is a region where there is potential for an increased local pressure due to low vacuum conductance. In this work, we used advanced vacuum modeling to simulate the local pressure increase around TFE tips and use this knowledge to optimize the geometry of TFE emitter (suppressor cap) module to increase conductance and improve lifetime. The model consists of a base vacuum chamber, emitter mount, emitter module and lens. For the emitter module (suppressor cap), four different geometries have been modelled and compared. A total pumping speed of 20L/s and tabulated material outgassing values for the components were employed, and MolFlow+ was used to perform vacuum simulations. The background pressure in the chamber was simulated across all four geometries, as shown in Fig. 1, and was verified to be consistent, at 1.5x10-9 torr. The cylindrical emitter module (baseline) showed a peak local pressure of 1.5x10-8 torr. The two beveled cylinders, with minor diameters 4.7mm and 3mm, showed notable improvements with local peak pressures of 7.5x10-9 torr and 6x10-9 torr respectively. The rounded design demonstrated the greatest reduction in peak pressure, with a local high of 4x10-9 torr which falls well within the acceptable operational limits, thereby preserving lifetime. Machine downtime is a critical factor for SEM tools used for wafer inspection and metrology making it essential to preserve and extend the lifetime of TFE’s to maintain optimal service intervals. The results from study were used to determine an optimized suppressor cap geometry for TFE modules, allowing for high conductance, and ultimately improved TFE stability and lifetime.

8:15am **VT1-TuM-2 New Advanced Home-Built Reactor for in-Situ Studies of ALD and ALE***, **Cristian van Helvoirt**, C. van Bommel, M. Merkx, J. Zeebregts, F. van Uittert, E. Kessels, A. Mackus,* Eindhoven University of Technology, Netherlands

In the field of nanotechnology atomic scale processing is getting more and more advanced and requires in-depth understanding of the reaction mechanisms of deposition and etching processes. In-situ diagnostics are essential for accomplishing this. Within our group a reactor is designed and installed capable for in-depth study of atomic layer deposition (ALD) and atomic layer etching (ALE) surface reactions, with the focus on infrared spectroscopy (IR) at sub-monolayer sensitivity.

In-situ IR spectroscopy has proven itself to be a powerful tool to study the mechanism of ALD and ALE. [1,2]. To improve sensitivity into the sub-monolayer regime, the technique becomes dependent on the substrate material. Solutions can be found using pressed powder, ATR (attenuated total reflection) for dielectrics or grazing incidence RAIRS (Reflection Absorption Infra-Red Spectroscopy) for metals. The wish to be able to perform this type of diagnostics in one tool made us design a new reactor with the capability for in-situ transmission and reflection IR spectroscopy. For this versatility the back flange is designed to be able to load samples vertically (for transmission) and horizontally (for reflection).

Based on the experiences within our group and the field, the system has a hot wall reactor that is equipped with a loadlock, has the capability to bias the substrate for ion energy control and has a cabinet to mount up to eight different precursor/inhibitor bubblers. The system is pumped down using a turbo-molecular pump backed with roughening pump, to be able to reach high vacuum levels. As an extra feature the setup has the option to install up to four plasma, light or particle sources at a 45-degree angle which is to expand the research in the field of surface science and plasma physics. These ports also give the capability for extra in-situ diagnostics, e.g. optical emission spectroscopy (OES), quadrupole mass spectroscopy (QMS), quartz crystal microbalance (QCM). This contribution will outline the background, design, and capabilities of this next generation home-built reactor.

[1] Goldstein *et al., J. Phys. Chem. C* **112**, 19530 (2008)

[2] Mameli *et al., ACS Appl. Mater. Interfaces* **10**, 38588 (2018)

8:30am **VT1-TuM-3 Improved Thermal Uniformity in Pedestal Heaters Through the Integration of Thermal Pyrolytic Graphite (TPG®)***, **Matt Gallaugher**, I. Nas, A. Murugaiah, J. Troha, D. Sabens,* Momentive Technologies

Thermal uniformity is a critical metric for pedestal heaters used in semiconductor thin film processing, particularly in chemical vapor deposition (CVD) and atomic layer deposition (ALD). Heaters made of aluminum alloys have a reasonable inherent thermal conductivity (~150 W/mK), but thermal conductivities of stainless-steels and nickel alloys used in higher temperature applications are much poorer (~10-20 W/mK). As a result, stainless steel and nickel alloy heaters have poorer thermal uniformity, unless complex engineering solutions such as multiple heating zones are implemented. A simple alternative is possible: embedding a high thermal conductivity material, such as Thermal Pyrolytic Graphite (TPG®), inside a billet of stainless-steel to passively improve the thermal uniformity of the heater. The unique properties of the TPG® (~1700 W/mK in-plane, ~10 W/mK out of plane thermal conductivity) serve to distribute the heat across the surface of the heater for greater temperature uniformity. The advantage of this “thermally conductive billet” approach is that it can be flexibly integrated into different heater designs, enabling machining on both its bottom surface (heating coils and/or cooling loops) and its top surface (mesas, backside gas, etc.). A simplified schematic of this design is shown in Figure 1. To demonstrate the concept, a stainless-steel billet with embedded TPG® was made into a single zone, 8” heater to reveal the thermal uniformity improvement. Greater than 2x improvement in uniformity was realized, as shown by the variation (standard deviation / average) measured via a thermal camera (Figure 2). In addition, local azimuthal variations were eliminated, leading to a more symmetric profile. These real-world results were used to create a thermal-mechanical model, which was scaled up to conceptual 12" stainless-steel heater designs with both one and two heating zones. The models demonstrated improved thermal uniformity changes in all cases: >2x improvement. Although this work sought to optimize the heater temperature uniformity, the thermally conductive billet and/or the heating pattern could be designed to optimize the wafer thermal uniformity as well, including using two zone temperature control with superior intra-zone thermal uniformity.The integration of TPG® is a key technological path for passively improving the thermal uniformity of pedestal heaters used in more demanding applications.

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