

ALD for Manufacturing

Room Tampa Bay Salons 5-9 - Session AM-MoP

ALD for Manufacturing Poster Session

AM-MoP-1 Implementing Statistical Process Control for Atomic Layer Deposition Tools in an Academic Facility to Meet Industrial Expectations, Ronald Reger, Birck Nanotechnology Center, Purdue University; **Anh Ho,** Birck Nanotechnology Center, Purdue University.; **Rich Hosler,** Birck Nanotechnology Center, Purdue University

As academic nanofabrication facilities expand their role in advanced research and prototype development, the demand for industrial-level process stability and repeatability in Atomic Layer Deposition (ALD) has become essential. At the Birck Nanotechnology Center, we have implemented a comprehensive Statistical Process Control (SPC) framework applied to multiple Fiji ALD systems to enhance process reliability. The key metrics, including film thickness, uniformity, growth-rate, refractive index, surface roughness, precursor delivery stability, and overall tool-health indicators, were continuously tracked using control charts, capability analyses, and automated data-logging integrated into routine operations. Over several years, SPC-driven maintenance strategies, precursor delivery stability, and recipe standardization have enabled improvements in within-wafer and wafer-to-wafer uniformity, reduced run-to-run variability, and enhanced long-term reproducibility. Several dielectric ALD processes now demonstrate statistically stable performance with sustained operation within established control limits. This work not only demonstrates the value and practicality of applying formal SPC methodologies within an academic cleanroom, effectively bridging research-grade flexibility with industry-grade reliability, but also contributes significantly to building the data foundation for a digital twin model for educational purposes. The results offer a model for academic facilities aiming to improve tool performance, build user confidence, and meet industry-aligned research expectations.

AM-MoP-2 Anti-Deposition ALD- Al_2O_3 Coatings against Silicon Chloride Byproduct for Capacitance Manometers, Hidenobu Tochigi, Keigo Iwamoto, Takuya Ishihara, Azbil corporation, Japan

In semiconductor manufacturing processes such as dry etching and thin-film deposition, including chemical vapor deposition (CVD) and atomic layer deposition (ALD), capacitance manometers are widely used as essential vacuum pressure sensors to monitor and control the pressures of process gases. Conventionally, diaphragm materials such as nickel-based alloys and polycrystalline aluminum oxide (Al_2O_3) are employed to ensure durability under chemically harsh environments. Sapphire, a single crystal of Al_2O_3 , is known for its excellent chemical stability, and we have developed MEMS-based pressure sensor chips entirely fabricated from sapphire [1]. In actual application, long-term drift and zero-point shift of the sensors have been observed during semiconductor manufacturing processes, which are presumed to be caused by byproduct deposition on the sensor surfaces.

In particular, processes using silicon-chloride precursors are known to generate chlorine-containing reactive intermediates and byproducts that can potentially deposit on the sensor surfaces. Previous studies on ALD processes have reported that a self-limiting surface reaction mechanism, in which SiCl-containing precursors selectively react with reactive surface functional groups such as -OH and -NH, and further adsorption is suppressed once these reactive sites are consumed [2-5]. Based on this concept, we hypothesized that similar self-limiting reactions could occur on -OH-terminated Al_2O_3 surfaces deposited by ALD and could consequently suppress the continuous formation of SiCl-related deposits on the sensor surfaces. If effective, this mechanism could be applied as a byproduct deposition mitigation strategy for capacitance manometers used in similar processes.

To verify this hypothesis, Al_2O_3 coatings were deposited by ALD using trimethylaluminum and H_2O over the entire internal surfaces of capacitance manometers, and their behavior under SiCl-based process environments was evaluated. As a result, the ALD-coated manometers showed no such degradation, whereas uncoated manometers exhibited zero-point shifts of approximately 40% of full scale and pronounced pressure hysteresis, which exhibited excellent an anti-deposition effect. In addition, the deposited Al_2O_3 film quality was examined in detail by X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy (TEM).

References

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AM-MoP-3 Enabling Vacuum Process Monitoring with Time-of-Flight Spectroscopy, Klaus Bergner, Marco John, Andreas Trützschler, VACOM, Germany; **Christopher Gray,** VACOM, Belgium

The increasing complexity of industrial vacuum processes requires broader and deeper knowledge of the vacuum itself. A crucial aspect for increasing quality demands is the necessity of in-situ monitoring and control of pressure and residual gas composition within vacuum processes. A consequence of advanced process control is the reduction of production errors, prevention of failures or major damage in combination with increased operating time. Traditional monitoring devices like hot cathodes or quadrupole mass spectrometers are both only able to measure either pressure or residual gas composition. Therefore, these devices are only conditionally suited for complete process control of vacuum processes. With our novel wide-range vacuum monitor NOVION® industrially available pressure and gas analyzation is possible.

In this talk we present the fundamental principles of the novel vacuum monitor and explain the compact combination of well-known time-of-flight spectroscopy with our own patented ion trap. Within different application cases we discuss advantages and limits of this technology and demonstrate with one single device wide range gas analysis, simultaneous measurement of total and partial pressures, leak detection for Helium and detection of air leaks. With these combined capabilities the novel vacuum monitor is able to quickly capture the complete pressure and gas composition measurement at various stages of the vacuum process chain.

AM-MoP-4 Additively Manufactured Silicon Carbide Process Components Enabling Stable ALD/ALE Under Harsh Semiconductor Manufacturing Environments, Youngsuk Jung, Ji-Won Oh, Shinhu Cho, MADDE, Republic of Korea

Silicon carbide (SiC) has been widely adopted as a chamber material for advanced semiconductor manufacturing due to its excellent thermal stability, chemical resistance, and plasma durability. However, as atomic layer deposition (ALD) and atomic layer etching (ALE) processes continue to evolve toward higher aspect ratio features, plasma-enhanced conditions, and extended process runtimes, conventional manufacturing routes for SiC components increasingly limit achievable performance, particularly in terms of thermal uniformity, weight reduction, and geometric flexibility.

In this work, we focus on the advantages of additively manufactured SiC process components as a next-generation hardware solution for stable ALD and ALE operation. Additive manufacturing enables design-for-additive-manufacturing (DfAM) approaches that allow the realization of customized, complex internal structures such as optimized gas flow channels, lattice-supported geometries, and locally tailored wall thicknesses. These design freedoms directly address key performance requirements in ALD/ALE chambers, including improved temperature uniformity, reduced thermal mass, and lightweight structures that facilitate faster thermal response and improved process controllability.

The presented SiC components are fabricated using a proprietary SiC-dedicated additive manufacturing platform, followed by a fully integrated post-processing route that includes densification and chemical vapor deposition (CVD) SiC coating. This end-to-end manufacturing capability, spanning from DfAM to final surface engineering, enables precise control over both bulk geometry and surface properties critical for plasma-facing and chemically aggressive ALD/ALE environments.

The interaction of additively manufactured and CVD-coated SiC components with representative ALD/ALE process conditions is discussed with an emphasis on structural integrity, contamination behavior, and long-term stability under repeated thermal and plasma cycling. The results demonstrate that additively manufactured SiC hardware provides a practical pathway to performance optimization beyond what is achievable with conventionally manufactured SiC components, highlighting its potential role in next-generation ALD and ALE manufacturing platforms.

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