ALD for Manufacturing
Room On Demand - Session AM1
Equipment Design/Modeling/Large Format/Precursor Delivery

AM1-1 Closed Loop Control of ALD/ALE Precursor Dose Delivery*, Jim Ye, J. Ding, V. Saptari,* MKS Instruments, Inc.

Consistent precursor delivery is needed in ALD/ALE processes for generating a stable and homogenous deposition. Unstable deposition will cause defects and create wafer to wafer and batch to batch variations. Further improvements in ALD/ALE process throughput and cutting the waste of precursors will require a tighter control on precursor dose delivery to the process chamber.

Previously, concepts of ALD/ALE precursor concentration control have been reported. However, there are two potential problems in this approach. First, tuning the concentration of precursor is a relatively slow process which can be accomplished by either varying the temperature of precursor container or adjusting the dilution/carrier gas flow. They do not have enough bandwidth to handle faster varying changes in the flow. The second problem is that a constant concentration will not guarantee a constant dose in each precursor pulse due to other factors such as a switch drift.

In this work, we present a concept solution involving a gas sensor and a pulse MFC. The gas sensor measures the precursor concentration out of the source in real time and feeds the readings to a pulsed MFC immediately downstream to the sensor. The pulse MFC generates ALD/ALE precursor pulses. It continuously adjusts the total flow rate (pulse height) or pulse duration for each precursor pulse to achieve a constant dose of the precursor to the processing chamber.

AM1-2 Efficiency Characterization of Reactor-Scale Gas Exchange by CFD*, Anton Persson,* Linköping University, Sweden*; Ö. Danielsson,* Physicomp AB, Sweden*; H. Pedersen, M. Karlsson,* Linköping University, Sweden

To utilize the sequential surface chemical reactions essential to ALD processes, the gas mixture in the ALD reactor needs to be exchanged between the metal precursor pulse and reagent pulse. This is commonly done through a continuous flow of carrier gas (purge) between the pulses and is often vital for a successful ALD process. Insufficient exchange can lead to unintentional reactions, which in turn may cause poor film thickness uniformity or formation of structural defects. In contrast, excessive purging leads to prolonged process times and waste of carrier gas. While the optimal purge time can be obtained from extensive experimental work, such studies are seldom reported for new ALD processes or fully understood at the full wafer scale, and is reactor design specific. ALD process development therefore has a lot to gain from a simple, yet powerful modelling approach to study gas transport at the reactor scale.

This work implements methods common in e.g. ventilation modeling to investigate efficiency aspects in gas exchange. An ALD reactor for 200 mm substrates with six in-plane, symmetrically positioned gas channels was modelled using computational fluid dynamics (CFD). It was assumed that the precursor partial pressure is small in relation to the partial pressure of the carrier gas, such that changes in the overall velocity field between pulse and purge steps may be neglected. Several configurations were tested, where precursor and reagent entered from opposing or asymmetric directions, with different carrier gas flow rates equivalent to N2 in a range of 50-200 sccm per inlet.

Purge times were quantified by the residence time distribution (RTD). It was shown that RTD was primarily a function of total mass flow rate and reactor geometry, and less affected by pulse time.

Moreover, precursor usage efficiency was characterized by the local mean age (LMA) measure, which represents the mean time for a particle to reach a certain location in the reactor in a steady state situation, calculated from the inlet. It was seen that the constant carrier gas flow in some configurations caused “blocking effects”, obstructing the precursor to spread uniformly over the substrate. Thus, care should be taken to engineer the flow field for efficient precursor usage.

While the model is subject to simplifications, the general trends and relative performance among test cases are expected to be accurate. Once the main design frame is established, promising configurations could be analyzed further by extending the model, e.g. by taking reversible adsorption on reactor walls into account.

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