Fast plasma ALD employing de Laval Nozzles for high velocity precursor injection

Abhishekkumar Thakur[1], Jonas Sundqvist[2], Stephan Wege[1], Mario Krug[2]
[1]Plasway-Technologies GmbH, [2]Fraunhofer IKTS

a.thakur@plasway-technologies.de

ALD based self-aligned multiple patterning (SAxP) has been the key process to continued chip scaling. SAxP demands PEALD for low temperature, conformal deposition of spacers on photoresist features for the subsequent pitch splitting. ALD is limited by low thru put that can be improved by raising the growth per cycle (GPC), using new precursor, preforming batch or Spatial ALD, shrinking the ALD cycle length, or omitting purge steps. Today's latest and highly productive platforms facilitate very fast wafer transport in and out of the ALD chambers. Current 300 mm ALD chambers for high volume manufacturing are mainly top-down or cross-flow single wafer chambers, vertical batch furnaces, or spatial ALD chambers.

In our research developing fast PEALD processes, we use top down showerhead gas flow to ignite a 60 MHz plasma (CCP) in a 300 mm chamber. The chamber has been modified to attain precursor pulses of ≤10 ms along with good uniformity using our patented ring injector with integrated de Laval nozzles enabling high speed, all-round precursor injection across the wafer. We used the well-known TMA-O_2 PEALD process to deposit Al_2O_3 for the hardware development and the productivity benchmarking.

Initially we used a linear capillary injector for PEALD of Al_2O_3 at room temperature (30 °C), wherein we shrunk the TMA pulse length from 2000 ms down to 15 ms maintaining the constant 1.7 Å GPC, which confirmed the self-limiting nature of the TMA half-reaction. With the de Laval ring injector the saturation started at 10 ms of TMA pulse length, which is the tested switching limit of the electro-pneumatic ALD valve. The process linearity and the saturation curve indicated the ALD nature of the process. For 50 ms of TMA pulse, a wide ALD temperature window (30-120 °C) with constant 1.3 Å GPC was extracted. Even with very short pulses we achieved a very good uniformity from wafer centre to the edge. XPS analysis of the deposited Al_2O_3 indicated that the film deposited at 120 °C were more oxidized than the films at 30 °C with the single injector. However, the elemental composition for films deposited with TMA pulse of 10 ms vs. 50 ms was indistinguishable. A surface carbon contamination was observed due to the wafer exposure to the outer atmosphere post processing. However, angular XPS depth profiling revealed no detectable amounts of carbon in the "bulk of the film". The complete ALD process optimization results including plasma pulse optimization, conformality and, 300 mm wafer scale uniformity will be presented at the conference.