Evaluating the Performance of *In Situ* PECVD Chamber Cleaning Gases on an Applied Materials P-5000 DxL Reactor

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Carbon based perfluorocompounds such as C_2F_6 are widely used in the semiconductor industry.[1-3] The potential impact of these molecules on global warming has become an increasing concern in recent years.[1-6] Major U.S. semiconductor manufacturers and the U. S. Environmental Protection Agency (EPA) have issued a memorandum of understanding (MOU) that calls for voluntary reduction or elimination of PFC emissions.[7] In addition, the World Semiconductor Council has declared an industry-wide goal of 10% reduction of PFC emissions (MMTCE) by 2010 based on 1995 emissions.[7,8]

Although estimates vary, it is generally accepted that over 70% of the PFCs emitted from the semiconductor manufacturing processes are derived from *in situ* cleaning of residues from the chamber walls inside plasma-enhanced chemical vapor deposition (CVD) reactors. PFC emissions arise from both the undestroyed PFC feed gas and the plasma-generated CF_4. Several approaches to reduce PFC emissions during PECVD chamber cleaning are being pursued. These approaches include: 1) optimizing C_2F_6-based *in situ* cleaning;[9-12] 2) replacing C_2F_6 with an alternative PFC for *in situ* cleaning;[13-16] 3) utilizing dilute NF_3 for *in situ* cleaning;[17] and 4) adopting NF_3-based remote downstream cleaning technology.[18-19] Chamber cleaning performance depends on reactor, film composition, and various process parameters. Process optimization is a balancing act. Trade-offs between lower MMTCE and other important factors such as shorter clean time must be considered.

We report PECVD *in situ* chamber cleaning studies performed on a common production platform (Applied Materials P-5000 DxL chamber) following 1.0 µm TEOS oxide deposition using the following fluorine-containing gases: C_2F_6, C_3F_8, *c*-C_4F_8, C_4F_8O, and NF_3. For each cleaning gas, we performed a design of experiments (DOE) to determine the optimized cleaning process with regards to feed gas flow rates, O_2/PFC ratio, process pressure, and RF power. We then evaluated the cleaning time, gas usage, PFC destruction efficiency, and global warming impact (MMTCE) under optimized cleaning conditions for each gas relative to the standard C_2F_6 process.

Our data show that the standard C_2F_6 recipe can be successfully optimized for significant reductions in emissions and gas usage. The optimized C_2F_6 clean provides an MMTCE reduction of up to 51% and a gas usage reduction of up to 40% relative to the standard C_2F_6 recipe. Optimized clean recipes for the alternative fluorocarbon gases yield similar reductions, but there are trade-offs in terms of increased clean time and higher CF_4 and COF_2 emissions. In addition, the costs of qualifying and facilitizing a new chemical must be considered. The best chamber cleaning performance is obtained with a dilute NF_3 process: A 94% reduction in MMTCE is obtained with a 77% reduction in gas usage and an 11% reduction in clean time. Results from the evaluation of these gases on a common production platform is consistent with previously reported optimization work conducted at semiconductor fabrication sites.[10,17,19]

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