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AIR PRODUCTS

# Reducing the Cost Of Ownership of CVD Chamber Cleaning While Minimizing Environmental Emissions

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MATERIALS

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RELIABILITY

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INTEGRATION

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INNOVATION

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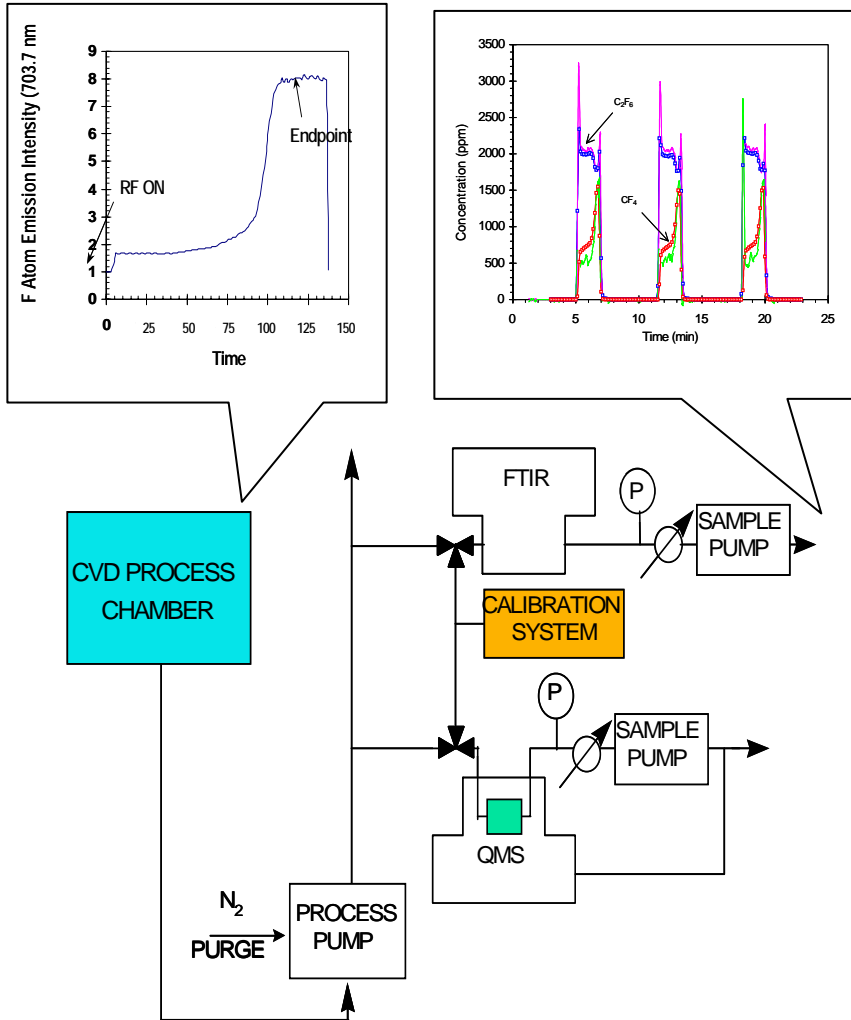
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*Air Products and Chemicals, Inc.*

# Background

- Many DCVD chambers are cleaned using an *insitu* plasma etch process
- Choice of plasma chemistry and process optimization are opportunities to reduce both emissions and cost of the module
- Applied Materials PECVD chambers (DxL, DxZ) are typically cleaned using  $\text{CF}_4/\text{N}_2\text{O}$  and  $\text{C}_2\text{F}_6/\text{O}_2$  plasmas
- $\text{CF}_4$ -based chamber cleans are inefficient in terms of gas utilization ( $\sim 5\%$ ) and have large  $\text{CF}_4$  emissions
- $\text{C}_2\text{F}_6$ -based chamber cleans are usually not optimized regarding emission and gas consumption
- We investigated alternative chemistries for cleaning PECVD reactors following  $\text{SiN}_x$  deposition for Silane chambers:
  - $\text{C}_2\text{F}_6/\text{N}_2\text{O}$ -based process
  - $\text{C}_4\text{F}_8/\text{N}_2\text{O}$ -based process
- ... for TEOS chambers:
  - $\text{C}_2\text{F}_6/\text{O}_2/\text{NF}_3$ -based process
  - $\text{NF}_3/\text{He}$ -based process



# Process Development

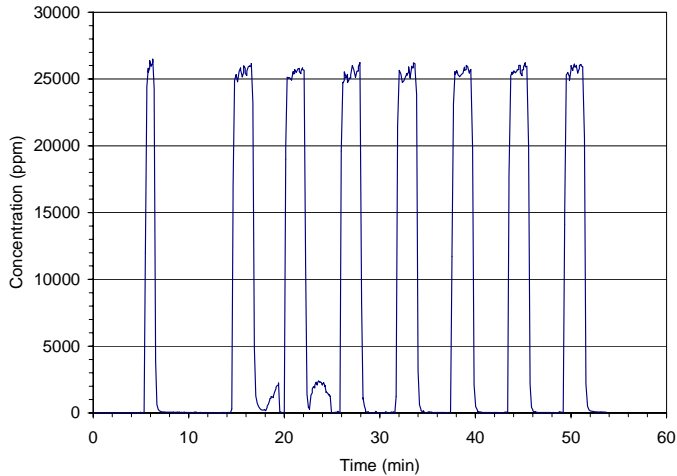


- Applied Materials DxL, DxZ (6 and 8 inch):  $SiN_x$ ,  $SiO_2$
- Establish baseline emissions and gas usage
- Minimize PFC emissions and gas usage while maintaining an acceptable clean time
- Measure response surfaces
  - Emissions =  $f(P, \text{flow rate, concentration})$
  - Clean Time =  $f(P, \text{flow rate, concentration})$



# Example: Baseline CF<sub>4</sub> Chamber Clean

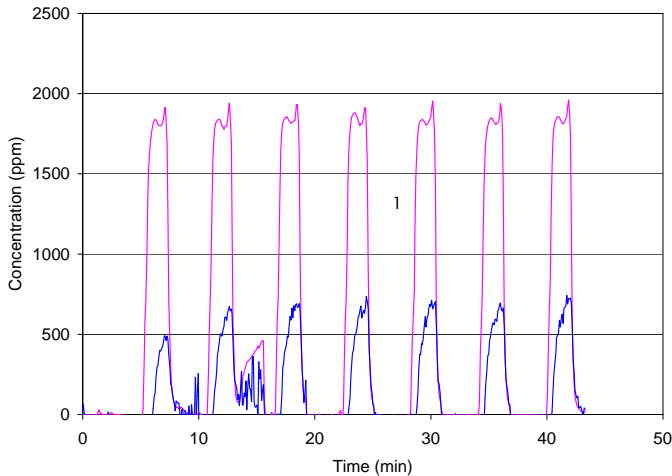
SiN PECVD: CF4 CLEAN



CF<sub>4</sub>

CF<sub>4</sub> (1500 sccm), N<sub>2</sub>O (750 sccm), 5.0 torr, 800 W, (EPD + 20 % Overetch)

CF4 CLEAN (FTIR): SiN PECVD



SiF<sub>4</sub>

HF

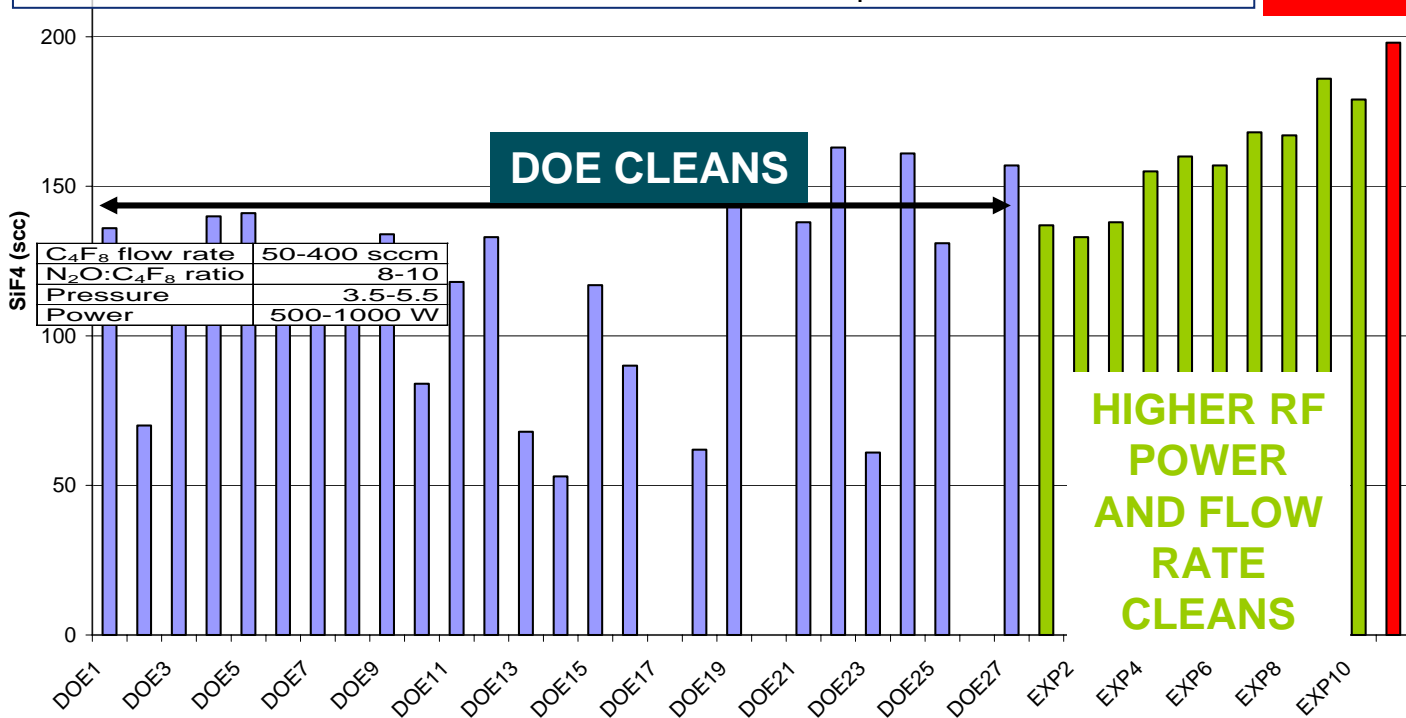
1.4 μm SiN <sub>x</sub>	CF <sub>4</sub> (scc)	SiF <sub>4</sub> (scc)	HF (scc)	Clean Time (s)
1	2927	200	30	
2	2822	196	50	101
3	2835	200	56	101
4	2851	199	55	101
5	2943	198	55	101
6	2857	194	54	100
7	2878	197	58	100
<b>AVE</b>	2873	198	51	101

**PFC = 20×10<sup>-9</sup> MMTCE**  
**Gas usage= 12 g**



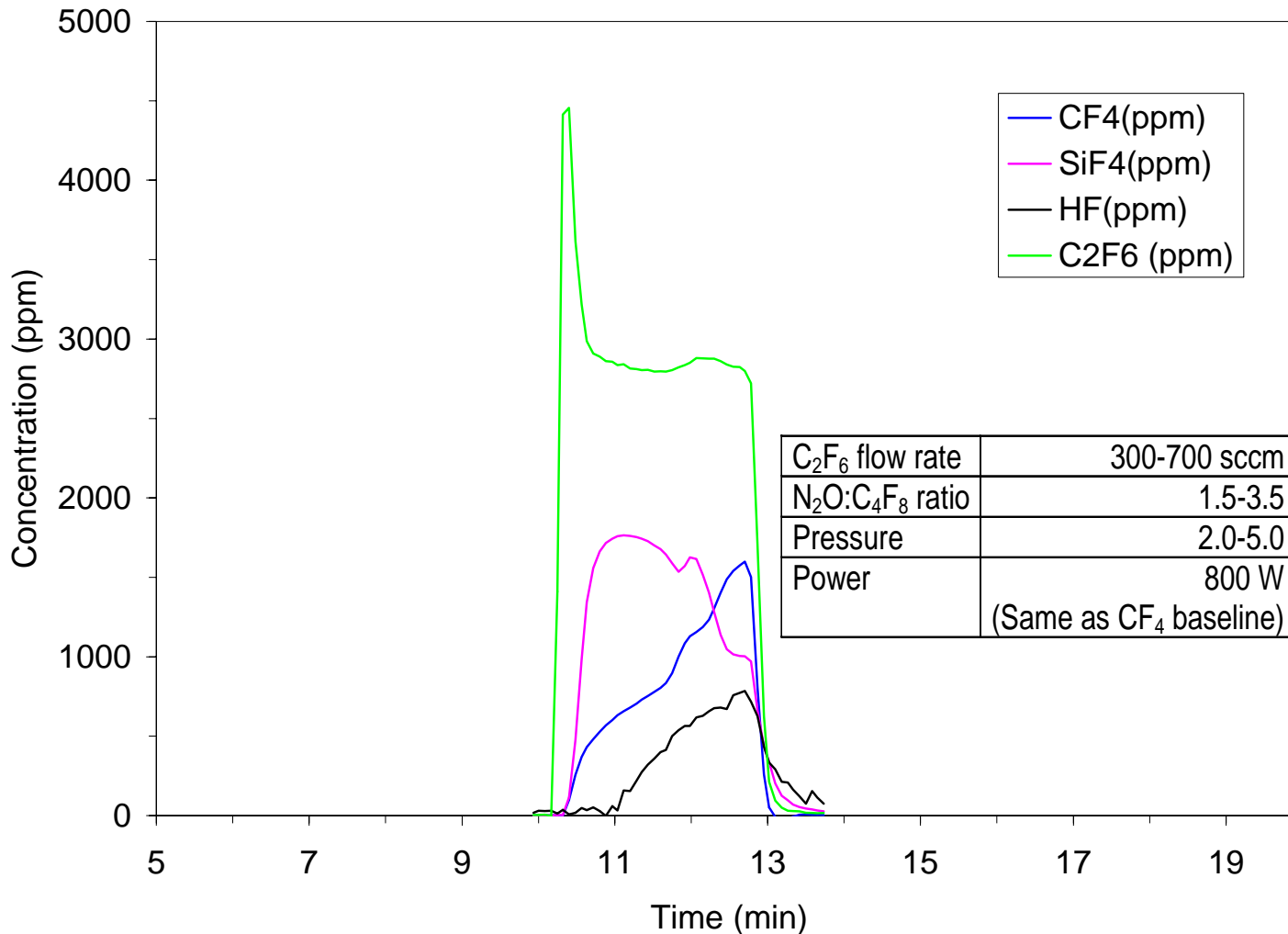
# Evaluation of C<sub>4</sub>F<sub>8</sub> Clean

- EPD difficult because of weak F-atom emission
- Flow Stability Faults
- SiF<sub>4</sub> emissions indicate clean effectiveness (15-50 % lower than for the baseline CF<sub>4</sub> process)

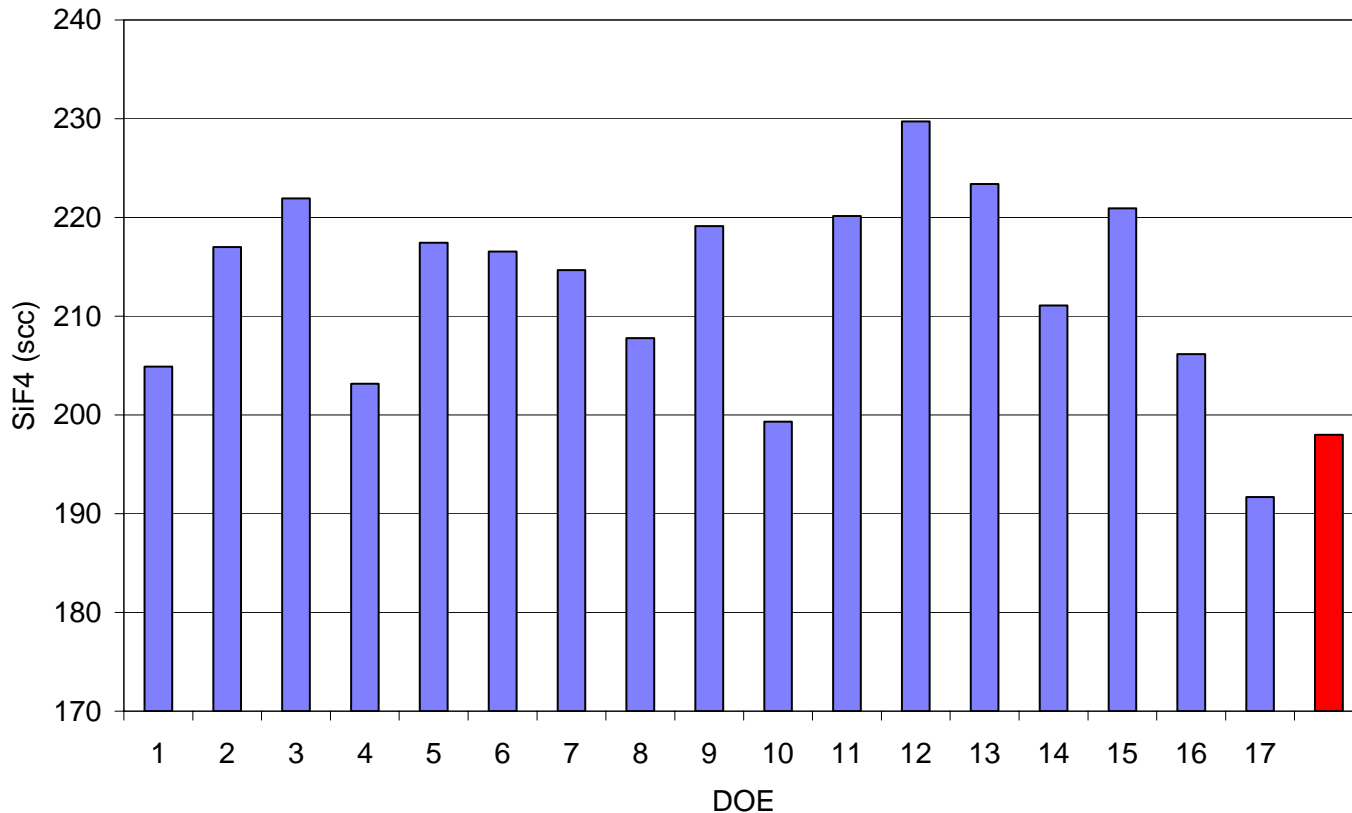


# C<sub>2</sub>F<sub>6</sub> Process Development

C<sub>2</sub>F<sub>6</sub> CLEAN: C<sub>2</sub>F<sub>6</sub> (300), N<sub>2</sub>O (750), 3.5 T, 800 W



# SiF<sub>4</sub> Emissions

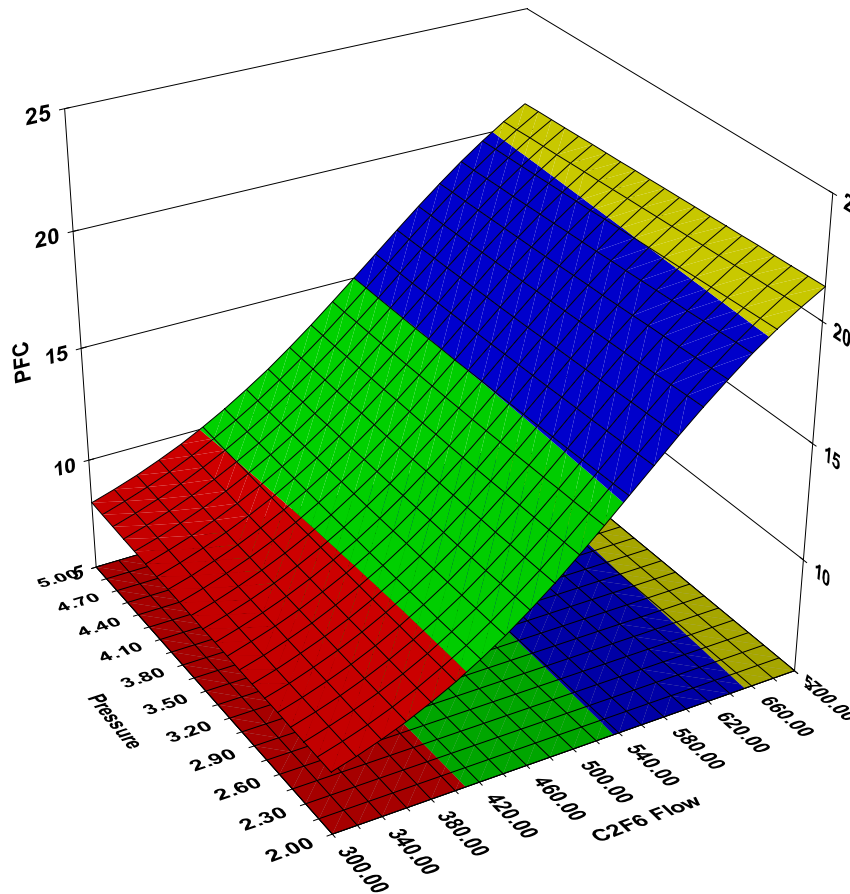


CF<sub>4</sub> CLEAN

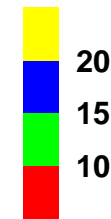
- All but one of the C<sub>2</sub>F<sub>6</sub>-based processes have higher SiF<sub>4</sub> emissions than the baseline CF<sub>4</sub> process
- SiF<sub>4</sub> emissions indicate that the C<sub>2</sub>F<sub>6</sub> processes effectively remove the entire SiN<sub>x</sub> residue from the CVD chamber



# PFC Emissions Response Surface



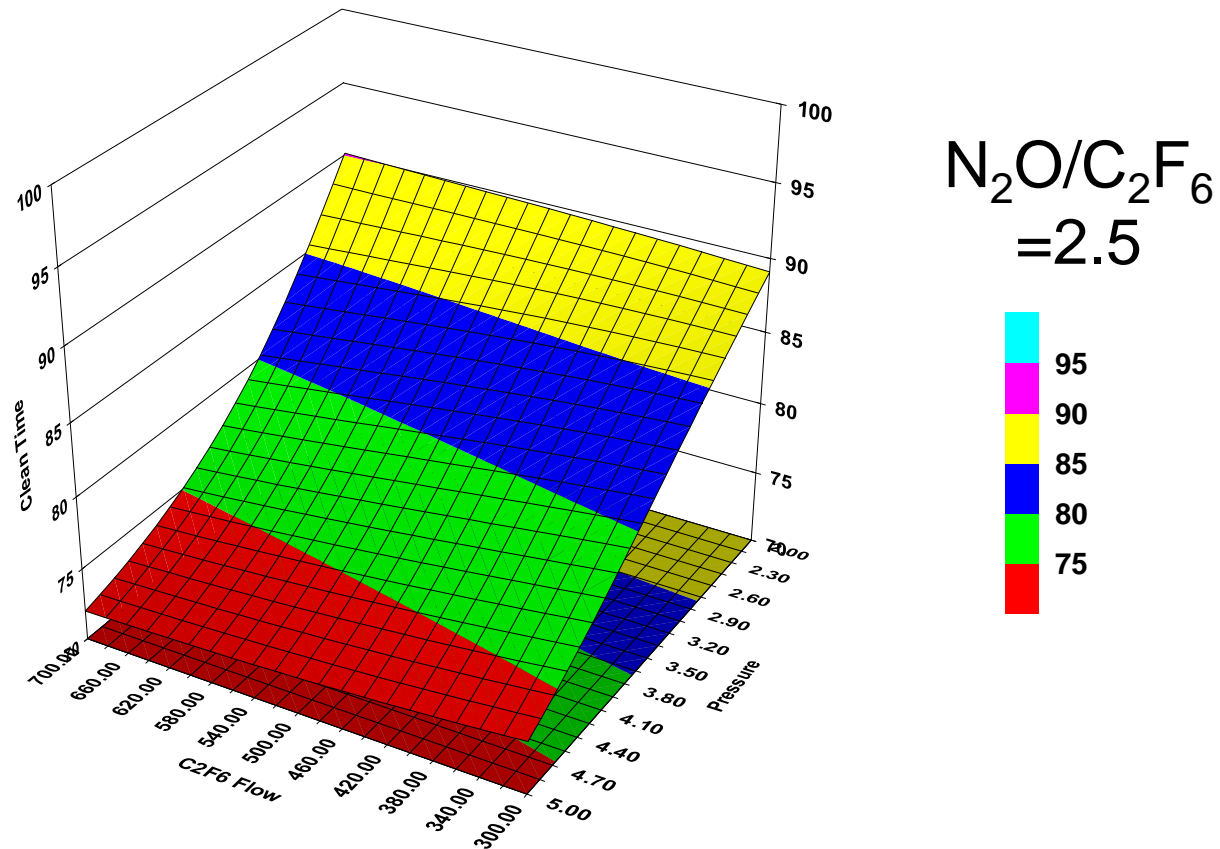
$$\text{N}_2\text{O}/\text{C}_2\text{F}_6 = 2.5$$



- Lower PFC emissions favored by lower C<sub>2</sub>F<sub>6</sub> flow rates and lower N<sub>2</sub>O/C<sub>2</sub>F<sub>6</sub> ratio



# Clean Time Response Surface



- Faster cleans favored by higher  $C_2F_6$  flow rates, lower  $N_2O/C_2F_6$  ratios, and higher pressures.
- All  $C_2F_6$  processes are faster than baseline  $CF_4$  clean



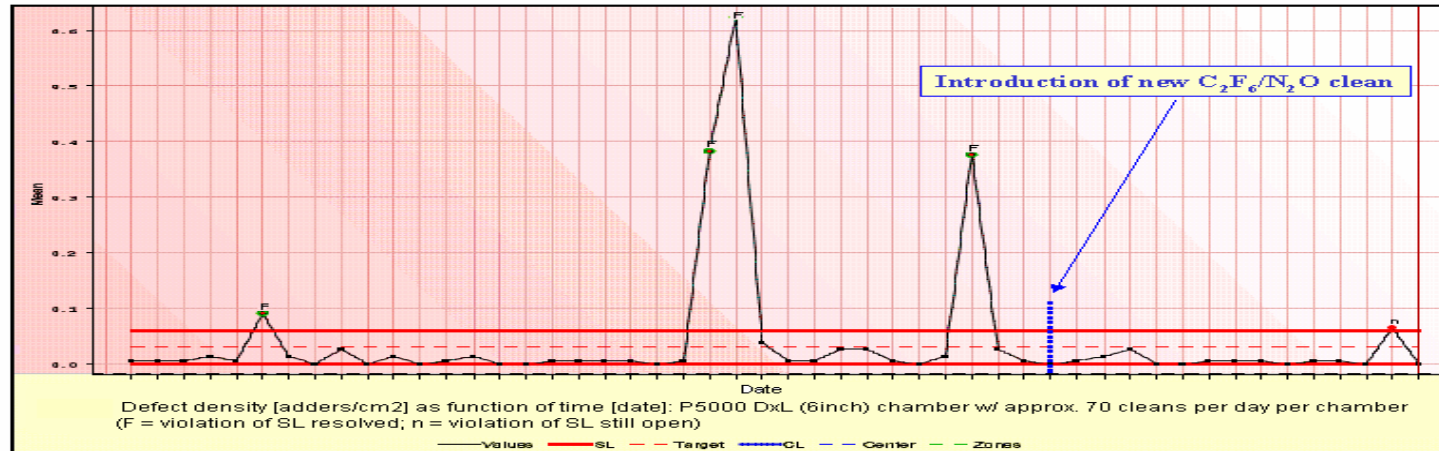
# Optimized C<sub>2</sub>F<sub>6</sub> Clean

	CF <sub>4</sub> -based	C <sub>2</sub> F <sub>6</sub> -based
C <sub>2</sub> F <sub>6</sub> /CF <sub>4</sub> (sccm)	1500	300
N <sub>2</sub> O (sccm)	750	750
Pressure (torr)	5.0	3.5
RF (W)	800	800
Clean time (s)	101	82
PFC (MMTCE)	20.0×10 <sup>-9</sup>	7.8×10 <sup>-9</sup> (-61 %)
SiF <sub>4</sub> (scc)	198	203
Gas usage (g)	11.8	3.7 (-68 %)

- C<sub>2</sub>F<sub>6</sub> clean effectively removes all of the SiN<sub>x</sub> residue
- PFC emissions have been reduced 61 %
- Gas usage has been reduced 68 %



# Marathon Testing



- Defect density and other chamber conditions are indistinguishable from the baseline CF<sub>4</sub> chamber clean
- More than 750,000 wafers have been processed at various Infineon sites



# Summary

## Silane Clean Optimization:

- The  $C_2F_6$ -based chamber clean reduces gas usage and PFC emissions 68 % and 61 %, respectively, relative to the baseline  $CF_4$  process
- The  $C_2F_6$ -based chamber clean has successfully been qualified for production and the transition of all silane-based PECVD chambers (P5000 DxL) to the new  $C_2F_6$ -based chamber clean is nearly completed.

## TEOS Clean Optimization:

- Lean  $C_2F_6$ : emission, consumption, and clean time reduction
- Marathon testing (6 months) completed to prove production capability (some hardware issues recently revealed)

