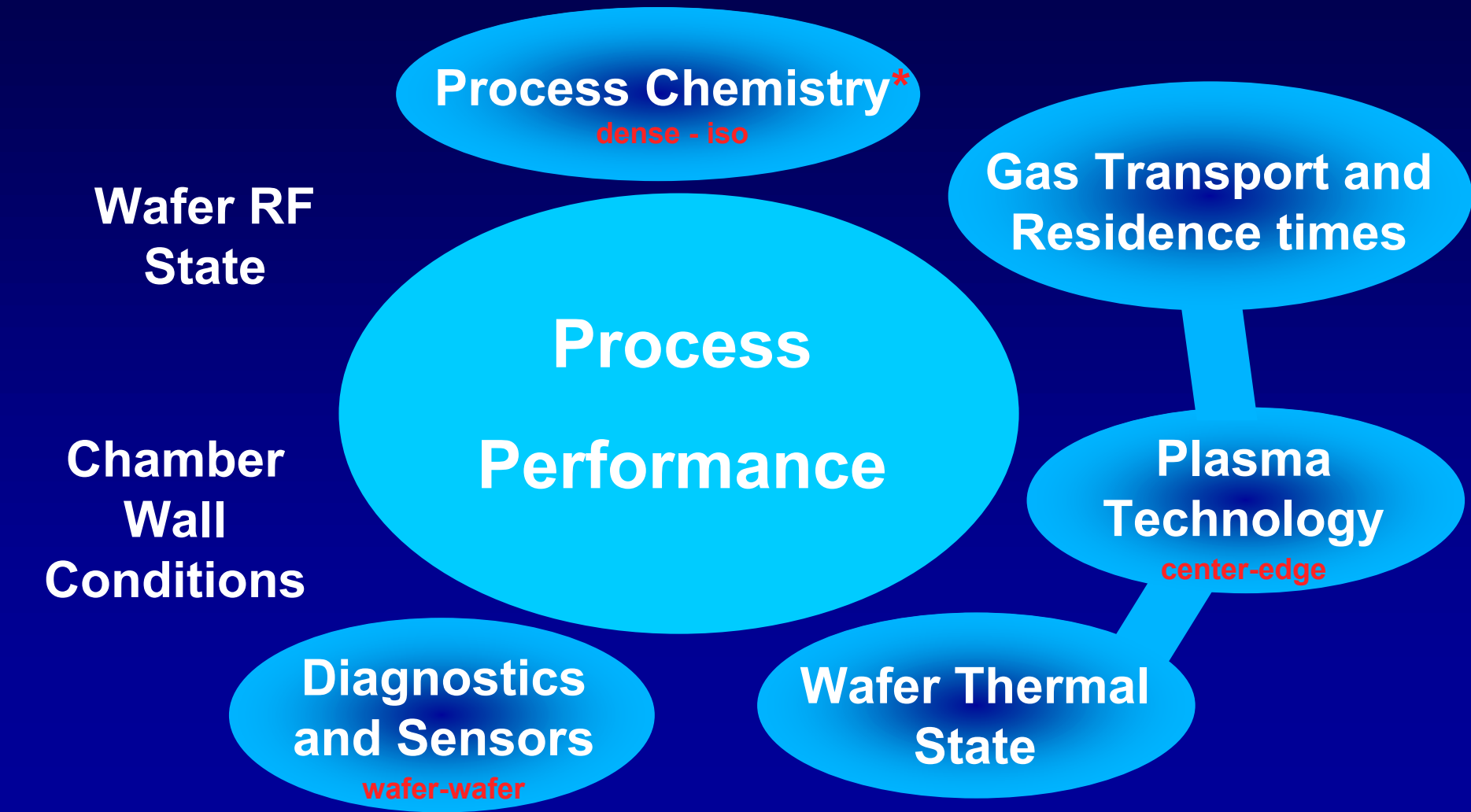
Sidewall Passivation Mechanism of CH_xF_y Added Polysilicon Gate Etch Processes

Th. Lill, F. Ameri, S. Deshmukh, Songlin Xu, D. Podlesnik, J. Holland
Applied Materials, Silicon Etch Division, Santa Clara, USA

L. Vallier, O. Joubert
CNRS/LTM, Grenoble, France

PEUG Meeting
Sunnyvale, January 2002

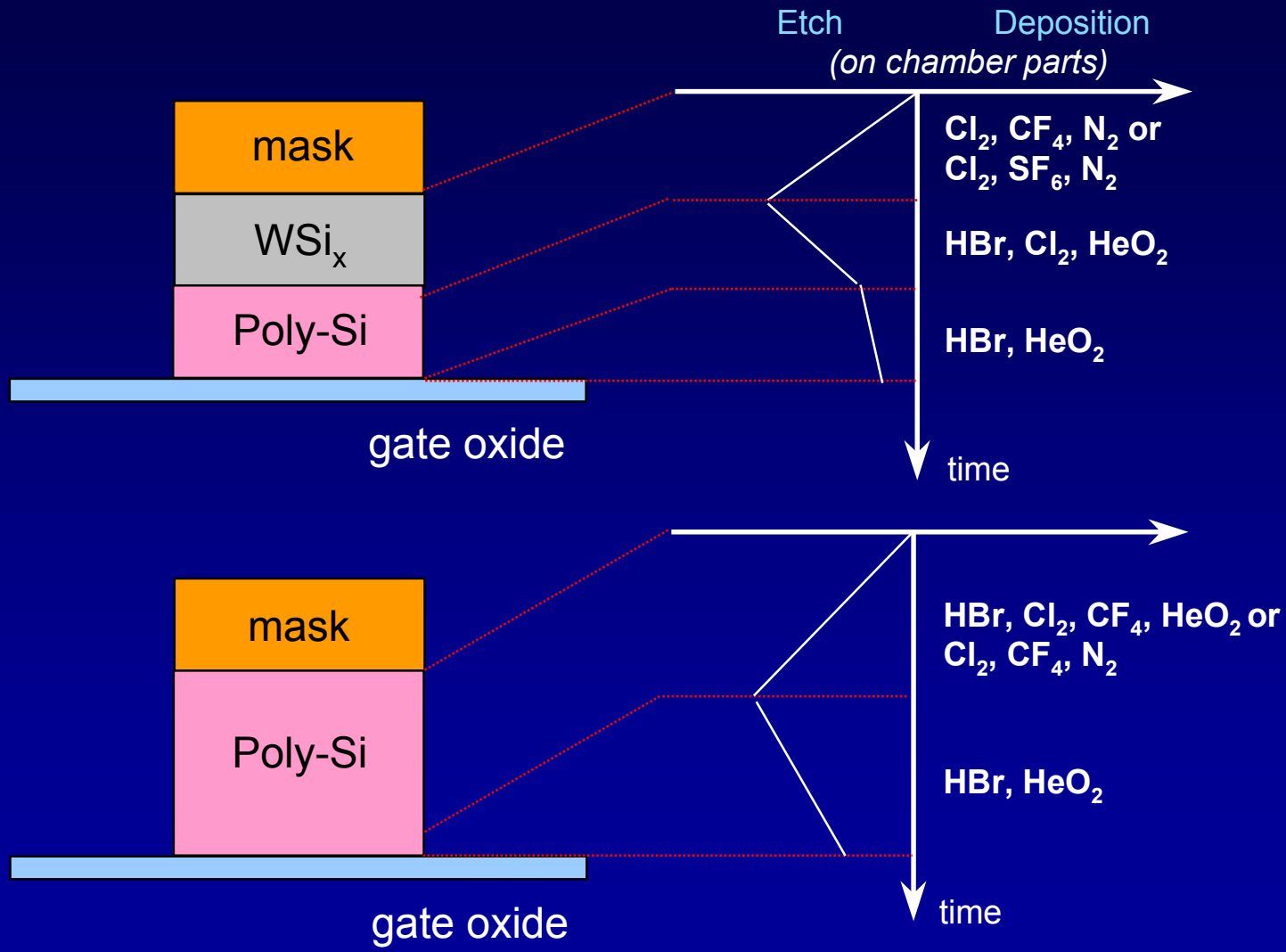
Key Factors for Control of Critical Dimensions



Outline

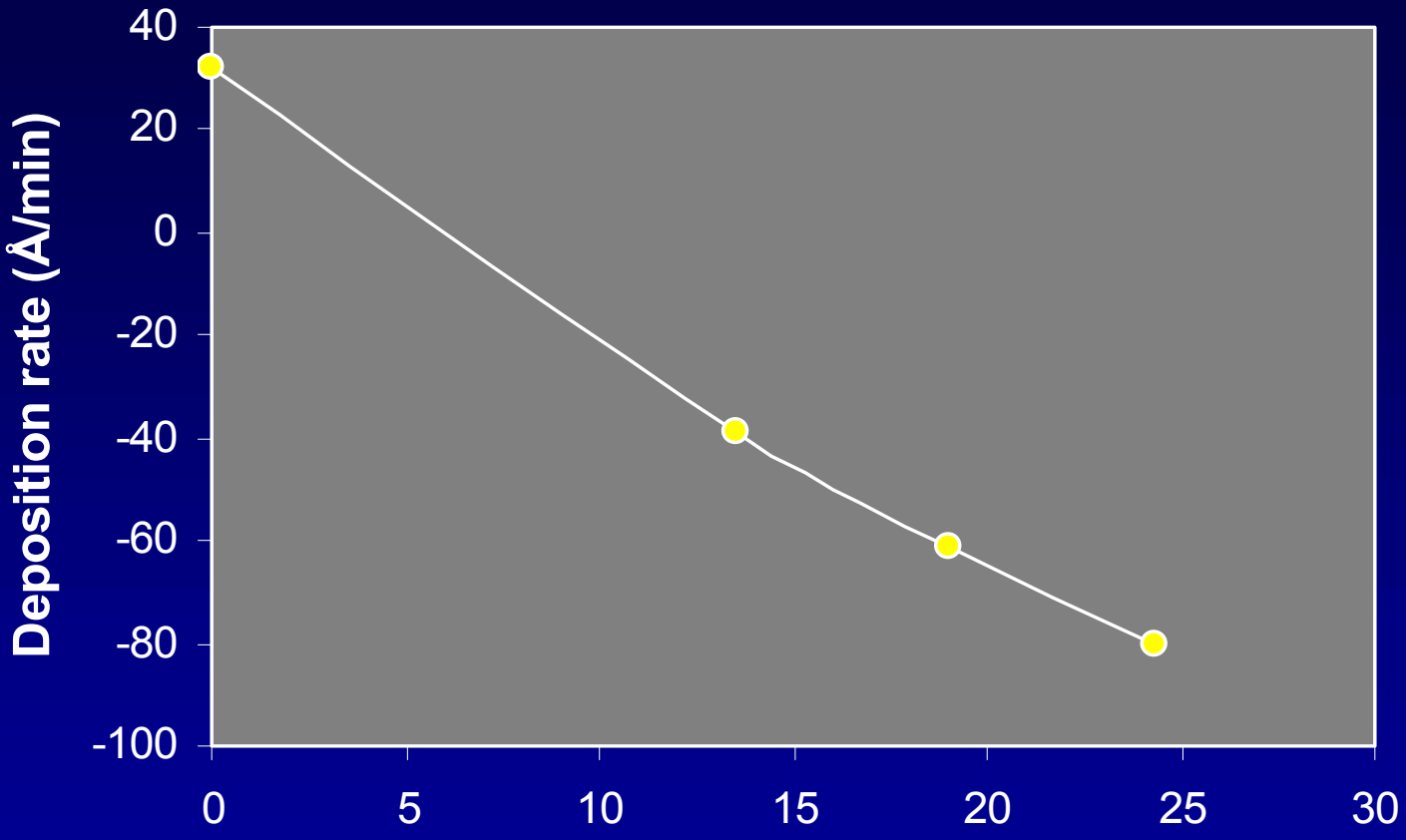
- Evidence for carbon formation with HBr / CF_4 gas mixture
- XPS data for CF_4 containing gate etch processes
- Line width evolution for CF_4 free and CF_4 added processes
- Model for sidewall passivation mechanism
- Dual gate etching behavior for CF_4 added gate processes

Possible designs of selfcleaning gate processes



See also: Tammy Zheng et al., PEUG 11/99

Wall deposition / SiO_2 removal vs. CF_4 concentration

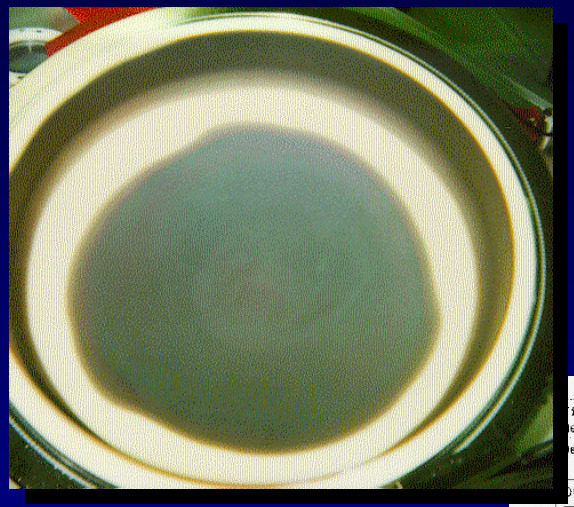


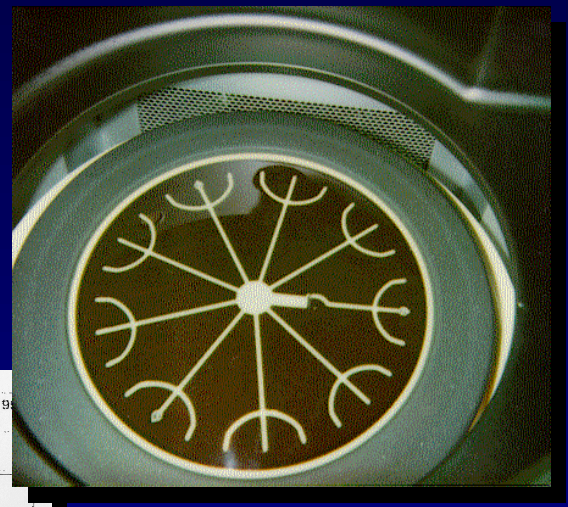
Measured with QCM / coupon technique.
(4 mTorr / total flow 200 sccm / W_s/W_b = 5 :1)

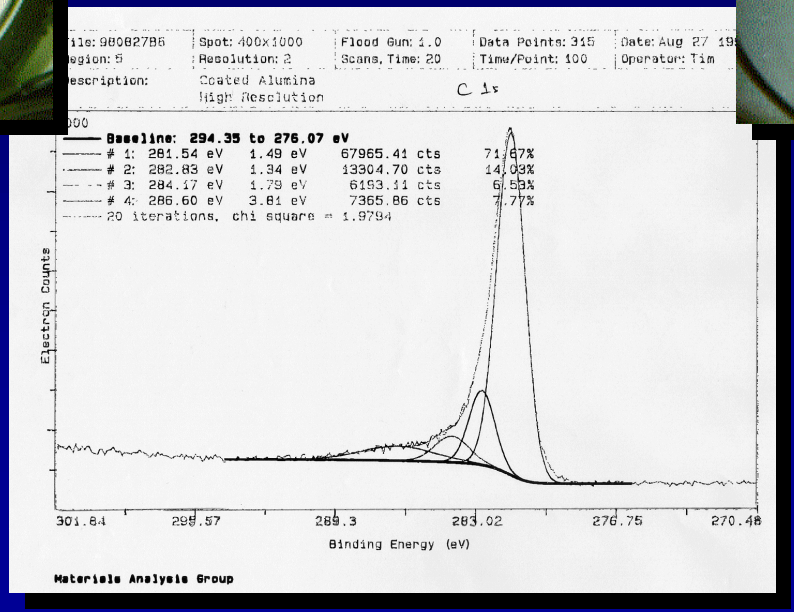
CF_4 added gate chemistry is cleaning walls for sufficiently high flows.

P. Nallan

Experimental evidence for the existence of carbon based polymer deposition

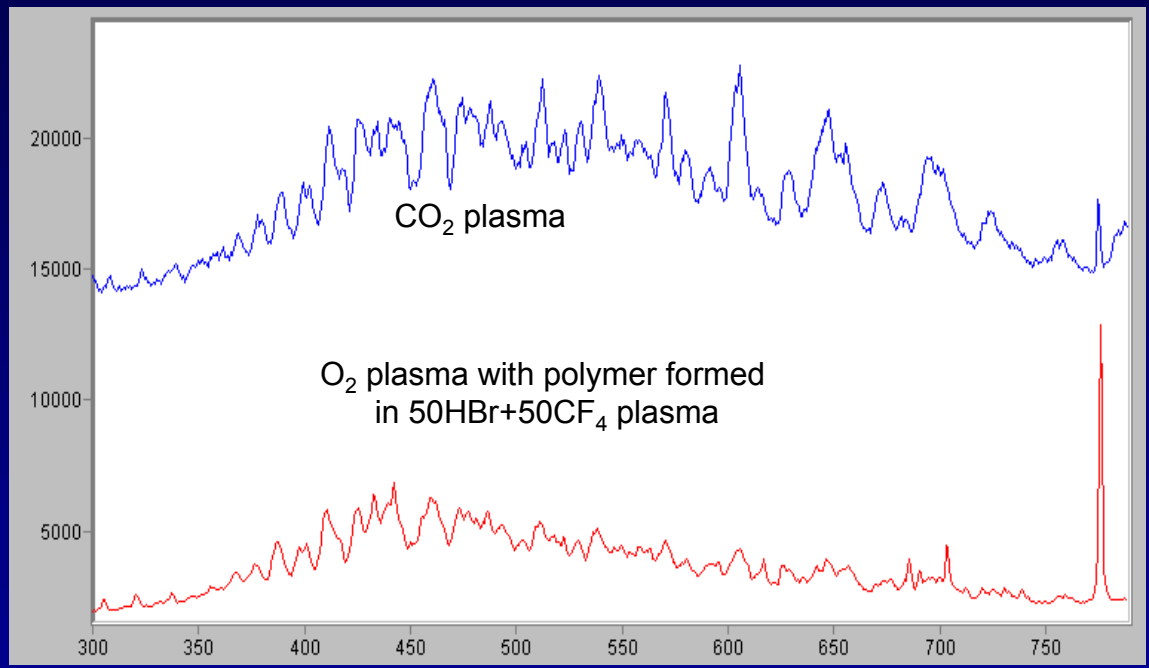






HBr/CF4=4:1; CF4/O2=8:1, 8 sccm HeO2; 25 sccm CF4; 40 % Cl2, 4 mTorr; Ws/Wb=10:1; 1h

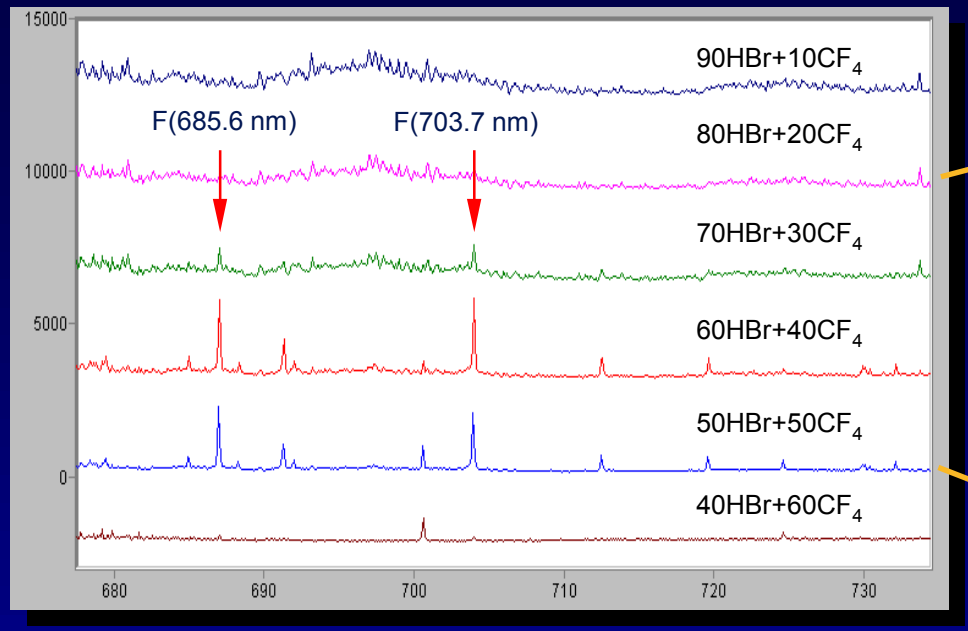
Comparison of Polymer Decomposition Spectrum with CO_2 Emission Spectrum



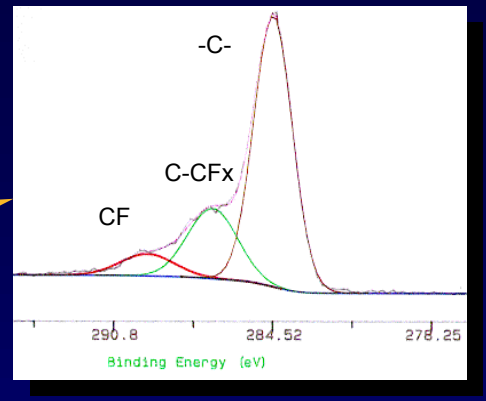
Formation: 100sccm(HBr+CF_4), 6mTorr, 600Ws
Detection: 100O_2, 6mTorr, 600Ws

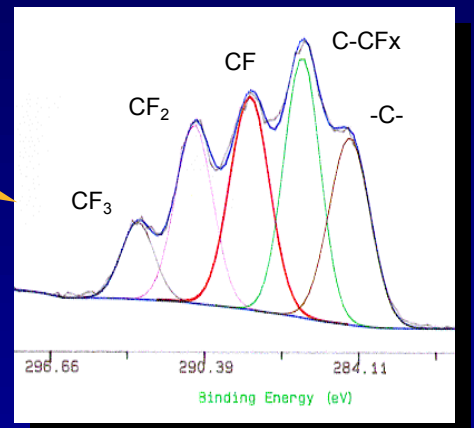
CO_2 plasma and O_2 decomposition spectrum for polymer covered wall show similar signature - indication that polymer is carbon based.

Chamber wall polymer composition vs. HBr / CF_4 ratio

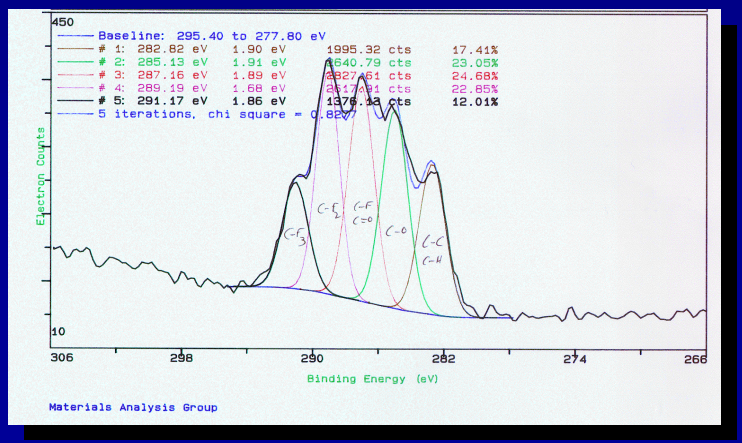


Formation: 100sccm($HBr+CF_4$), 6mTorr, 600Ws
Detection: 100O_2, 6mTorr, 600Ws



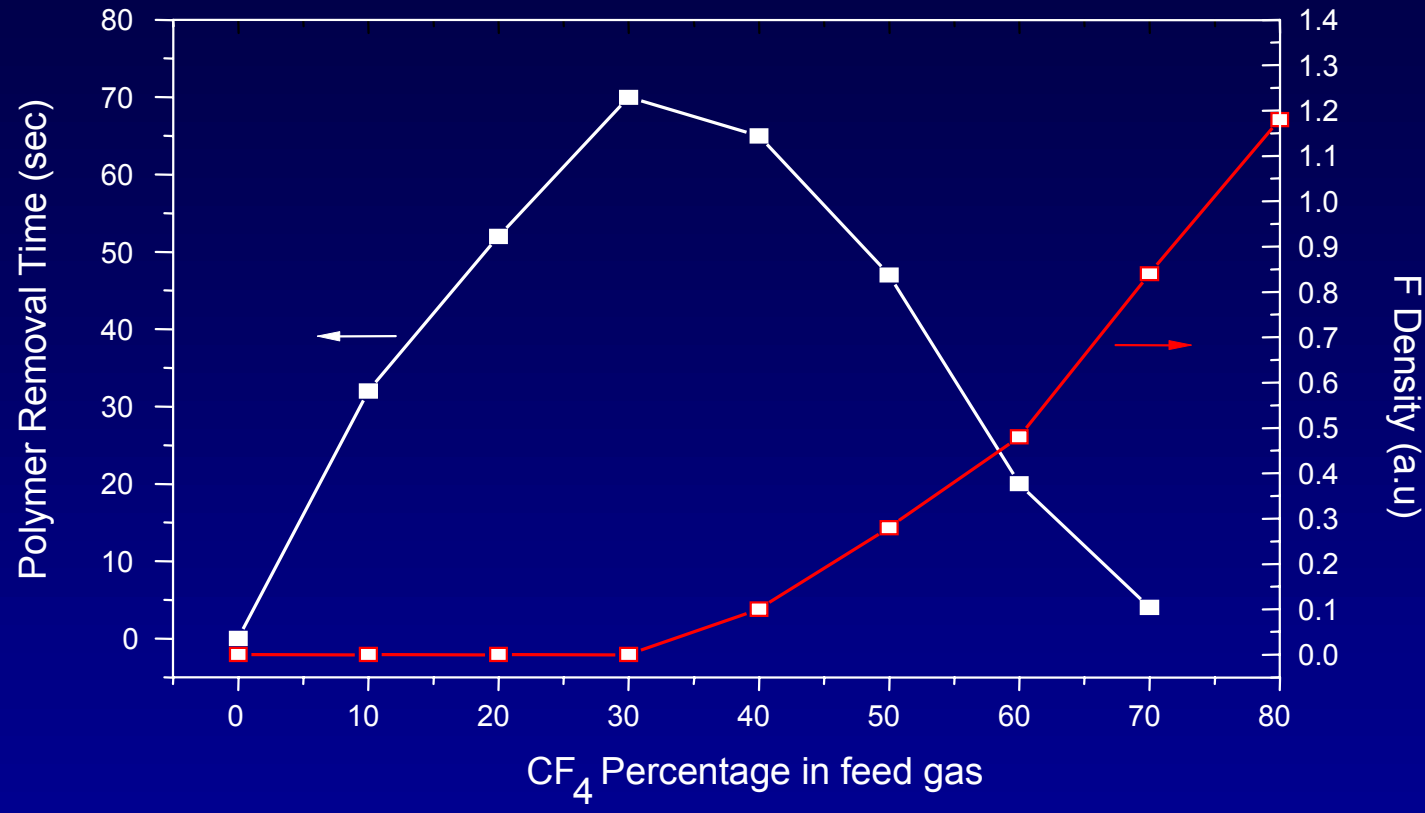


Polymer contains more fluorine when CF_4 flow is increased.



For comparison:
Chamber wall polymer created by CH_2F_2 plasma.

Correlation between Polymer thickness and composition



Deposition: 100sccm($HBr+CF_4$), 6mTorr, 600Ws, 0Wb, blank oxide wafer

Removal: 100O_2, 6mTorr, 600Ws

Polymer contains more fluorine when CF_4 flow is increased. Max. thickness for 20 to 30 % CF_4.

C formation and removal for $HBr / Cl_2 / CF_4 / HeO_2$ process

Basic reaction:

$$CF_4 \rightleftharpoons CF_x + F$$

$$HBr \rightleftharpoons H + Br$$

Consecutive reaction:

$$H + F \rightleftharpoons HF$$

$$nCF_x \rightleftharpoons C,F\ polymer$$

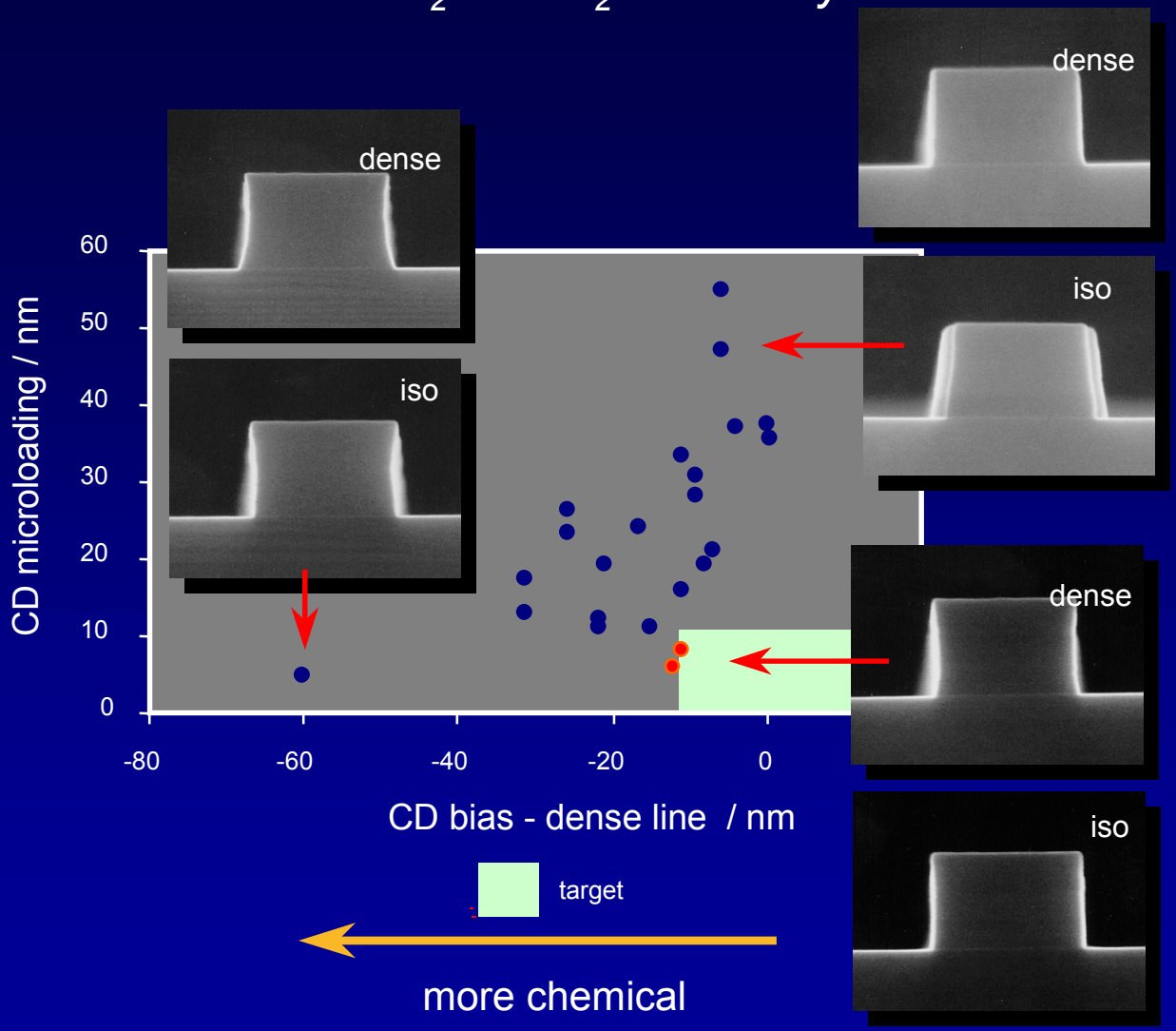
$$C,F\ polymer + F \rightleftharpoons mC_yF_z$$

Competing reaction:

$$C,F\ polymer + O_2 \rightleftharpoons CO_2 + F$$

Experimental data for poly-Si etch variation

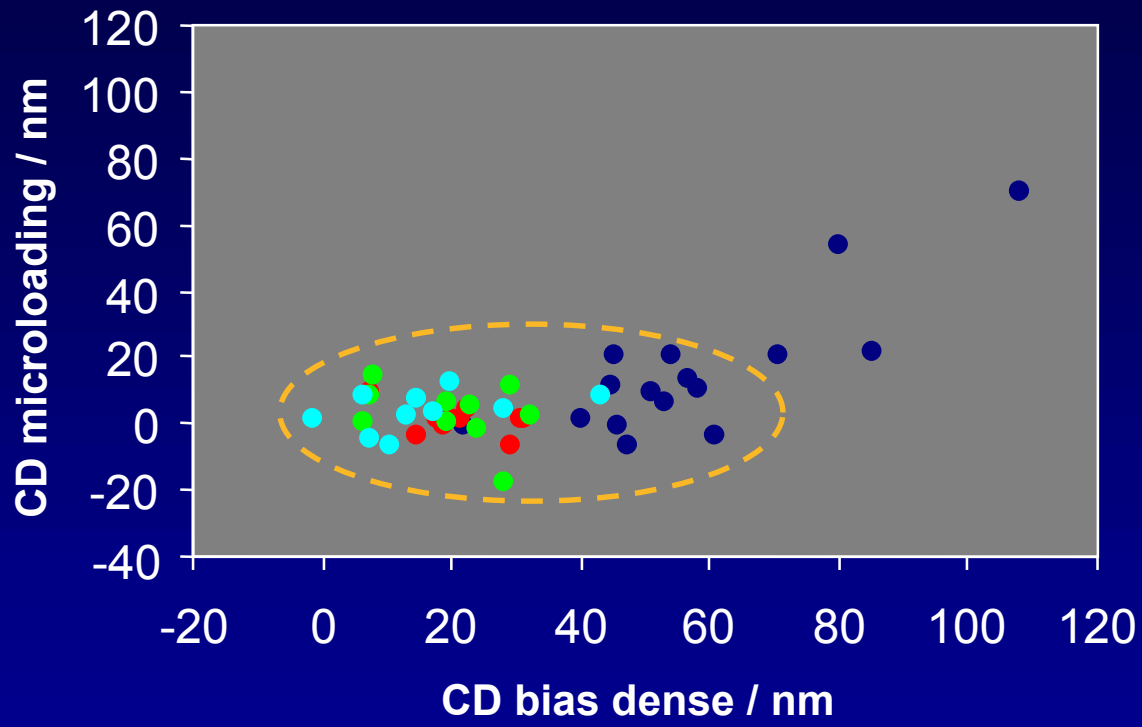
- $HBr / Cl_2 / HeO_2$ chemistry -



Strong CD microloading when CD bias gain is targeted.

Experimental data for poly-Si etch variation

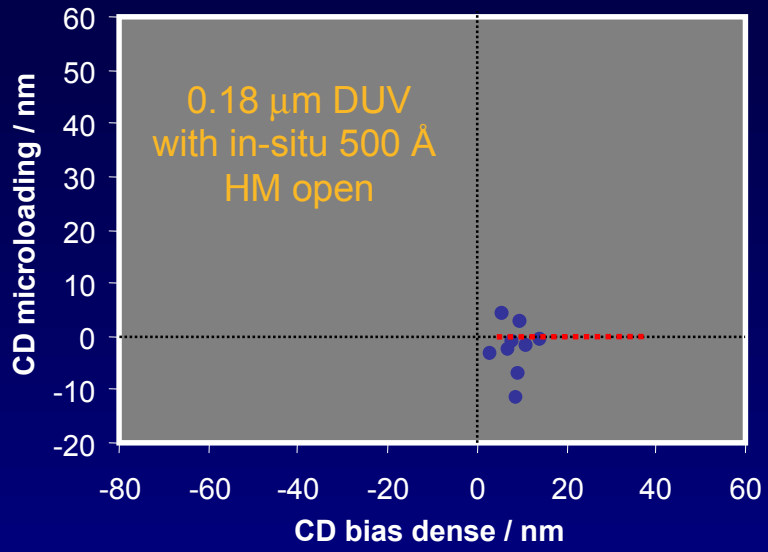
- $HBr / Cl_2 / CF_4 / HeO_2$ chemistry -

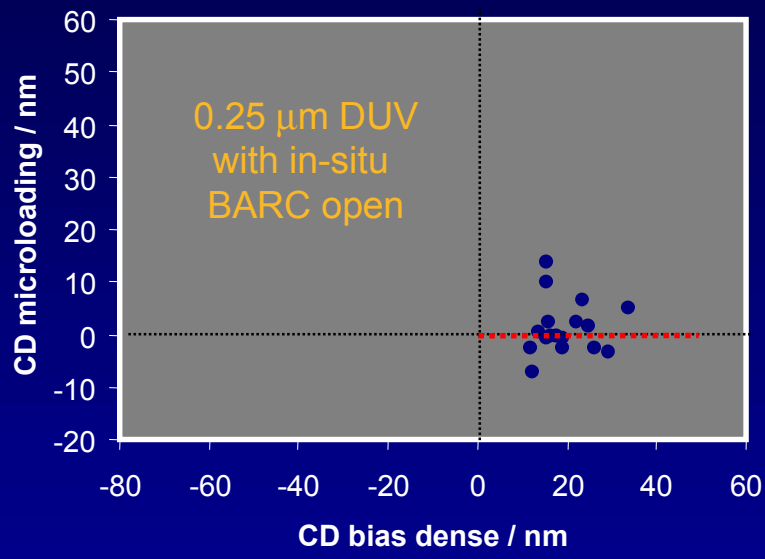


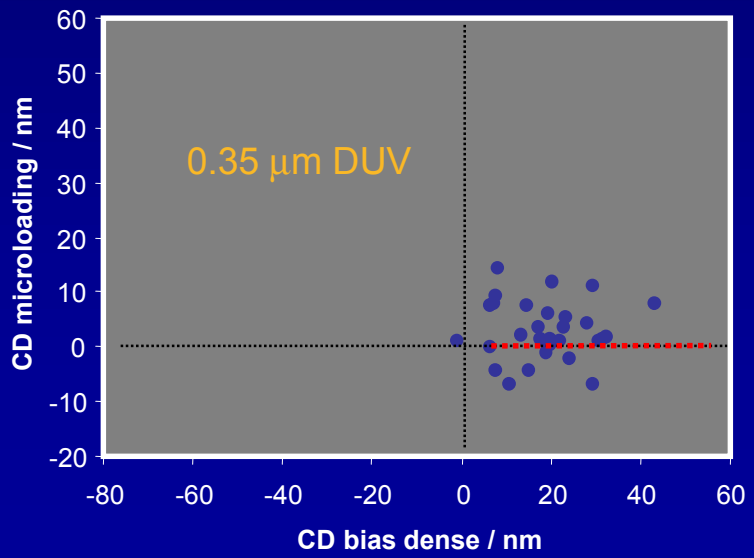
Conclusion: Even for very large CD gains of the dense line, the CD μ-loading is excellent - between -20 and 20 nm (nominal line width 300 nm).

Experimental data for poly-Si etch variation

- $HBr / Cl_2 / CF_4 / HeO_2$ chemistry -





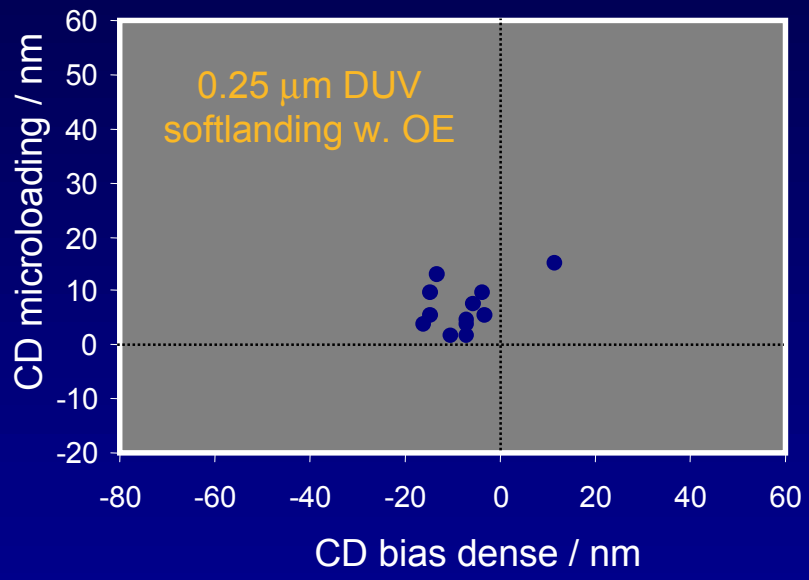


CD microloading between –10 and 10 nm.

Experimental data for poly-Si etch variation

-HBr / Cl_2 / CF_4 / HeO_2 chemistry –

Very high CF4 flow



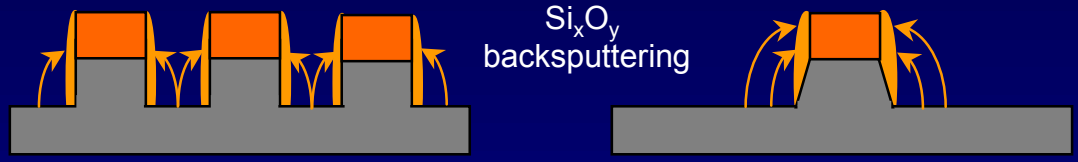
Source / bias power: 5 to 9
CF_4 / O_2 3 to 6
25 % CF_4 (vs. 12 % standard).

Again, very low CD microloading observed. In contrast to the other examples, negative CD bias has been measured (excessive fluorine).

Simplified microloading mechanisms
Traditional vs. CF_4 added chemistry

Traditional chemistry

- Passivation by backsputtering-



$Si_{sputtered} + O_{gas} \rightarrow Si_xO_{y;sidewall}$

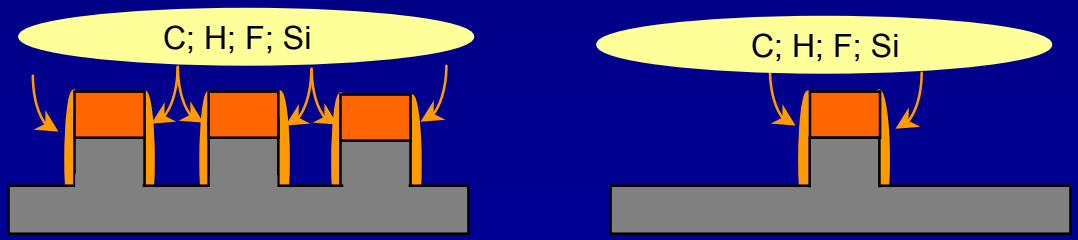
$SiO_{sputtered} + O_{gas} \rightarrow Si_xO_{y;sidewall}$

Open area sensitive

Sensitive to ARDE

CF_4 added chemistry

-Gas phase passivation-



$CF_{4;gas} + Si_{surface} \rightarrow CF_{x;gas} + SiF_{y;gas}$

$HBr_{gas} \rightarrow H^* + Br^*$

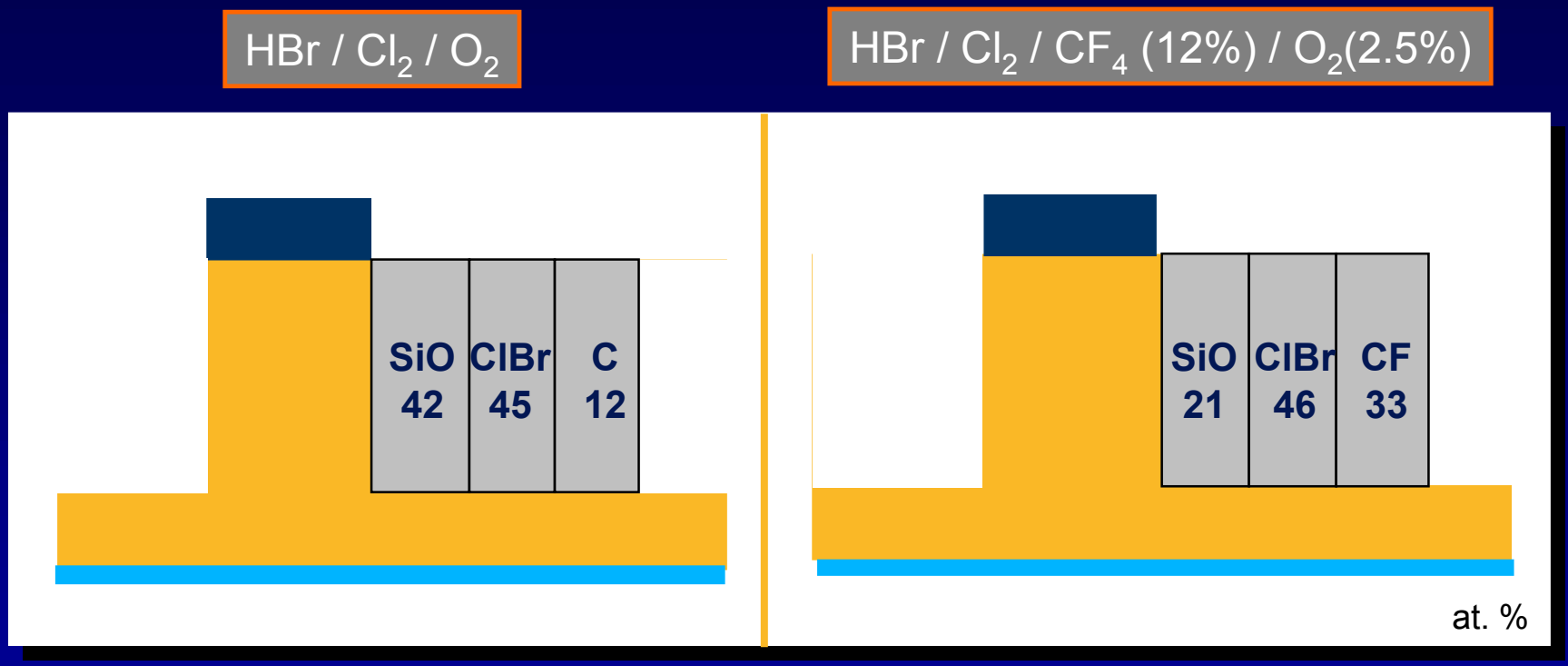
$CF_{x;gas} + H^* \rightarrow -[CH_xF_y]-_{sidewall}$

Less sensitive to open area

Sensitive to ARDE

Influence of CF4 addition on sidewall passivation layer formation

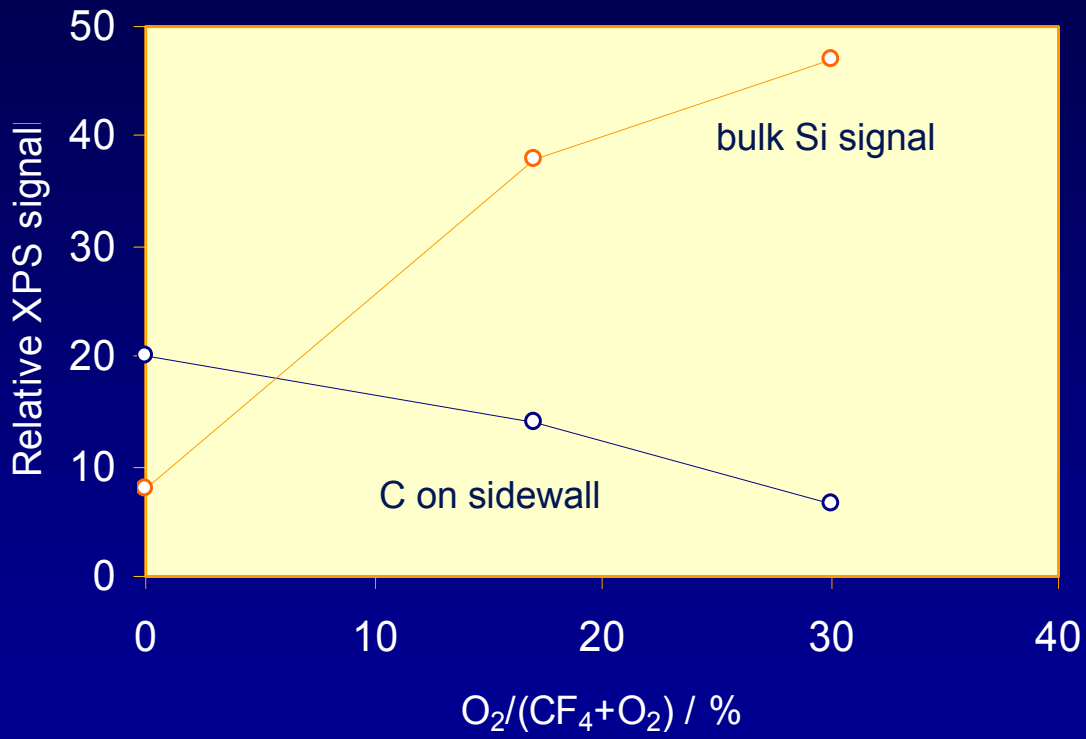
- XPS analysis on resist mask wafers -



The SiO_XCl_Y based passivation film is transformed into a CF_xCl_Y based passivation film when CF_4 is added to the standard $HBr/Cl_2/O_2$ chemistry.

Sidewall passivation as function of CF_4 / O_2 ratio

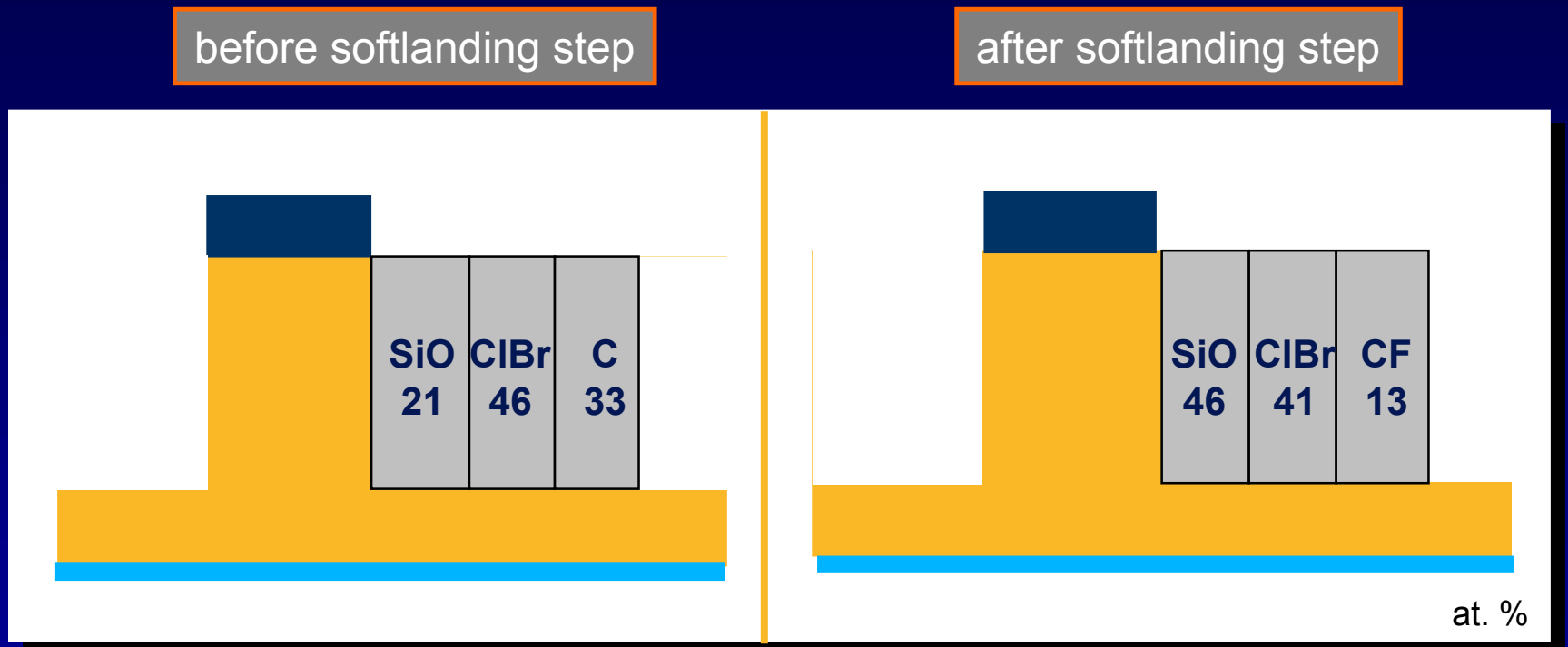
- XPS analysis on resist mask wafers -



Carbon concentration in sidewall layer increases and overall thickness increases as O_2 concentration in feed gas is reduced.

Behavior of CF_4 containing sidewall passivation during softlanding step

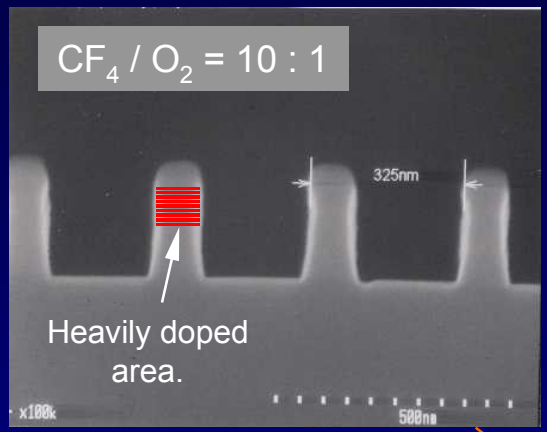
- XPS analysis on resist mask wafers -

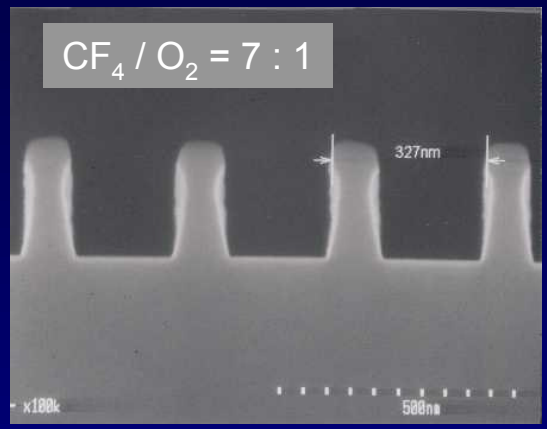


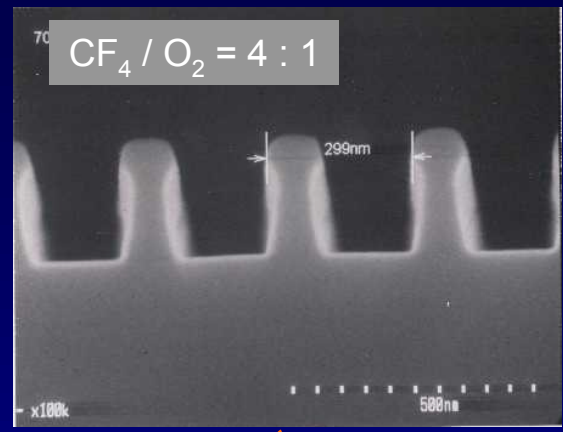
$HBr / Cl_2 / CF_4 / O_2$ main etch
$HBr / Cl_2 / O_2$ softlanding

CF based polymer is consumed during O_2 rich softlanding step. SiOx based polymer is formed instead.

Behavior of CF_4 containing sidewall passivation during softlanding step vs. CF_4/O_2 ratio in main etch

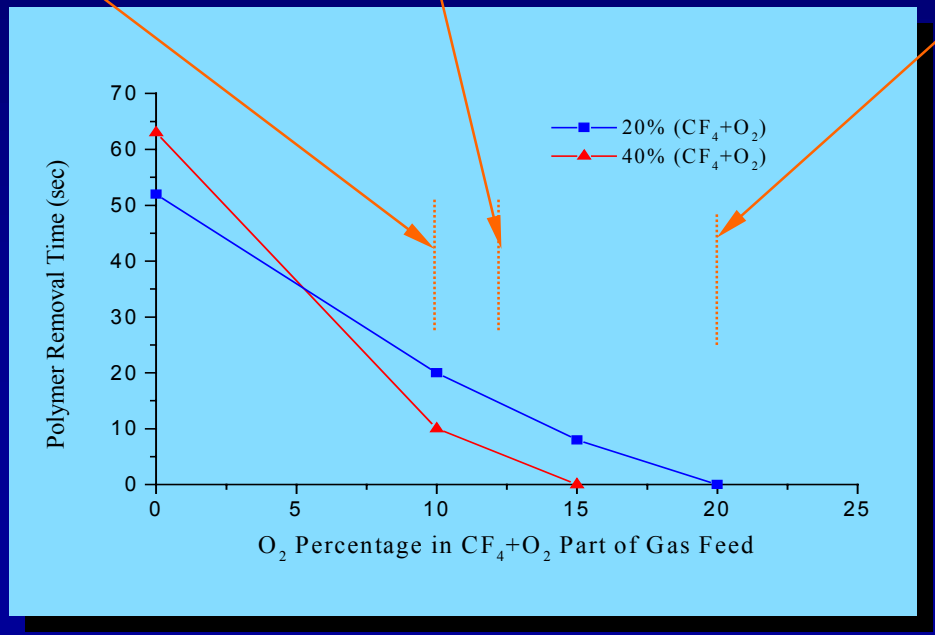






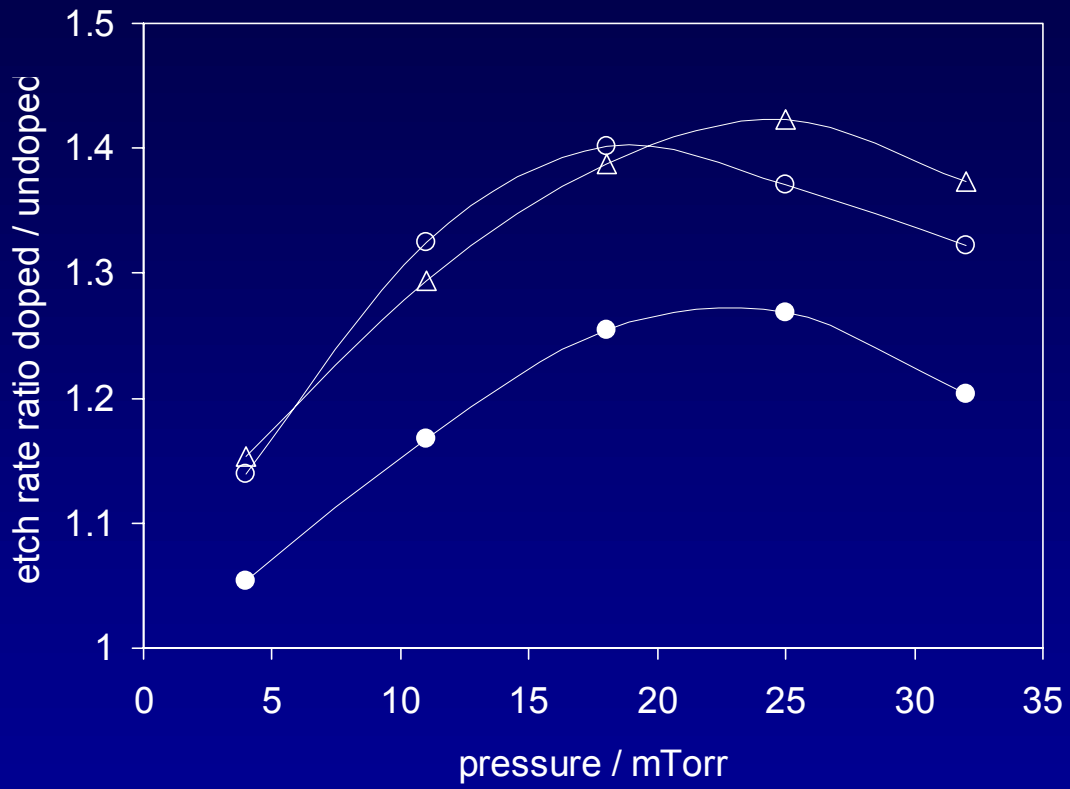
Heavily n-doped, not annealed wafer. Etched with CF4 added main etch, softlanding, overetch.

Chamber wall polymer thickness analysis studied with decomposition spec-troscopy.



Deposition:
60HBr+40(CF_4+O_2), 6mTorr, 600Ws, 0Wb, blank oxide wafer
Removal:
100O_2, 6mTorr, 600Ws

Doped/undoped selectivities for F free, CF_4 added and NF_3 added processes



No effect observed for NF3 addition.
This could point to carbon inhibitors rather than fluorine effect as mechanism for lowered doping sensitivity (not confirmed by XPS).

Open triangles:	baseline
Full circles:	CF4 addition
Open circles:	NF3 addition

Summary

CF_4 addition to traditionally HBr / Cl_2 / O_2 based poly gate etch chemistries has been shown to:

- reduce or eliminate the amount of polymer formation in the reactor (selfcleaning concept)
- improve the dense / iso CD bias difference due to a change in sidewall composition (deposition mechanism)
- reduce doped / undoped etch rate and CD bias differences

CD microloading of < 5 nm, doped / undoped CD differences of < 5 nm, and CD bias uniformities of < 7 nm range across the wafer have been obtained on 300 mm wafers with this chemistry.