

# Influence of quartz window temperature on plasma composition during STI etch

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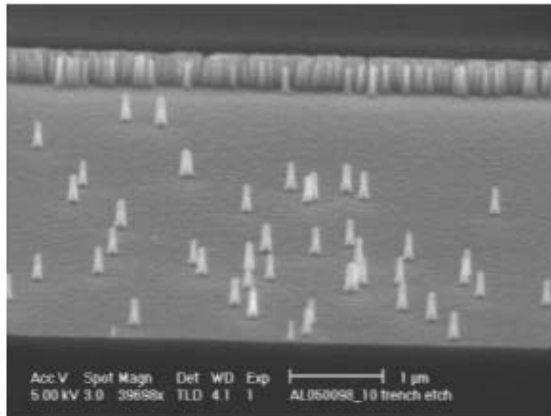
- **Introduction**
  - Problem description
  - Main cause of etch stop phenomenon
- **Experimental results**
  - Spectra analysis
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  - Wafer temperature measurement
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# Introduction

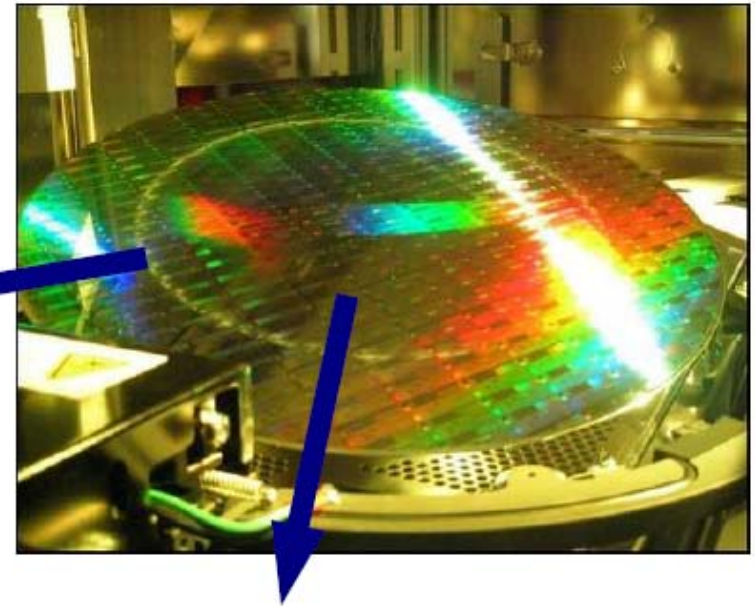
- Wafer-to-wafer reproducibility is a major concern in etching processes
- The chamber surface conditions are an important cause of process drifts that must be controlled
- In this work we report about process drift observed during STI etching

# Problem description

## STI etching in $\text{Cl}_2/\text{O}_2/\text{N}_2$

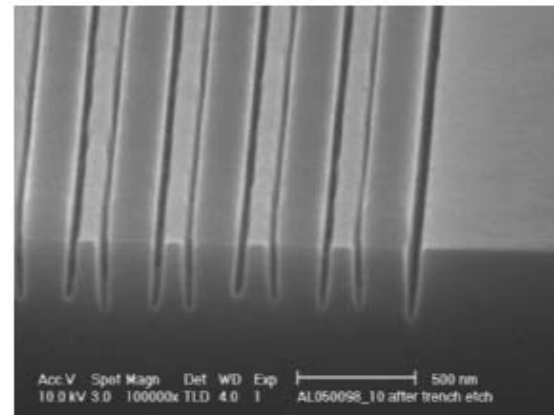


Rough border zone



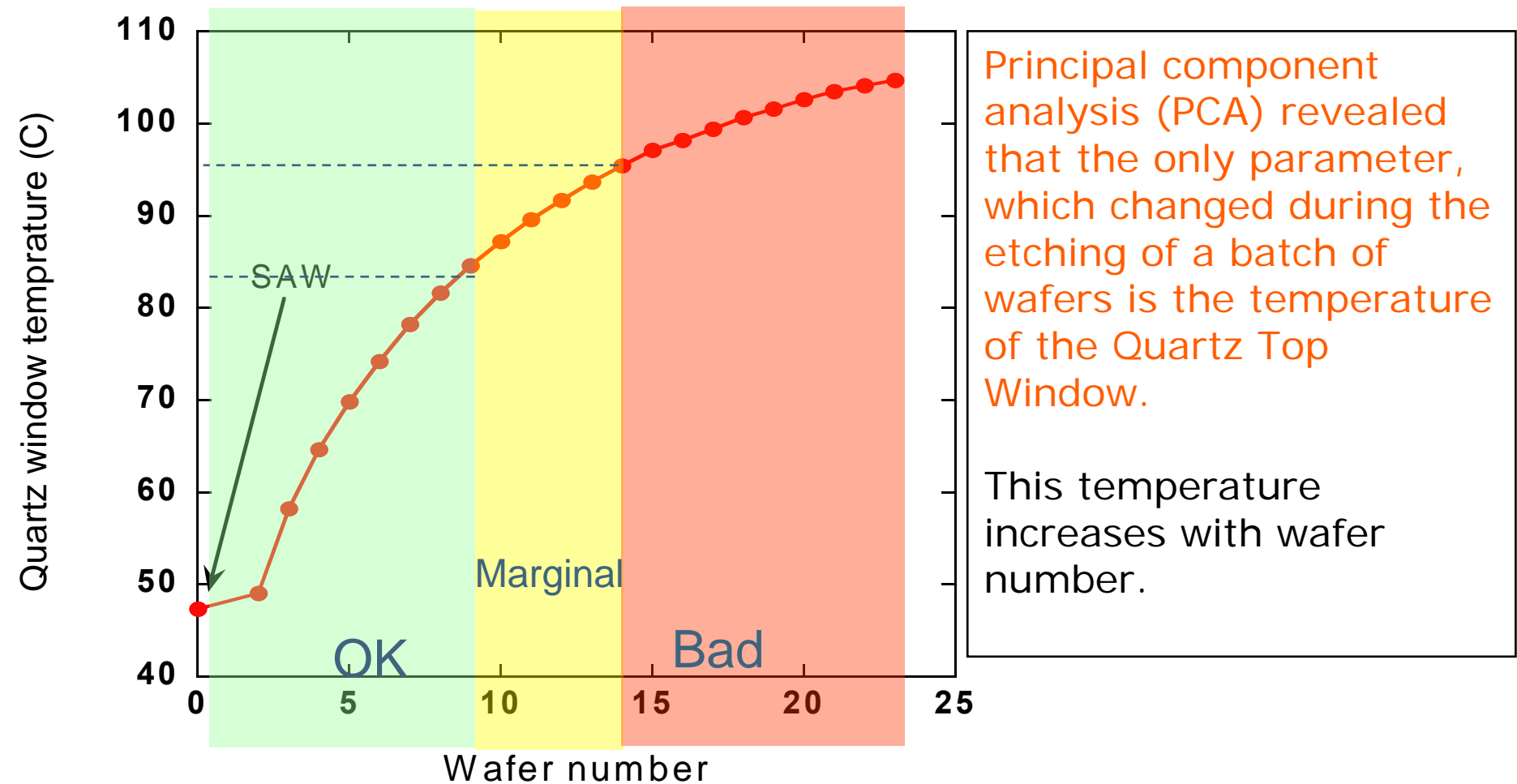
During etching of one batch (25 wafers) it was observed:

- 1-9 wafers were OK
- 10-25 wafers were not OK



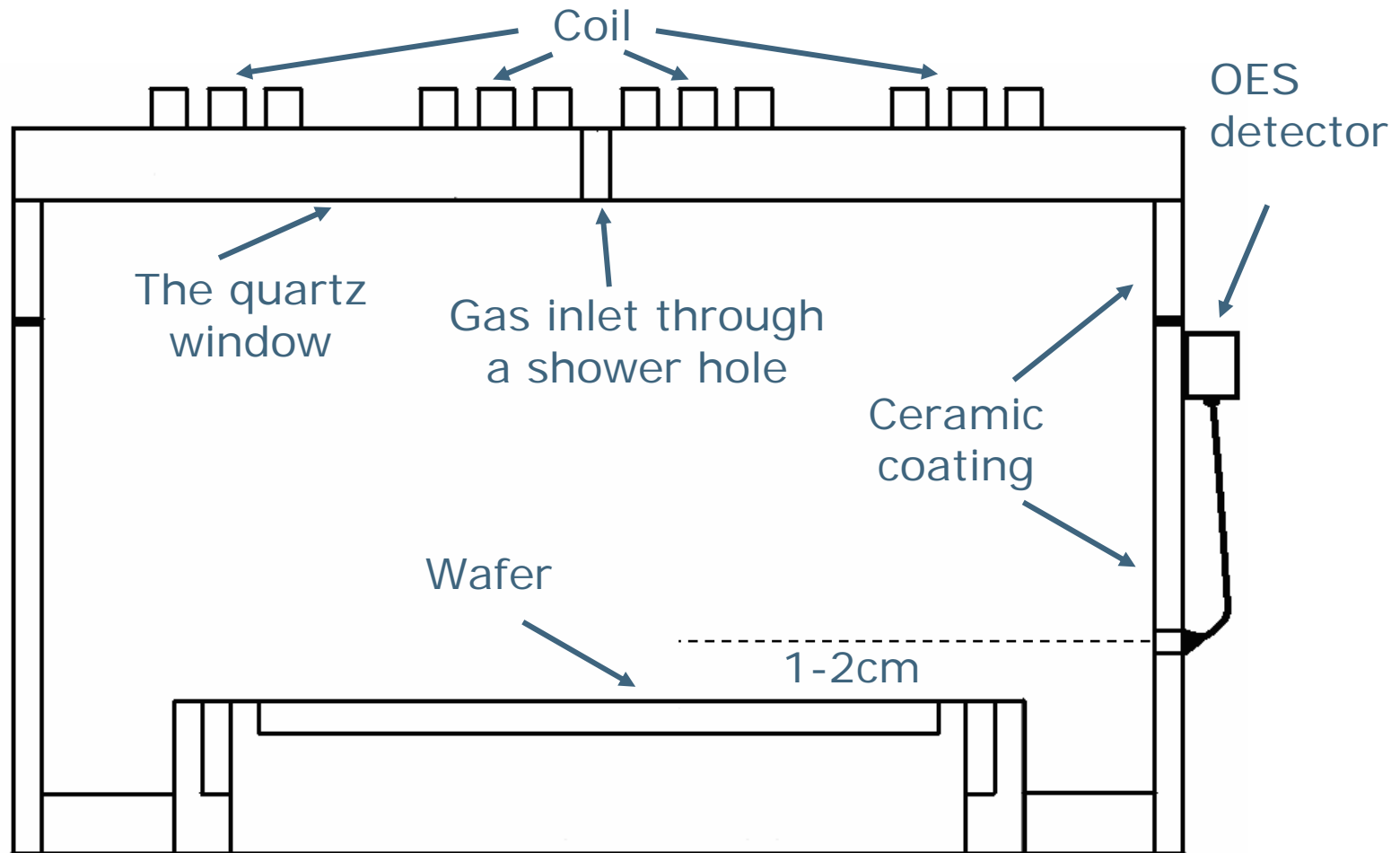
Etch stop

# Problem starts when quartz window temperature (QWT) is above 83°C



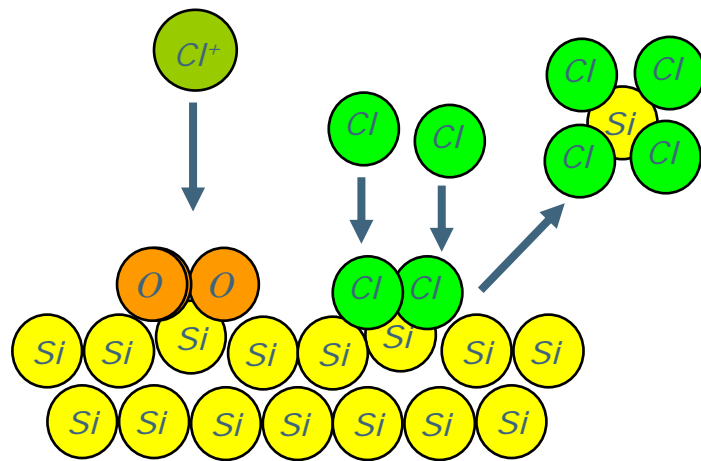
# Chamber scheme

All experiments are carried out in 2300 Versys Kiyo etch chamber from Lam Research.

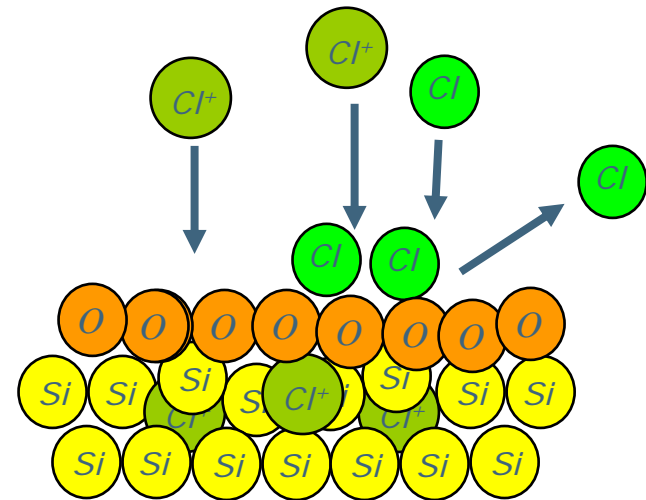


# Etch stop mechanism during Si etching

## Effect of O concentration



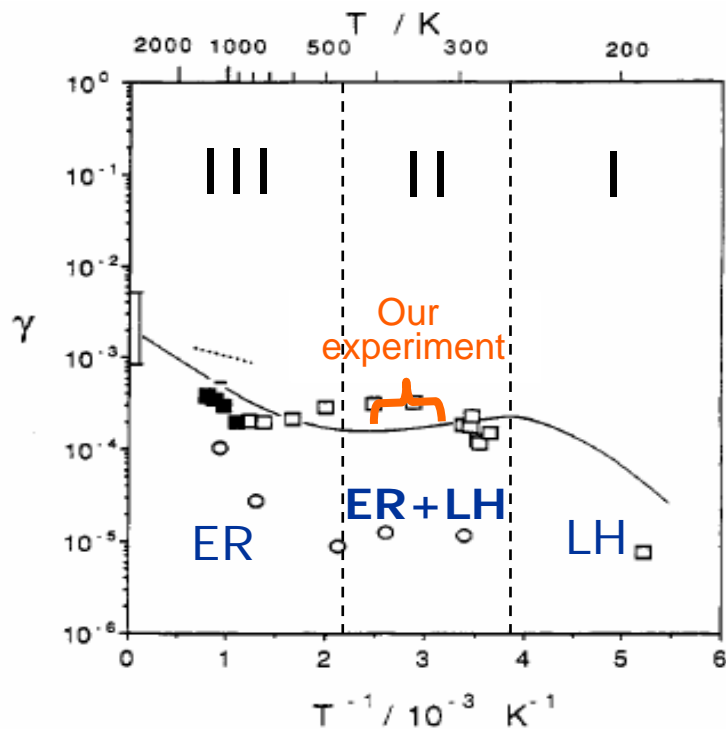
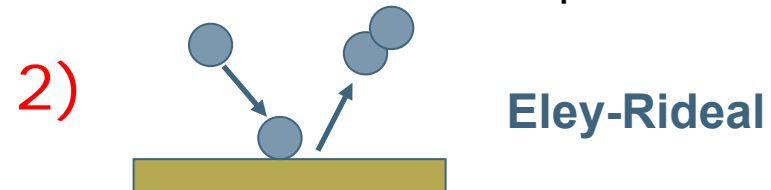
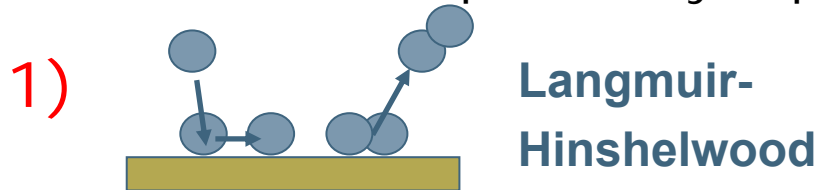
Silicon Etching



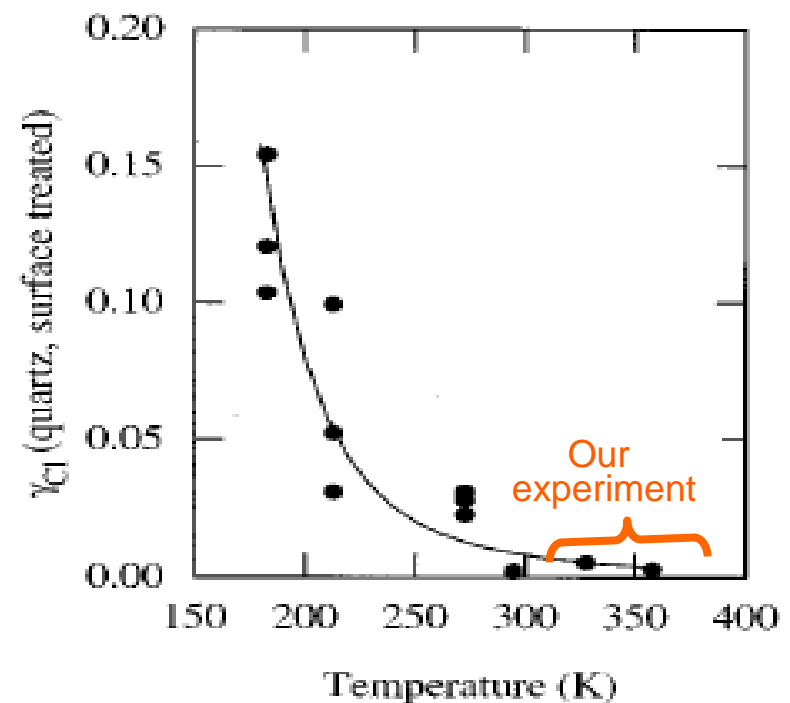
Etch Stop

Hypothesis for linking etch stop with quartz window temperature:  
Increase of O concentration can be related to a reduced surface recombination on the quartz window

- Recombination takes place on active sites on the surface.
- Recombination probability depends on the surface temperature



Kim Y. C. and Boudart M., *Langmuir* **7** (1991) 2999

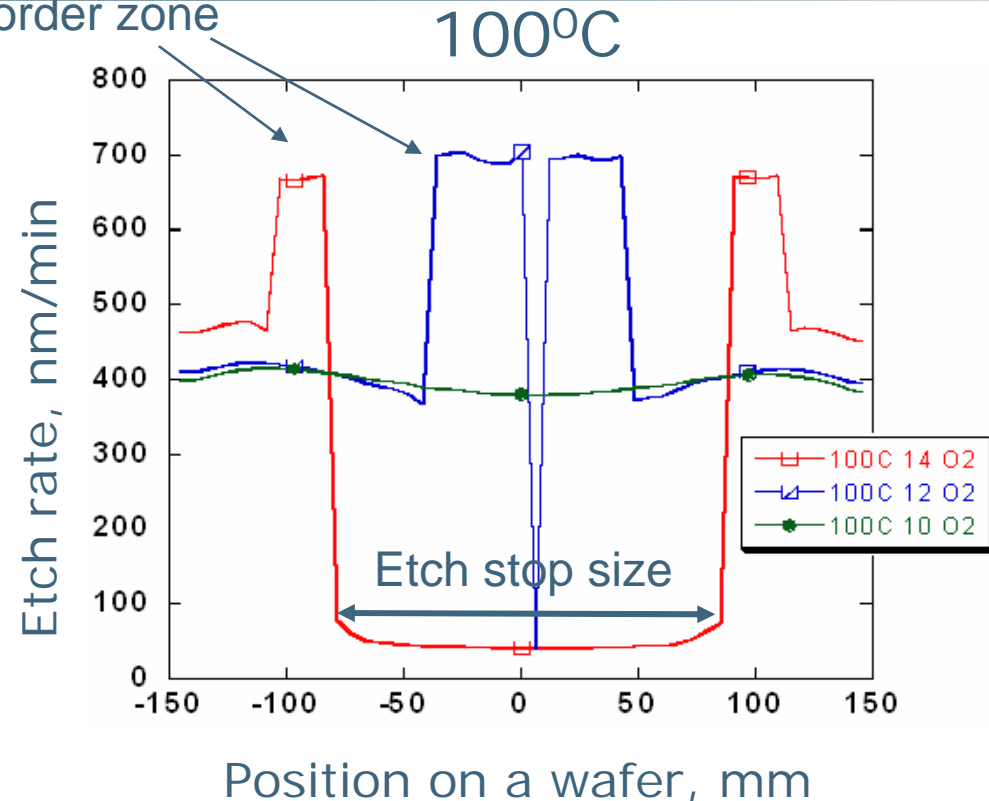
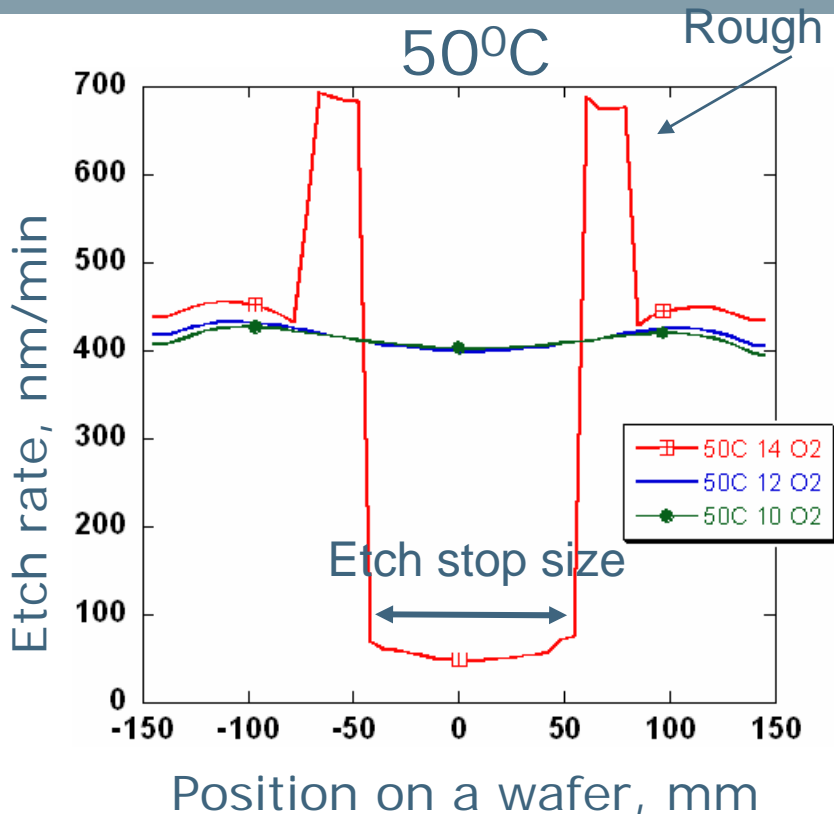


G.P. Kota et al., *J. Vac. Sci. Technol. A* 16.1., (1998), 270-277

# Experiment validation

- Studying the effect of O<sub>2</sub> addition, pressure, power
  - To reproduce the etch stop phenomenon
- The concentration of species was measured using optical emission spectroscopy combined with actinometry
  - The chosen actinometer is Ar, the intensities of O(777nm), Cl(837nm), and N(746nm) were compared with the intensity of Ar(750nm) and Ar(811nm)
- Test wafers (all 12 Inch)
  - SiO<sub>2</sub> on Si and poly-Si/SiO<sub>2</sub>/Si 300mm wafers
  - Si etch rate and oxide thickness were measured by KLA Tencor SCD100 spectroscopic ellipsometer

# Higher O<sub>2</sub> concentration has a similar effect as increasing Quartz Window Temperature



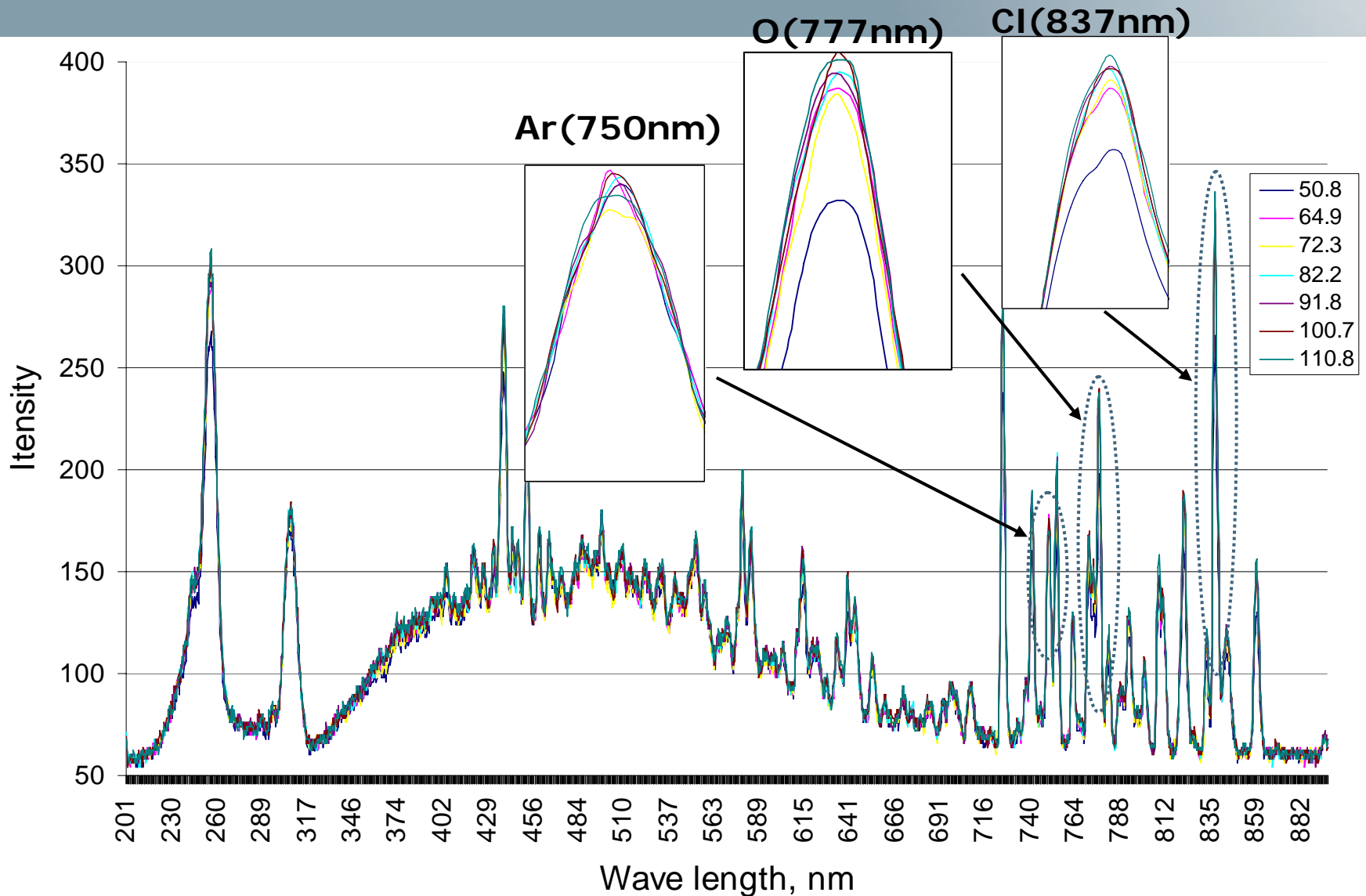
- If O<sub>2</sub> concentration increased above 20%, we get an etch stop
- The similar effect is observed when quartz window temperature is increased

# Experiment description (spectra)

- Spectra were recorded in one recipe with 5 steps: Cl<sub>2</sub> plasma, O<sub>2</sub> plasma, N<sub>2</sub> plasma, Cl<sub>2</sub>/O<sub>2</sub> plasma and STI plasma at different pressures and TCP powers in the quartz window temperature range from 50°C to 110°C
- Blanket SiO<sub>2</sub> wafers were used, each wafer was treated at different quartz window temperature with 10°C increment

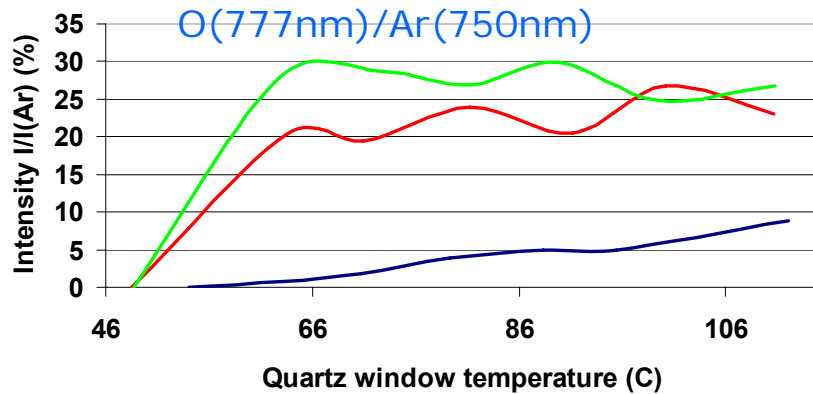
Step Description	CL2	O2	N2	CL2/O2	STI
Pressure (mtorr)	40	40	40	40	40
TCP RF Power (w)	1000	1000	1000	1000	1000
Bias RF Power (w)	0	0	0	0	0
Bias RF Voltage (v)	0	0	0	0	0
Bias RF Control Mode	Voltage	Voltage	Voltage	Voltage	Voltage
Bias Power Learned (w)	0.6	0.5	0.7	0.6	0.6
Gas Injection Ratio	Center	Center	Center	Center	Center
Cl2 (200.0 sccm)	<b>100</b>	0	0	<b>50</b>	<b>100</b>
He (500.0 sccm)	0	0	0	0	0
Ar (500.0 sccm)	<b>10</b>	<b>10</b>	<b>10</b>	<b>10</b>	<b>10</b>
O2 Lo (20.0 sccm)	0	0	0	0	<b>10</b>
O2 Hi (200.0 sccm)	0	<b>100</b>	0	<b>50</b>	0
N2 (100.0 sccm)	0	0	<b>90</b>	0	<b>18</b>
Inner ESC Temp (degC)	60	60	60	60	60
Outer ESC Temp (degC)	60	60	60	60	60
Step Type	Time	Time	Time	Time	Time
Process Time (sec)	15	15	15	15	15
OverEtch (%)	0	0	0	0	0

# O and Cl peaks increase with QWT, Ar is constant

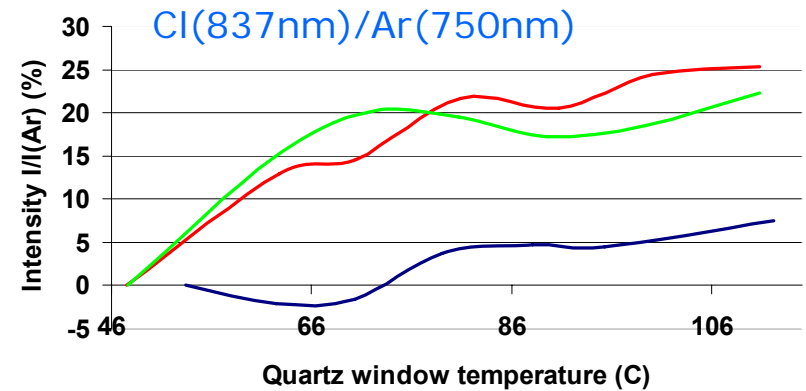


# O and Cl intensities increase with QWT and pressure

## O<sub>2</sub> plasma



## Cl<sub>2</sub> plasma

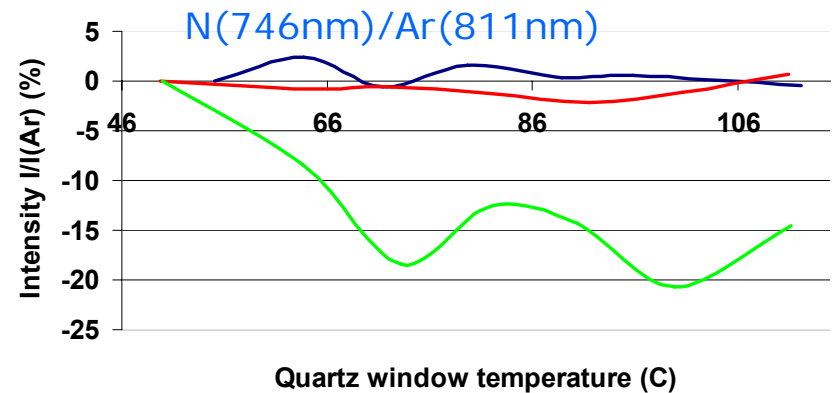


20 mtorr

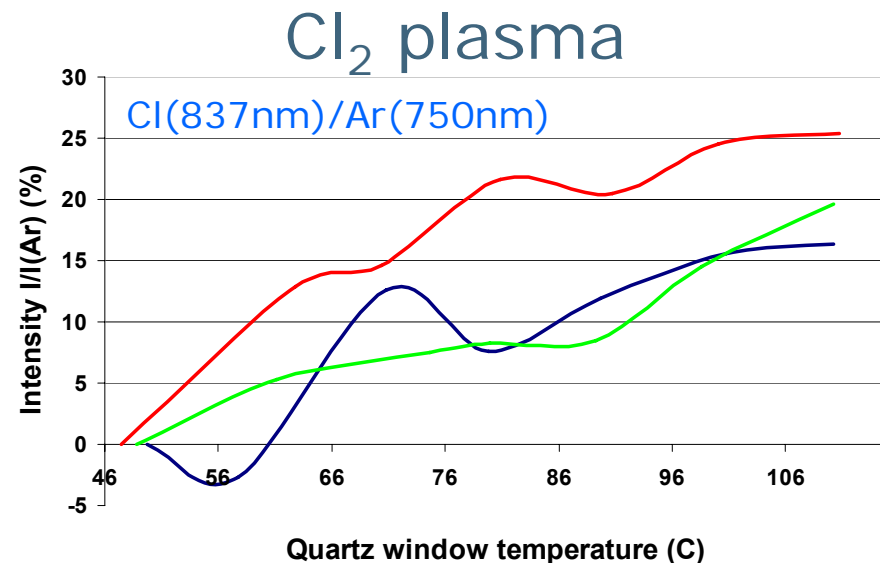
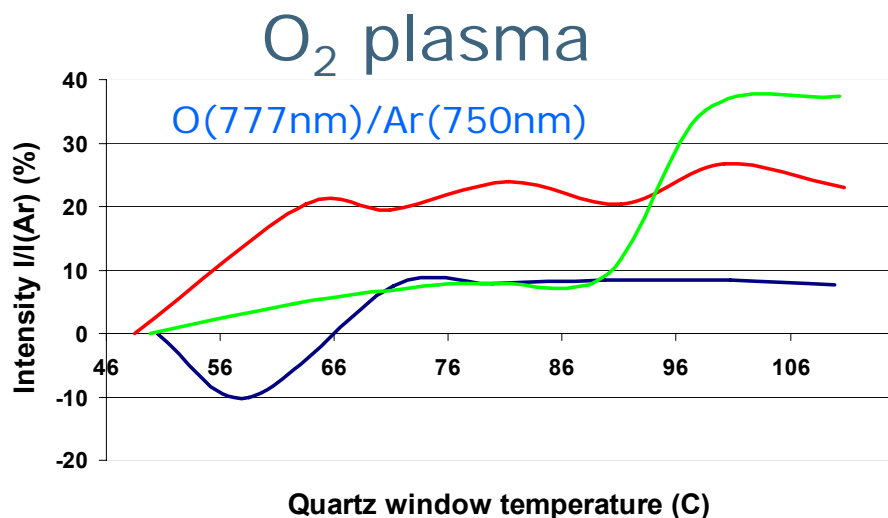
40 mtorr

60 mtorr

## N<sub>2</sub> plasma



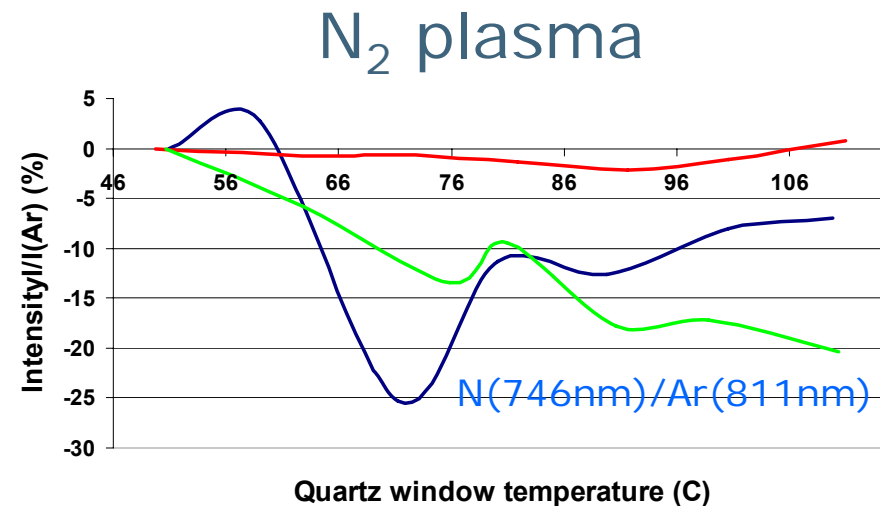
O and Cl intensities increase with QWT and have parabolic dependence on power



700 W

1000 W

1300 W



# Experiment description (Si etch rate)

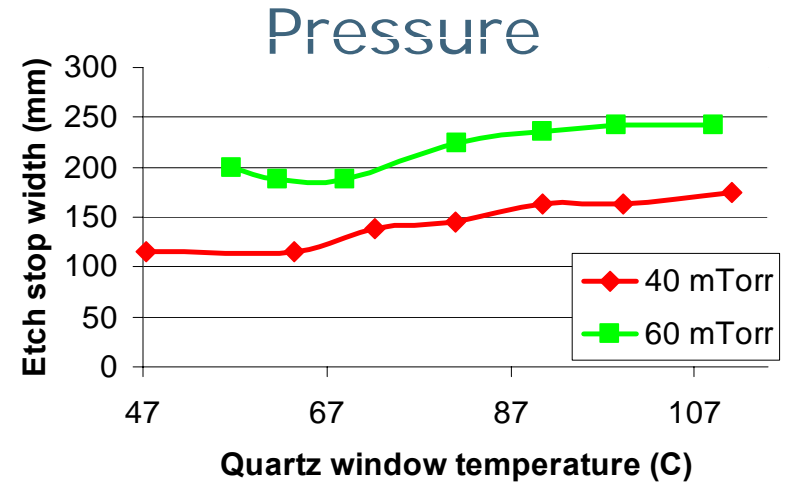
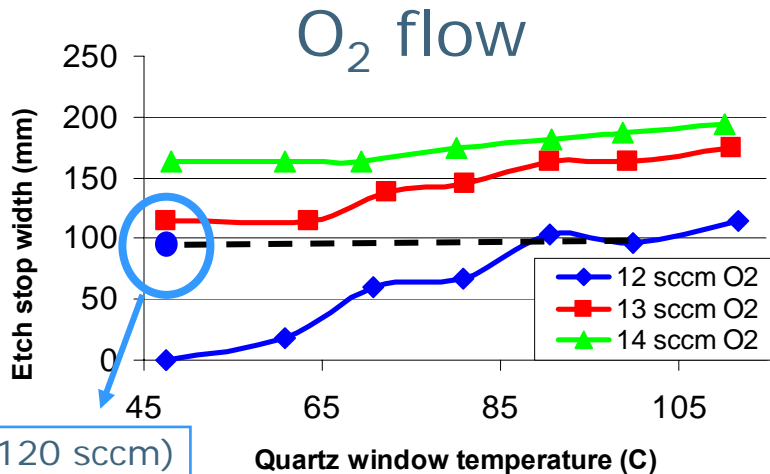
■ To quantify the etch stop, we measured the etch rate on blanket poly-Si wafers and used the size of the etch stop in the middle of the wafer as a metric for the etch stop phenomenon

■ Etch rate of poly-Si was measured at different:

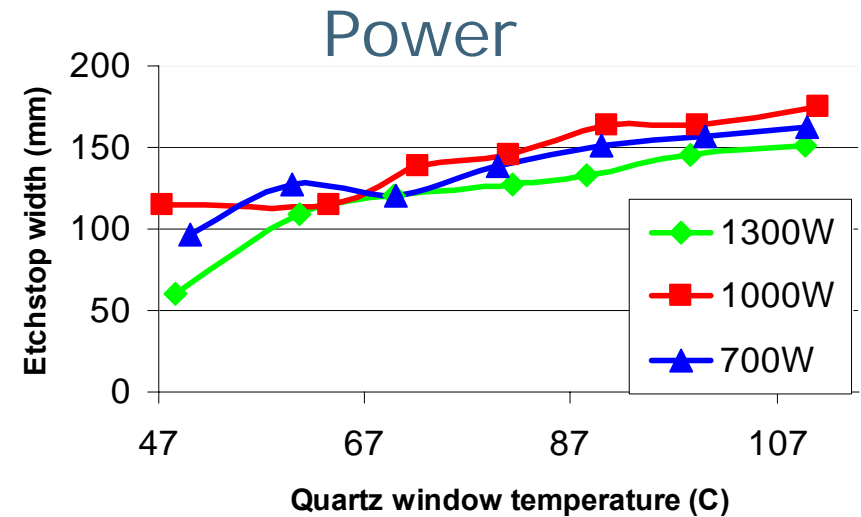
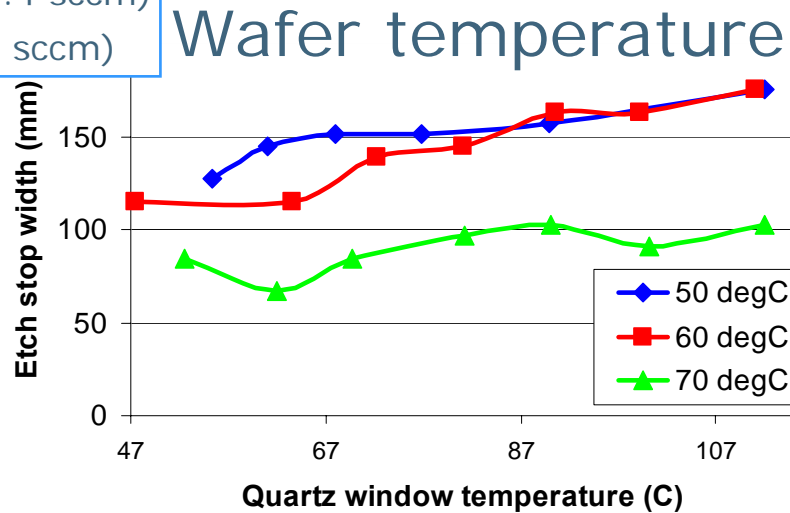
- O<sub>2</sub> flows
- pressures
- powers
- wafer temperatures

Step Description	BT	STI
Pressure (mtorr)	5	40
TCP RF Power (w)	350	1000
Bias RF Power (w)	0	0
Bias RF Voltage (v)	250	500
Bias RF Control Mode	Voltage	Voltage
Bias Power Learned (w)	122.9	264.8
Gas Injection Ratio	Center	Center
Cl2 (200.0 sccm)	0	<b>100</b>
He (500.0 sccm)	0	0
O2 Lo (20.0 sccm)	0	<b>13</b>
N2 (100.0 sccm)	0	<b>15</b>
CF4 (200.0 sccm)	<b>50</b>	0
Inner ESC Temp (degC)	60	60
Outer ESC Temp (degC)	60	60
Step Type	Time	Time
Process Time (sec)	5	15
OverEtch (%)	0	0

Etch stop size depends on O<sub>2</sub> flow, pressure and wafer temperature. Reference STI recipe: 100sccmCl<sub>2</sub>, 13sccmO<sub>2</sub>, 15sccmN<sub>2</sub>, 40mTorr, 1000W, 60°C(wafer T) – red curve



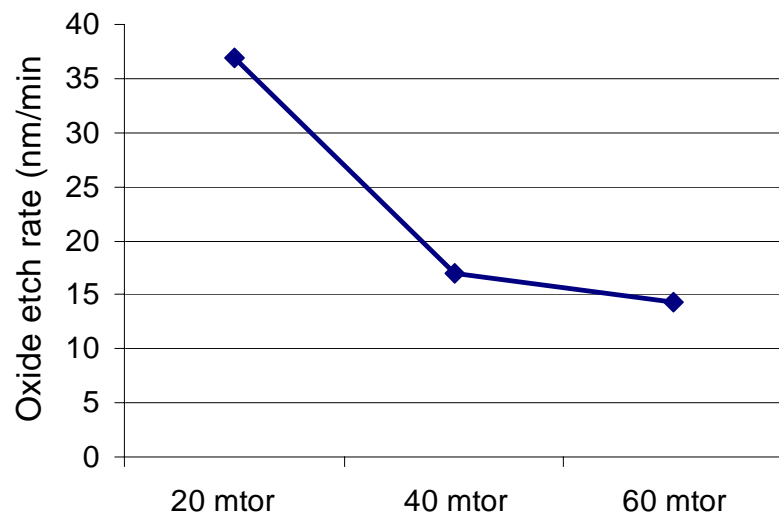
Cl<sub>2</sub>(120 sccm)  
O<sub>2</sub>(14.4 sccm)  
N<sub>2</sub>(16 sccm)



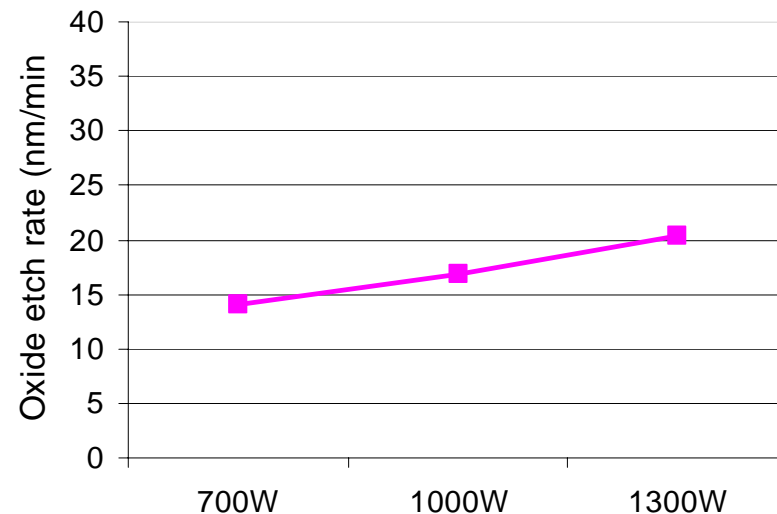
# Oxide etch rate increases with power, drops with pressure

We used blanket SiO<sub>2</sub> wafers for measuring of oxide etch rate in STI plasma (100 sccm Cl<sub>2</sub>/13 sccm O<sub>2</sub>/15 sccm N<sub>2</sub>)

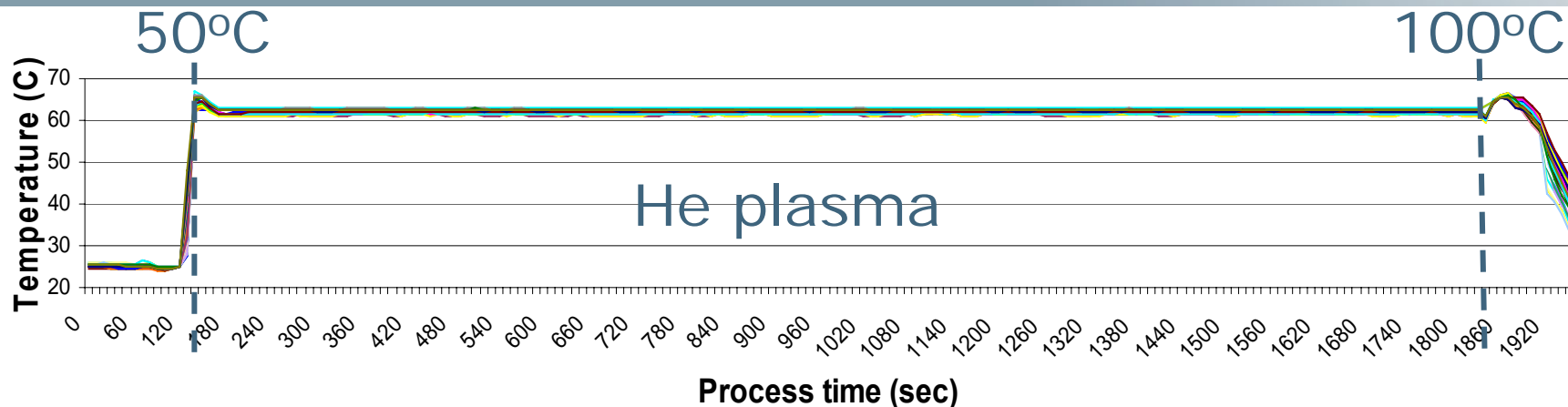
### Pressure



### Power



# Wafer temperature is constant when QWT increases

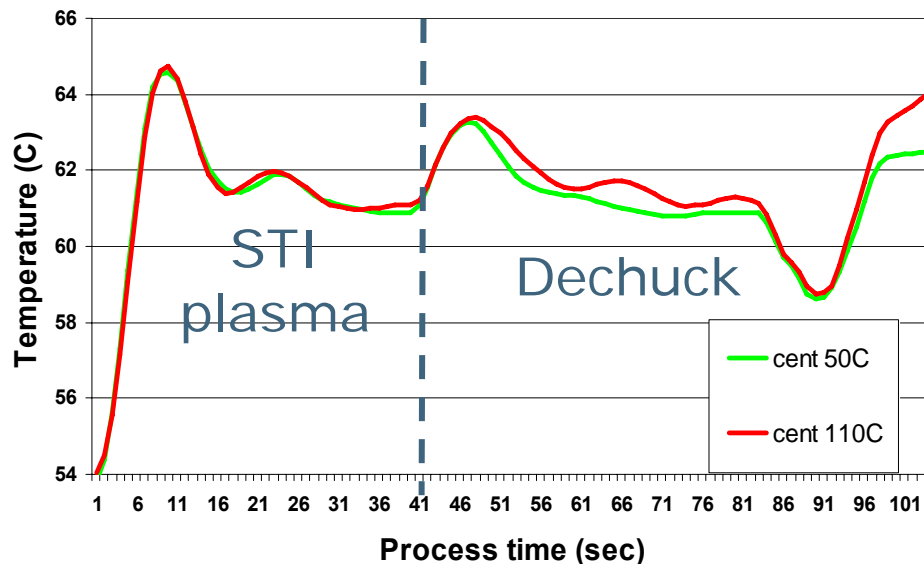


Wafer temperature was measured by OnWafer™ PlasmaTemp sensor wafer

Wafer temperature doesn't change with increasing of quartz window temperature

Etch stop causes only due to increasing of oxygen concentration

## Centre sensor temperature



# Summary

- We observed increase of oxygen concentration with increase of quartz window temperature in accordance with LH+ER – mechanism of surface recombination
- Etch stop width increases with O<sub>2</sub> flow and pressure, but decreases with wafer temperature and independent of power
- The quartz window temperature has no influence on wafer temperature

# Conclusions

- Etch stop during STI etch is caused by increase of oxygen concentration in the plasma
- The increase of oxygen concentration is related to reduced recombination on the hot quartz window
- The quartz window temperature must be controlled in order to provide reproducible processes which are sensitive to oxygen concentration