

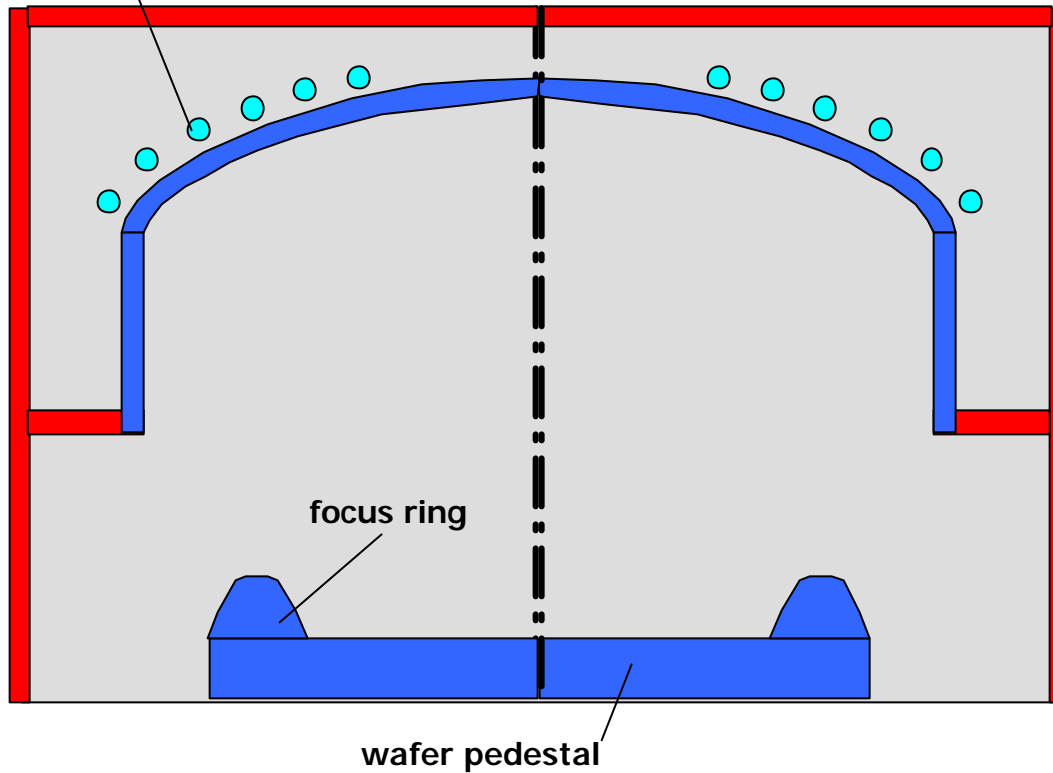
PLASMA SIMULATIONS
OF AN
ICP $\text{BCl}_3 / \text{Cl}_2$ DISCHARGE
INA
DPS REACTOR



Research & Software, L.L.C.

COMPUTATIONAL GEOMETRY: DPS Etch Reactor

6 coil ICP antenna
(800 W)



Inlet Flow:

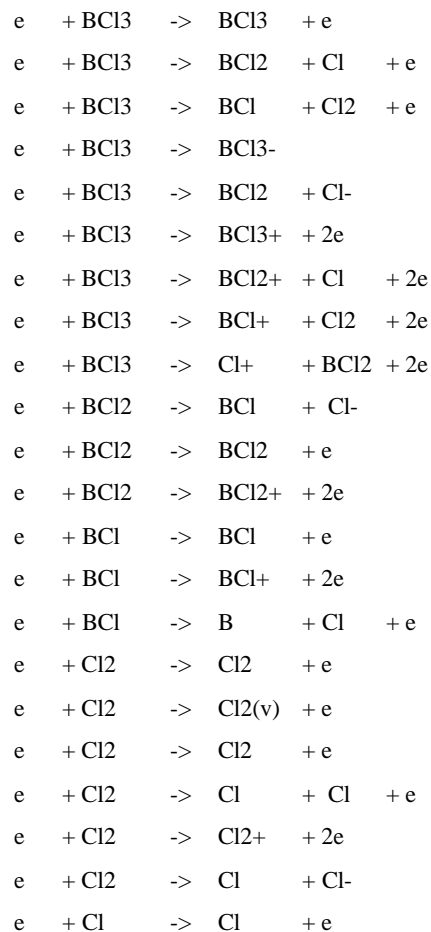
60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂

Boundary Conditions

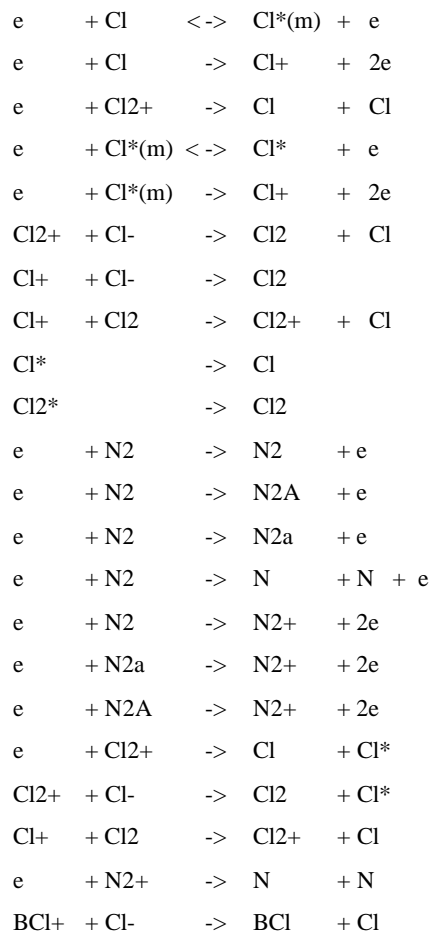
Press = 4 - 40 mTorr

BCI3 / CI2 CHEMISTRY SET:

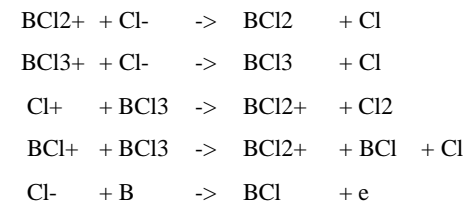
Plasma Reactions



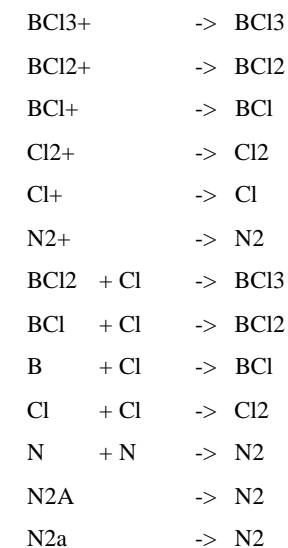
Plasma Reactions



Plasma Reactions



Surface Reactions



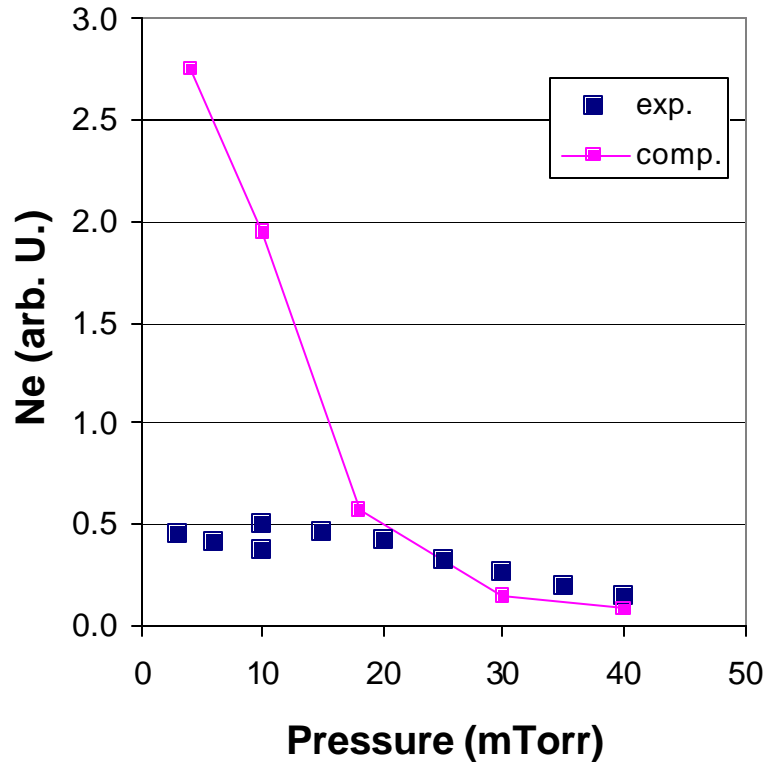
PLASMATOR RESULTS

BCL3 ETCHING

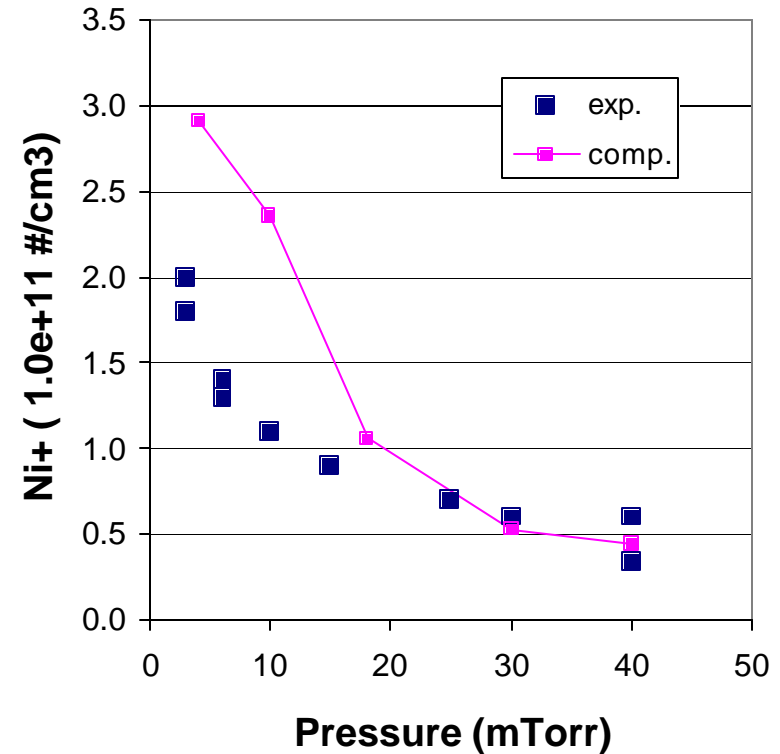
COMPARISON TO EXPERIMENTS:

PLASMATOR Results - Pressure Variation Effects on Electron and Positive Ion Density

Electron Density Signal



Ion Density



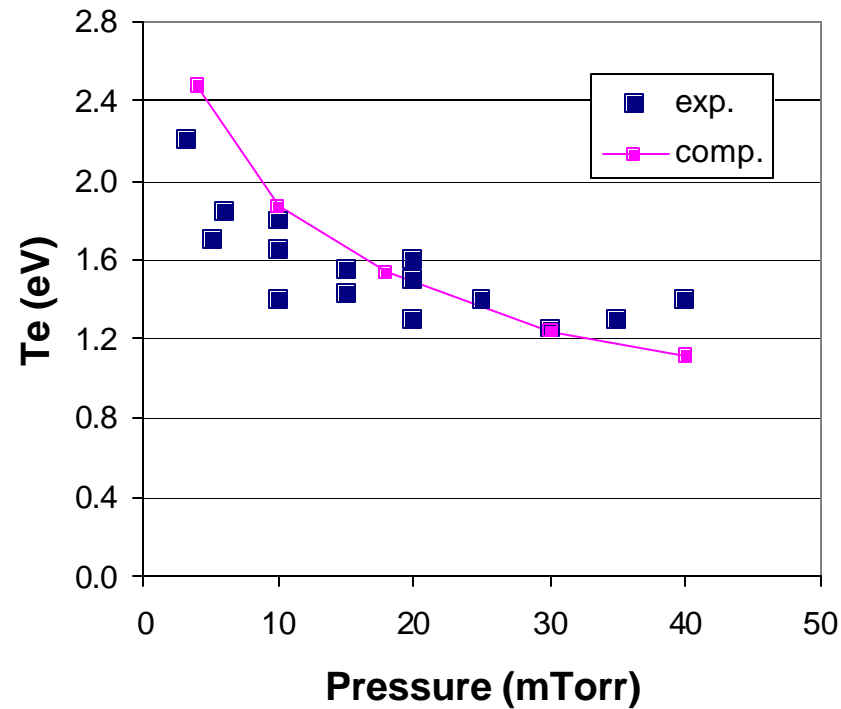
Reactor Conditions:

60 sccm Cl₂; 40 sccm BCl₃; 10 sccm N₂; 800 W ICP

* Malyshev, et. Al., J. Vac. Sci. Technol. A 18(3), 849, May/June 2000

COMPARISON TO EXPERIMENTS:

PLASMATOR Results - Effect of Pressure Variation on Electron Temperature

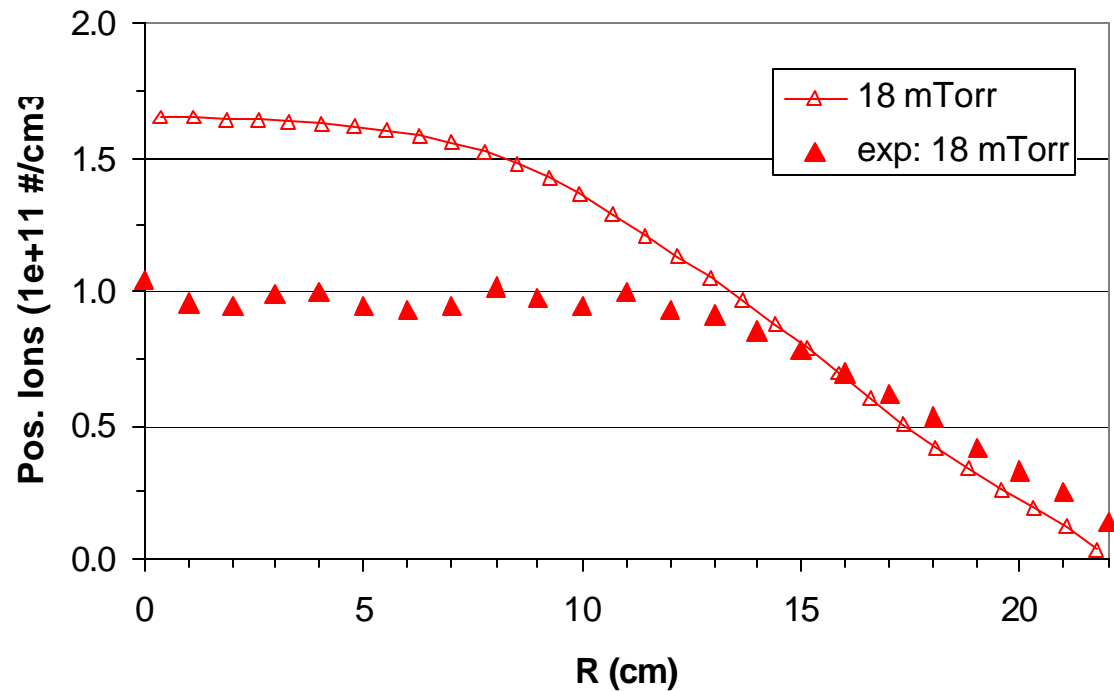


Reactor Conditions:

60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂
800 W ICP

* Malyshev, et. Al., J. Vac. Sci. Technol. A 18(3), 849, May/June 2000

COMPARISON TO EXPERIMENTS: PLASMATOR Results - Ion Density Distribution



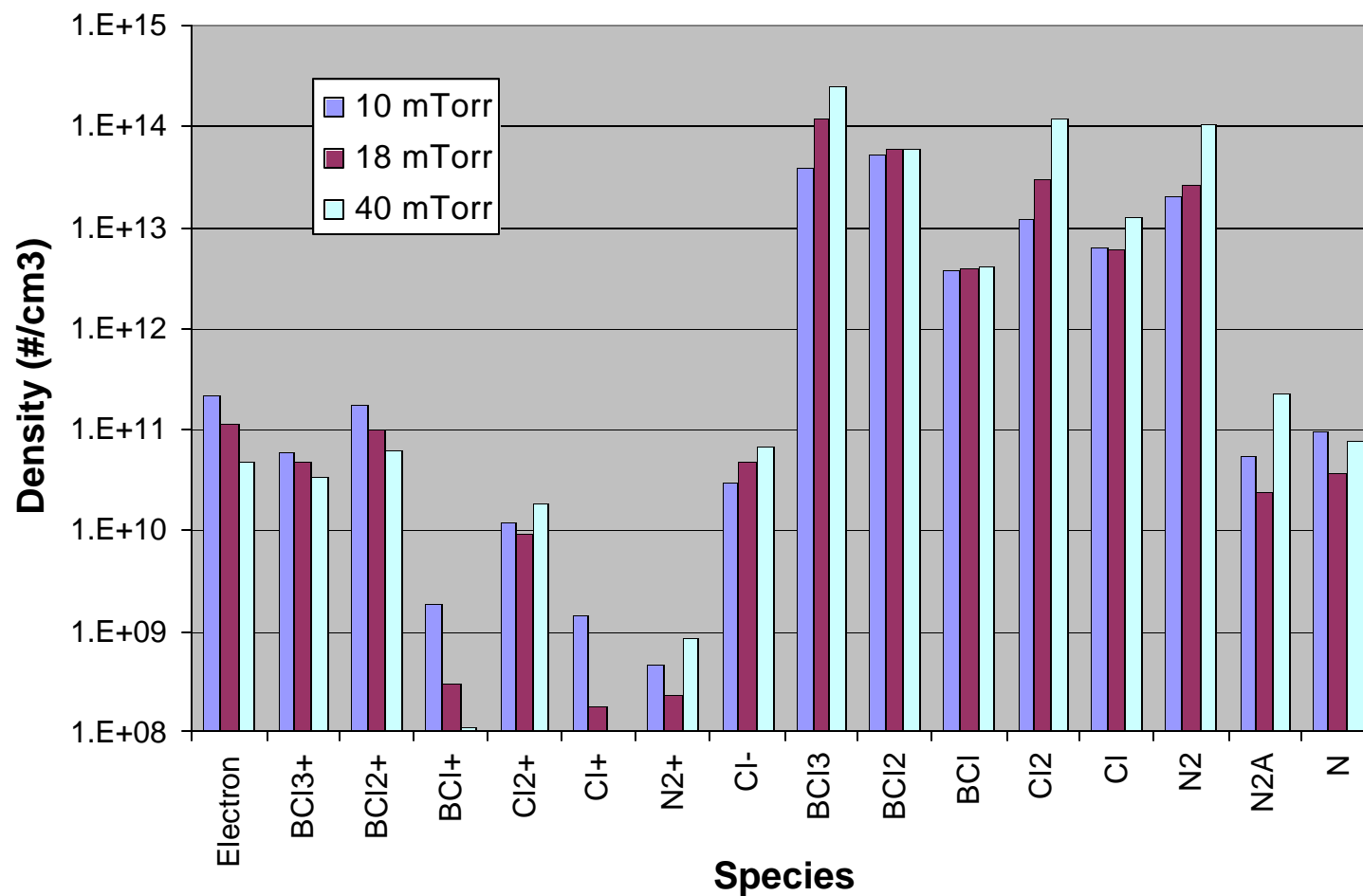
Reactor Conditions:

60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂
800 W ICP

* Malyshev, et. Al., J. Vac. Sci. Technol. A 18(3), 849, May/June 2000

PLASMA COMPOSITION:

PLASMATOR Results - Average Densities



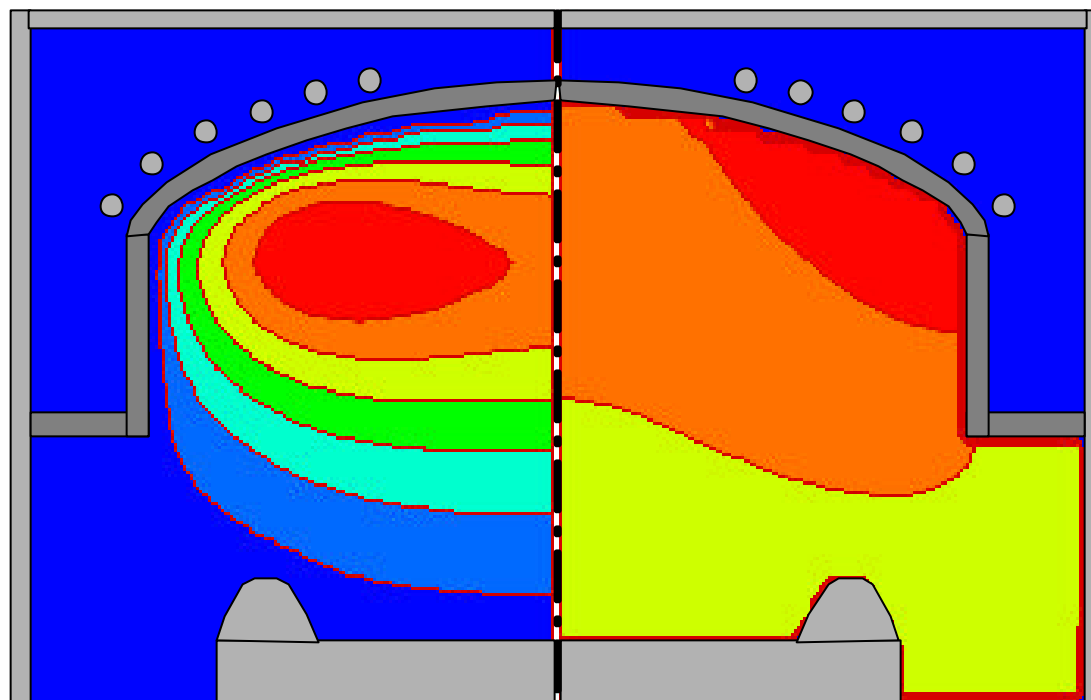
Reactor Conditions:

60 sccm Cl₂; 40 sccm BCl₃; 10 sccm N₂; 800 W ICP

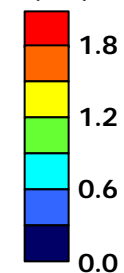
PLASMA COMPOSITION:

PLASMATOR Results - Electron Density and Temperature Distribution

Ne
($10^{11}\#/cm^3$)



Te
(eV)



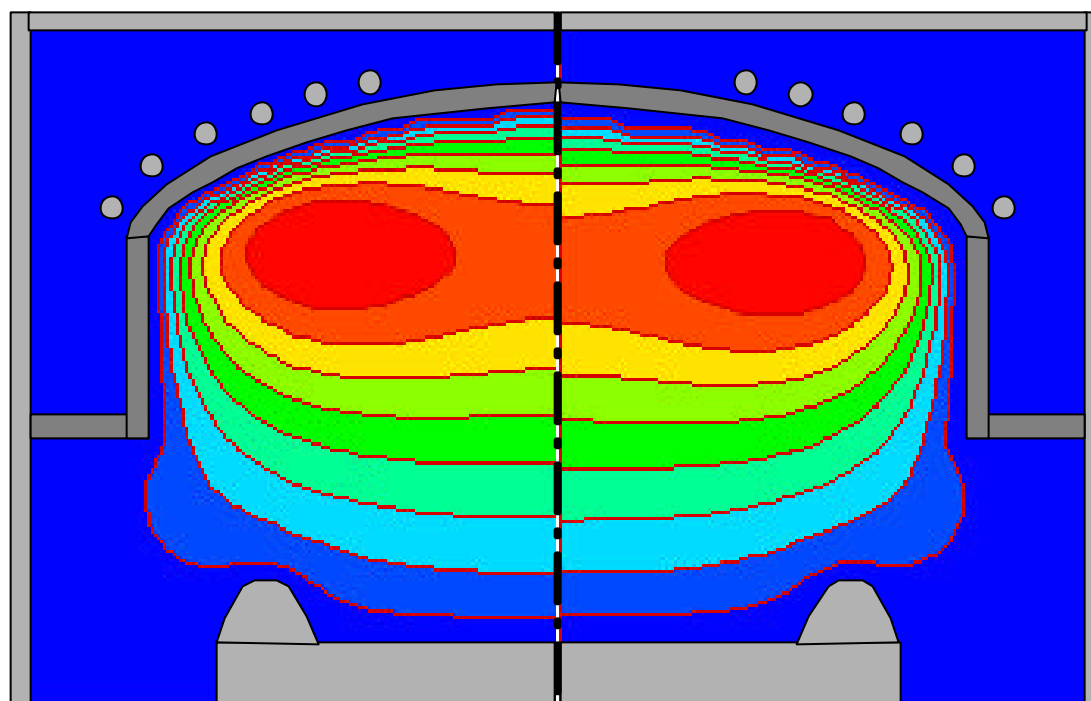
Reactor Conditions:

60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂
18 mTorr
800 W ICP

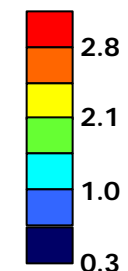
PLASMA COMPOSITION:

PLASMATOR Results - Principal Ions: BCL3+ and BCL2+ Density Distribution

BCL3+
($10^{11}\#/cm^3$)



BCL2+
($10^{11}\#/cm^3$)



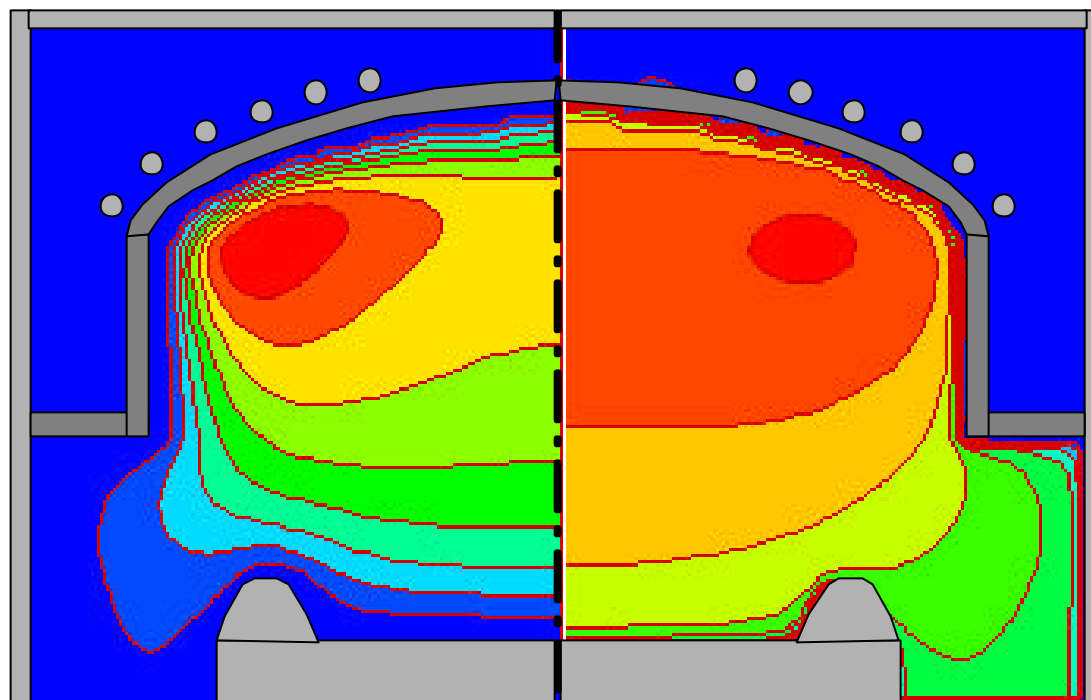
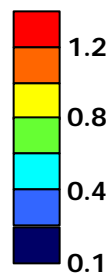
Reactor Conditions:

60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂
18 mTorr
800 W ICP

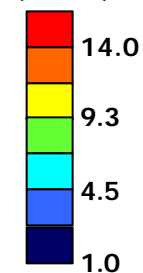
PLASMA COMPOSITION:

PLASMATOR Results - Negative Ion Density and Plasma Potential Distribution

CL-
($10^{11}\#/cm^3$)



Potential
(Volts)



Reactor Conditions:

60 sccm Cl₂
40 sccm BCl₃
10 sccm N₂
18 mTorr
800 W ICP

SUMMARY:

Computations were conducted of the $\text{BCl}_3 / \text{Cl}_2 / \text{N}_2$ process in the Applied dome reactor. The additive rare gas mixture was not included in the simulations. The flow rates were 60 sccm Cl_2 , 40 sccm BCl_3 , and 10 sccm N_2 for pressures ranging from 4-40 mTorr. A six-turn coil was used to inductively couple 800 W. No pedestal bias was used. The computational geometry and plasma chemistry set are shown in slides 2 and 3, respectively.

The resulting variations of electron emission (OES presumed proportional to electron density) and positive ion density with respect to pressure are shown in slide 5. The general decrease of electron and positive ion density with increasing pressure is captured well by the computations. At pressures below 15 mTorr, however, the computation over estimates the electron and ion densities. Most significant is the experimental trend of constant electron density at low pressure (<15 mTorr). The computation does not point to this behavior. Further analysis is being conducted in an effort to understand this trend. As the pressure decreases, the electron energy distribution function (EEDF) becomes increasingly non-Maxwellian. Since the OES technique assumes that the EEDF has a Maxwellian tail, its error increases as the pressure decreases. Boltzmann simulations will be undertaken to explore the implications of this effect on both the simulations and the experiments. Slide 6 shows the electron temperature variation with respect to pressure. The computations capture both the trend and magnitude of the variation. Slide 7 shows the radial ion density distribution. The computations do a reasonable job of predicting the shape and magnitude, although the peak density is over-estimated. Slide 8 shows the average densities of each computational species as the pressure increases. The dominant ion is found to be BCl_2^+ while the main dissociated product is always BCl_2 . As the pressure increases, the magnitude of Cl^- also increases until the negative ions outnumber the electrons at pressures near 40mTorr. Slides 9-11 show the spatial distributions of electron density and temperature, BCl_3^+ and BCl_2^+ density, and Cl^- density and plasma potential for the 18mTorr case. The electron density and temperature peak near the middle of the coils, as expected. The BCl_3^+ and BCl_2^+ densities mirror each other, although, the BCl_2^+ peak density is twice as high as that of the BCl_3^+ . Most interesting, perhaps, is the trapping of Cl^- in the plasma potential well, as shown in slide 11.

In general, the comparisons between experiments and computations are very reasonable. The electron temperature and positive ion variations with pressure are well represented. At pressures below 15 mTorr, the computation fails to predict constant electron temperature as the experiments suggest. This discrepancy remains under investigation.