Queen's University Belfast

Nagoya University

東京工業大学 Tokyo Institute of Technology

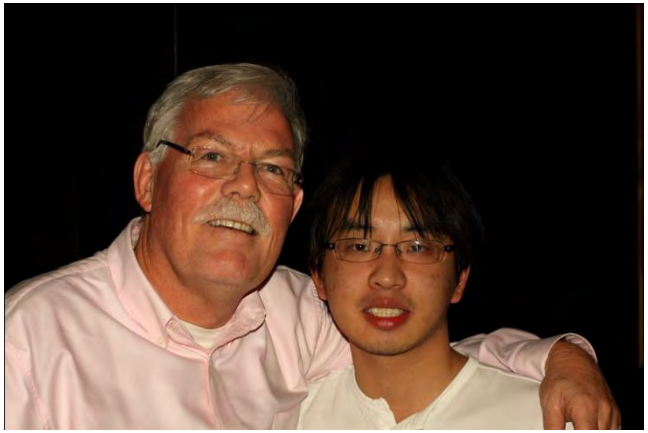
Study of Electronegativity in Inductively Coupled Radio-Frequency Plasma with Langmuir Probe

International Training Program
Queen's University Belfast

Dept. Energy Sciences
Tokyo Institute of Technology
Hotta Lab
D1 Bin Huang (黄　斌)

About Queen's

Director: Prof. Bill Graham



Cooperator: Mr. Mujahid

Main building of Queen's

Introduction to ICP

Inductively Coupled Plasma (ICP)

Type: planar/cylindrical

Principle:

time-varying current through coil

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time-varying magnetic field

↓

induces azimuthal electric currents

↓

break down forming plasma

Oxygen ICP application

- **Semiconductor manufacture**

Ashing:

Oxygen +polymers /organics → CO_2+H_2O

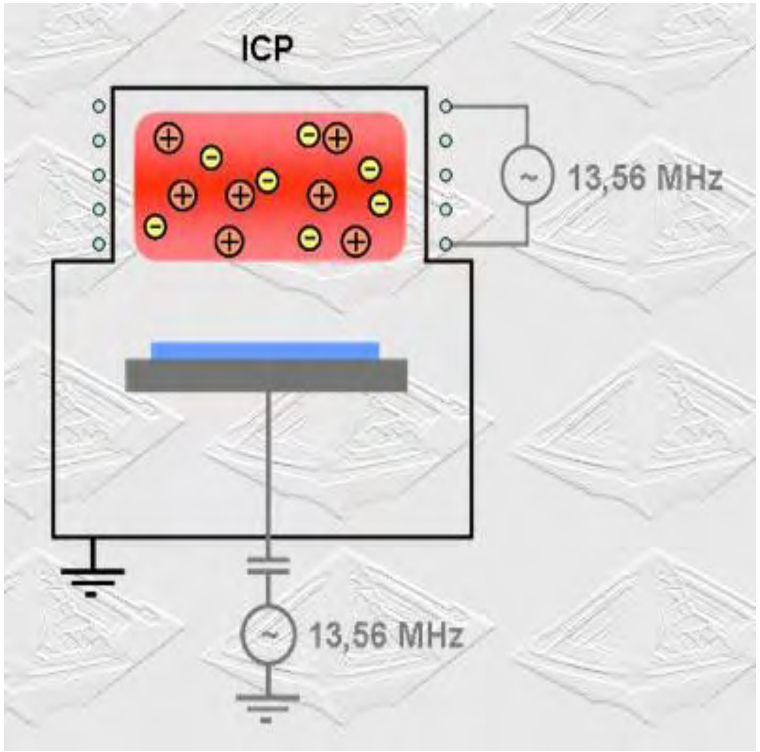

photo resist is applied to the wafer

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photo mask hardens/illuminates resist

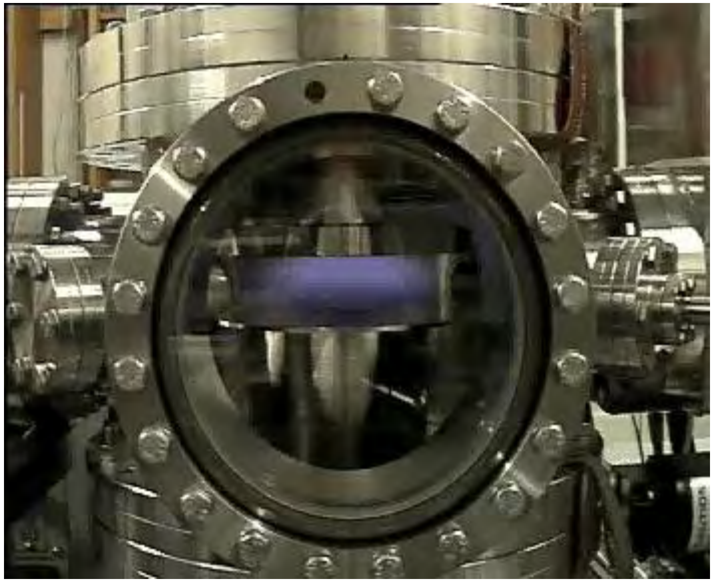
↓

Deposition/etching

↓

Cleaning wafer

Oxygen ICP characteristics



Negative ions:

O^-, O_2^-, O_3^- ,etc

Two operation regimes:

E-mode: low power, low density, capacitive discharge.

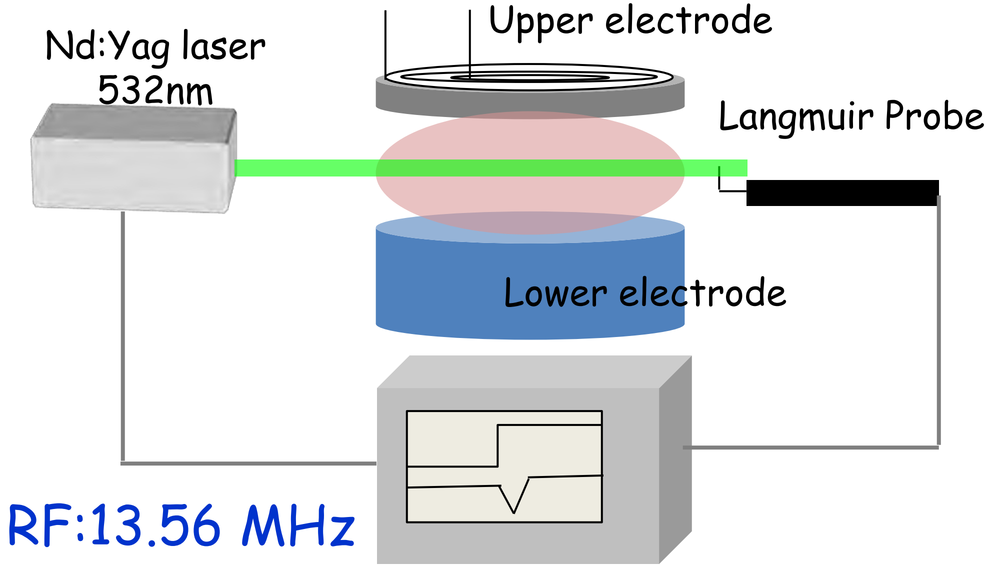
H-mode: high power, high density, inductively discharge.

E-H transition:

change of electron density, EEDF, coil current, light emission, etc.

Photo-detachment measuring system

GEC reference cell



Schematic of photo-detachment measurement system

Electrode diameter: 165.1 mm
Electrode gap: 40.5 mm

Photo-detachment diagnostics

Diagnostics principle:

Photo-detachment electron current

$$A^- + h\nu = A + e$$

electron affinities:
O^-:1.46 eV; O_2^-:0.44 eV
Nd:YAG laser(532 nm): hv=2.33 eV

Suffice to photo-detach both species

Advantages:
- Less perturbing
- Better time resolution
- Capacity of measuring ion temperature

Photodetachment fraction Vs laser energy

Experimental:

Negative ion density:

$$\frac{\Delta I_e}{I_e} = \frac{n_-}{n_e}$$

I_e: probe current
n_e: background density
ΔI_e: instantaneous current

Theoretical:

Photo-detachment fraction:

$$\frac{\Delta n_-}{n_-} = 1 - \exp\left(-\frac{E}{S}\frac{\sigma_{pd}}{h\nu}\right)$$

E:incident laser power
S:beam cross-sectional area
σ_{pd}: photo-detachment cross section of negative ion

Deviate from theory:

thermionic electron emission
laser ablation of the probe surface

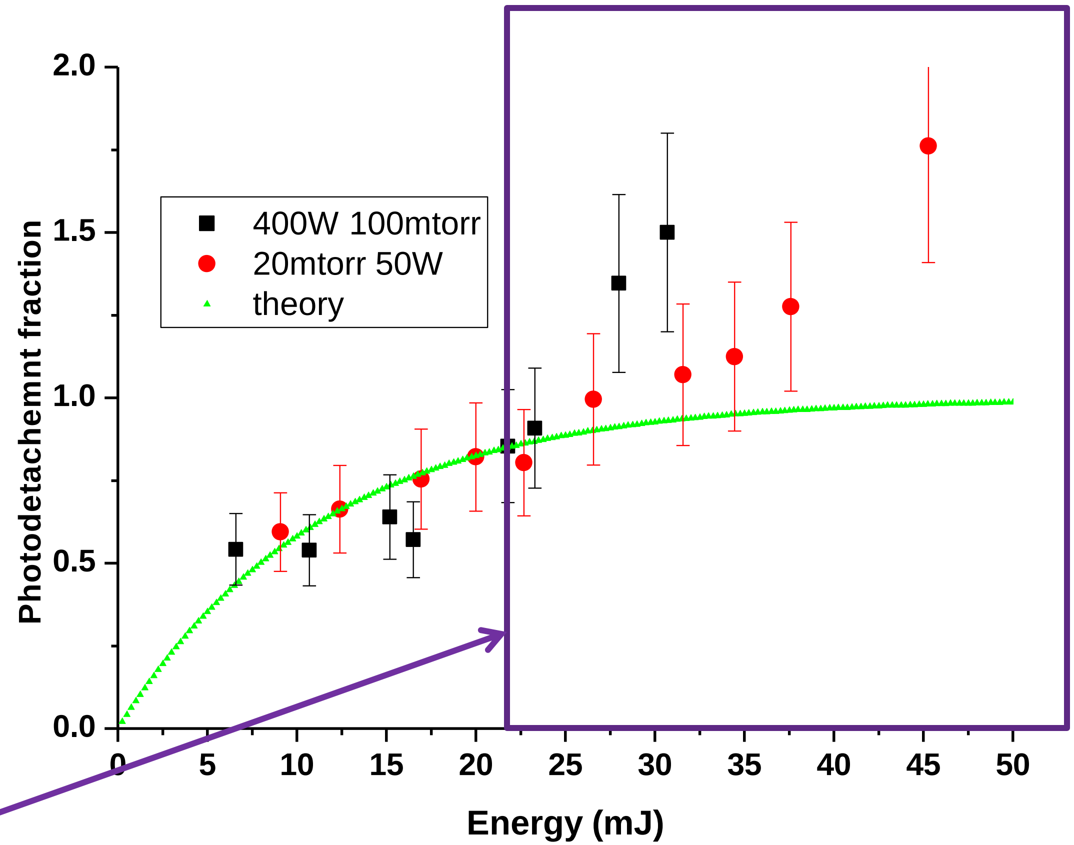
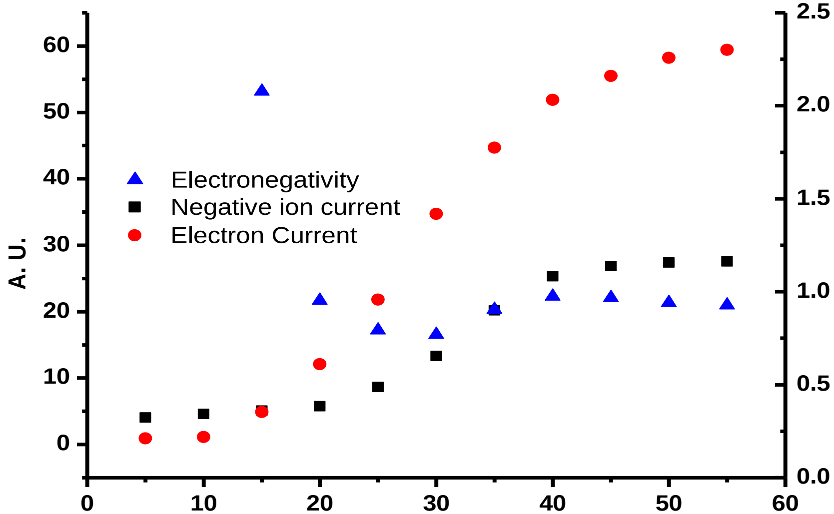


Photo-detachment fraction against energy measured with probe 1.25 cm from lower electrode with laser diameter of 5 mm.

Electronegativity Vs probe bias

Capacitive mode:

Electronegativity stablize @45 V

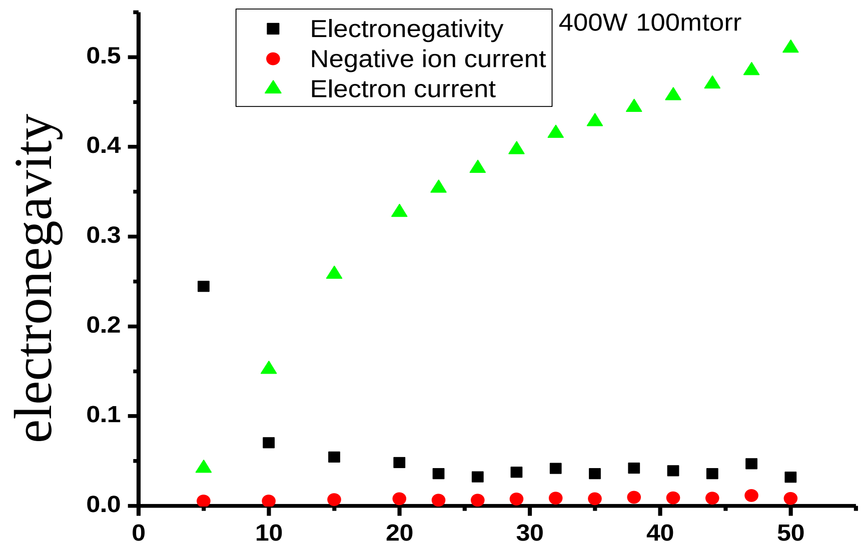


Probe bias voltage

Electronegativity (blue), Negative ion current (black) and electron current (red) against probe bias voltage in capacitive mode.

Inductive mode:

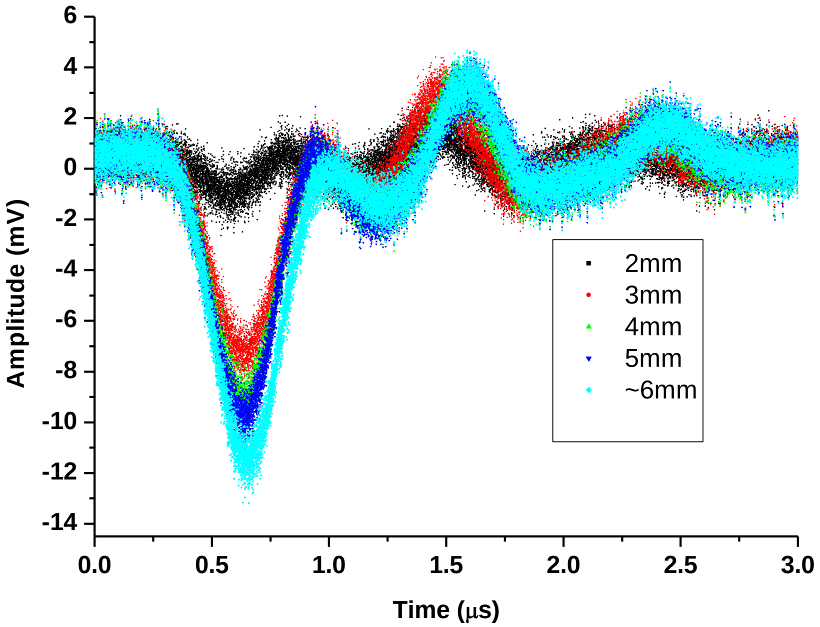
Electronegativity stablize @30 V

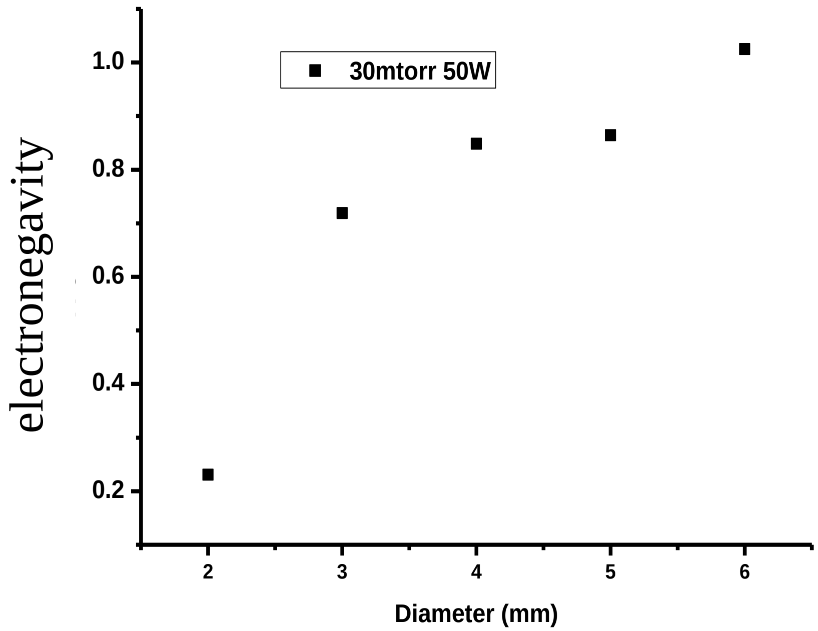


Probe bias voltage

Electronegativity (black), Negative ion current (red) and electron current (green) against probe bias voltage in inductive mode.

Electronegativity Vs laser diameterr



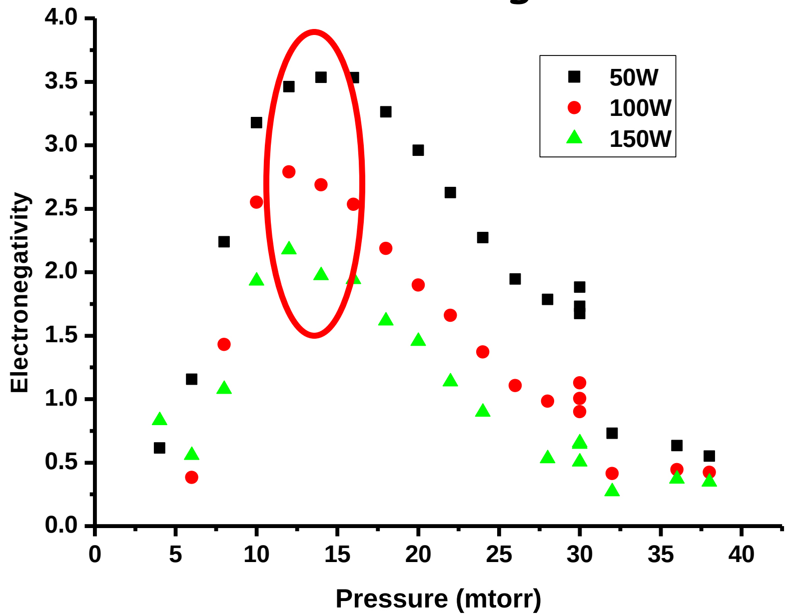


Electronegaticity stablizes @ 5 mm

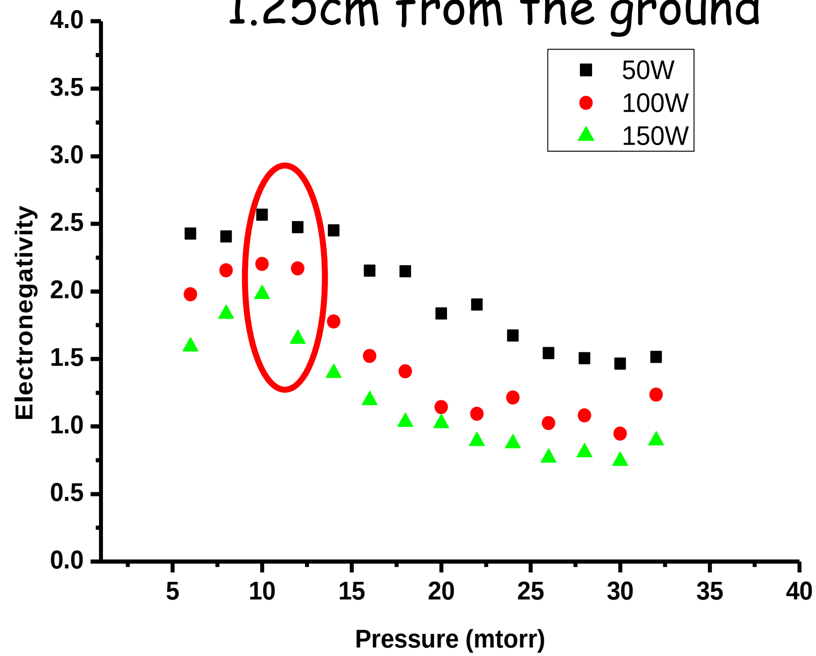
Electronegativity against pressure

Capacitive mode

2cm from the ground



1.25cm from the ground



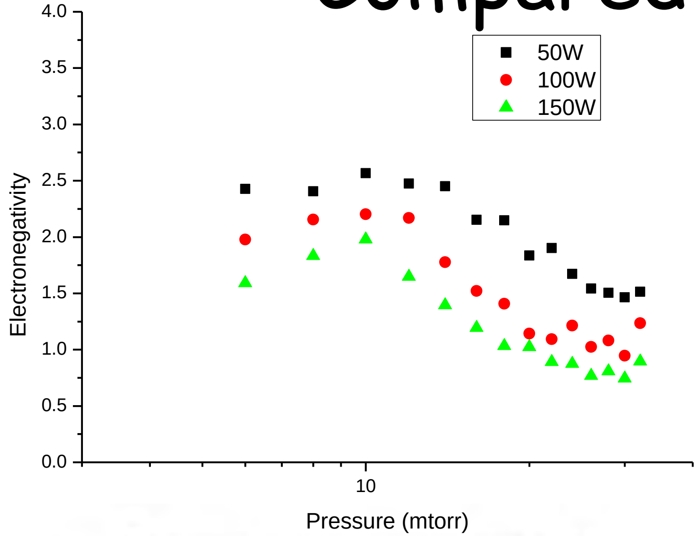
Peak electronegativity when RF power fixed:

O^- is produced by dissociative attachment of O_2 and destroyed by ion-ion recombination at low pressures. At higher pressures it is lost due to detachment.

Electronegativity decreased when RF power increase:

Electron density increases while negativity ion density is almost constant

Electronegativity against pressure Compared with simulation



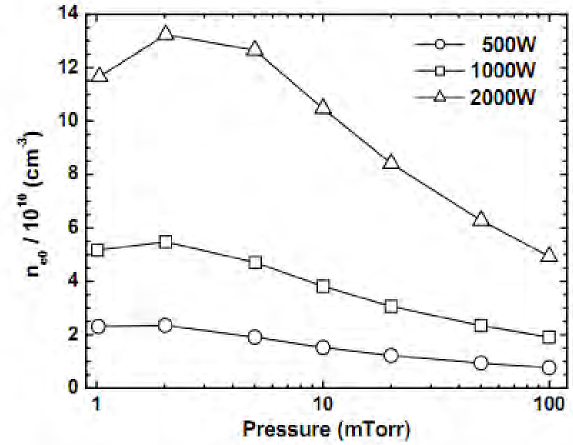


Figure 3.2. Core electron density n_{e0} versus pressure at 500, 1000 and 2000 W of absorbed power.

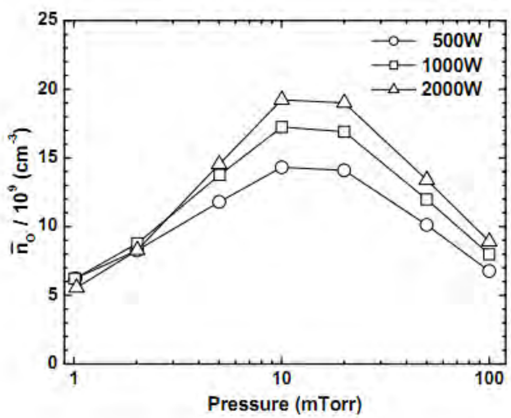


Figure 3.3. Average negative ion density $\bar{n}_{o}$ versus pressure at 500, 1000 and 2000 W of absorbed power.

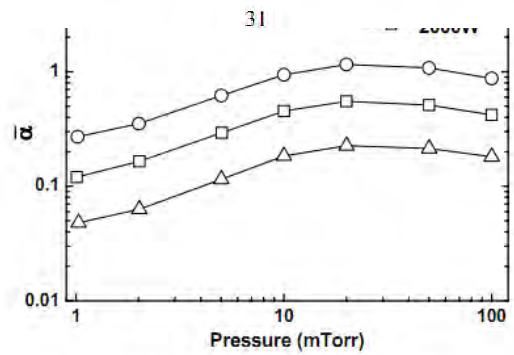


Figure 3.4. Average electronegativity $\bar{\alpha}$ versus pressure at 500, 1000 and 2000 W of absorbed power.

From Corrmac. Corr Ph.Dthesis

Conclusion & future work

‹ Conclusion: ›

➢ Laser energy, laser diameter and probe bias voltage were calibrated and suitable parameters were selected for photo-detachment measurement.

➢ Electrongativity were measured at different positions in capacitive mode.

➢ The relationship between electronegaticity and pressure & RF power is consistent with simulation.

‹ Future work: ›

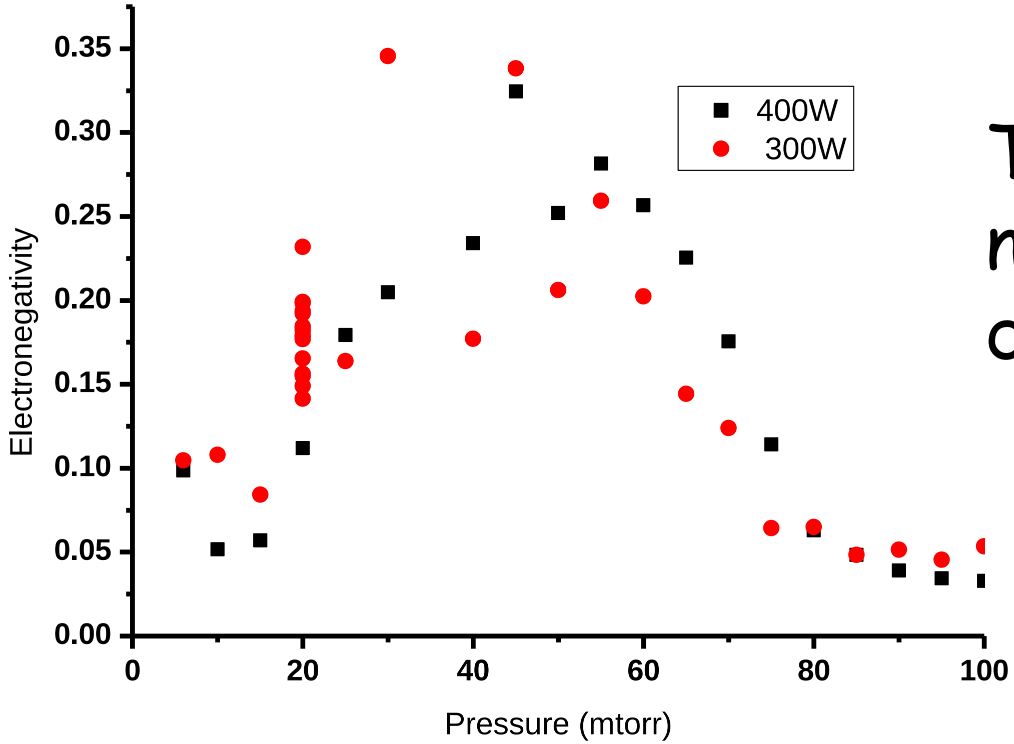
Measuring electronegativity against pressure in inductively mode

THANK YOU

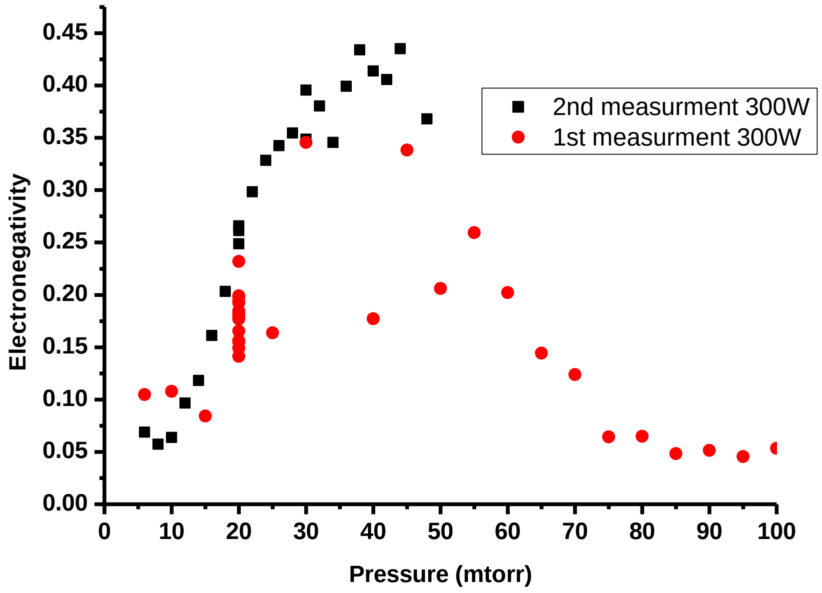

KINGS & QUEENS
Golders Green 13
TRANSDEV

Electronegativity against pressure

Inductive mode
1.25 cm from lower electrode

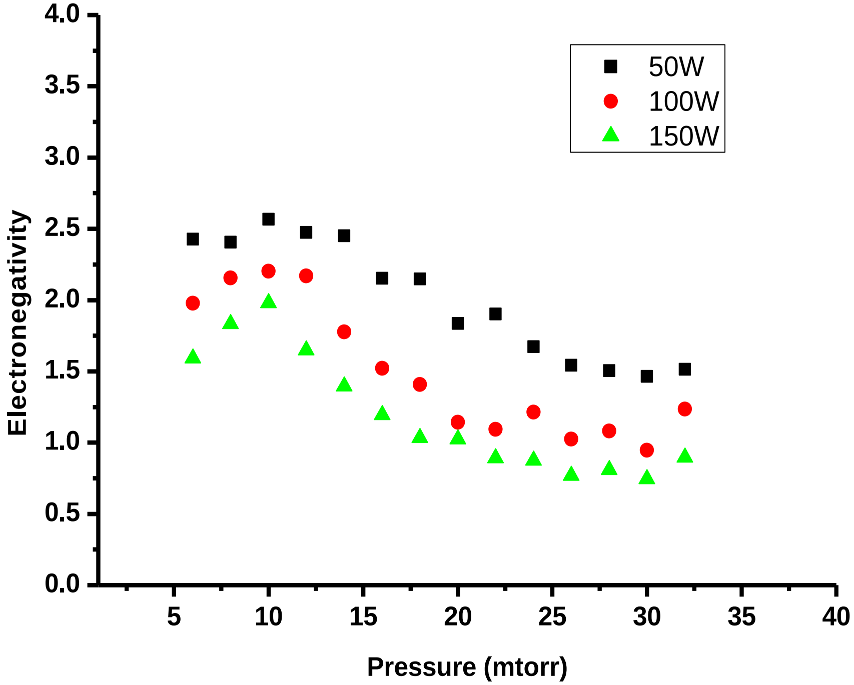


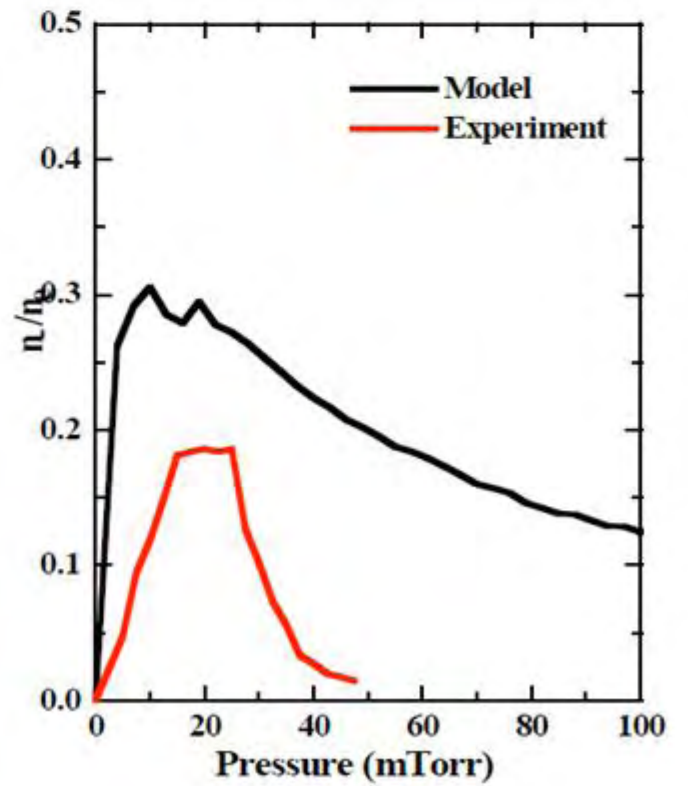
The relationship is not clear and should do again.



Electronegativity
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
90
100
Pressure (mtorr)
2nd measurment 300W
1st measurment 300W

Electronegativity against pressure Compared with simulation





Global model

From Corrmac. Corr thesis

Self introduction

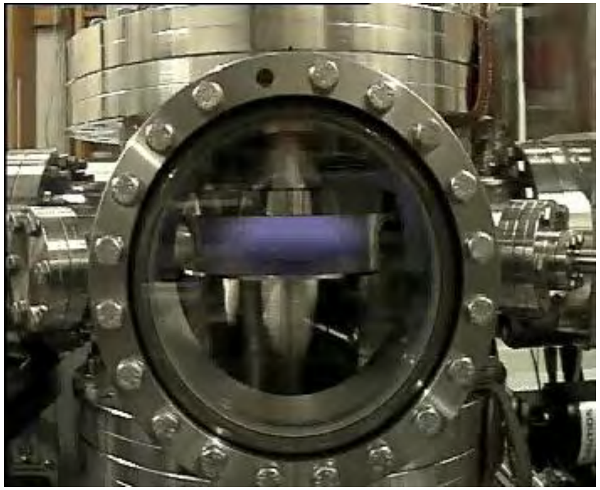
Name: Bin Huang (黄 斌)

Hometown : Suzhou, China (蘇州,中国)

Research in Tokyo Tech:
Xe gas jet type Z-pinch EUV source

Research in Queen's:
Oxygen radio-frequency ICP

Oxygen Inductively Coupled Plasma



Two operation regimes:

E-mode: low power, low density, capacitive discharge.

H-mode: high power, high density, inductively discharge.

Negative ions:

O^-, O_2^-, O_3^-, etc

O2- is less than 10%

‹ Application: ›

◇surface modification
◇fabrication of chips
◇thin film deposition

E-H transition:

change of electron density, EEDF, coil current, light emission, etc.