Investigation of SF_6 and C_4F_8 plasma at ICP chamber of ASE™ tool with SEERS

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Advanced Silicon Etching -(ASE) Chamber

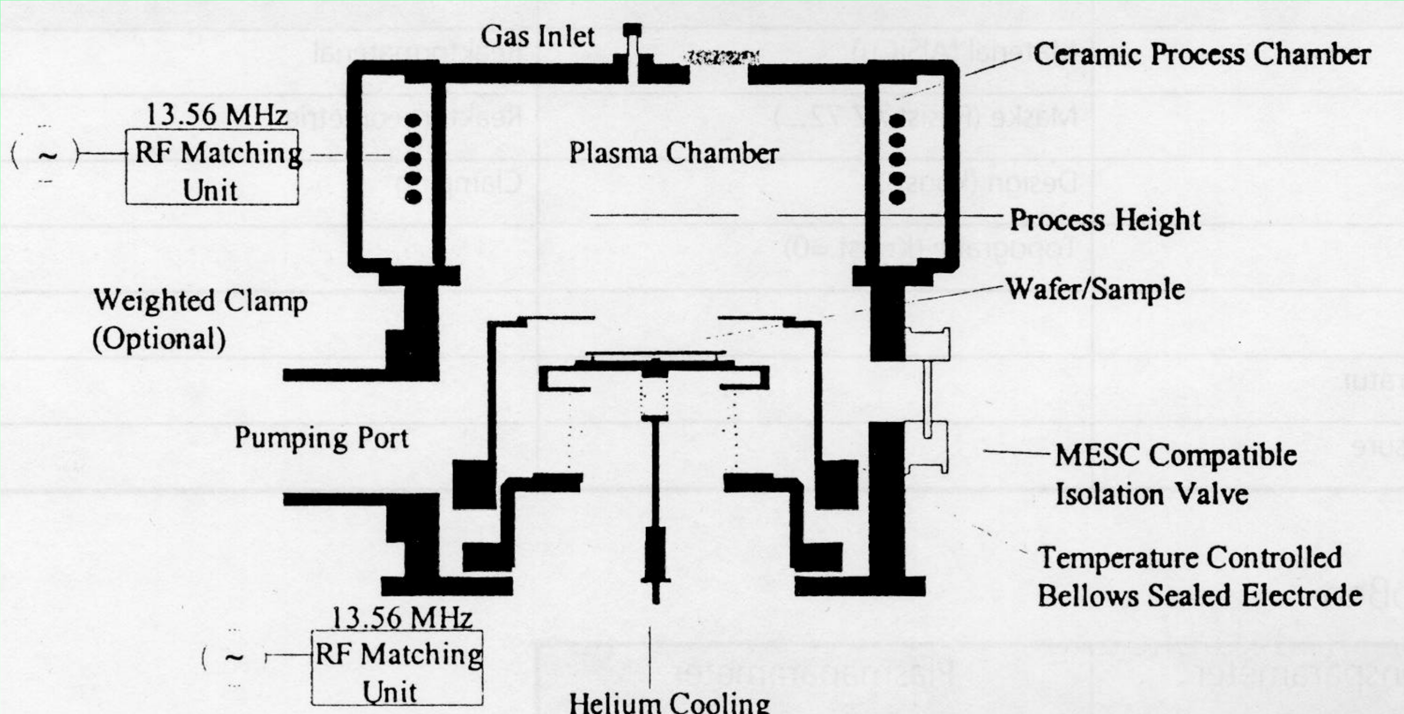

Figure 1. Schematic

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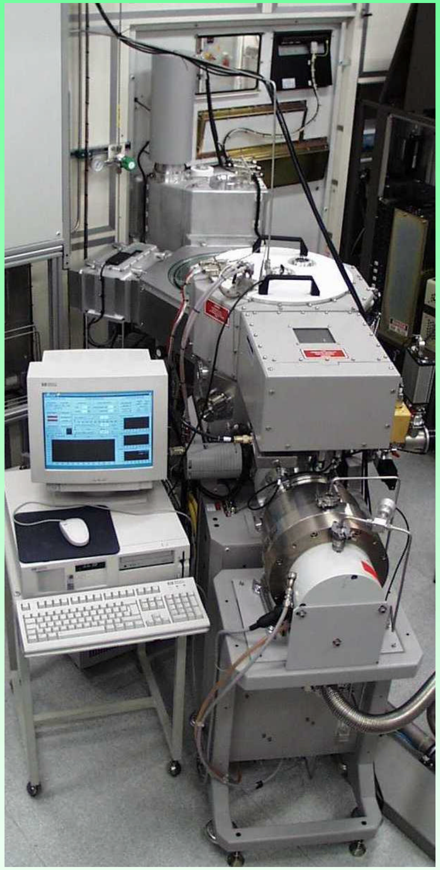
Clustertool with ASE Chamber

frontside



ASE-Chamber with HERCULES

Deposition and Etching

Deposition

Electron Impact Dissociation:

$$CF_4 + e^- \rightarrow CF_x^{+} + CF_x^{\cdot} + F^{\cdot} + e^-$$

Polymeric Passivation Layer:

$$nCF_x^{\cdot} \rightarrow nCF_2(ads) \rightarrow nCF_2(f)$$

$F^{\cdot}$ Removes Passivation Layer:

$$nCF_2(f) + F^{\cdot} \xrightarrow{ion\ energy} CF_x(ads) \rightarrow CF_2(g)$$

Silicon Etched by $F^{\cdot}$

Etching

Electron impact:

$$SF_6 + e^- \rightarrow S_xF_y^{+} + S_xF_y^{\cdot} + F^{\cdot} + e^-$$

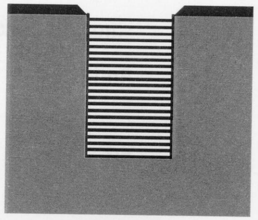
$F^{\cdot}$ Etches Silicon:

$$Si + F^{\cdot} \rightarrow Si\text{-}nF$$

$$Si - nF \xrightarrow{ion\ energy} SiF_x(ads)$$

$$SiF_x(ads) \rightarrow SiF_x(g)$$

- Sequential Passivation and Etch Steps
  - Step 1 Deposit passivation layer
  - Step 2 Remove passivant from base + etch Si



- Repeat steps to required etch depth

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Deep trenches in bulk silicon

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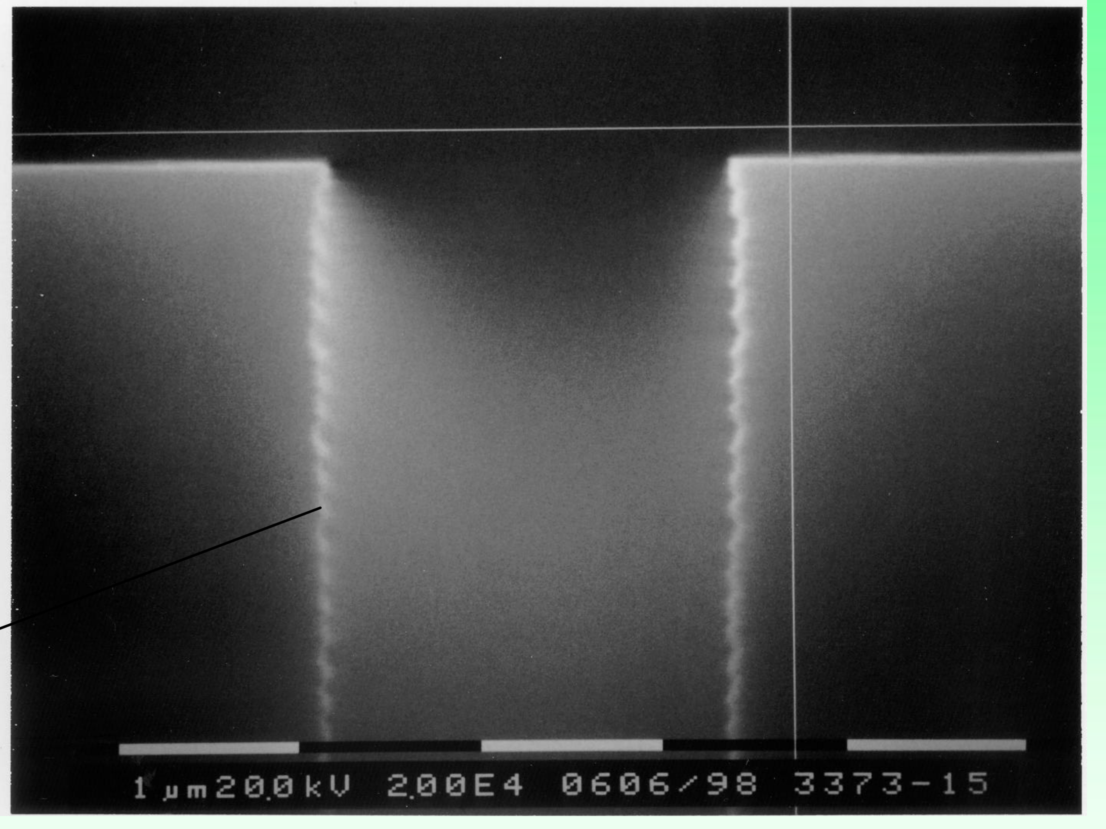
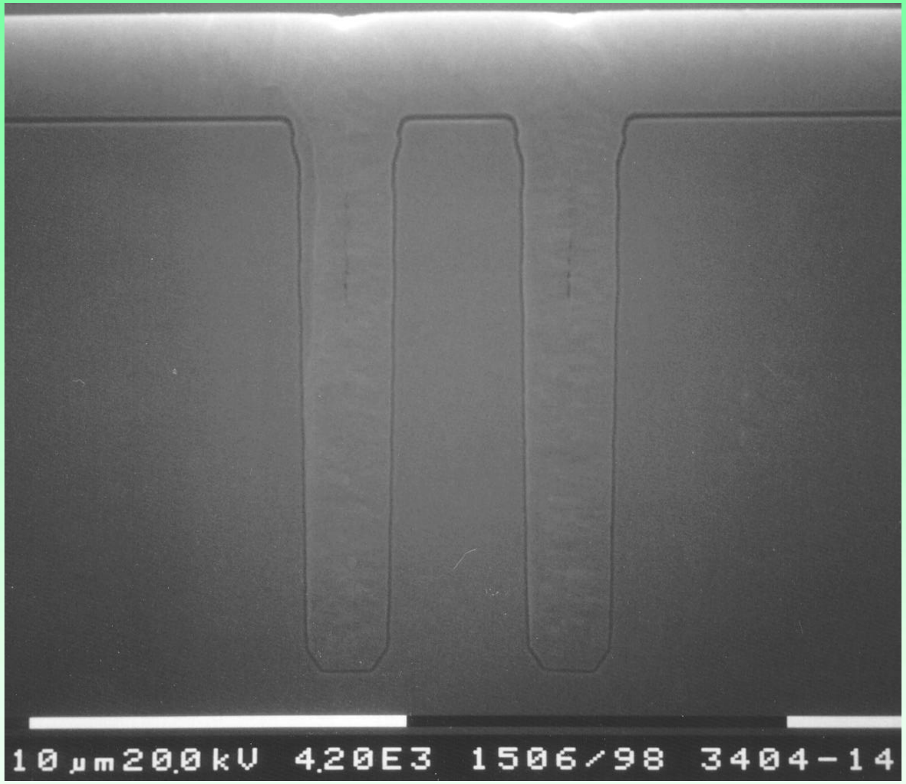
Sidewall



Smooth sidewall

Scallops from
dep/etch process

10 µm deep trench in bulk Silicon (filled)



1: two step dry etching
2: wet etching (sidewall smoothing)
3: filling (oxide + poly-si)

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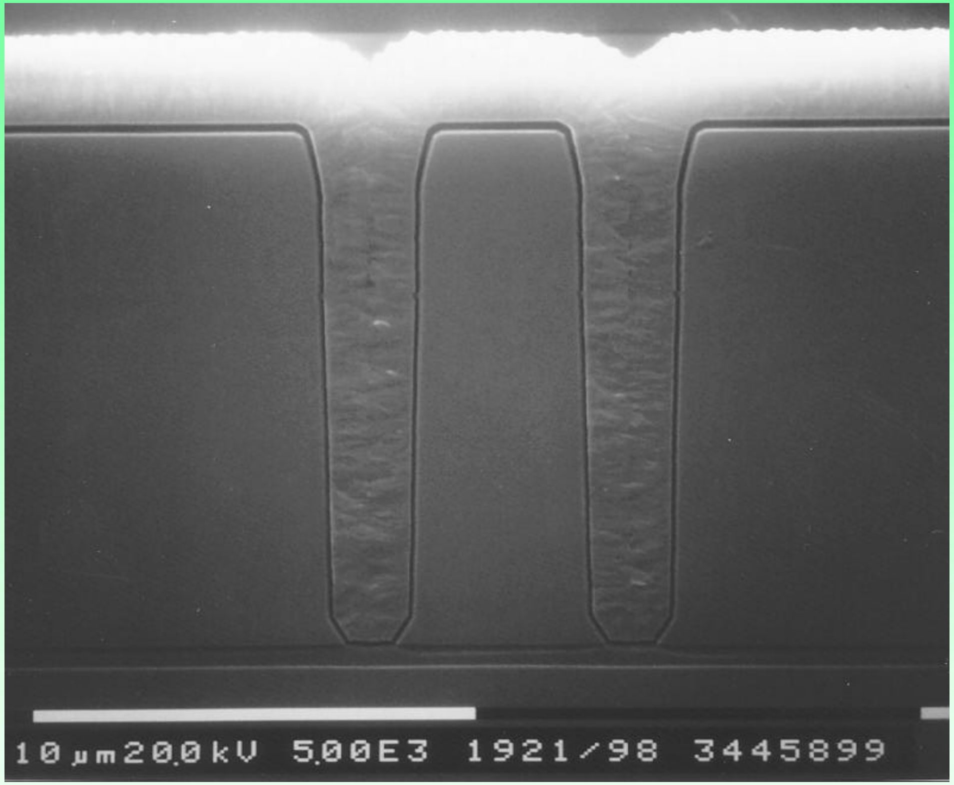
12 µm deep trench with stop of oxide (filled)



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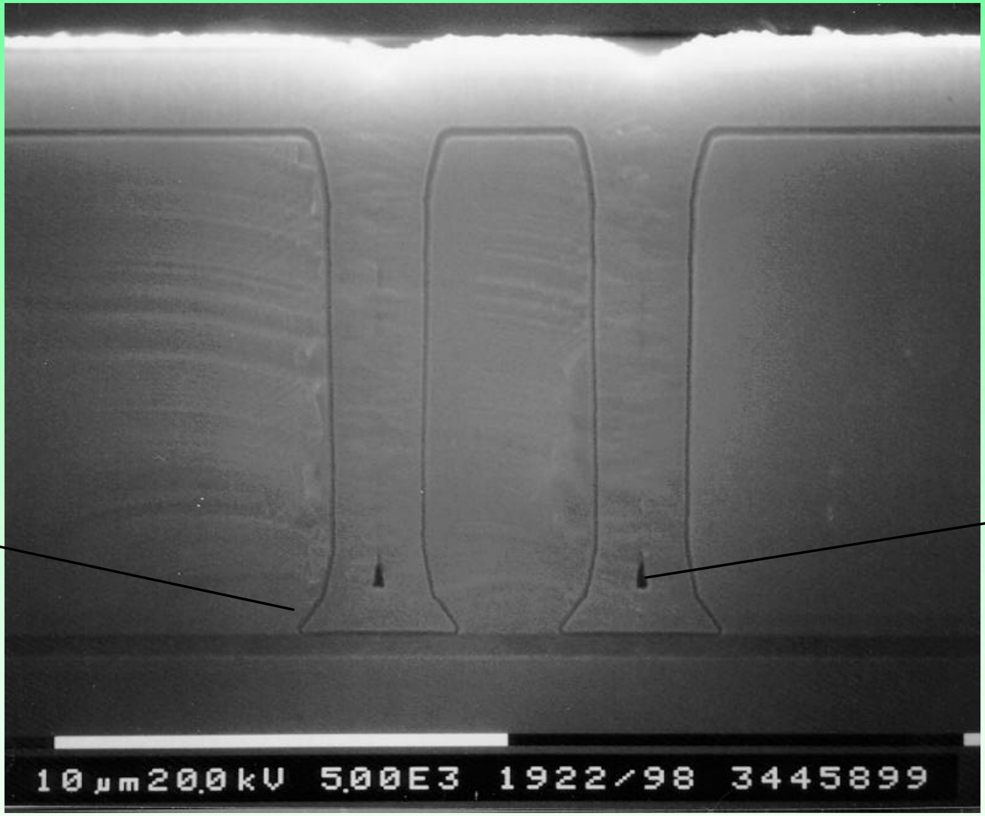
Problem: stop on oxide (endpoint)

12 µm deep trench with stop of oxide (filled)

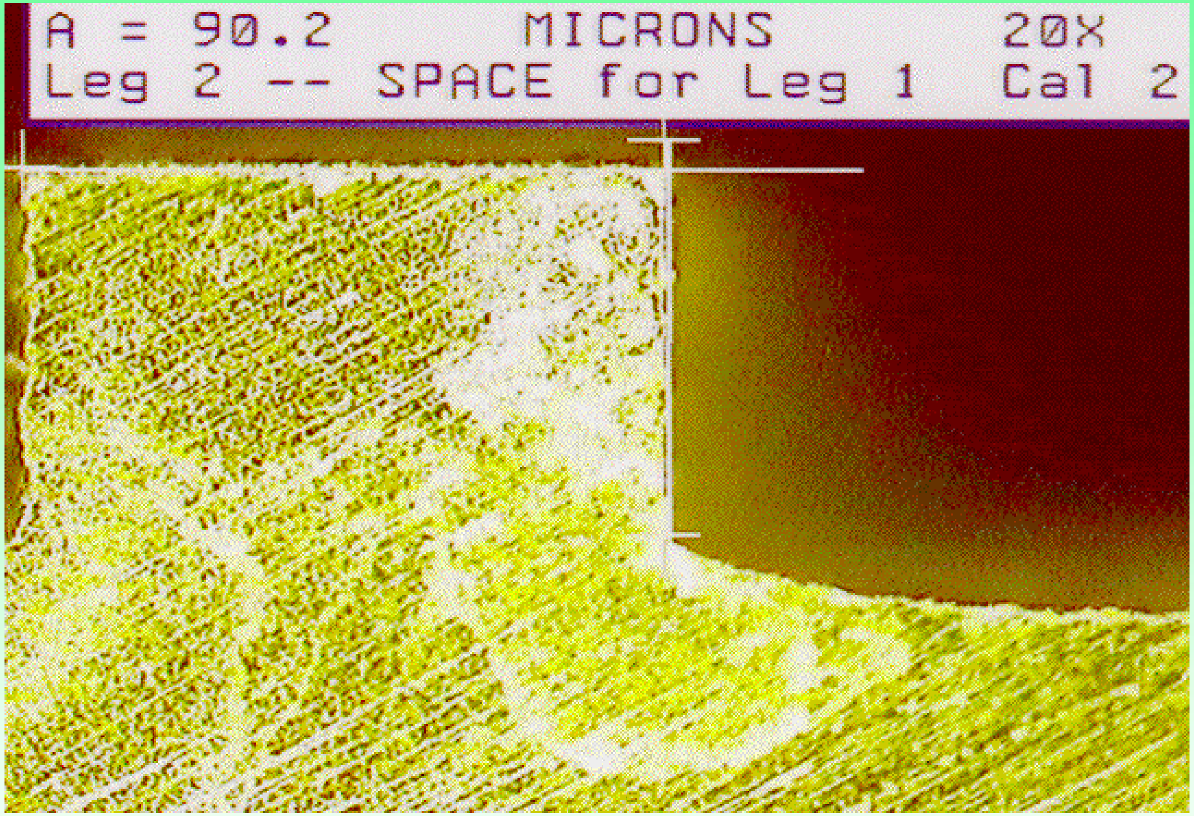
notching in the overetch



void

burried oxide

Deep silicon etching



good profile control

~ 200 µm deep

Endpoint Detection Techniques

- Interferometry/Reflectometry
  - Detection of change in reflectance/interference when buried oxide is reached
  - Typical source wavelength 436nm: (Reflectometry)
  - Typical source wavelength 840nm: (Interferometry)
- Optical Emission Spectroscopy
  - Detection of decrease in Fluorine consumption i.e. increase in Fluorine emission when buried oxide is reached
  - Typical wavelength monitored 704nm F line

Interferometry

- Advantages
  - Can be used for low exposed Si area wafers
- Disadvantages
  - Smooth signal difficult to obtain
  - Signal change at endpoint is sensitive to wafer to wafer variations e.g.
    - Buried oxide layer thickness, surface roughness variation with depth
  - Endpoint feature typically >300um []required in central region of wafer
  - Endpoint detected at slowest etch-rate region of wafer
  - Several setup runs required to overcome the effect of endpointing at the centre, on features sizes >> than features of most interest.
  - Fully automated system cost > $100k

Optical Emission Spectroscopy

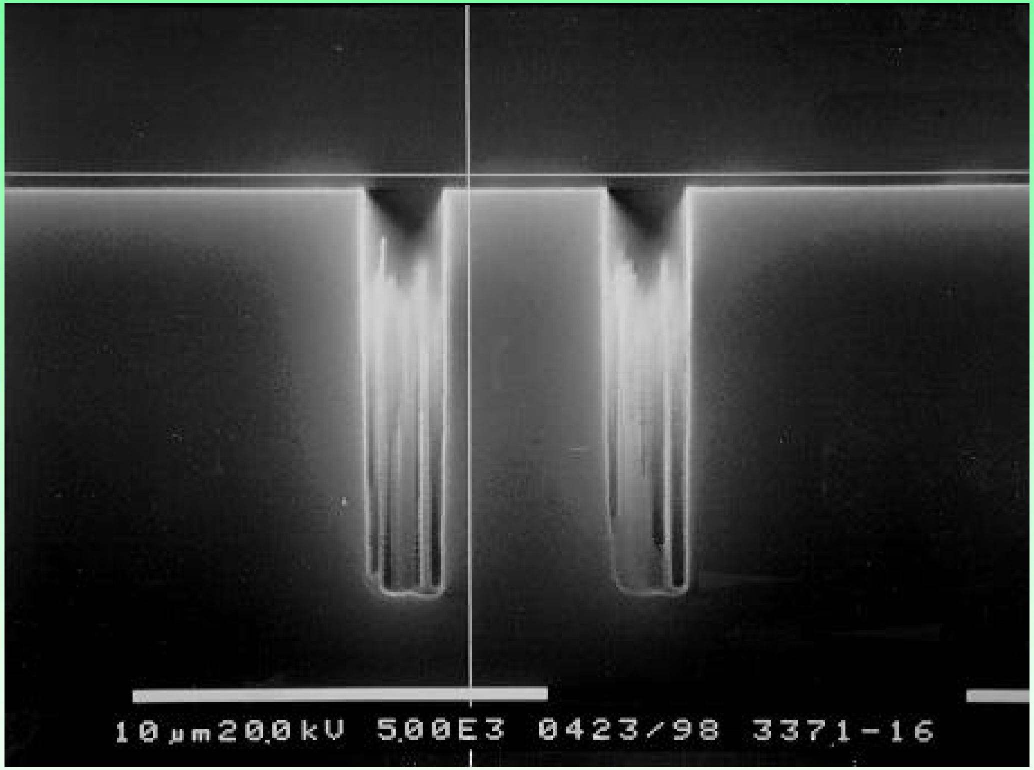
- Advantages
  - Low cost
  - Simplicity
  - Dedicated mask pattern not required
  - Endpoint detection less likely to be too late
- Disadvantages
  - Poor endpoint signal for exposed Si area < 10% due to low signal to noise ratio

In development:

- Reliable end-point detection for exposed Si area <5%

Problem: Processcontrol !

grass : result of to much passivation



Dep.-time to long
or
dep.-flow to high
or
platenpower to low

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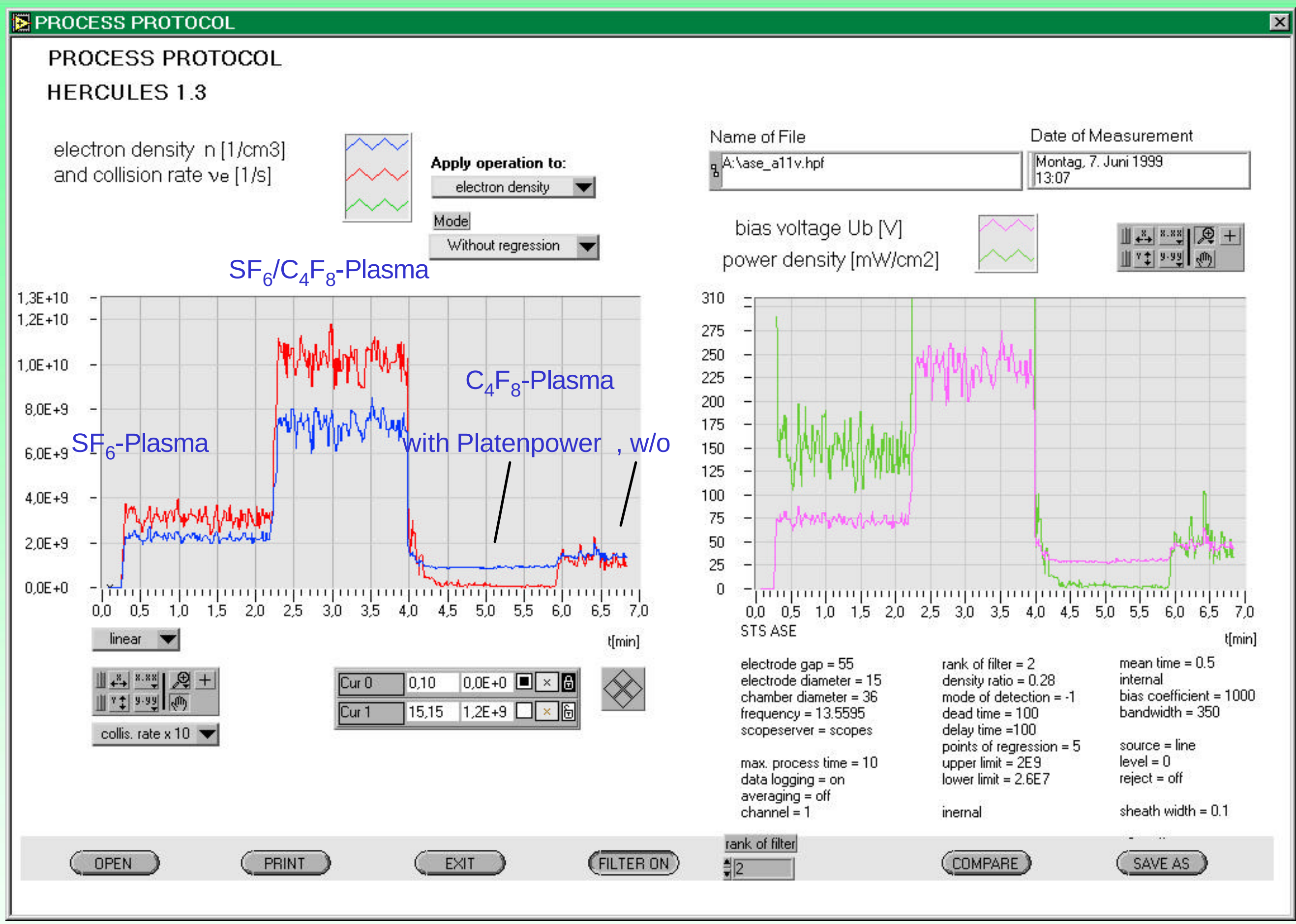
First SF_6 and C_4F_8-Plasma



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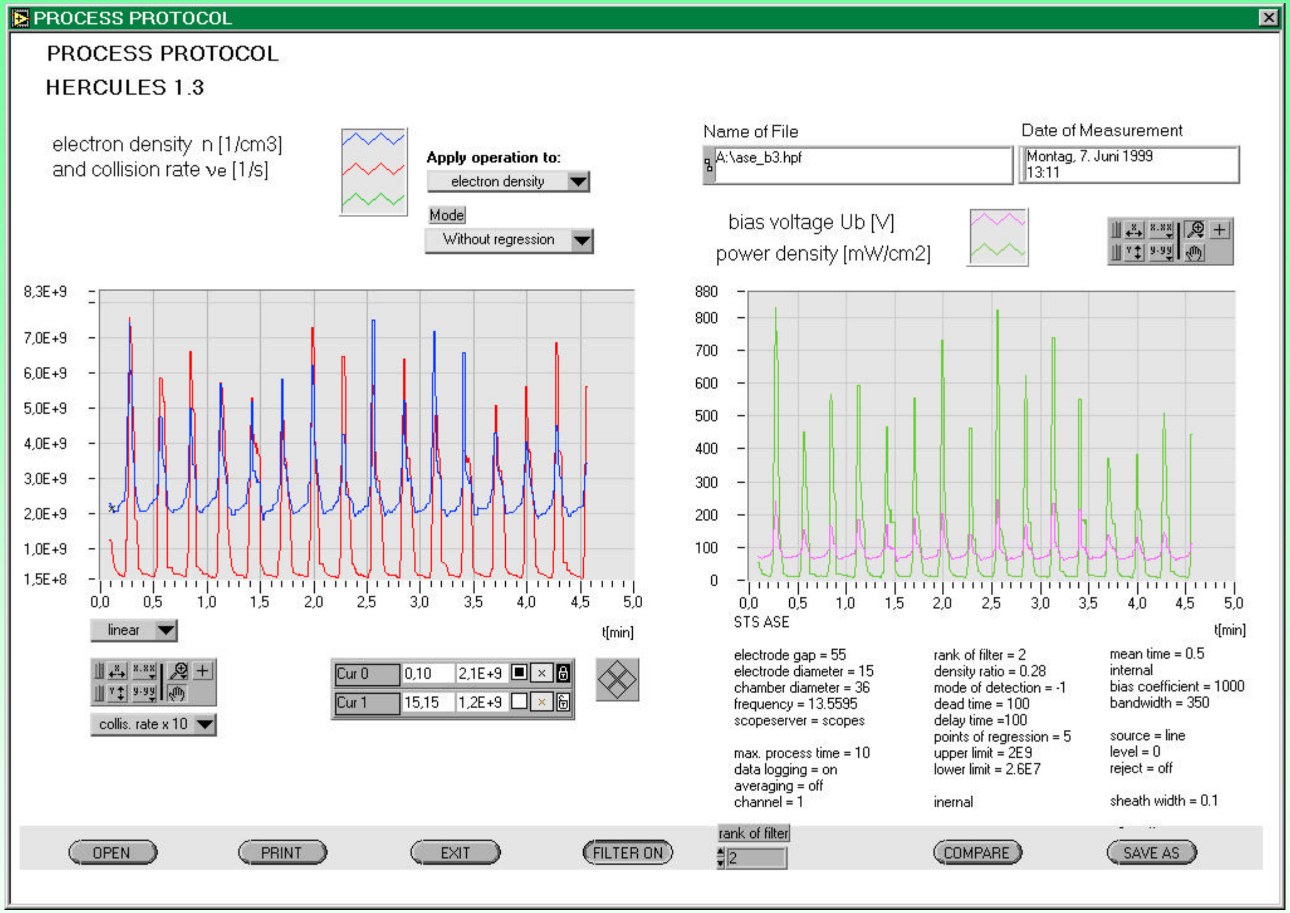
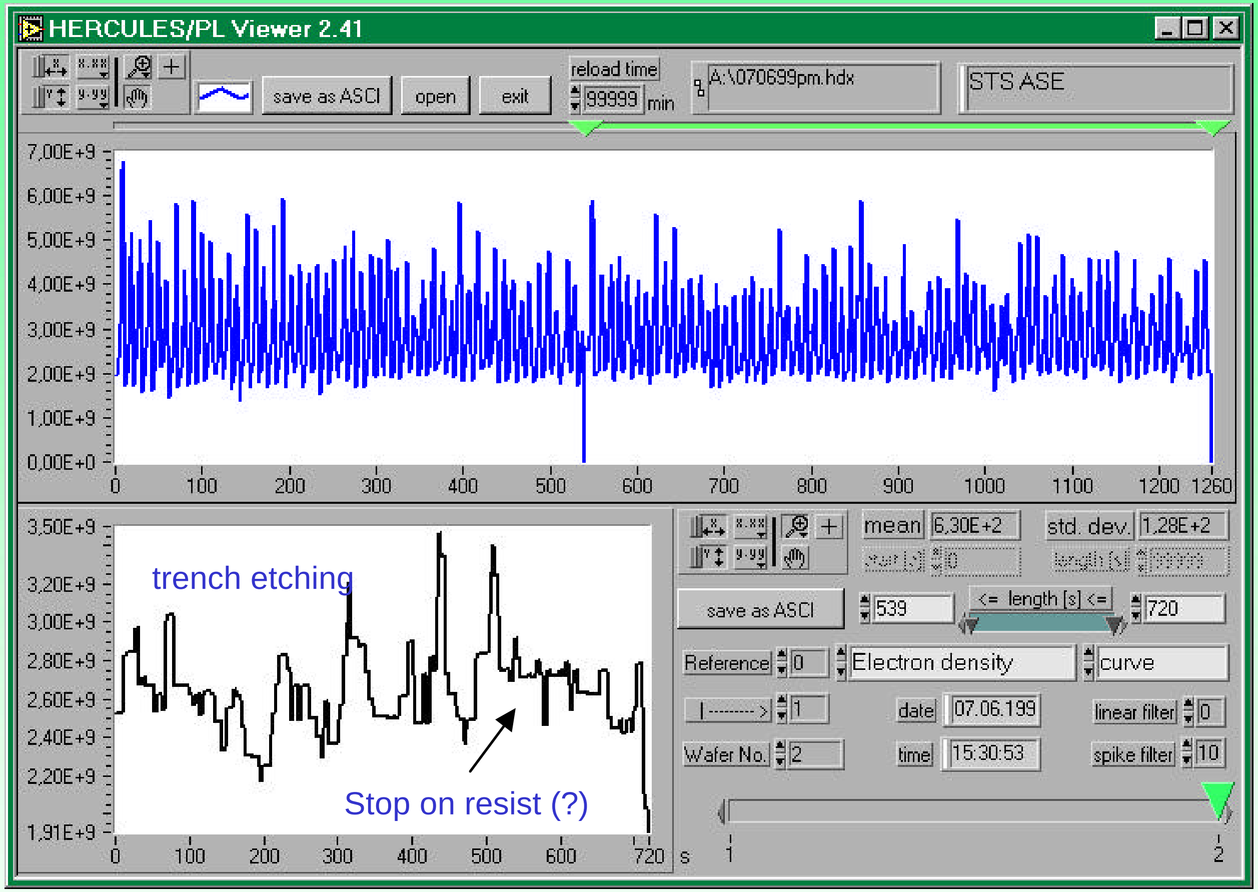
Switched Dep/Etch-Process



Trench etching with stop on resist



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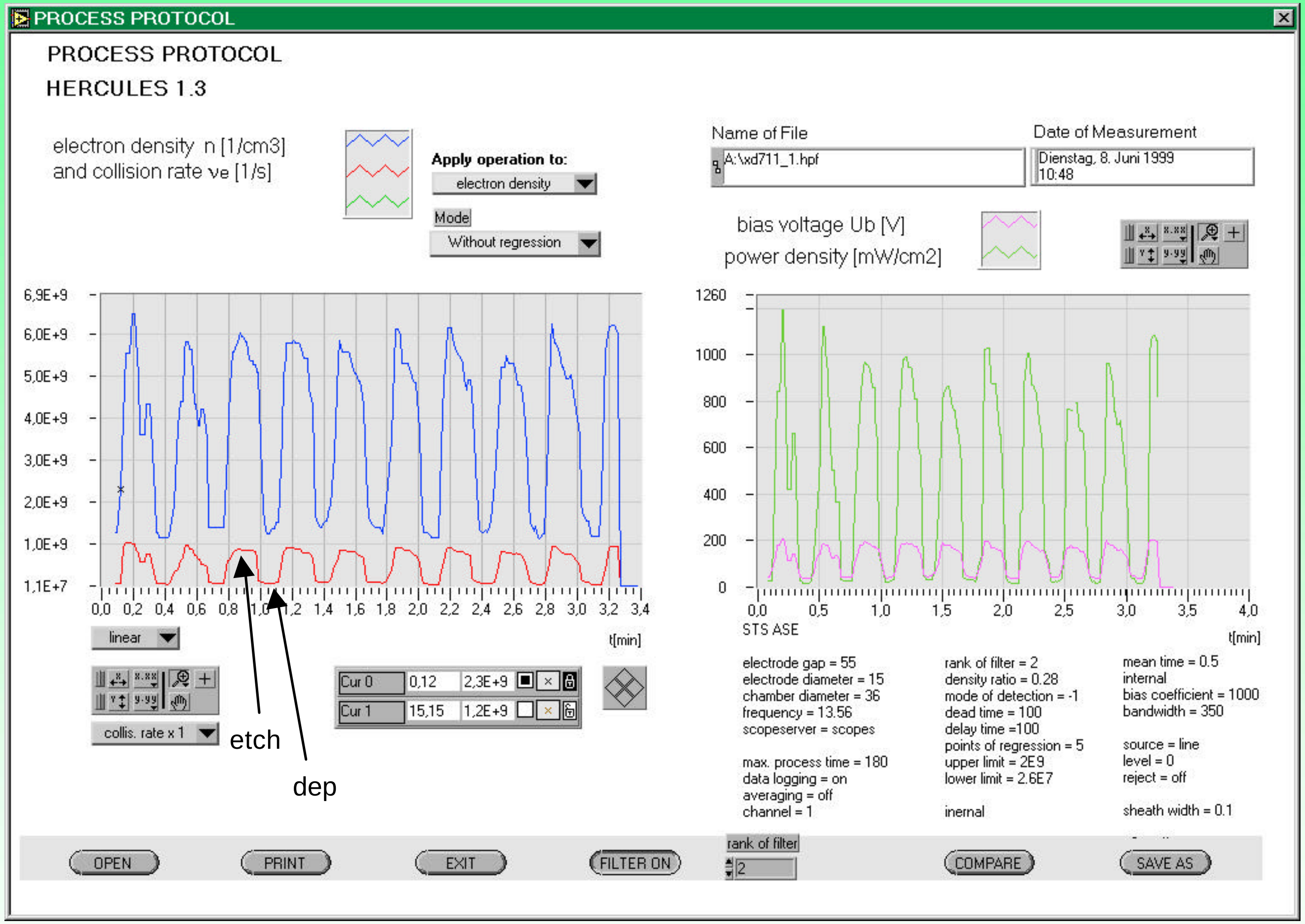
Process: Deep silicon etching

Dep.: C_4F_8 100 sccm, 1000W,15mTorr
Etch: SF_6 130 sccm, O_2 13 sccm, 1000W, 15W, 36 mTorr



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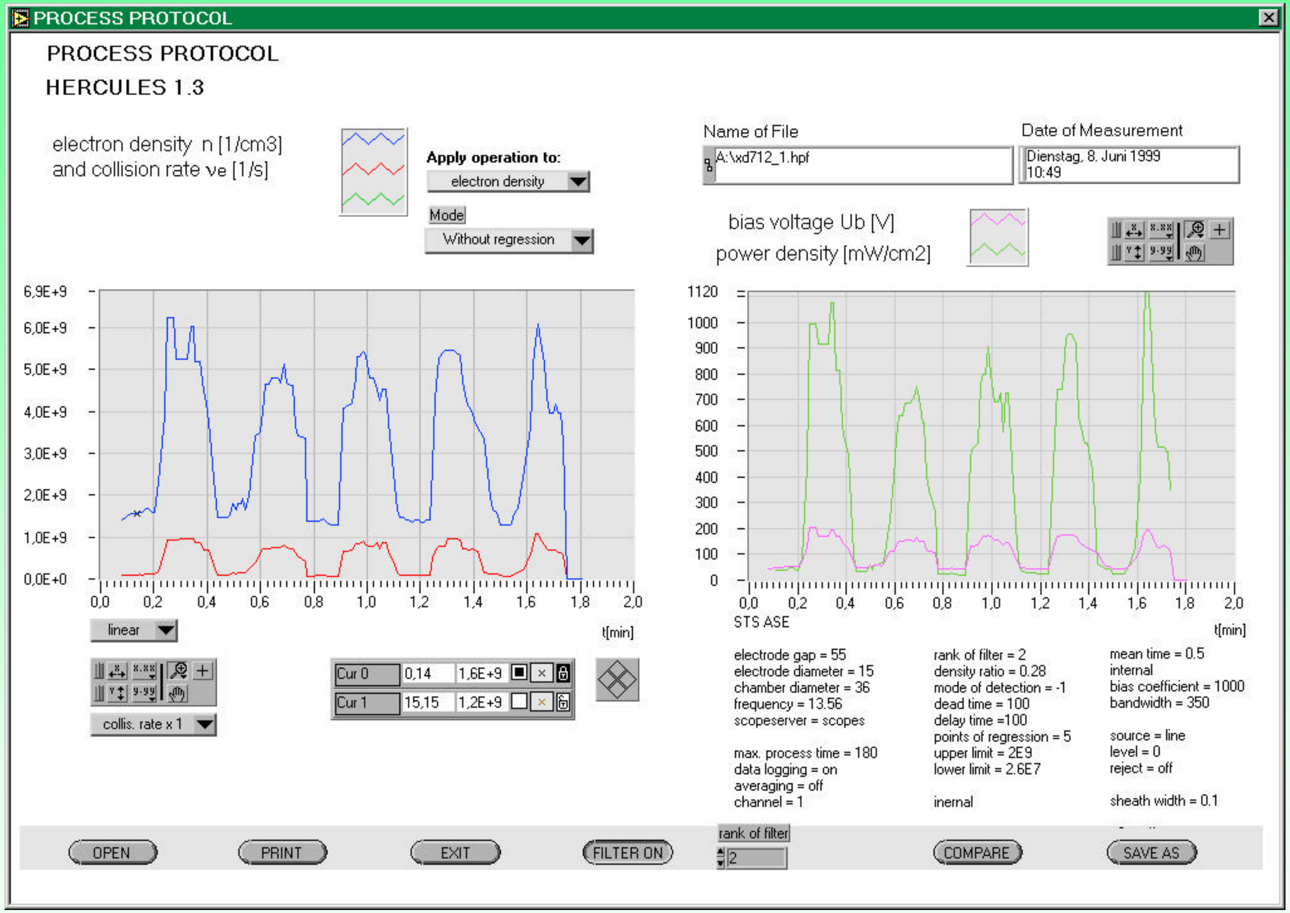
Pressure variation



Dep: 15 mTorr
etch: 22 mTorr

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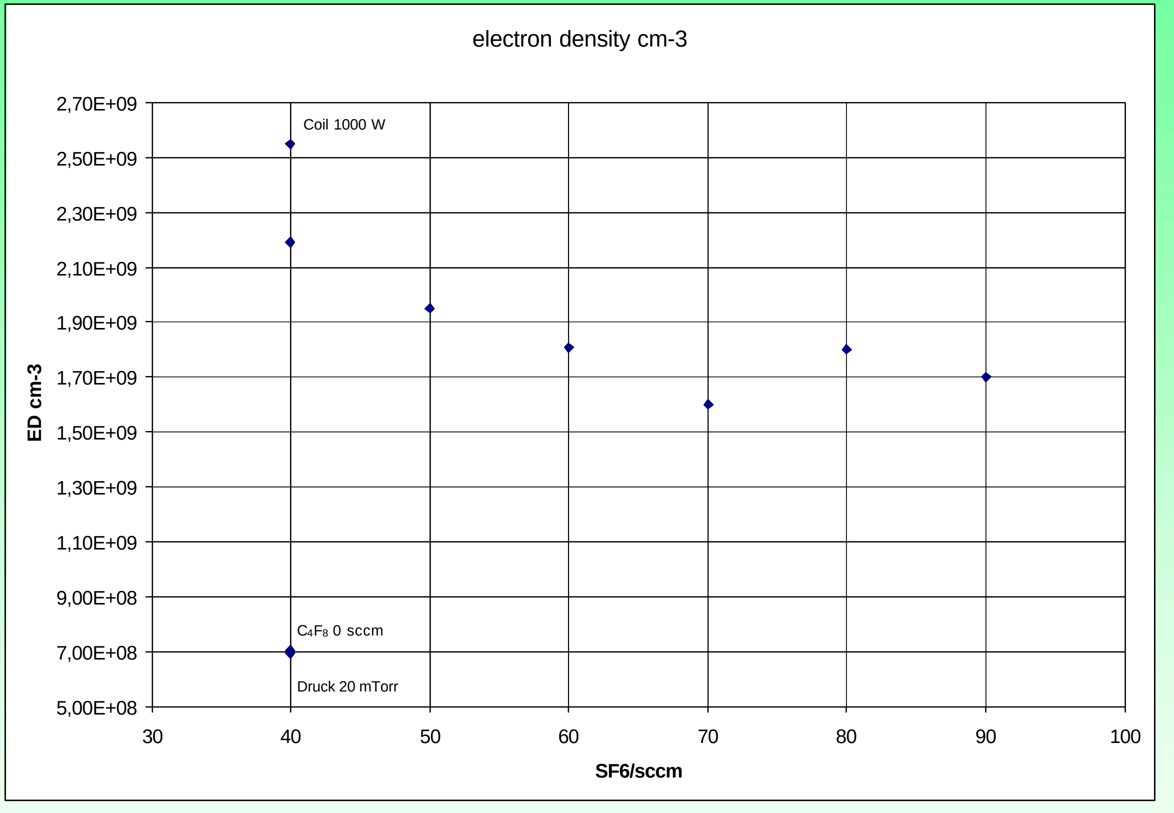
Electron density vs. SF_6-flow



Coil_Power 800W
Platen_Power 15 W
Pressure 15 mTorr
C_4F_8-Flow 90 sccm
Chuck Temp. 20 °C
He backside 10 Torr

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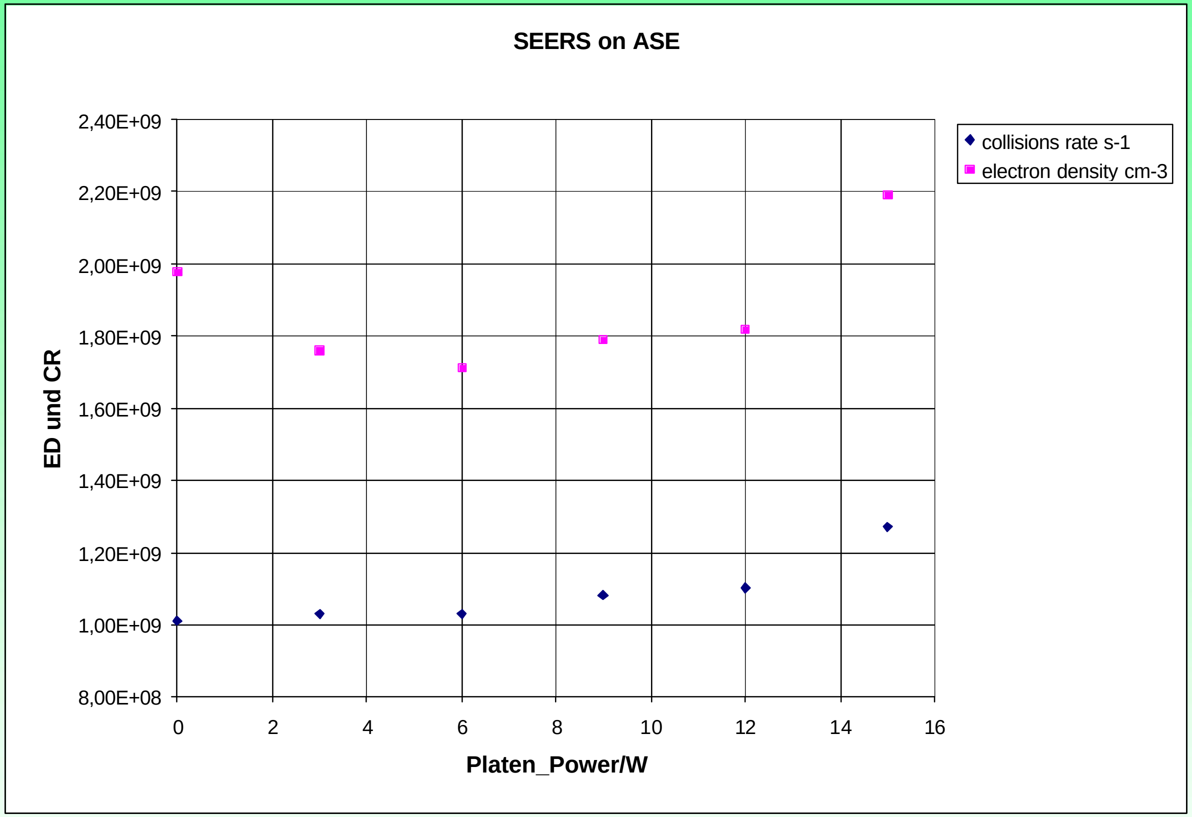
Electron density and collision rate vs. Platen_Power



Coil_Power 800W
Pressure 15 mTorr
SF_6-Flow 40 sccm
C_4F_8-Flow 90 sccm
Chuck Temp. 20 °C
He backside 10 Torr

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