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Investigations on two different plasma tools by SEERS, OES and electrical measurements

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2.2. Investigations on two different plasma tools

SEERS, electrical and OES measurements

- 2.2.1. Comparison of SEERS, results on different tools
- 2.2.2. Additional tests with the HERCULES equipment
- 2.2.3. Analysis of CF_4 processes with SEERS at a parallel plate system
- 2.2.4. Analysis of CF_4 processes with OES at a parallel plate system
- 2.2.5. Comparison of CF_4 process data between SEERS and OES
- 2.2.6. Summary of this chapter

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2.2.1. Comparison of SEERS values on different tools

Parallel Plate System
(ZWG plasma etching tool)
chamber diameter: approx. 12 in
- max. wafer diameter: 4 in
- max. CCP power: 600W

SENTECH SI 600 D
(plasma etching system)
- chamber diameter: approx. 10 in
- max. wafer diameter: 4 in
- max. CCP power: 600W
- max. µ-wave power: 600W

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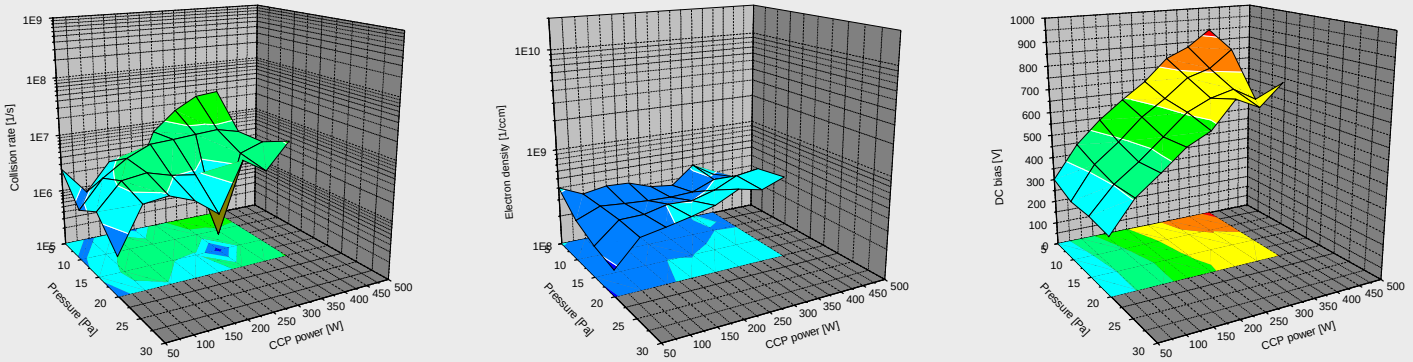
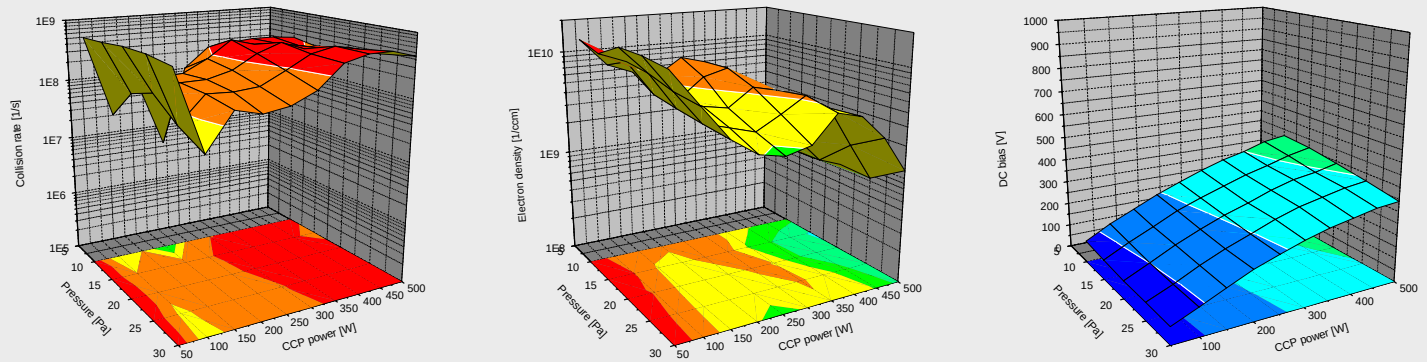
2.2.1. Comparison of SEERS values on different tools

Comparison of SEERS values for **Ar** at 10Pa and 50sccm with CCP only

Upper row: Collision frequency, electron density and DC bias measured at the parallel plate system



Lower row: Collision frequency, electron density and DC bias measured at the SENTECH system



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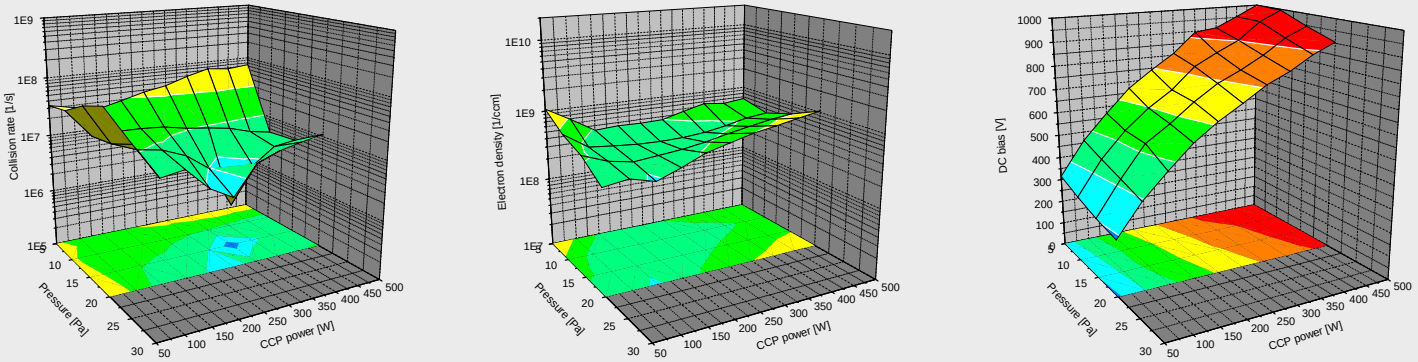
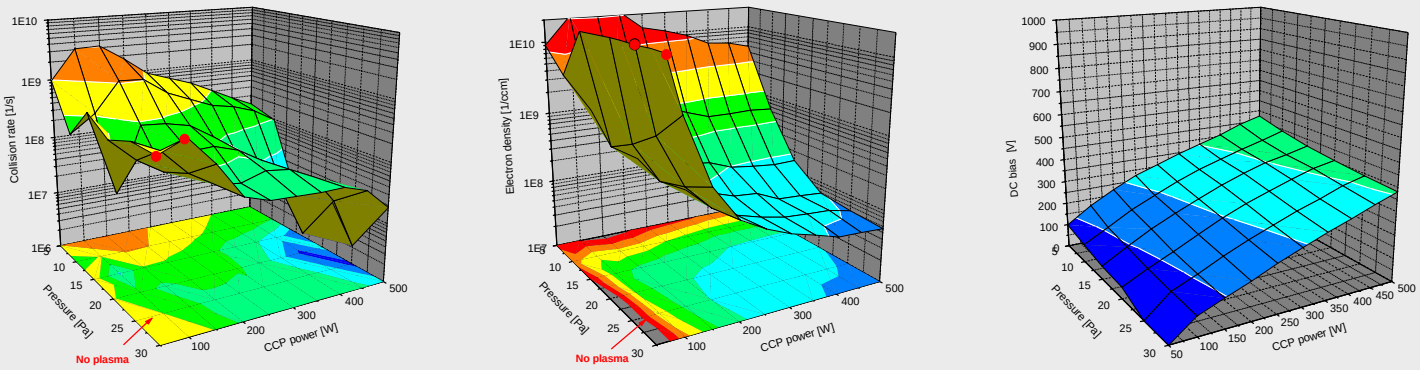
2.2.1. Comparison of SEERS values on different tools

Comparison of SEERS values for N_2 at 10Pa and 50sccm with CCP only

Upper row: Collision frequency, electron density and DC bias measured at the parallel plate system



Lower row: Collision frequency, electron density and DC bias measured at the SENTECH system



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2.2.1. Comparison of SEERS values on different tools

Resumé of HERCULES testing on different tools

- Identical recipe parameters in different tools yield different plasma parameters. The tool construction and the HERCULES setup has an inpact on the SEERS algorithm results.
- We observed a decreasing electron density at increasing CCP power which might be a hint for a HERCULES problem with the SENTECH SI 600 D
- The very high collision frequencies and electron densities under some conditions at low CCP power are currently not well understood.

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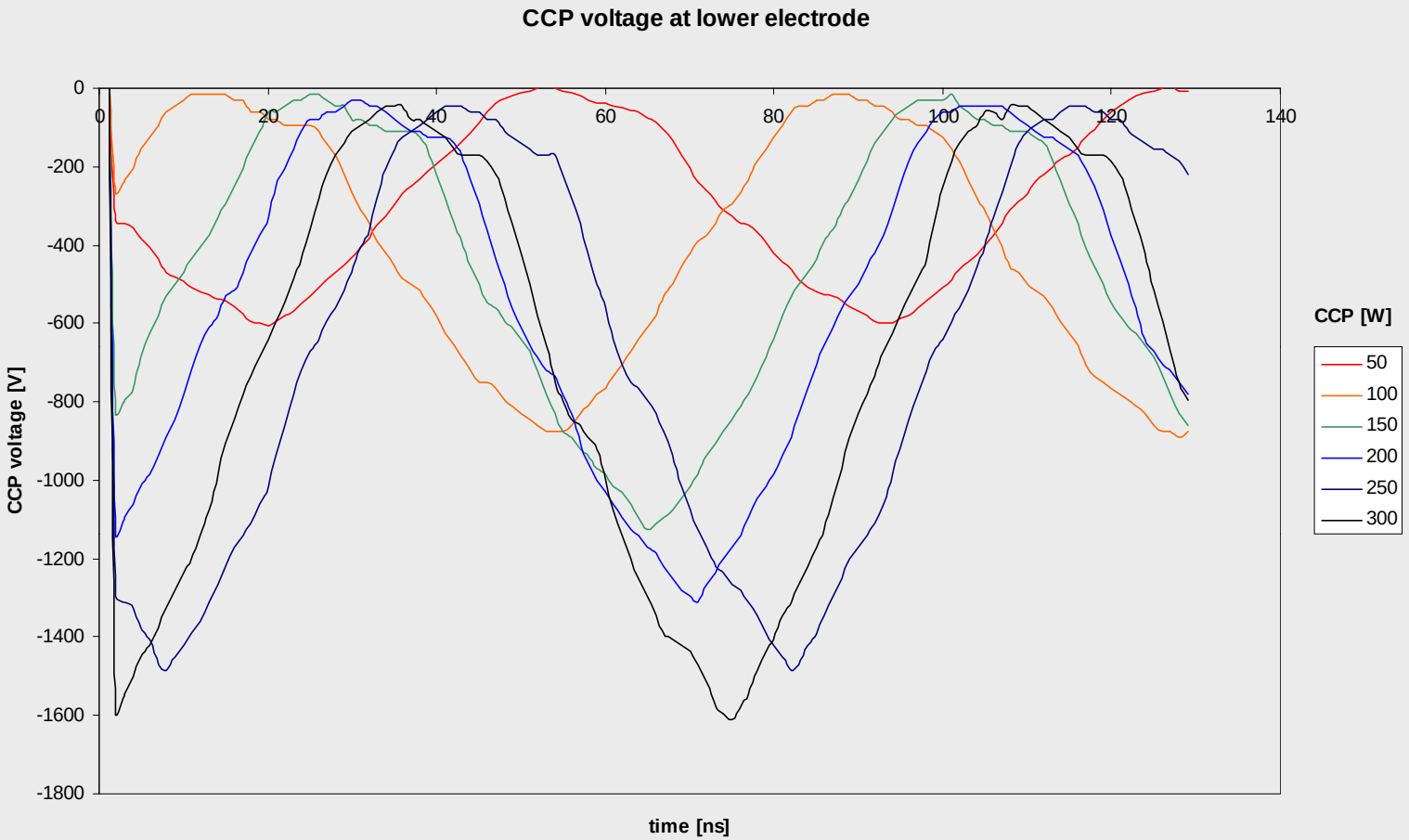
2.2.2. Additional tests with the HERCULES equipment

To understand some of the HERCULES results we have analyzed the CCP voltage.



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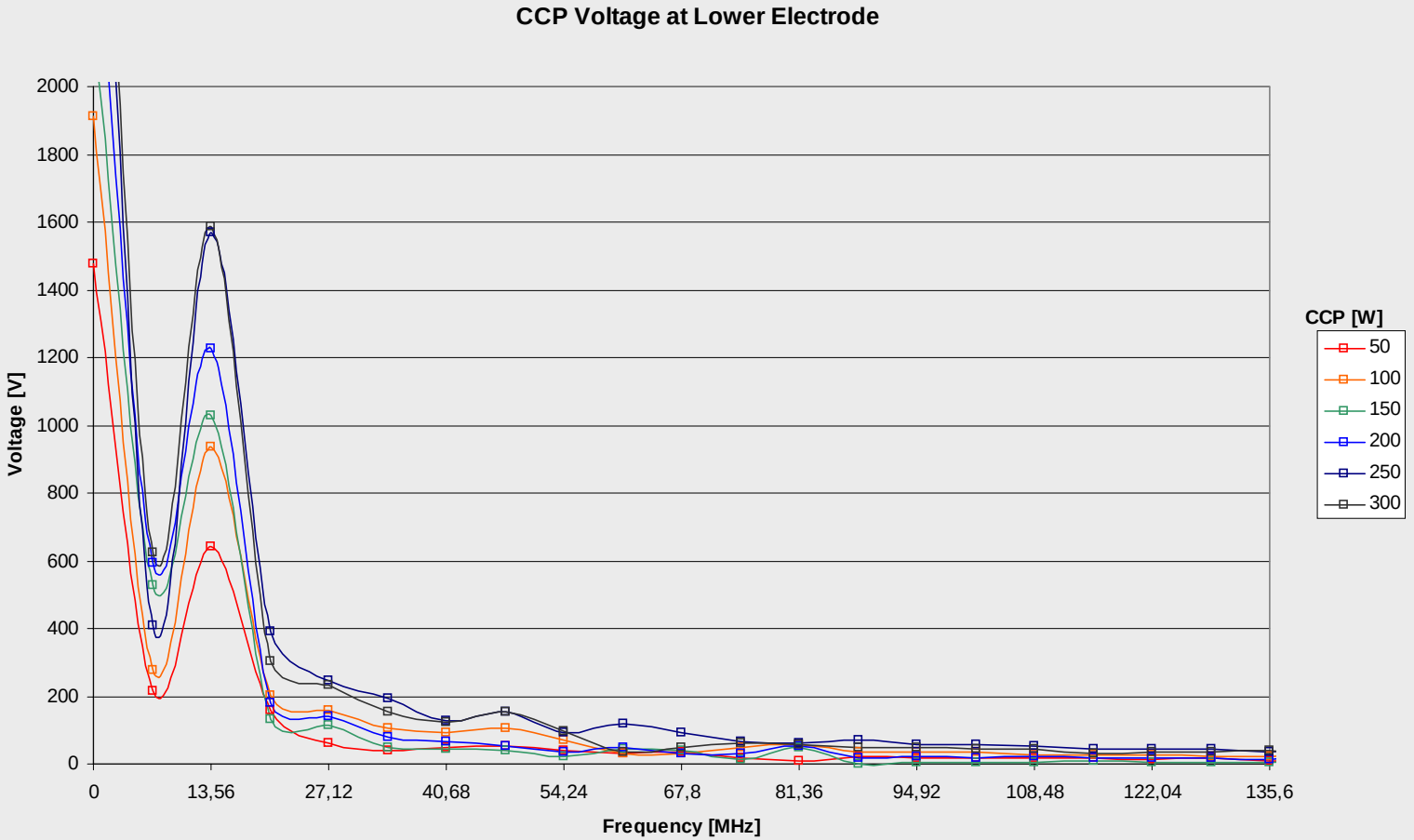
2.2.2. Additional tests with the HERCULES equipment

The Fourier spectrum shows the main peak at 13.56 MHz. The strong intensity at zero results from the DC offset. Harmonics can be found at higher CCP settings, but the condition of a sinusodial rf voltage is approximately fulfilled.



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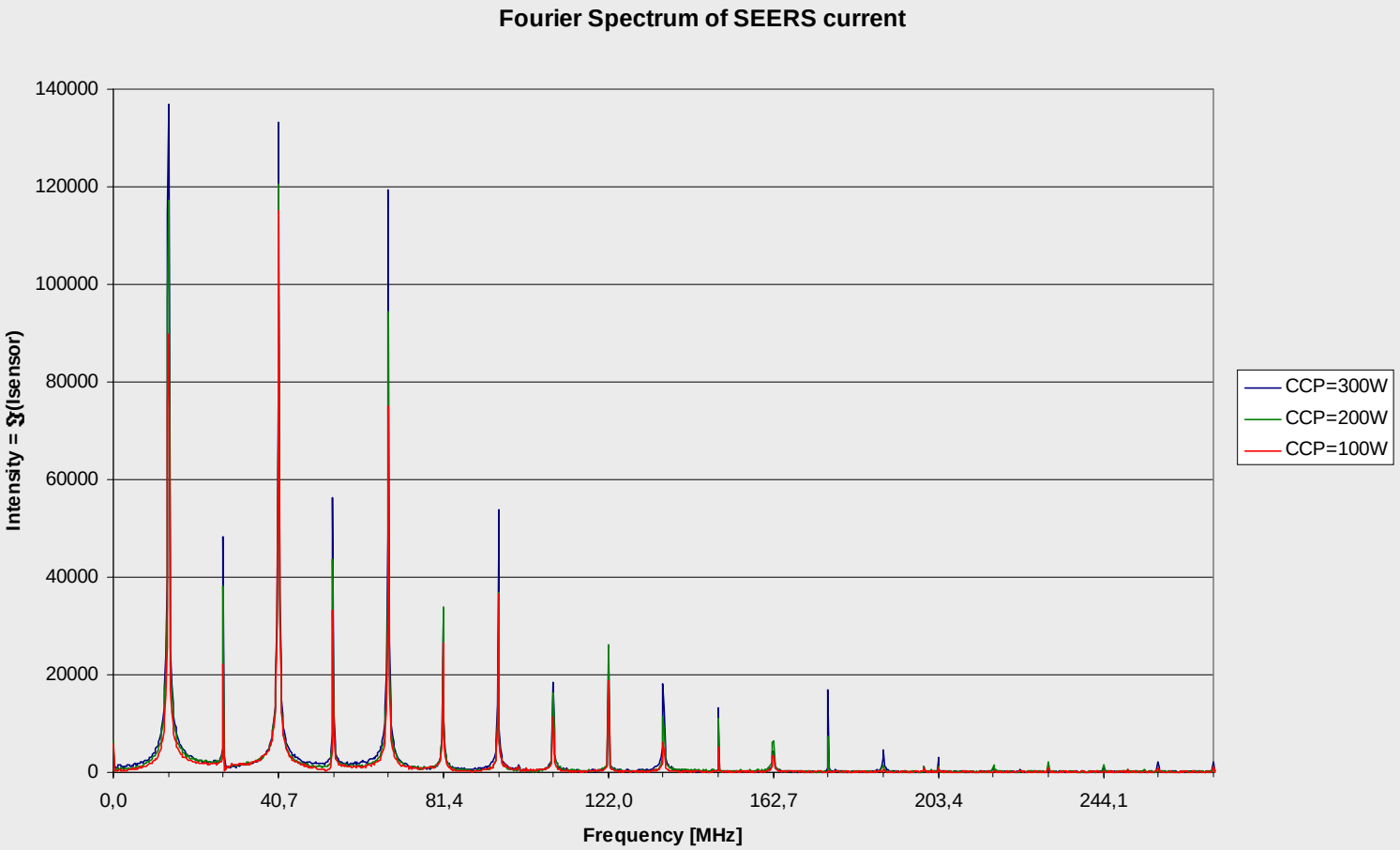
2.2.2. Additional tests with the HERCULES equipment

The Fourier spectrum of the SEERS current shows strong needle-shaped harmonics.
Plasma self resonance frequencies could not be found between 13 and 500 MHz.



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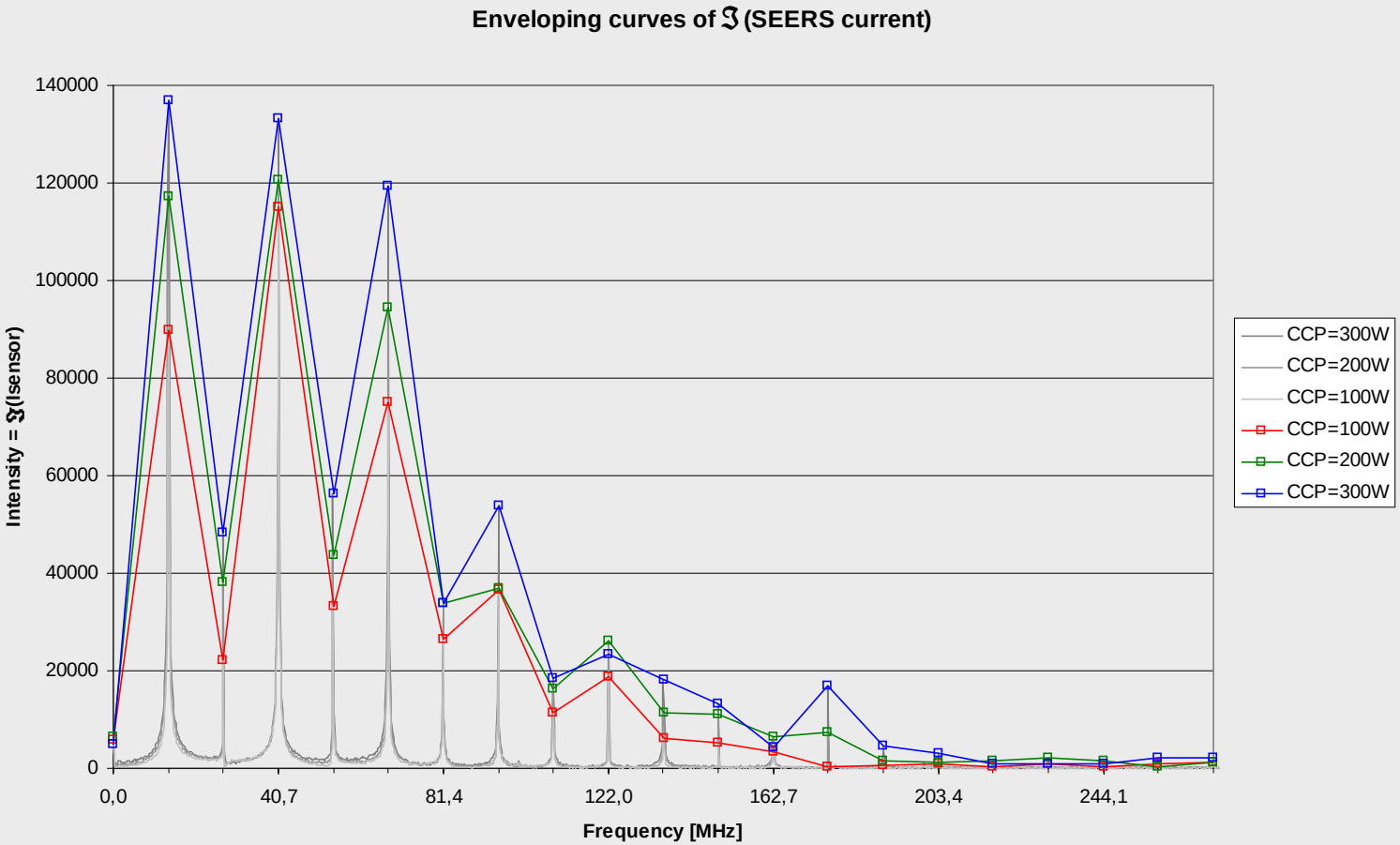
2.2.2. Additional tests with the HERCULES equipment

The enveloping curves of the Fourier spectrum look like the SEERS spectra in the small window displayed by older versions of HERC/PL.



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2.2.2. Additional tests with the HERCULES equipment

- The HERCULES results on our etching tools differ from the results described by Michael Klick et. al. for the same gases.
- It appears that tool construction parameters are the reason for the differences in our HERCULES results.
- CCP spectrum analysis shows that the sinusodial rf voltage condition is fulfilled, therefore the different SEERS values must also be caused by mechanical parameters inside the etching tool.
- Fourier spectrum analysis of the SEERS current do not show plasma self resonance frequencies independent from 13,56 MHz, so the electron density in the plasma cannot be calculated directly to verify the SEERS values.

➢ Michael Klick, Wolfgang Rehak and Marita Kammeyer, “Plasma Diagnostics in rf Discharges Using Nonlinear and Resonance Effects“, Jpn. J. Appl. Phys. Vol. 36 (1997)

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2.2.3. Analysis of CF_4 processes with SEERS at ZWG

- This series of experiments was meant to show the usability of HERCULES in a semi-realistic etching process
- The following experiments were run with a constant flow of mixed gases. The experiment series were made from different CCP power settings and variious gas mixtures of CF_4 and O_2. 1% of Ar was added for Optical Emission Spectroscopy (OES) purposes. This low portion of Ar has no significant impact on the HERCULES parameters: Collision frequency and electron density.

2.2.3. Analysis of CF_4 processes with SEERS at ZWG

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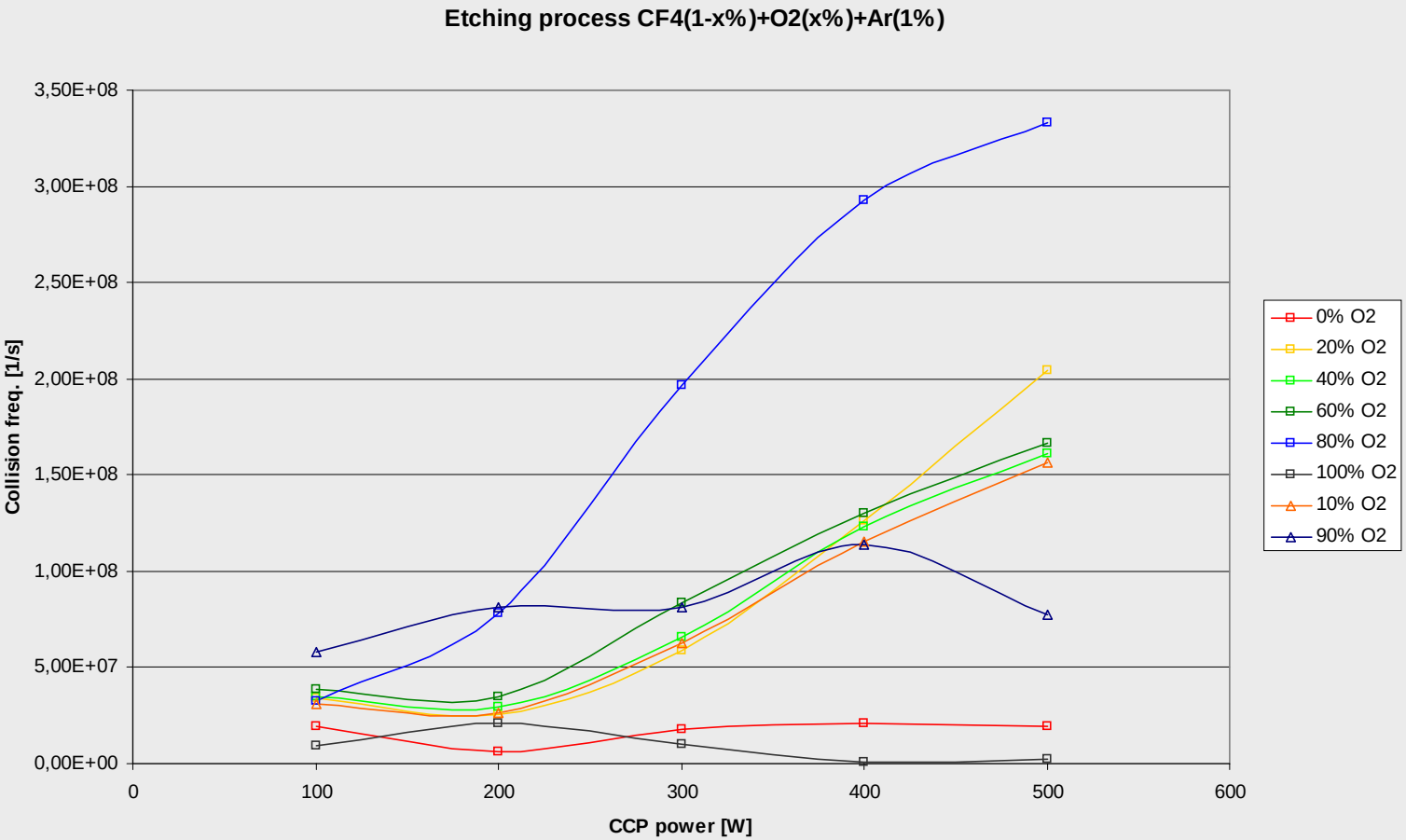

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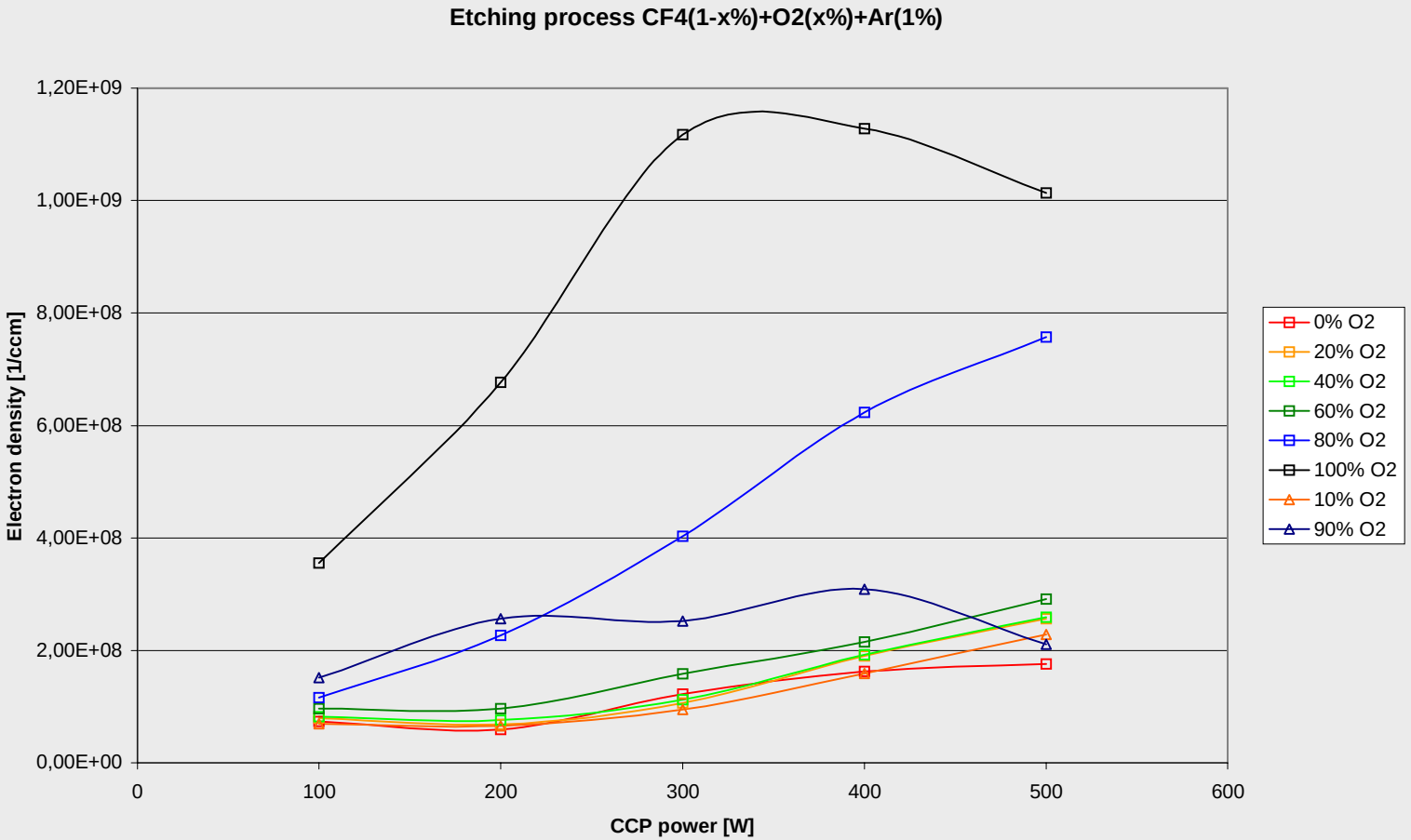
2.2.3. Analysis of CF_4 processes with SEERS at ZWG

In general, the SEERS electron density is increasing with higher CCP power. However, the different trends at high O_2 levels have to be further examined.



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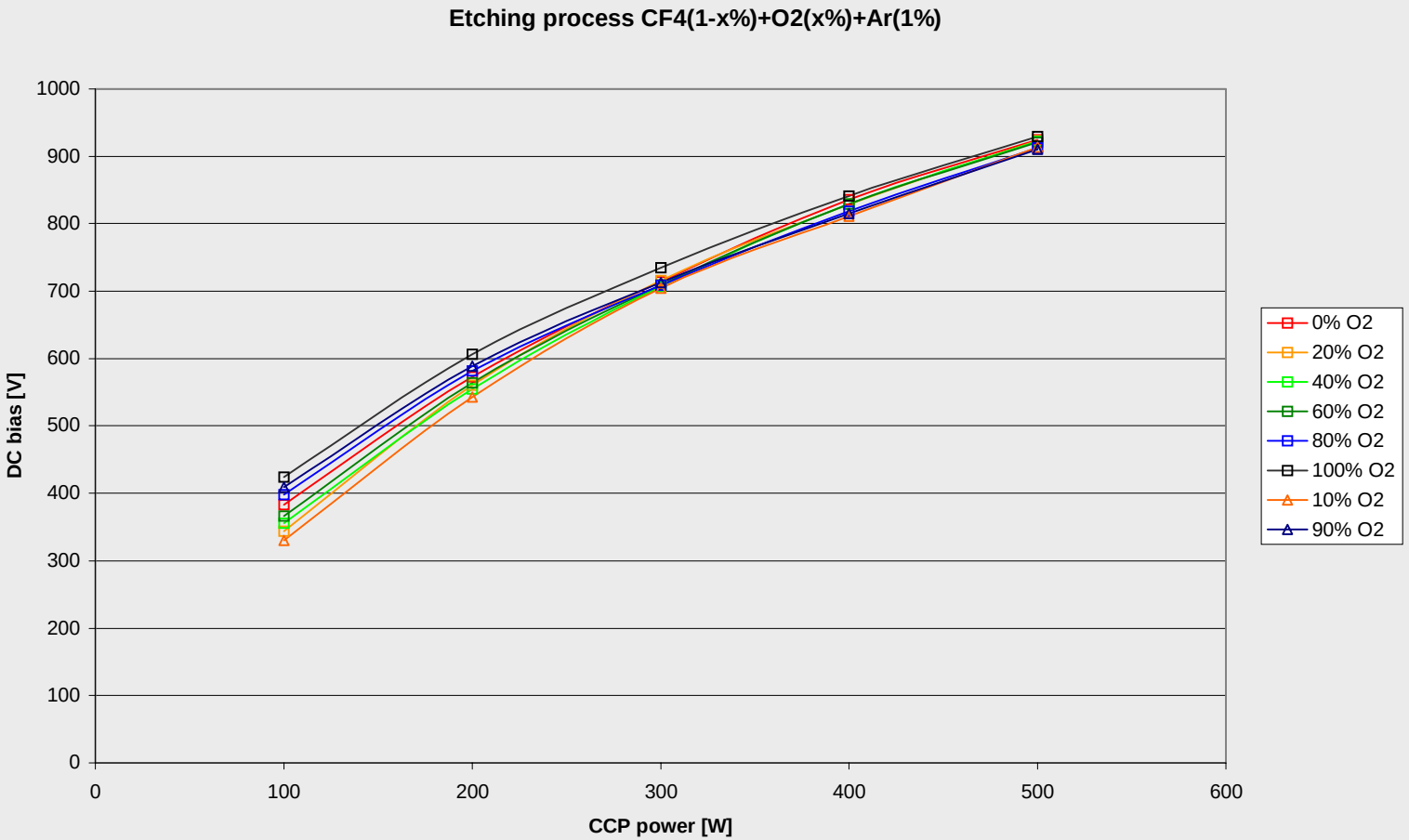
2.2.3. Analysis of CF_4 processes with SEERS at ZWG

The DC bias seems to be a good indicator for the CCP power. The gas mixture has only minor impact.



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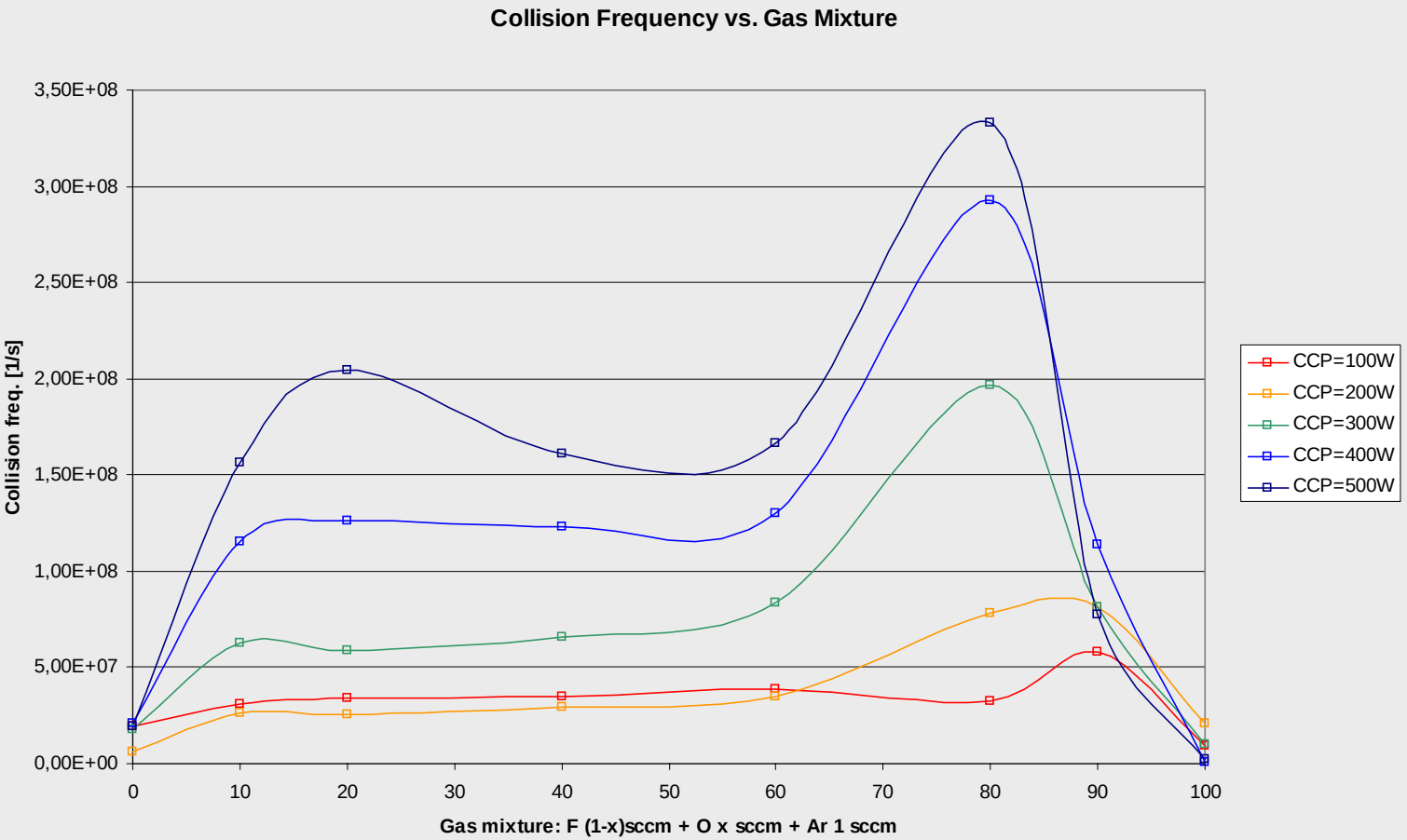

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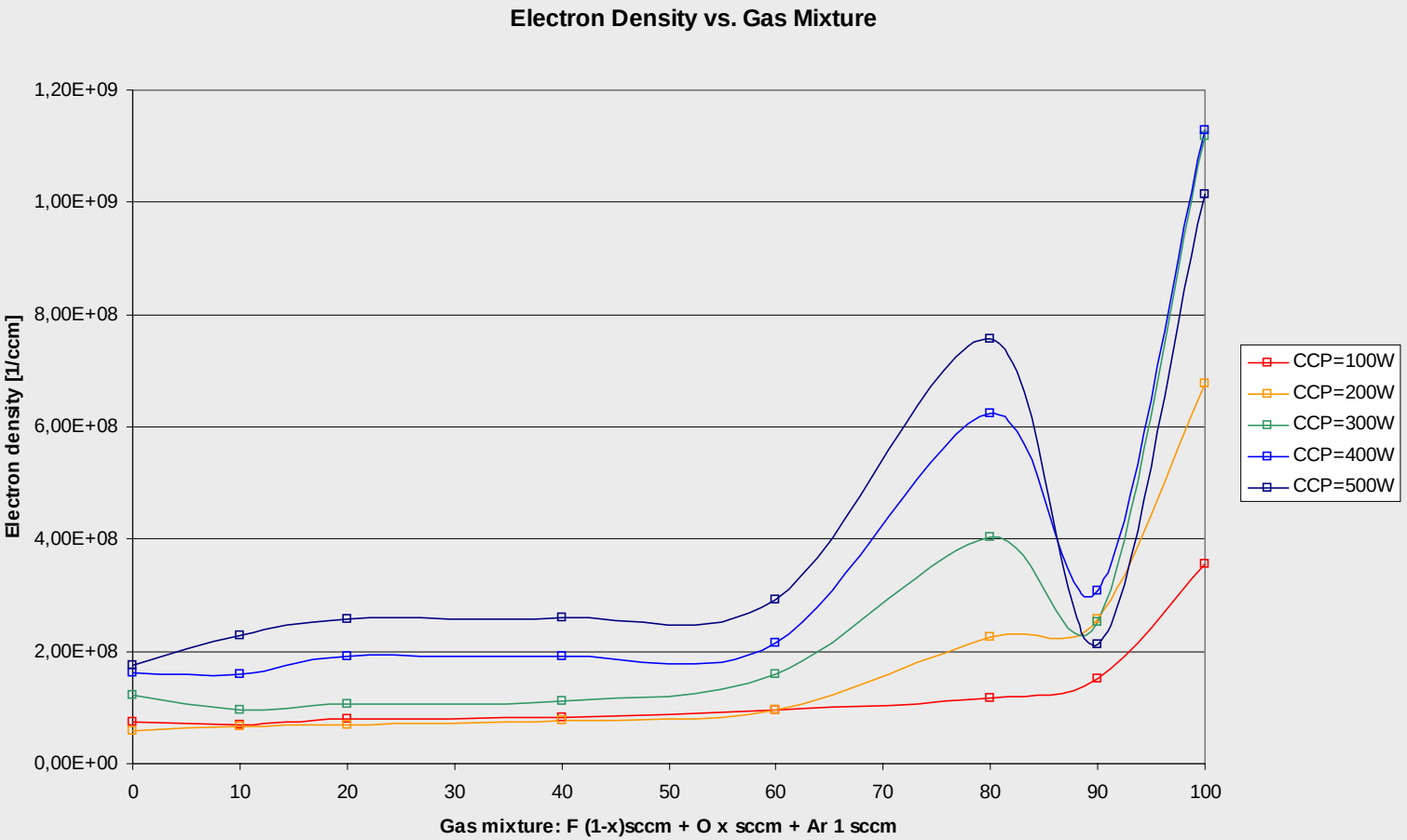
2.2.3. Analysis of CF_4 processes with SEERS at ZWG



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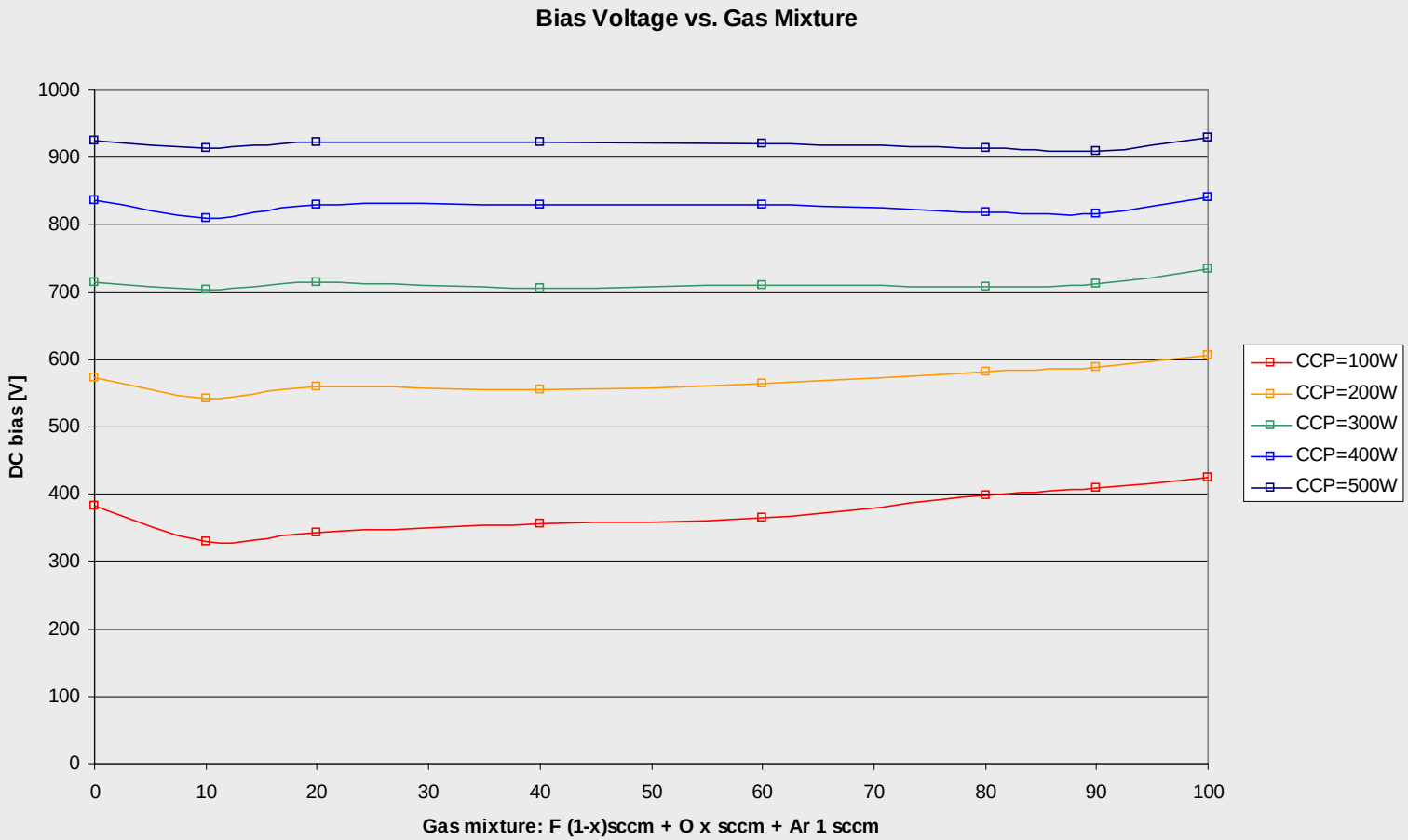
2.2.3. Analysis of CF_4 processes with SEERS at ZWG

The DC bias voltage determined in the match box is nearly independent from the gas mixture.



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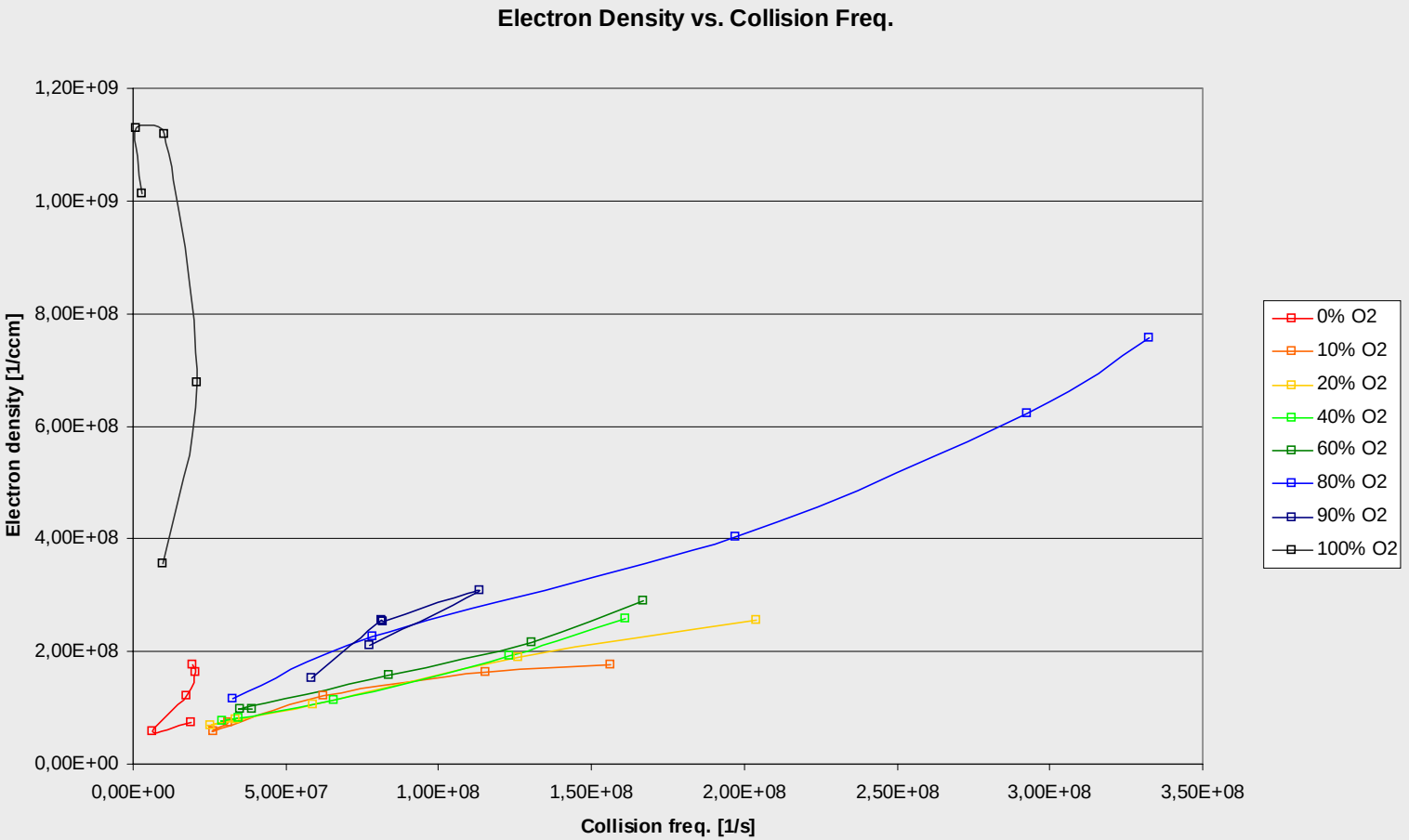
2.2.3. Analysis of CF_4 processes with SEERS at ZWG

The electron density versus collision freq. ratio is nearly independent of rf power but depends on the gas mixture.



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2.2.4. Analysis of CF_4 processes with OES at ZWG

SpectraMax OES

- 1024*128 px CCD matrix
- Monochromator with 3 different gratings
- GPIB Interface for control and measurement

Optical Emission Spectroscopy

- OES does not disturb the plasma process
- OES is immune to HF problems
- Deposited layers on the viewport disturb OES measurements
- OES can deliver independend values to verify SEERS results

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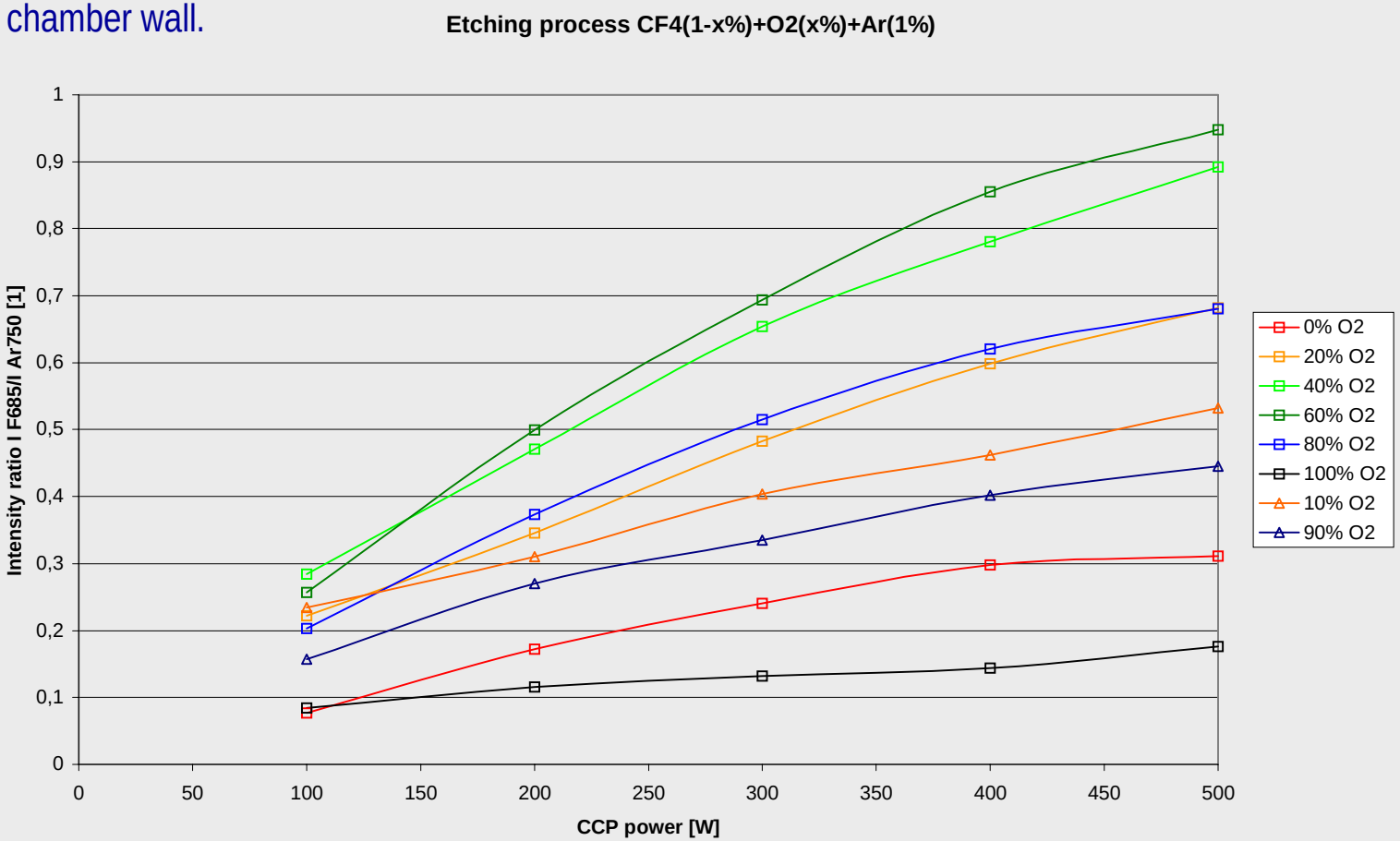
2.2.4. Analysis of CF_4 processes with OES at ZWG

The intensity of atomic Fluorine increases with higher CCP and shows an interesting maximum at about 50% oxygen. The remaining F intensity at 100% O_2 results from desorption off the chamber wall.



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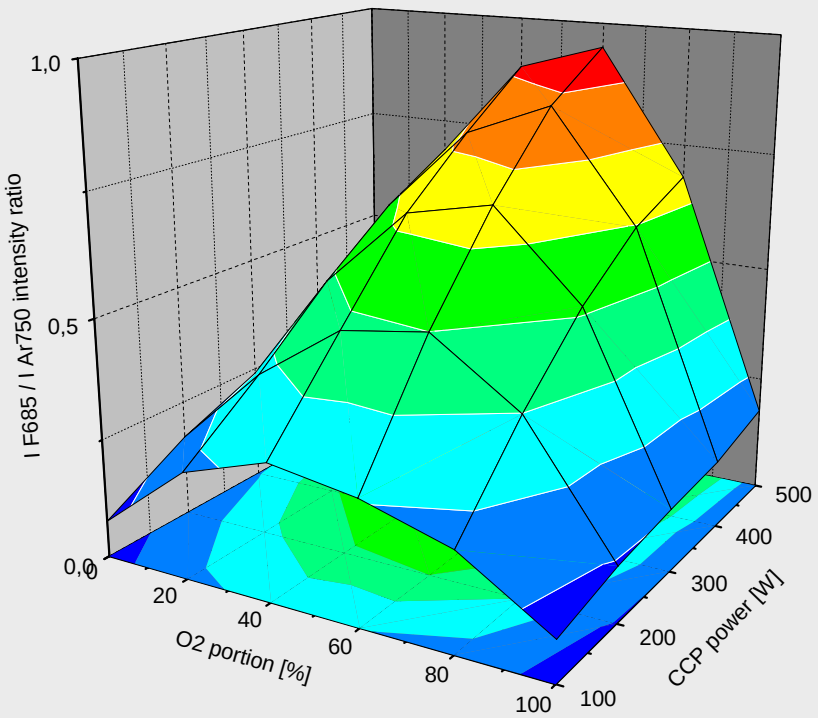

The x-axis shows the oxygen portion in the plasma. The fluor portion is 100% - x-value.

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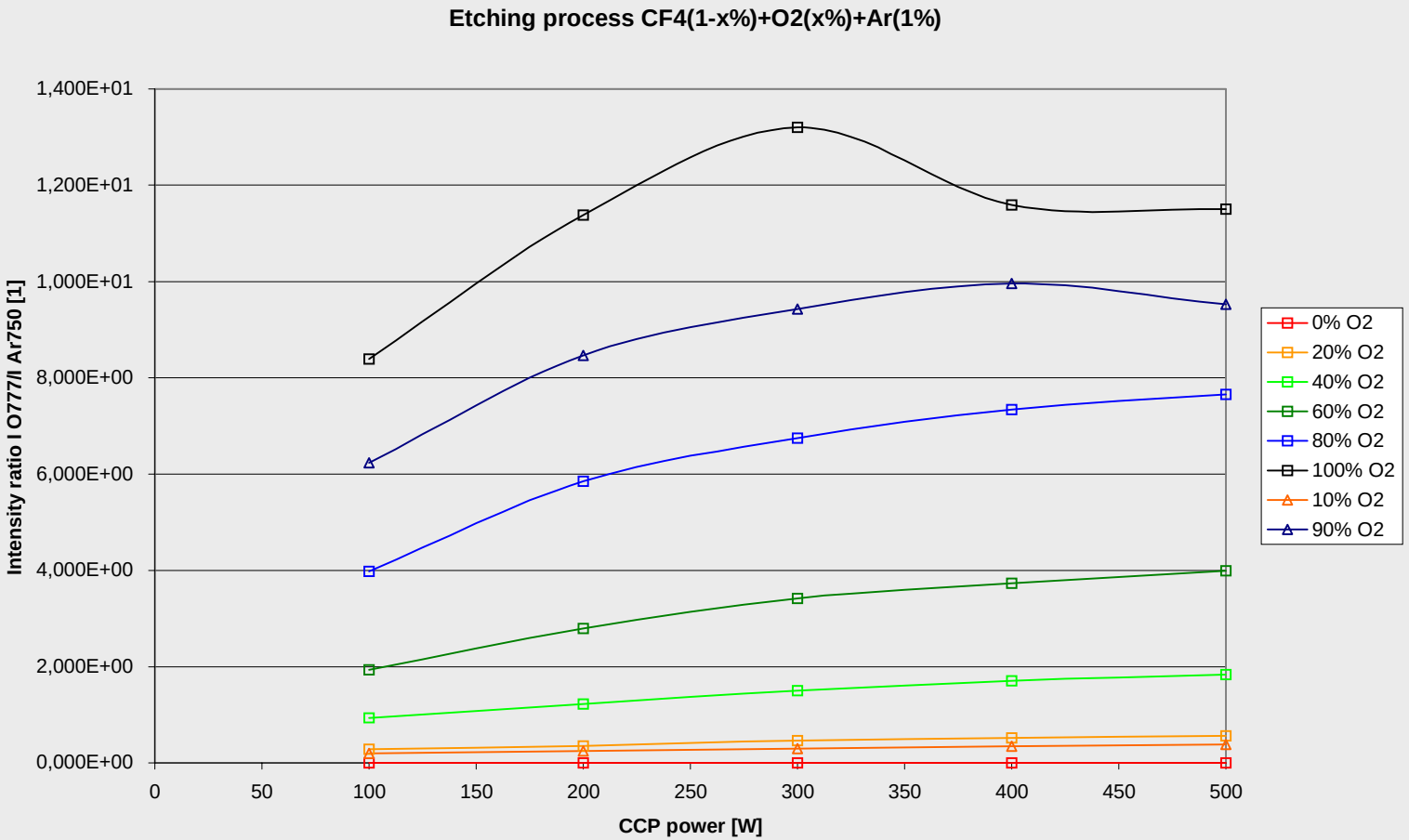
2.2.4. Analysis of CF_4 processes with OES at ZWG

This diagramme shows the OES dependence of CCP to the oxygen concentration.



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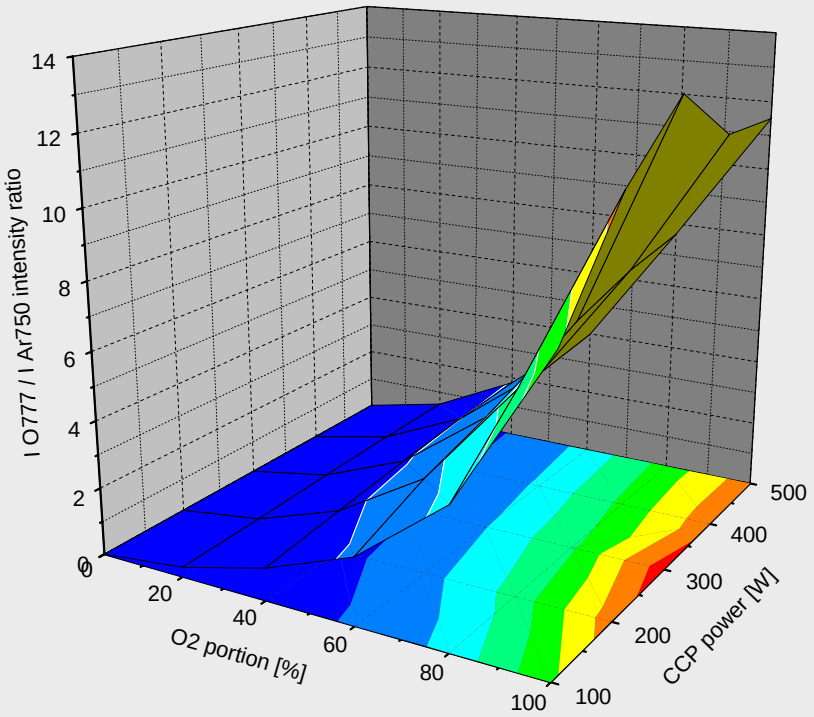
2.2.4. Analysis of CF_4 processes with OES at ZWG

This diagramme shows the OES dependence of CCP to the oxygen concentration.
Changing CCP between 300 and 500W makes only little difference in the intensity ratio.



The x-axis shows the oxygen portion in the plasma. The fluor portion is 100% - x-value.

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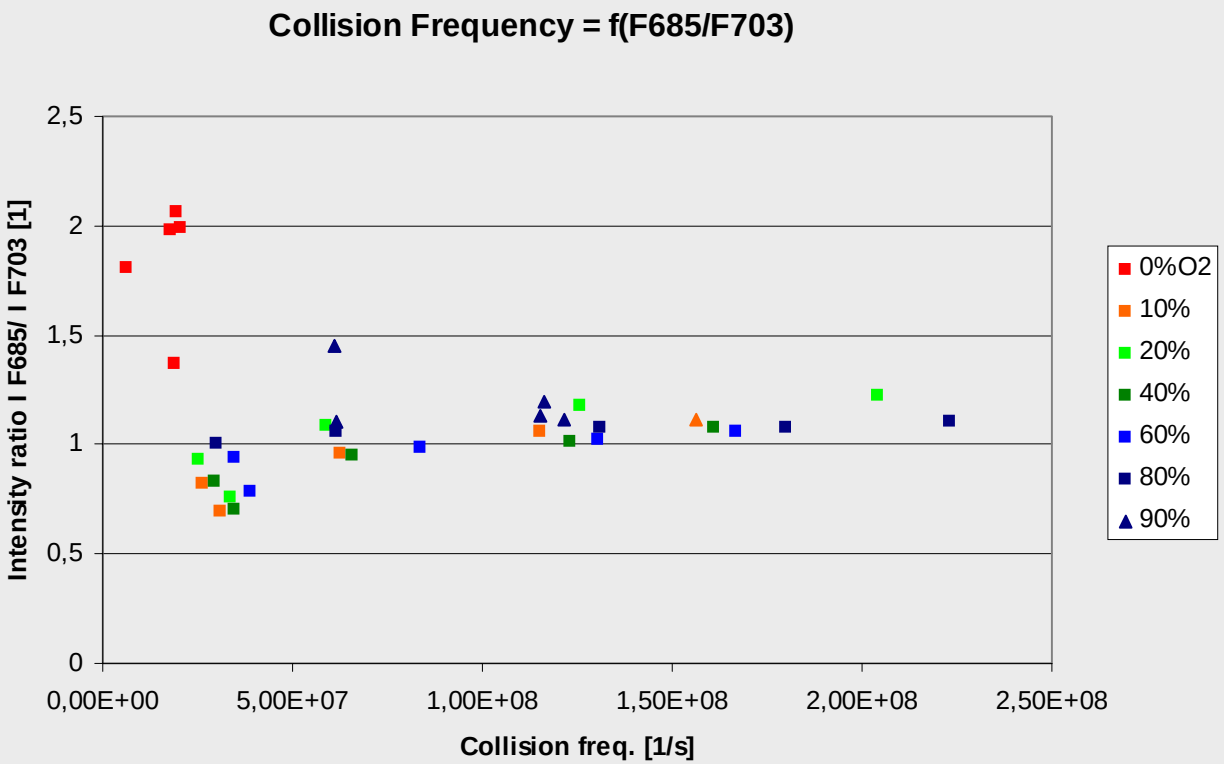
2.2.5. Comparison between SEERS and OES

This diagramme shows the Fluorine intensity ratio I685/I703 as a function of the collision rate.



2.2.5. Comparison between SEERS and OES

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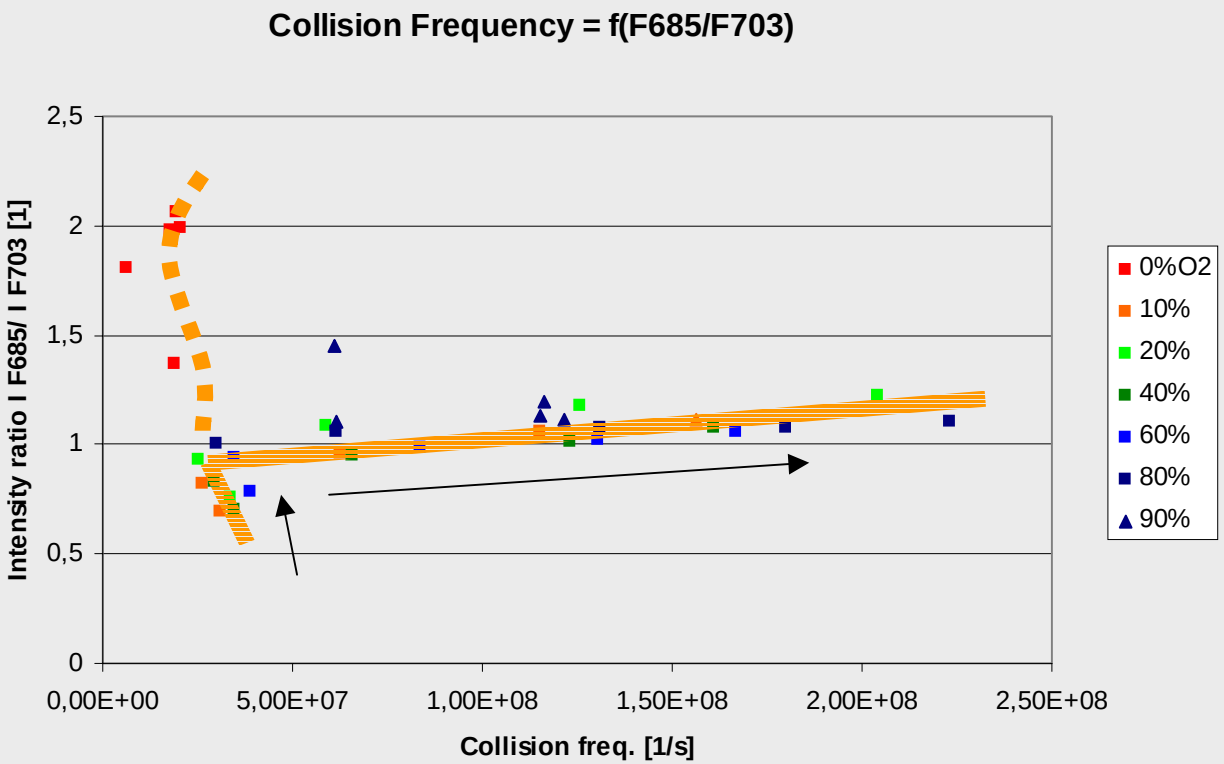
The CCP power increases in the marked direction. The corner of the orange approximation line lies between 200 and 300W.



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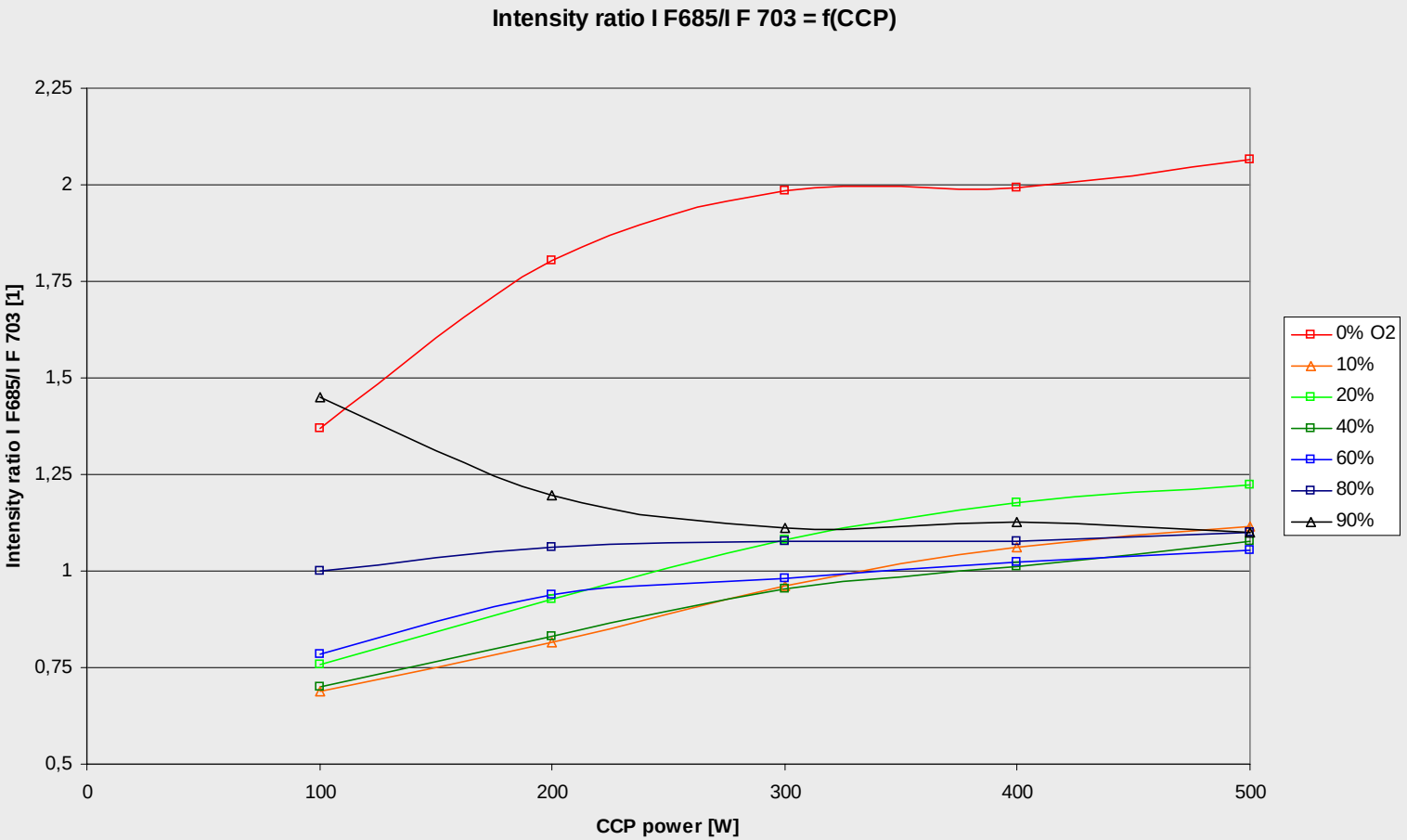
2.2.5. Comparison between SEERS and OES

The direct comparison of CCP power and and the F685/F703 OES intensity ratio does not show this pronounced corner.



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2.2.6. Summary and Conclusion

- Experimental HERCULES results of pure gases cannot be used on different etching tools without knowing the specific impact of tool characteristics on SEERS.
- The collision frequency versus electron density ratio is a sentive measure for CF_4 and O_2 gas mixtures. The settings of the MFCs and the SEERS values have been verified with OES.
- The OES measurements show a maximum in the concentration of atomic Fluorine when the O_2 fraction is at about 50%. HERCULES shows no representation for this effect.
- CCP power settings below 300W cause a different trend for the collision frequency which is up to now not well understood.
- Further experiments are necessary to understand the impact of the plasma system specifics on the SEERS model.