Langmuir Probe used in experimental and numerical investigations of the phase-shift effect in capacitively coupled plasma discharges*

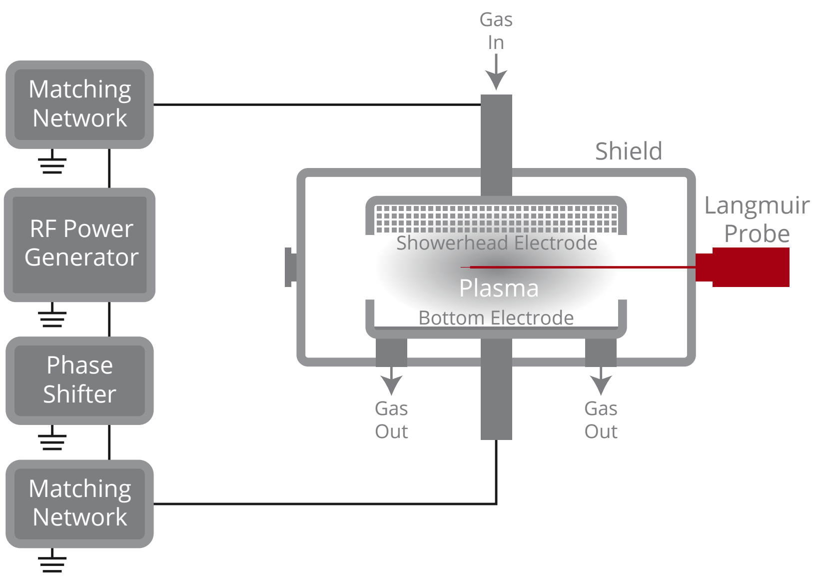
THE STUDY

Radio frequency capacitively coupled plasma (CCP) discharges have many applications in the semiconductor industry, including surface treatment, film deposition and etching. High plasma density and high spatial uniformity have a significant influence on plasma processing, and are therefore two critical issues that invite many studies. There have been many methods proposed to improve plasma uniformity in a high-frequency CCP discharge, such as special-shaped electrodes, but when these are used, a better plasma uniformity can only be obtained under a specific discharge frequency. Most recently, phase-shift control in very high frequency CCPs has been seen to achieve good plasma uniformity.

Recent experiments on the phase-shift effect have used an optical probe, but the optical probe could not measure the plasma density, especially the electron energy distribution function (EEDF). In this study, the authors have used a Langmuir Probe to measure the electron density and the EEDF in phase-shift controlled CCPs. To verify the experimental results, a 2D fluid model was also used to calculate the electron densities at various phase differences.

METHOD:

The experiment was set up as follows:

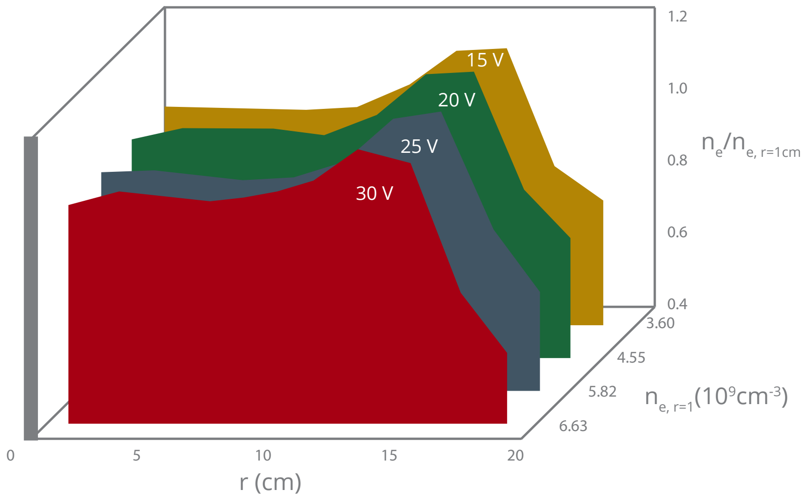


The Langmuir probe was installed through some view ports on the side of the cylindrical chamber. The Langmuir probe could move in the radial direction and so could measure the radial distribution of the plasma characteristics. An insulated tungsten wire, 10mm x 0.4mm, was used as the probe tip.

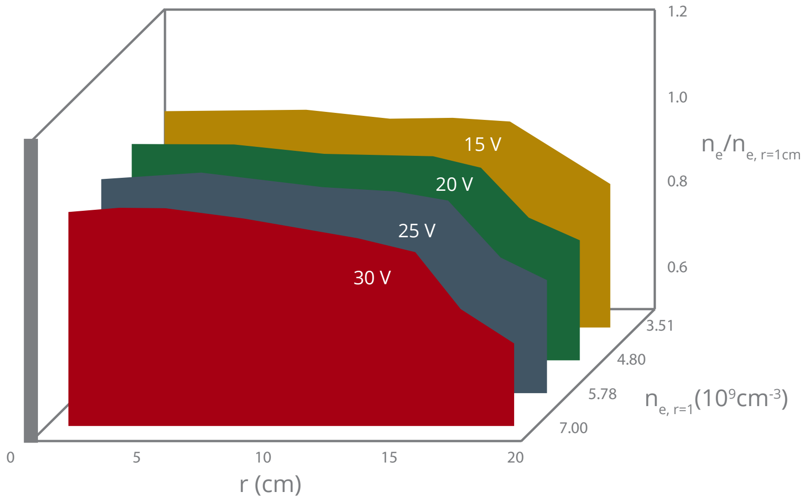
Two sources with the same frequency were then applied on the top and bottom electrodes at the same time, and the phase shift between them varied from 0 to π.

FINDINGS

The following graph illustrates the radial distributions of the electron density measured at different voltages at a phase difference equal to 0:



The next graph illustrates the radial distributions of the electron density measured at different voltages at a phase difference equal to π:



The authors found that the electron density has an off-axis peak near the radial edge when the phase difference is equal to 0 due to the electrostatic edge effect, and the best radial uniformity is observed at a phase difference equal to π. When the voltage was increased, the best radial uniformity was achieved at lower phase shift values. The authors also found that the electron energy probability function has a two temperature structure at all the selected phase differences at r = 1–15 cm. These results indicate that by adjusting the phase difference between the top and bottom electrodes, the radial uniformity of the electron density can be improved.

CONCLUSION:

The authors conclude by suggesting that this method can be used to generate large-area uniform plasmas in high-frequency CCP discharges.

REFERENCES

* Fei Gao, Yu-Ru Zhang, Shu-Xia Zhao, and You-Nian Wang.
“Experimental and numerical investigations of the phase-shift effect in capacitively coupled discharges”.
Physics of Plasmas 21, 083507 (2014); doi: 10.1063/1.4892948.
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