Influence of harmonic ratio of the frequencies in the independent control of ion energy and ion flux in dual capacitively coupled radio frequency plasma

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Capacitively coupled radio frequency (CCRF) plasma is widely studied in recent years because of its simpler design and high efficiency for different material processing applications. A negative dc potential develops between the bulk plasma and the power electrodes, which is termed as 'self-bias' in RF plasma. This self-bias is generated because of the geometrical asymmetry of the electrodes, which can be achieved by appropriately design the area of the powered and the grounded electrodes. However, independent control of the dc self-bias in single frequency CCRF plasma is not possible, since the changing in any operating parameters change the most of the plasma parameters. In these circumstances, dual frequency CCRF plasma could be useful in controlling the separate control of the dc self-bias and plasma density, which respectively determine the ion energy and ion flux. In addition, the dc self-bias could be artificially generated by an electrical asymmetry effect by means of dual frequency CCRF plasma even though the electrodes are geometrically symmetric. It has been observed recently that the polarity of the dc self-bias could be controlled by adjusting the phase angle between the applied radio frequency voltage waveforms [1-3].

Based on nonlinear global model [2], a dual frequency capacitively coupled radio frequency plasma driven by different frequencies of harmonic ratio 1 to 12 has been studied. Fluid equations for the ions inside the plasma sheath have been considered to determine the voltage-charge relations of the plasma sheath. Geometrically symmetric as well as asymmetric cases with finite geometrical asymmetry of 1.2 (ratio of electrodes area) have been considered to make the study more reasonable to experiment. In this presentation, details of the model and the results will be discussed. It has been found that the control of dc-self bias is possible only with the even numbers of frequency ratio. It has been also observed that the influence of phase angle between the two waveforms are prominent in lower harmonic ratio and the influence is almost negligible for higher harmonic ratio. So, for the higher harmonic ratio, only the driving voltages of the waveforms can be used as a controlled parameter, whereas for lower harmonic ratio, the phase angle can be also used as one of the controlled parameters.

Acknowledgements: The authors acknowledge the financial support of project FONDECYT 11130048.

References

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