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MODELLING OF CHLORINE INDUCTIVE DISCHARGES

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Abstract. III–V compounds such as GaAs, InP or GaN-based materials are increasingly important for their use in optoelectronic applications, especially in the telecommunications and light detection industries. Photonic devices including lasers, photodetectors or LEDs, require reliable etching processes characterized by high etch rate, profile control and low damage. Although many problems remain to be understood, inductively coupled discharges seem to be promising to etch such materials, using Cl_2/Ar, Cl_2/N_2 and Cl_2/H_2 gas chemistries. Inductively coupled plasma (ICP) sources meet most of the requirements for efficient plasma processing such as high etch rates, high ion densities and low controllable ion energies. However, the presence of a negative ion population in the plasma alters the positive ion flux, reduces the electron density, changes the electron temperature, modifies the spatial structure of the discharge and can cause unstable operation. Several experimental studies and numerical simulation results have been published on inductively coupled Cl_2/Ar plasmas but relatively few systematic comparisons of model predictions and experimental data have been reported in given reactor geometries under a wide range of operating conditions. Validation of numerical predictions is essential for chemically complex plasma processing and there is a need to benchmark the models with as many measurements as possible.

In this paper, comparisons of 2D fluid simulations with experimental measurements of Ar/Cl_2 plasmas in a low pressure ICP reactor are reported (Corr et al. 2008). The electron density, negative ion fraction and Cl atom density are investigated for various conditions of Ar/Cl_2 ratio, gas pressure and applied RF power in H mode. Simulations show that the wall recombination coefficient of Cl atom (γ) is a key parameter of the model and that neutral densities are very sensitive to its variations. The best agreement between model and experiment is obtained for $\gamma = 0.02$, which is much lower than the value predicted for stainless steel walls ($\gamma = 0.6$). This is consistent with reactor wall contaminations classically observed in such discharges. The plasma electronegativity decreases with RF power and increases with Cl_2 content. At high pressure, the power absorption and distribution of charged particles become more localized below the quartz window. Although the experimental trends are well reproduced by the model, the calculated charged particle densities are systematically overestimated by a factor of 3-5. The reasons for this discrepancy are discussed in the paper.

Experimental studies have also shown that low-pressure inductive discharges operating with electronegative gases are subject to instabilities near the transition between capacitive (E) and inductive (H) modes. A global model, consisting of two particle balance equations and one energy balance equation, has been previously proposed to describe the instability mechanism in SF_6/ArSF_6 (Lieberman et al. 1999). This model, which agrees qualitatively

well with experimental observations, leaves significant quantitative differences. In this work, this global model is revisited with Cl_2 as the feedstock gas (Despiau-Pujo and Chabert 2009). An alternative treatment of the inductive power deposition is evaluated and chlorine chemistry is included. Old and new models are systematically compared. The alternative inductive coupling description slightly modifies the results. The effect of gas chemistry is even more pronounced. The instability window is smaller in pressure and larger in absorbed power, the frequency is higher and the amplitudes of oscillations are reduced. The feedstock gas is weakly dissociated (~16%) and Cl_2^+ is the dominant positive ion, which is consistent with the moderate electron density during the instability cycle.

References

Corr, C. S., Despiau-Pujo, E., Chabert, P., Graham, W. G., Marro, F. G. and Graves, D. B.: 2008, *J. Phys. D.: Appl. Phys*., **41**, 185202.

Despiau-Pujo, E. and Chabert, P.: 2009, *Plasma Sources Sci. Technol*., **18**, 045028.

Lieberman, M. A., Lichtenberg, A. J. and Marakhtanov, A. M.: 1999, *Appl. Phys. Lett*., **75**, 3617.