Modelling of cathode boundary layer discharges in Kr/Cl_2 mixtures

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A two-dimensional self-consistent fluid model was used to study the properties of Cathode Boundary Layer Discharges operating in Kr/Cl_2 mixtures at tens of torr. The plasma is sustained by direct current pulses with an approximate width of 200 ns, peak voltage of 500 V and a frequency of 10 kHz. Model results for the spatial profiles of the charged particle and excited species, the potential distribution, and the gas temperature are presented.

A Cathode Boundary Layer Discharge (CBL) [1] is a type of glow discharge that has been used to create high-pressure microdischarges. In this configuration, the cathode surface area available to the discharge is limited by an annular dielectric, forcing the discharge to operate in an abnormal glow mode at higher currents. The direct current (DC) operation mode is characterized by a positive slope in the current-voltage curve [1, 2] that gives the possibilities of parallel operation of multiple CBLs without individual ballast resistors. Operation of flat matrices of hundreds of CBLs have been reported [3], which could make possible macroscopic applications in surface modification, light sources and sources of reactive neutral and charged species.

Gas mixtures containing molecular chlorine (Cl_2) are widely used as plasma processing gases for etching of semiconductors, and Cl_2 is also an important component of gas mixtures used for rare-gas-halide lasers [4]. In this communication we present 2D self-consistent fluid model [5] results for Kr/Cl_2 (~1% Cl_2) discharges in CBL geometries sustained at tens of torr by a DC voltage pulse with an approximate width of 200 ns, peak voltage of 500 V and a frequency of 10 kHz. The thickness of the CBL electrodes was 150 μm, the dielectric thickness was 500 μm, and the hole diameter was 800 μm.

During the pulse-on period the main charged species are electrons and Kr^+ created by direct ionization from the ground state, forming a plasma with low electronegativity ($n_{Cl-}/n_e < 0.1$, n_{Cl-} and n_e are the Cl^- and electron and negative ion densities, respectively). In the pulse-off period electrons are very efficiently attached by Cl_2 creating Cl^-, and Kr^+ is lost by ion conversion into Kr_2^+ and by charge transfer to Cl_2^+. Consequently in the afterglow there is a three component ion-ion plasma with very high electronegativity ($n_{Cl-}/n_e \sim 1000$). The slow processes responsible for the afterglow plasma decay, ion-ion recombination and ambipolar diffusion, cause that at the end of the pulse there are still important concentrations of Cl^-, Cl_2^+ and Kr_2^+.

In the beginning of the pulse the discharge formation is located near the anode facing the hole. The charged particles move gradually towards the hole center, and then travel along the axis till reaching the cathode and spreading along it. During the pulse-off the species diffuse but remain essentially confined to the hole.

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References

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