

Modelling of crater formation in low-pressure glow discharges

Aranka Derzsi, Zoltán Donkó

Research Institute for Solid State Physics and Optics,
1121 Budapest, Konkoly-Thege M. street 29-33, Hungary

The main purpose of this study is to improve the understanding of low-pressure glow discharges by modelling and computer simulations. Analytical glow discharges, based on the sputtering of the sample-cathode by energetic heavy particles of the plasma, are of special interest in this study. The research focuses on the investigation of cathode sputtering processes and the dependence of crater formation on various discharge parameters, thermal effects, modes of operation.

The research is carried out based on a self-consistent two-dimensional heavy particle hybrid model – combining the fluid description of slow plasma species with the kinetic treatment of fast plasma particles in a Monte Carlo (MC) model – complemented with a heat transfer model for the calculation of the gas temperature profiles. The plasma species considered in the hybrid model are electrons, atoms and ions of the discharge gas (argon) and the sputtered atoms and corresponding ions of the cathode material (copper). As all the important plasma processes are expected to take place in the vicinity of the cathode, modelling studies also focus on this part of the discharge cell: in the simulations the length of the investigated region is 8-10 mm in front of the cathode, the diameter of the cylindrical anode is 4 mm. Typical results of the hybrid model are the discharge current, potential distribution, the density distributions of the plasma species, their flux and energy distributions at desired positions of the discharge region, ionization and excitation profiles as well as temperature distribution profiles. Besides these, the model also makes it possible to investigate the processes relevant to the erosion of the cathode: as the energy of the individual heavy particles hitting the cathode and the position of the bombardment are known in the MC model, the corresponding sputtering yields can be determined; the flux of sputtered atoms as a function of radial position results in the erosion rate that defines the crater profile formed during a certain time period of sputtering. Comparison of experimental data (obtained on a 4-mm Grimm-type source at IFW Dresden and on a simple discharge cell configuration set up in our lab) and simulation results showed good agreement proving that the model considers correctly the underlying processes responsible for cathode sputtering.

In this work various simulation results obtained by this hybrid model are presented for typical operating conditions of analytical glow discharge cells in dc mode. Further, results obtained by the model developed to suit the specific treatment needed to capture the characteristics of the pulsed operation mode are presented by taking into account the effect of the external circuit.