Plasma Dynamics in Capillary Discharges

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Abstracts: *Capillary discharge plasma is used frequently as a source of UV radiation, as an active media for EUV and soft X-ray lasers, for formation of plasma wave-guides to transport high power laser beams, and as plasma lens to focus beams of accelerated charged particles. A review of physical processes responsible for dynamics of plasma in capillary discharges is presented. The review is based on results of a number of MHD simulations as well as on their comparisons with various experiments.*

A through duct in a dielectric filled initially with a gas may conduct electric current leading to plasma formation. Such the form of gas discharges is usually called the capillary discharge. Capillary discharge plasma has various applications: a) as a source of UV radiation; b) as an active media for EUV and soft X-ray lasers; c) as a plasma wave-guide for high power laser beam transportation over substantially long distances; d) as a plasma lens to focus beams of accelerated charged particles; etc.. The talk presents a review of physical processes governing main properties of the capillary discharge plasma. The review is based on an analysis of a number of MHD computer simulations and on their comparison with experimental data.

Electric current flowing through the capillary discharge acts on the capillary plasma mainly in two quite different ways. Firstly, the electric current $\boldsymbol{j}$ excites azimuthal magnetic field $\boldsymbol{B}$. Thus, Amper's force proportional to $\boldsymbol{j}\times\boldsymbol{B}$ pinches the plasma towards the capillary axis. Secondly, the electric current causes the Joule heating of the plasma. The heating rate is proportional to $\boldsymbol{j}^2/\sigma$, where σ is the electric conductivity of the plasma. Magnetic field may also lead to minor consequences like modifications of thermal conductivity, etc..

In the limit of high electric current values, hot plasma and large capillary diameters the first effect prevails leading to the strong plasma compression towards the capillary axis. Plasma dynamics in this case is similar to its dynamics in classic Z-pinches. Parameters of the prefilled gas, the electric current amplitude and the capillary diameter determine maximum temperature of the plasma at stagnation, its density and the stagnation time. These relationships are discussed in the talk.

For weaker electric currents, relatively cold plasmas and smaller capillary diameters, the relatively strong Joule heating leads to the regimes, when Ampere's force effects become negligible in comparison with the plasma pressure effects. As a result, a quite simple mechanical and thermal equilibrium of the capillary plasma may be established. A simple model describing such the equilibrium in the case of hydrogen filled capillary is developed. The model gives the distribution of the electron temperature and density across the discharge.

The capillary discharges are often accompanied by the capillary wall evaporation caused by the high enough thermal flux to the walls. Physical processes determining of the capillary wall temperature as well as the methods allowing to take into account the evaporation are also considered.