7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Dynamic Plasma Contraction of the Weakly Ionized Non-Equilibrium Molecular Flow

M.N. Shneider[1], M.S. Mokrov[2], H. Zhong[3] and Y. Ju[1]
[1] Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ, USA
[2] Department of Aeronautics and Astronautics, Stanford, CA, USA
[3] Department of Mechanical Engineering, Stanford University, Stanford, CA, USA
e-mail (speaker): m.n.shneider@gmail.com

Contraction of the gas discharge, when current contracts from a significant volume of weakly ionized plasma into a thin arc channel, was attracted attention of scientists for more than a century. Studies of the contraction (also called constriction) mechanisms, besides carrying interesting science, are of practical importance for many applications, especially when contraction should be prevented. In this talk, the problems related to the dynamic contraction developing as a result of the thermal-ionization instability of the current channel inside a weakly-ionized non-equilibrium quasineutral positive column of a self-sustained glow discharges in molecular gas flow with external circuit (Fig. 1, left) will be considered. Transition from the uniform to contracted state was analyzed. It was shown that such transition experiences a hysteresis, and that the critical current of the transition increases when the pressure (gas density) drops[1,2] (Fig.1, right). It is important to note that in the hysteresis region, coexistence of the contracted and uniform state of the plasma in the discharge where the current flows along the density gradient of the background gas is possible.

The possibility of plasma-chemical instability in a flow of chemically reacting weakly ionized plasma was recently predicted and studied in low temperature plasma flow in DC glow discharge[3], as well as in high repetition rate nanosecond dielectric barrier discharges. [4] The results show that the plasma chemical instability affects the critical current for the transition between the homogeneous state and the contracted state originally triggered by the plasma thermal-ionization. The plasma-chemical instability can couple with the ionization-thermal instability via the endothermic and exothermic plasma-assisted combustion chemical reactions by changing the local temperature. Understanding the impact of chemical reaction kinetics on plasma instability will open more new applications for efficient ignition and material synthesis.

In addition, the problem of dynamic contraction in the large volume of non-equilibrium weakly ionized plasma is closely related to the problem of streamer to leader transitions in lightings and blue jets (transitions in lightning and "blue jets" (lightning-like phenomena in the upper atmosphere).[5]

References
[1] M.N. Shneider, M.S. Mokrov, G.M. Milikh, Phys. Plasmas 19, 033512 (2012)
[2] M.N. Shneider, M.S. Mokrov, G.M. Milikh, Phys. Plasmas 21, 032122 (2014)
[3] H. Zhong, M.N. Shneider, M.S. Mokrov, Y. Ju, J. Phys. D: Appl. Phys. 52, 484001 (2019)
[4] H. Zhong, X. Yang, X. Mao, M.N. Shneider, I.V. Adamovich, Y. Ju, PSST, 31, 114003 (2022)
[5] G.M. Milikh, M.N. Shneider, M.S. Mokrov, J. Geophys. Res. Space Physics, 119, (2014)

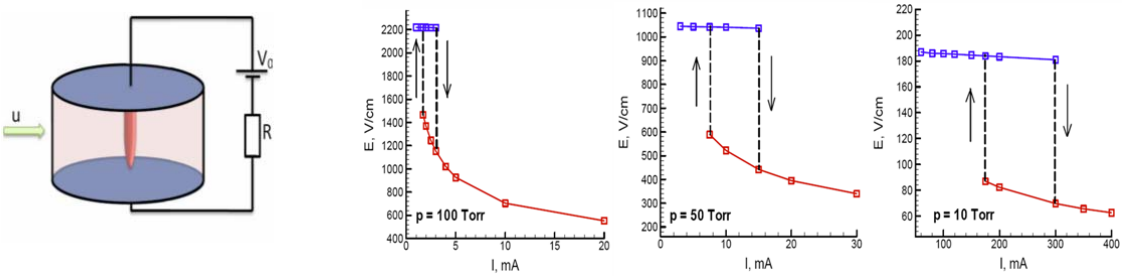

Figure 1. (Left): Contracting channel in axisymmetric cylindrical geometry (x,r) in our model. The arrow shows the gas flow with the velocity u. (Right): The "current-voltage characteristic" of the glow discharge in air flow at the different pressures and flow velocity u=50 m/s.[2] E is the electric field in the positive column. The blue and red branches shown in the figures correspond to the uniform and contracted regimes, respectively. To the left of the hysteresis region, the uniform state of the discharge is stable; in the hysteresis region, the homogeneous state is stable for relatively small perturbations, while finite perturbations of the plasma parameters exceeding certain critical values lead to the growth of the contraction channel; to the right of the hysteresis region, any fluctuations of the plasma parameters are unstable.