Studies on the Separate Control of PlasmaParameters in Atmospheric Pressure Dielectric Barrier Discharge System Based onDual-frequency Modulation

Qiu-Yue Nie [1], Zhonglin Zhang [1], Yaoge Liu [2], Shulei Zheng [1], and Guangye Xu [1]

[1]*Harbin Institute of Technology, China (P.R.C)*

[2]*Dutch Institute for Fundamental Energy Research, Netherlands*

Dielectricbarrier discharges (DBDs) provide a promising technology of generating non-equilibriumcold plasmas in atmospheric pressure gases. For both application-focused andfundamental studies, it is important to explore the strategy and the mechanism forenabling effective independent tuning of key plasma parameters in a DBD system.As a developing innovative technology, the modulation strategy withdual-frequency can effectively enhance plasma properties of atmosphericpressure DBDs and provide a possible approach to control and optimize the keyplasma parameters, even realize the separate control of the electron densityand gas temperature. In this work, we report numerical and experimental studiesof effects of dual-frequency excitation on atmospheric DBDs, and modulation aswell as separate tuning mechanism, with emphasis on dual-frequency coupling tothe key plasma parameters and discharge evolution. And the feasibility of aseparate and independent control over some key parameters (i.e. averagedelectron density and gas temperature) by using the dual-frequency modulationbased on strong nonlinear effects has been demonstrated. It is found that withan appropriately applied low frequency to the original high frequency, astrong nonlinear coupling between two frequencies governs the process ofionization and energy deposition into plasma, and thus raises the electrondensity significantly (e.g., three times in this case) in comparisonswith a single frequency driven DBD system. Nevertheless, the gas temperature,which is mainly determined by the high frequency discharge, barely changes. Besidesthe remarkable achievements of studies on the plasma parameter modulation byusing appreciate frequency matching, it is also observed that, with the variationin the ratio of amplitudes of dual frequency excitations, there exists a strongnonlinear coupling mode of discharge with significant increment of the averagedelectron density because of the nonlinear synergistic effect that governs theprocess of ionization. Moreover, it is shown that the phase shift between thedual frequencies also has an influence on the averaged electron temperature andelectron density. The results have demonstrated the possibility to apply thefrequency, amplitude and phase modulation for realization of a large operationwindow to optimize the plasma processing in dual-frequency DBD system, whichare of crucial importance for the further understanding of the duel-frequencymodulated atmospheric pressure DBDs and the promotion of their associatedapplications directly relevant to several key areas of the plasma technology,namely development and characterization of various plasma sources,characterization of plasma parameters, and modulation & optimization ofplasma processing.

This work was supportedby the National Natural Science Foundation of China under Grant No. 51577044and State Key Laboratory of Electrical Insulation and Power Equipment(EIPE17205).