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D. N. LAZUCHENKOV, N. M. LAZUCHENKOV

DETERMINATION OF THE PARAMETERS OF A SUPERSONIC DISSOCIATED RAREFIED PLASMA FLOW FROM THE CURRENT-VOLTAGE CHARACTERISTICS OF AN ISOLATED SYSTEM OF CYLINDRICAL PROBES

Institute of Technical Mechanics
of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine,
15 Leshko-Popelya St., Dnipro 49600, Ukraine, e-mail: lazuch.dn@gmail.com

The aim of this work is to develop a procedure for identifying the parameters of a collisionless plasma of a dissociated diatomic gas from the current-voltage characteristic of an isolated probe system. The measuring probe system is a cylindrical probe and a reference electrode made up of several cylinders, the electrodes being placed perpendicularly to the flow. Using the familiar theoretical and experimental relationships for the ion and the electron current to a cylinder, a mathematical model of current collection by the probe system in a jet of a laboratory gas-discharge dissociated plasma is constructed. The model includes the calculation of the equilibrium potential of the reference electrode as a function of the probe bias voltage.

Analytical relationships are obtained for determining the degree of plasma jet ion dissociation from the measured probe currents in the electron current saturation region with varying the reference electrode surface area. Under the adopted assumptions, the reliability of determination of the plasma dissociation degree depends only on the probe current measurement accuracy. The paper formulates restrictions on the probe system dimensions and the probe bias voltage under which the proposed method for measurement of the plasma dissociation degree is applicable. The density of charged particles and the electron temperature in a dissociated gas-discharge plasma jet are determined using the mathematical model constructed and the authors' procedure of current–voltage characteristic interpretation developed earlier. The procedure is based on determining the plasma parameter values such that the theoretical current–voltage characteristic best fits the experimental one.

The paper presents the results of a numerical study of the effect of the probe current measurement error on the accuracy of plasma parameter determination. Under the adopted assumptions, the reliability of determining the plasma dissociation degree is estimated as a function of the probe current measurement accuracy. The results obtained may be used in laboratory plasma diagnostics.

Keywords*: collisionless dissociated plasma jet, isolated probe system, cylindrical electrodes, mathematical model of current collection, equilibrium potential, degree of dissociation.*

1. Sapozhnikov G. I. Experimental study of an accelerated-ion flow and its interaction with models. Uchenye Zapiski TsAGI. 1971. V. 2. No. 1. Pp. 129-133. (in Russian).

2. Gabovich M. D. Physics and Technology of Ion Plasma Sources. Moscow: Atomizdat, 1972. (in Russian).

3. Chung, P. M., Talbot L., Touryan K. J. Electric Probes in Stationary and Flowing Plasmas. Springer-Verlag, 1975. 201 pp.
https://doi.org/10.1007/978-3-642-65886-0

4. Lazuchenkov D. M., Lazuchenkov M. M. Interpretation of probe measurements in a collisionless plasma flow. Teh. Meh. 2018. No. 1. Pp. 107-120. (in Russian).
https://doi.org/10.15407/itm2018.01.107

5. Lazuchenkov D. N., Lazuchenkov N. M. Simulation of the extraction of the kinetic parameters of the ionospheric plasma from the current-voltage characteristics of a cylindrical probe. Teh. Meh. 2019. No. 4. Pp. 107-118. (in Russian).
https://doi.org/10.15407/itm2019.04.107

6. Mott-Smith H., Langmuir I. The theory of collectors in gaseous discharges. Phys. Rev. 1926. V. 28. No. 5. Pp. 727-763.
https://doi.org/10.1103/PhysRev.28.727

7. Hoegy W. R., Wharton L. E., Current to a moving cylindrical electrostatic probe. Journal of Applied Physics. 1973. V. 44, No. 12. Pp 5365-5371.
https://doi.org/10.1063/1.1662157

8. Latramboise J. G. Theory of Spherical and Cylindrical Langmuir Probes in a Collisionless Maxwellian

Plasma at Rest. Report No. 100. Univ. of Toronto, Institute of Aerospace Studies. 1966. 210 pp. https://doi.org/10.21236/AD0634596

9. Godard R., Laframboise J. Total current to cylindrical collectors in collisionless plasma flow. Space Science. 1983. V. 31. No. 3. Pp. 275-283. https://doi.org/10.1016/0032-0633(83)90077-6

10. Choiniere E. Theory and Experimental Evaluation of a Consistent Steady-State Kinetic Model for Two-Dimensional Conductive Structures in Ionospheric Plasmas with Application to Bare Electrodynamic Tethers in Space : Ph.D. dissertation. University of Michigan, 2004. 288 pp.

11. Lazuchenkov D. N., Lazuchenkov N. M. Mathematical simulation of a supersonic collisionless plasma flow around a conducting cylinder. Teh. Meh. 2019. No. 1. Pp. 63-74. (in Russian). https://doi.org/10.15407/itm2019.01.063

12. Shuvalov V. A., Pis'mennyi N. I., Lazuchenkov D. N., Kochubey G. S. Probe diagnostics of laboratory and ionospheric rarefied plasma flows. Instruments and Experimental Techniques. 2013. V. 56. No. 4. Pp. 459- 467. https://doi.org/10.1134/S002044121304009X

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