ISSN 0020-4412, Instruments and Experimental Techniques, 2023, Vol. 66, No. 6, pp. 945–947. © Pleiades Publishing, Ltd., 2023.
Russian Text © The Author(s), 2023, published in Pribory i Tekhnika Eksperimenta, 2023, No. 6, pp. 56–58.

GENERAL EXPERIMENTAL TECHNIQUE

Initiation of a Volume Glow Discharge of Atmospheric Pressure in a Cylindrical Tube Using a Low-Current Surface Discharge in Argon

B. B. Baldanov[a,*]

[a] *Institute of Physical Materials Science, Siberian Branch, Russian Academy of Sciences, Ulan-Ude, 670047 Russia*

**e-mail: baibat@mail.ru*

Received February 17, 2023; revised March 29, 2023; accepted July 2, 2023

Abstract—An independent volumetric glow discharge was experimentally obtained at atmospheric pressure in an argon atmosphere. A volumetric glow discharge is realized in an electrode system consisting of a thin metal wire and a metal grid with a dielectric barrier and is ignited using an auxiliary discharge, a low-current surface discharge initiated at the end of a glass tube along the dielectric surface between the pointed cathode and a cylindrical metal anode.

DOI: 10.1134/S0020441223060088

1. INTRODUCTION

At present, to generate a spatially homogeneous nonequilibrium plasma at atmospheric pressure, various types of gas discharges are used (corona discharges, a discharge with a microhollow cathode, a capillary discharge, various types of dielectric barrier discharges) [1–7]. Atmospheric pressure glow discharge (APGD) is one of the effective and promising sources, while the discharge compares favorably with both the simplicity of the discharge geometry and the electrical equipment. The capabilities of APGD are of particular interest for biomedical applications due to the uniformity of the discharge glow and the relatively low voltage required to sustain the discharge.

In most studies, APGD is formed at small (millimeter) interelectrode gaps [8–10]. Under these conditions, the processes occurring in the cathode layer of microdischarges are predominant. And due to nonlocal effects in the plasma of microdischarges, it is possible to obtain electron energy distributions containing high concentrations of high-energy electrons at low gas temperatures. However, with an increase in the discharge current, the gas temperature also increases, as a result of which the regime of stable combustion of microdischarges is limited to the region of low currents and simple gas mixtures. Another problem is related to the fact that the plasma of microdischarges is small, which significantly narrows the scope of the discharge.

One of the main limitations is that, with increasing pressure, the glow discharge becomes unstable due to the transition of the discharge into a spark or arc discharge [11]. To increase the stability of a diffuse glow discharge at atmospheric pressure, special electrode geometries and various methods of excitation of a gaseous medium are used [12–15]. It should be noted that glow discharges are more stable in atomic gases and other light gases at high pressures [16].

2. EXPERIMENTAL TECHNIQUE

The scheme of the experimental gas-discharge source of bulk nonequilibrium (cold) plasma is shown in Fig. 1.

Gas discharge chamber *5* is a glass tube 125 mm long and 12 mm in diameter. The discharge chamber contains a thin metal wire, cathode *1* (diameter 1 mm), with a sharpened end with a tip radius of 25 μm. The cathode is mounted on the axis of the insulator *4* in a dielectric (polytetrafluoroethylene) housing shaped like a cylinder with a diameter of 7 mm. Anode *2* is a metal cylinder 10 mm long and 13 mm in inner diameter coaxially enclosing the tip cathode. Insulator *4* is equipped with longitudinal passage holes *3* to supply argon.

To stabilize the discharge, the cathode-tip is loaded with adjustable ballast *8*. Glass flask *5* coaxially covers grounded metal mesh *6*. From a regulated high voltage source *10*, DC voltage up to 20 kV is applied. Ballast resistance value *8* in the external circuit varies from 10 to 63 MΩ. Argon consumption $G < 2.8 \times 10^{-2}$ kg/s.

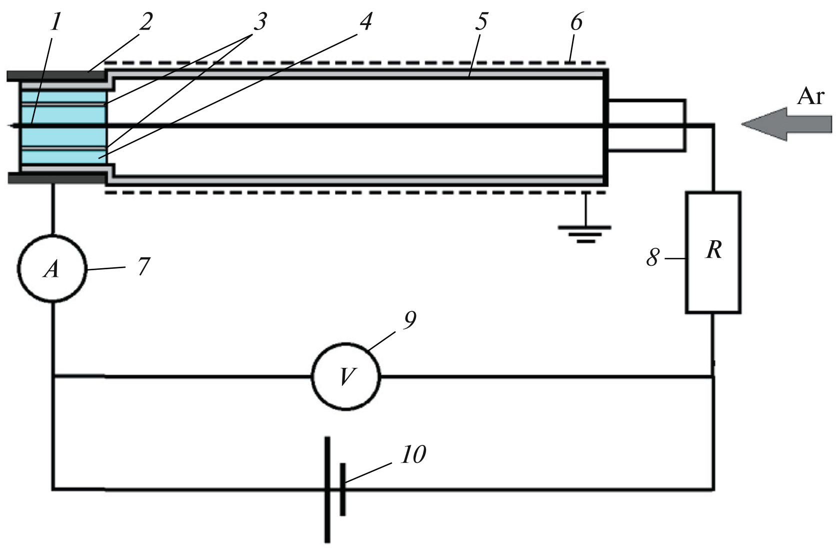


Fig. 1. Scheme of the experimental setup: (*1*) thin metal wire—cathode, (*2*) cylindrical anode, (*3*) through holes for gas pumping, (*4*) cylindrical insulator (polytetrafluoroethylene), (*5*) glass tube, (*6*) mesh metal electrode, (*7*) ammeter, (*8*) ballast resistance, (*9*) voltmeter, and (*10*) power supply.

3. RESULTS AND DISCUSSION

An independent volumetric glow discharge of atmospheric pressure is realized in a three-electrode system and is ignited using an auxiliary discharge (Fig. 2). The auxiliary discharge is a low-current surface discharge initiated at the end of a glass tube along the dielectric surface between the cathode-point *1* (Fig. 1) and a cylindrical metal anode *2* (Fig. 1) when applying high voltage (U = 11.2 kV) to the cathode.

Visually, the surface discharge is low-current streamer discharges in the form of thin current filaments, radially diverging from the cathode points towards the cylindrical metal anode. The intensity and number of occurrence of streamer discharges increases with increasing applied voltage.

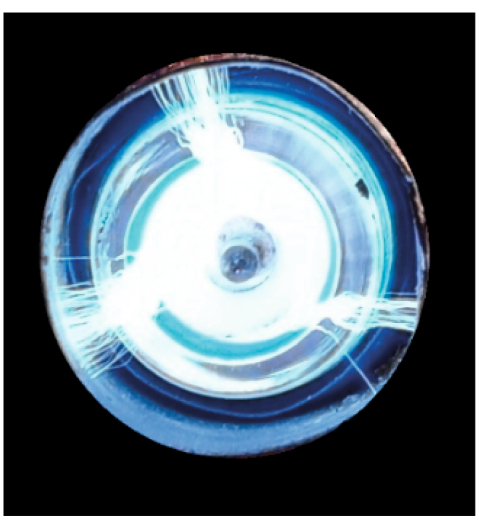


Fig. 2. Weak surface discharge. Discharge current I = 0.45 mA.

When initiating a low-current surface discharge at the end of a glass tube (Fig. 2), simultaneously a homogeneous volumetric glow discharge is ignited in an electrode system consisting of a thin metal wire *1* and metal mesh *6* with dielectric barrier *5*, which is used as a glass tube with a thickness d = 4 mm (Fig. 3a).

A photograph of a self-sustaining volumetric glow discharge at atmospheric pressure in the coaxial geometry of the electrodes is presented in Fig. 3a.

As can be seen, the glow discharge completely fills the cavity of the glass tube, while the glow over the entire volume is quite uniform and uniform (Fig. 3b).

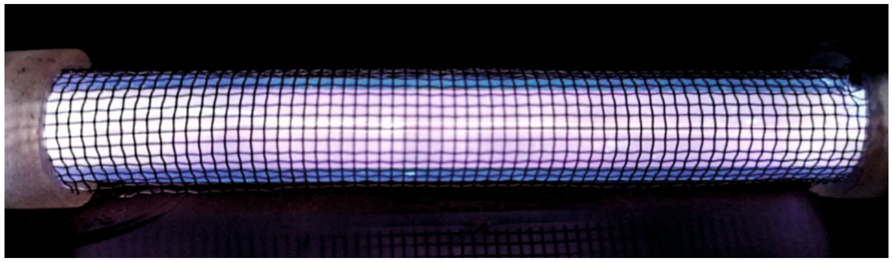
4. CONCLUSIONS

A volumetric self-sustaining glow discharge of atmospheric pressure at direct current has been experimentally implemented in a three-electrode system, in which low-current surface discharge between a pointed cathode and a cylindrical metal anode is used as an auxiliary discharge.

FUNDING

The work was supported by the state task of the Ministry of Science and Higher Education of the Russian Federation (scientific topic 0270-2021-0001).

(a)



(b)

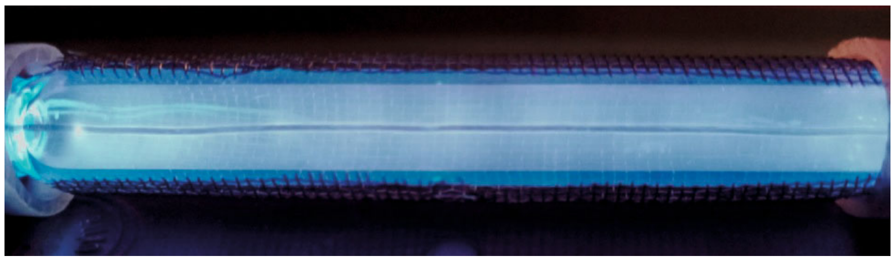


Fig. 3. Photograph of an independent volumetric glow discharge at atmospheric pressure.

REFERENCES

1. Roth, J.R., Rahel, J., Dai, X., and Sherman, D.M., *J. Phys. D: Appl. Phys.,* 2005, vol. 38, p. 555. https://doi.org/10.1088/0022-3727/38/4/007
2. Temmerman, E., Akishev, Yu., Trushkin, N., Leys, Ch., and Verschuren, J., *J. Phys. D: Appl. Phys.,* 2005, vol. 38, no. 4, p. 505. https://doi.org/10.1088/0022-3727/38/4/001
3. Becker, K.H., *Non-Equilibrium Air Plasmas at Atmospheric Pressure, Series in Plasma Physics,* London: IOP Publ., 2005.
4. Dudek, D., Bibinov, N., Engemann, J., and Awakowicz, P., *J. Phys. D: Appl. Phys.,* 2007, vol. 40, p. 7367. https://doi.org/10.1088/0022-3727/40/23/017
5. Iza, F., Kim, G.J., Lee, S.M., Lee, J.K., Walsh, J.L., Zhang, Y.T., and Kong, M.G., *Plasma Processes Polym.,* 2008, vol. 5, no. 4, p. 322. https://doi.org/10.1002/ppap.200700162
6. Tynan, J., Law, V.J., Ward, P., Hynes, A.M., Cullen, J., Byrne, G., Daniels, S., and Dowling, D.P., *Plasma Sources Sci. Technol.,* 2010, vol. 19, p. 015015. https://doi.org/10.1088/0963-0252/19/1/015015
7. Locke, B.R. and Shih, K.-Y., *Plasma Sources Sci. Technol.,* 2011, vol. 20, p. 034006. https://doi.org/10.1088/0963-0252/20/3/034006
8. Becker, K., Kersten, H., Hopwood, J., and Lopez, J.L., *Eur. Phys. J. D,* 2010, vol. 60, p. 437. https://doi.org/10.1140/epjd/e2010-00231-4
9. Arkhipenko, V.I., Callegari, T., Safronau, Y.A., and Simonchik, L., *IEEE Trans. Plasma Sci.,* 2009, vol. 37, p. 1297. https://doi.org/10.1109/TPS.2009.2020905
10. Arkhipenko, V.I., Kirillov, A.A., Safronau, Y.A., and Simonchik, L., *Eur. Phys. J. D,* 2010, vol. 60, p. 455. https://doi.org/10.1140/epjd/e2010-00266-5
11. Kunhardt, E.E., *IEEE Trans. Plasma Sci.,* 2000, vol. 28, p. 189. https://doi.org/10.1109/27.842901
12. Korolev, Yu.D., *Russ. J. Gen. Chem.,* 2015, vol. 85, p. 1311. https://doi.org/10.1134/S1070363215050473
13. Akishev, Yu.S., Deryugin, A.A., Elkin, N.N., Kochetov, I.V., and Trushkin, N.I., *Plasma Phys. Rep.,* 1994, vol. 20, p. 437.
14. Akishev, Yu.S., Deryugin, A.A., and Kochetov, I.V., *Fiz. Plazmy* (Moscow), 1994, vol. 20, no. 6, p. 585.
15. Semenov, A.P., Baldanov, B.B., and Ranzhurov, Ts.V., *Instrum. Exp. Tech.,* 2020, vol. 63, no. 2, p. 284. https://doi.org/10.1134/S0020441220020050
16. Fridman, A., *Plasma Physics and Engineering,* New York: Taylor, 2004.