PACS: 52.80.-s

Effect of air humidity on emission of nanosecond discharge during point-to-point gap breakdown

D. V. Beloplotov, V. F. Tarasenko*, A. N. Panchenko, and D. A. Sorokin

Institute of High Current Electronics, SB RAS, Tomsk, 634050 Russia
** E-mail: vf.tarasenko@hcei.ru*

Received 15.01.2026; revised 2.02.2026; accepted 20.02.2025

The optical properties of nanosecond discharges excited by voltage pulses of 0.7 and 13 ns duration were studied in air with different humidities at atmospheric pressure. The transition from a diffuse to a contracted discharge, characterized by a non-uniform radiation distribution along the gap, was investigated. Optical emission spectra of the plasma of these discharges were obtained in various modes. It was confirmed that during nanosecond breakdown, a diffuse plasma "channel" (diffuse discharge) arises as a result of the collision of counter-propagating streamers of large diameter. It was established that, with a relatively long pulse duration, a diffuse discharge forms in the gap, which then contracts. The discharge channel consists of individual filaments and is characterized by a white glow. It is shown that the plasma emission spectra of diffuse and contracted discharges differ from each other by the presence of a broadband continuum, as well as intense atomic and ionic lines of oxygen, nitrogen, hydrogen, and the electrode material. It has been established that increasing relative air humidity increases the spectral energy density of metal atoms and ions, as well as broadband radiation. A hypothesis has been put forward to explain the appearance of a broadband continuum in humid air during a contracted discharge.

Keywords: non-uniform electric field, nanosecond discharge, atmospheric air, water vapor, hydrogen continuum, luminous tracks.

REFERENCES

1. Korolev Y. D. and Mesyats G. A. Physics of pulsed breakdown in gases, URO-PRESS, chapter 5, 1998.

2. Babich L. P. High-Energy Phenomena in Electric Discharges in Dense Gases: Theory, Experiment and Natural Phenomen, Futurepast. Inc. USA: Arlington, Virginia, 2003.

3. Roupassov D. V., Nikipelov A. A., Nudnova M. M., and Starikovskii A. Y., AIAA journal **47** (1), 168–185 (2009). https://doi.org/10.2514/1.38113

4. Wang D. and Namihira T., Plasma Sources Science and Technology **29** (2), 023001 (2020). https://doi.org/10.1088/1361-6595/ab5bf6

5. Pulsed Discharge Plasmas: Characteristics and Applications / ed. Shao T., Zhang C. Singapore: Springer Nature, 2023.

6. Koval'chuk B. M., Kremnev V. V., and Mesyats G. A., Dokl. AN SSSR **191** (1) 76–78 (1970) [in Russian].

7. Runaway Electrons Preionized Diffuse Discharges / ed. Tarasenko V. F. New York: Nova Science Publishers, Inc., 2014.

8. Bazelyan E. M. and Raizer Y. P. Spark discharge, CRC press, 1997.

9. Minesi Nicolas, Stepanyan S., Mariotto Pierre, Stancu Gabi Daniel, and Laux Christophe, Plasma Sources Science and Technology **29** (8), 085003 (2020). https://doi.org/10.1088/1361-6595/ab94d3

10. Pai D. Z., Lacoste D. A., and Laux C. O., Plasma Sources Science and Technology **19** (6), 065015 (2010). https://doi.org/10.1088/0963-0252/19/6/065015

11. Parkevich E., Medvedev M., Ivanenkov G., Khirianova A., Selyukov A., Agafonov A., Korneev P., Gus'kov S., and Mingaleev A., Plasma Sources Science and Technology **28** (9), 095003 (2019). https://doi.org/10.1088/1361-6595/ab3768

12. Parkevich E. V., Khirianova A. I., Shpakov K. V., Khirianov T. F., and Popov N. A., Physical review E **112** (6), 065211 (2025). https://doi.org/10.1103/bq1x-2p4t

13. Almazova K. I., Belonogov A. N., Borovkov V. V., Khalikova Z. R., Ragimkhanov G. B., Tereshonok D., and Trenkin A. A., Plasma Sources Science and Technology **30** (9), 09502 (2021). https://doi.org/10.1088/1361-6595/aba8cc

14. Tarasenko V. F., Beloplotov D. V., Panchenko A. N., and Sorokin D. A., Surfaces **6** (2), 214–226 (2023). https://doi.org/10.3390/surfaces6020014

15. Tarasenko V. F., Beloplotov D. V., Lomaev M. I., Panchenko A. N., and Sorokin D. A., Usp. Prikl. Fiz. (Advances in Applied Physics) **11** (4), 312–319 (2023) [in Russian].

16. Tarasenko V. F., Beloplotov D. V., Panchenko A. N., and Sorokin D. A., Plasma Science and Technology **26** (9), 094003 (2024). https://doi.org/10.1088/2058-6272/ad34aa

17. Tarasenko V. F., Beloplotov D. V., Sorokin D. A., and Xin Y., Applied Physics, № 6, 40–46 (2024) [in Russian].

18. Shao T., Tarasenko V. F., Zhang C., Lomaev M. I., Sorokin D. A., Yan P., Kozyrev A. V., and Baksht E. Kh., Journal of Applied Physics **111** (2), 023304 (2012). https://doi.org/10.1063/1.3677951

19. Shcherbanev S. A., Khomenko A. Y., Stepanyan S. A., Popov N. A., and Starikovskaia S. M., Plasma Sources Science and Technology **26** (2), 02LT01 (2016). https://doi.org/10.1088/1361-6595/26/2/02LT01

20. Tarasenko V. F., Baksht E. Kh., Vinogradov N. P., and Sorokin D. A., Opt. Spectr. **130** (12), 1487–1495 (2022). https://doi.org/10.21883/EOS.2022.12.55234.4014-22.

21. Van der Horst R. M., Verreycken T., Van Veldhuizen E. M., and Bruggeman P. J., Journal of Physics D: Applied Physics **45** (34), 345201 (2012). https://doi.org/10.1088/0022-3727/45/34/345201

22. Brisset A., Tardiveau P., Gazeli K., Bournonville B., Jeanney P., Ouaras K., Magne L., and Pasquiers S., Journal of Physics D: Applied Physics **54** (21), 215204 (2012). https://doi.org/10.1088/1361-6463/abe81e

23. Liqiang Q. I. and Yajuan Z., Journal of Hazardous Materials **256–257**, 10–15, (2013). http://dx.doi.org/10.1016/j.jhazmat.2013.04.019

24. Efanov V. M., Efanov M. V., Komashko A. V., Kriklenko A. V., Yarin P. M., and Zazoulin S. High-voltage and high-PRF FID pulse generators. in *Ultra-wideband, short pulse electromagnetics 9*. / eds. Sabath F., Giri D. V., Rachidi F., Kaelin A. New York: Springer-Verlag, 2010, pp. 301–306. https://doi.org/10.1007/978-0-387-77845-7

25. Tarasenko V. F., Beloplotov D. V., and Lomaev M. I., IEEE Transactions on Plasma Science **44** (4), 386–392, (2016). https://doi.org/10.1109/TPS.2016.2528581

26. Nunomura S. and Ezumi N., Applied Physics Express **17** (11), 116001 (2024). https://doi.org/10.35848/1882-0786/ad87aa

Об авторах

Белоплотов Дмитрий Викторович, к.ф.-м.н., старший научный сотрудник, Институт сильноточной электроники СО РАН (634050, Россия, г. Томск, пр. Академический, 2/3). E-mail: dv.beloplotov@hcei.ru SPIN-код: 1677-3530, AuthorID: 688871

Тарасенко Виктор Федотович, д.ф.-м.н., главный научный сотрудник, Институт сильноточной электроники СО РАН (634050, Россия, г. Томск, пр. Академический, 2/3). E-mail: vf.tarasenko@hcei.ru SPIN-код: 2449-8880, AuthorID: 18759

Панченко Алексей Николаевич, д.ф.-м.н., старший научный сотрудник, Институт сильноточной электроники СО РАН (634050, Россия, г. Томск, пр. Академический, 2/3). E-mail: an.panchenko@hcei.ru SPIN-код: 3964-2162, AuthorID: 21478

Сорокин Дмитрий Алексеевич, к.ф.-м.н., заведующий лабораторией, Институт сильноточной электроники СО РАН (634050, Россия, г. Томск, пр. Академический, 2/3). E-mail: da.sorokin@hcei.ru SPIN-код: 6447-6366, AuthorID: 614296