DOI: 10.34854/ICPAF.52.2025.1.1.192

SPECIAL FEATURES OF THE INITIAL PHASE OF LOW-INDUCTIVE VACUUM SPARK DISCHARGE *)

[1,2]Stepanov L.V., [1,2]Antsiferov P.S., [1,3]Matyukhin N.D.

[1]*Institute of Spectroscopy of Russian Academy of Science, Moscow, Russia,* isan@isan.troitsk.ru
[2]*National Research University Higher School of Economics, Moscow, Russia,* hse@hse.ru
[3]*Moscow Institute of Physics and Technology (National Research University), Dolgoprudny, Russia,* info@mipt.ru

Investigations of the extreme ultraviolet (EUV, λ = 8 - 25 nm) radiation sources are actual now due to their potential applications in nanolithography [1-2]. Electrical discharge plasma is one of the most technically simple sources of such radiation. Extensive experience with low-inductive vacuum spark plasma has been accumulated in ISAN and the present work is devoted to the study of the possibility of its use as a source of EUV radiation.

One of the difficulties of carrying out experiments with high-current spark discharges is related to poor reproducibility of their spatial structure and temporal dynamics. Detection of radiation by means of the microchannel-plate (MCP) detectors, that exhibit high spatial and temporal resolution, makes it possible to reveal the features of plasma dynamics that cannot be noticed using averaging techniques (see, e.g., [3]). In the present work, we report the results obtained by the usage of simultaneous detection of the spatial structure and spectral composition of the XUV emission of plasma of a 50-kA vacuum spark by means of the MCP detectors with frame temporal resolution of 20 ns. Experimental scheme and tools have been described in work [4]. It was shown, that there are several stages, which are reproduced from discharge to discharge. The most interesting point is the appearance of the EUV radiation of multicharged iron ions (up to Fe VIII) immediately after the start of discharge (200-300 ns after discharge initiation). During this period the voltage, initially applied to the discharge gap, is not yet drop to 0. Then the radiation of multicharged ions of Fe disappears and appears again after 400 ns as a result of the start of the pinching process. It is possible, that runaway electrons are responsible for this effect [4].

The marked phenomenon gives rise to the idea of separation in time of the initial stage of discharge giving emission of multicharged ions from next part of discharge by effective current breaking. Realization of such variant of discharge could be the basis of the discharge produced plasma radiation source with low level of debris. There proposed the scheme of the discharge, that allows reduce discharge time from ~10 μs to ~ 1 μs with help of damping the discharge circuit. This scheme is realized and it is shown that at such configuration the phase with emission of multicharged ions is preserved. The discharge dynamics and radiation intensity in the range of extreme ultraviolet have been studied in dependence of the value of the spacing between the electrodes. Now we plan further optimization of the discharge as radiation source.

References

[1]. Beckers J.; van de Ven T.; van der Horst R.; Astakhov D.; Banine V. *Appl. Sci.* **2019**, *9*, 2827.
[2]. V.Y. Banine, K.N. Koshelev, and G.H.P.M. Swinkels, J. Phys. D: Appl. Phys. 44, 253001 (2011).
[3]. P.S. Antsiferov and L.A. Dorokhin. *Plasma Physics Reports*, 2022, Vol. 48, No. 11, pp. 1246–1253.
[4]. P.S. Antsiferov, L.V. Stepanov, and N.D. Matyukhin. *Plasma Physics Reports*, 2024, Vol. 50, No. 6, pp. 742–748.

*) abstracts of this report in Russian