Electrode system configuration influence on micropinch discharge emission characteristics

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Abstract. Article is concerned with electrode system geometry influence on high-current low-inductance vacuum spark discharge plasma development and its emissive characteristics.

1. Introduction
Pulse spark discharges are known to be intense sources of vacuum ultraviolet, x-ray radiation and charged particles flows [1]. In such discharges electrodes erosion products make major contribution in discharge plasma material, and they determine spectral composition of plasma radiation. In high-current low-inductance vacuum spark (HLVS) formation of hot dense plasma is possible due to pinching effect [2].

In previous works we started to investigate the influence of electrode system configuration on radiating plasma development in HLVS [3]. Those experiments were carried out on the same experimental setup with one discharge current and triggering circuit parameters. Herewith voltage polarity influence on each electrode material contribution in discharge plasma was studied.

For commonly used in such setups electrode configuration with pointy inner electrode and plane outer electrode sufficient dependence of elemental plasma composition on voltage polarity was found out. It should be noted that anode material radiation was observed in all cases.

Present article is concerned with electrode system geometry influence on HLVS discharge plasma development and its emissive characteristics.

2. Experimental setup
Experimental setup was fully described in our previous works [3]. Electrode system is presented on figure 1. In present paper inner electrode was made in form of a cylinder with flat base 20 mm in diameter. Outer electrode was in form of a needle with diameter 3 mm (“plane-point” configuration). Each electrode was made of different material (one of steel, the other of copper) in order to determine presence of their material in discharge plasma. Elemental composition of HLVS discharge plasma was studied by means of Kα radiation of each electrode material from interelectrode gap. Two focusing spectrographs with spatial resolution (FSPR-1D/2D) assembled according to Johann scheme were used for spectra registration.

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Spectrographs were placed on two sides of vacuum chamber and either was adjusted to material of one of electrodes. At the same time pinhole images of the discharge in x-ray range were obtained (figure 3) [3].

Spectra of $K_\alpha$ radiation obtained and corresponding densitograms are represented on figure 4.

Figure 1. Electrode system of the experimental setup.

Figure 2. Electric field intensity in interelectrode gap of experimental setup.

Figure 3. X-ray pinhole image of HLVS discharge.

Figure 4. $K_\alpha$ spectra and corresponding densitogram of copper (a) and iron (b).
3. Discussion
Measurements for “plane-point” configuration were made only with inner plane electrode acting as anode. In case of reverse polarity, dishonorable discharge developed between the edge of the plane electrode and outer current conductor. This phenomenon was confirmed by x-ray pinhole imaging. The disruption was caused by high electric field intensity near the edge of plane cathode and the proximity of the outer current conductor.

$K_{\alpha 1}$ and $K_{\alpha 2}$ spectral lines of pointy copper cathode’s material are distinguished on figure 4a. They are radiated from the area 2 mm in length and 1 mm distant from cathode. In the same time $K_{\alpha}$ radiation of erosion products of inner anode (iron) are practically non-existent (figure 4b).

Absence of plane anode erosion products radiation can be explained in the following way. In this case, electric field intensity near the plane inner electrode increases from its center to its edges. Due to this initial plasma expands in interelectrode gap from cathode to anode by a wide cone. In this case anode area, bombarded by electron beam, grows by several times. Power density deposited on the anode surface diminishes respectively and so does the surface heating. Since metal vapor emission occurs mostly in direction normal to electrode surface, with distance from the discharge axis the beam intersects smaller area of anode material vapor. As a result ionization rate of vaporized material decreases as well as extra influx of electrons from anode region and secondary electrons from cathode. For this reason inflow of erosion products in discharge gap decreases sufficiently.

One can notice the shift of pinching area from discharge axis on the most of pinhole images of the discharge in “plane-point” configuration. It can be seen that this shift occurs in the direction of maximum of electrical field intensity, which is evidence of initial electrical field distribution influence on the following plasma distribution and emission characteristics of the discharge.

4. Conclusions
- Unlike configurations with pointy anode, in case of configuration with plane anode $K_{\alpha}$ radiation of anode material is not observed. Its absence can be explained by the influence of electric field intensity distribution.
- $K_{\alpha}$ spectral lines of pointy cathode’s material are radiated from the area 2 mm in length and 1 mm distant from cathode.
- Experiments provide evidence of initial electrical field distribution influence on the following plasma distribution and, as a result, on emission characteristics of HLVS discharge.

References
[1] Papernyi V L and Lebedev N V 2014 Plasma Physics Reports 40 78-82
[2] Sarantsev S A 2015 Physics Procedia 71 165-170
[3] Bashutin O A, Vovchenko E D, Dodulad E I, Savjolov A S and Sarantsev S A 2012 Plasma Physics Reports 38 235-243
[4] Bashutin O A, Vovchenko E D, Savjolov A S and Sarantsev S A 2010 Problems of Atomic Science and Technology 6 168-170