Publ. Astron. Obs. Belgrade No. 61 (1998), 9 – 12 *Invited lecture*

THE EFFECT OF CATHODE TEMPERATURE ON THE ELECTRIC FIELD DISTRIBUTION IN CATHODE FALL REGION OF THE KISELEVSKII PLASMA SOURCE

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The glow discharges at atmospheric pressure and higher are characterized by some typical features of cathode region such as small spatial size of layers (about tens microns) and high gradients of temperature, particle concentration, electric fields etc. It is result in significant deviation of plasma from equilibrium state. It is the reason of different plasma instabilities in cathode region and results in the contraction and arc breakdown.

In the present work the effect of cathode temperature on parameters of cathode fall region and negative glow is investigated in glow discharge in helium at atmospheric pressure named as Kiselevskii plasma source (KPS) (Kiselevskii et al 1983, Arkhipenko et al 1997). This discharge is unique in itself, because it exists at atmospheric pressure and higher, has the stable characteristics and can be used as spectral source of line and continuous spectrum and the source of excitation of spectra in atomic emission spectroscopy as well.

The discharge was produced in hermetic chamber between round anode and flat copper cathode. The flow of working gas helium was ~ 4 l/min. The impurity concentration in helium flow was not over 0.01%. The discharge was formed by source of direct current varying from 0.05 up to 15 A. The distance between electrodes can be change from 0,5 up to 8 mm.

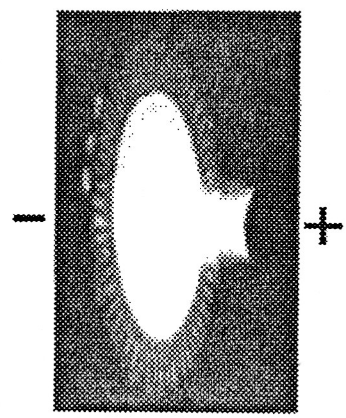

Fig.1.

The image of discharge is shown in Fig.1 One can see, that it has the following structure: the luminous thin disk (less than 1 mm) of negative glow is located above cathode surface, and the luminous column by a diameter of 3-5 mm is propagated toward the anode. There is dark space between these luminous regions. The end of the anode is covered with a bright luminous layer. Negative cathode glow has ring structure, which is created by zones of different plasma luminescence. The luminescence at the disk edge is nonuniform and also consists of alternating dark and light zones.

The diameter of a negative glow depends on a discharge current and

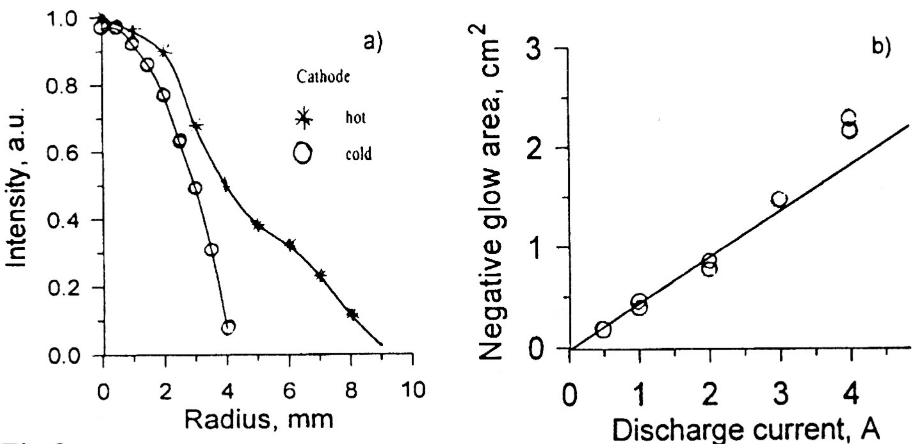

Fig.2.

cathode temperature. In a Fig. 2a the cross distributions of He I (450.1 nm) line intensity in negative cathode glow for two regimes: at cold and hot cathodes are shown. The cold cathode regime was realized by special design cathode with water cooling. Thus the cathode temperature did not exceed 100 °C. At the hot cathode the heat was took away from cathode surface by central tube, which was used as cathode holder. In this case the cathode temperature was about 500 °C. At the cold cathode and current 1 A the negative glow has a diameter about 7-8 mm. In case of hot cathode the luminescence is spreaded on the cathode and can reach about 20 mm in dia. At that the cathode luminescence diameter practically does not depend on the distance between electrodes (2 - 10 mm).

The dependence of the cathode negative glow size on current was investigated in cold cathode regime (Fig.2b). In this case the bounds of negative glow in radial direction rather sharp and luminescence size can be determined. The area of negative cathode glow region grows linearly when the current increases up to 3 A and grows faster at currents higher than 3 A that, apparently, is connected with heating of cathode.

In papers Suzdalov I. I. (1972) and (Kiselevskii et al 1983) the voltage-current characteristic of glow discharge at atmospheric pressure was investigated as $U = f(I)$. It grows in the current range from 0.3 up to 2 A (Suzdalov I. I. 1972) and up to 5 A (Kiselevskii et al 1983). Thus the discharge voltage increases from 180 up to 250 V (Fig.3a, crosses). When current exceeds these values, glow discharge breakdown in arc regime (Fig.3a, bottom curve). One of the reasons of this breakdown can be heating of the cathode. At such conditions, apparently, the emitting properties of cathode and conditions in cathode fall region are changed. It is demonstrated by changes of discharge characteristics such as: the negative glow region size and potential fall on electrodes. At once after discharge ignition at current 1 A the diameter of negative glow is about 8-9 mm. When the cathode temperature increases up to ~ 500 °C the luminous area is increased more than two times. Thus the discharge voltage is increased on 10 – 20 V.

In Fig.3b the dependencies of voltage fall on electrodes for two cathode regimes are shown. At the minimal interval, the voltage on electrodes, apparently, corresponds to cathode voltage fall, because in this case the positive column does not exist, and the type of negative glow practically does not depended on distance between electrodes. One can see, that in case of the hot cathode the voltage fall on 80 V higher than at cold cathode. In both cases the increase of distance between electrodes as well as positive column grows result

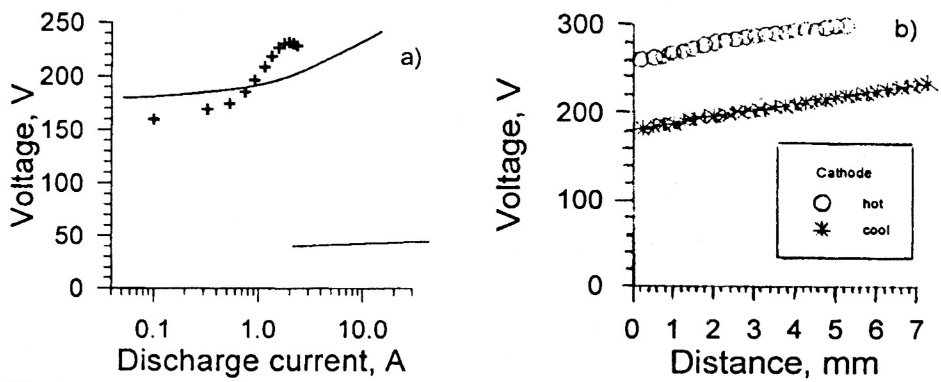

Fig.3.

in the approximately identical increase of voltage about 50V.

Using the cathode special designed by authors for effective cooling of cathode the glow discharge having the rise current-voltage characteristic was produced in more widely current range (Fig.3a). So at current increase from 0.05 up to 15 A the voltage) on electrodes is increased from 180 up to 240 V (Fig.3a, continuous curve). At that the discharge breakdown is not occurred. To increase the current over 15 A in our experiment was impossible because of insufficient parameters of current source, and small cathode cross size. The applied electric power was reached of ~ 4 kW.

The potential distribution of KPS is typical for glow discharges i.e. there is significant cathode fall (Kiselevskii et al 1983). The electric field distribution in cathode fall region was measured by H_β line broadening. The experimental H_β line profiles registered in the KPS cathode fall region contained the two broadening peaks. The distance between peaks and line center is defined by constant electrical field resulting in the Stark splitting of the H_β line. Electric field value measured by H_β line Stark broadening is ~ 60 kV/cm. Its distributions along anode-cathode axis for cold and hot cathodes are

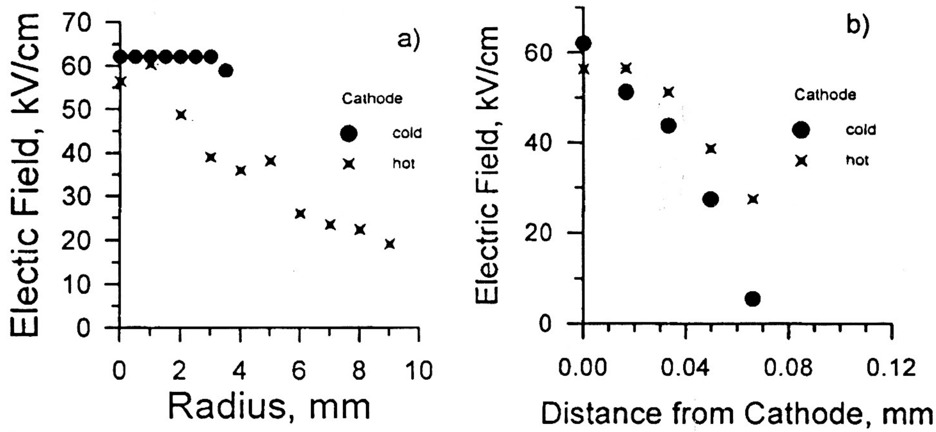

Fig.4.

shown in Fig.4. One can see, that cathode fall region has about 100 microns long for hot cathode and less than 80 microns long for cold. The maximum electric field in cathode fall region in both cases is practically equal. It gives that the longitudinal size of cathode fall for hot cathode is higher than for cold that well corresponds to applied voltage at these regimes (Fig.3b).

The essential difference in field distribution in cathode area between cold and hot regimes is observed in radial direction (Fig4b). When cathode is cold the magnitude of field in a radial direction does not change right up till the luminescence bound. In this case, as already mentioned above, the luminescence has sharp bounds. That is why the field was determined on distance less than 4 mm from axis.

At the hot cathode the field is decreased in radial direction more smoothly: in distance of 5 mm the magnitude of electric field decreases twice in comparison with one at axis, and at edge of negative glow in three times. It should be noted, that the feature of radial distribution at 4 mm is connected to dark ring zone of negative glow (Fig.1).

Thus, the received results show that the cathode temperature essentially effects on the KPS cathode fall region and spatial potential distribution.

The work have been performed at financial support of Belarussian Found of Fundamental Researches (project Ф96-086).

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