LOW-VOLTAGE ARC PLASMA IN THREE-ELECTRODE SYSTEM

V. Bakaht, A. Martsinovskiy, V. Yur'Yev

LOW-VOLTAGE ARC PLASMA IN THREE-ELECTRODE SYSTEM

V.G. Baksht, A.M. Martsinovskiy and V.G. Yur'yev.

A.F. Ioffe Physical-Technical Institute, Academy of Sciences of the U.S.S.R., Leningrad, K-21 U.S.S.R.

Investigations of grid influence on gas discharge plasma are few and not systematical /1/. There are no such investigations for high plasma concentration ($n_e \sim 10^{12} - 10^{14}$ cm^{-3}), though this problem becomes significant for practical applications /2/. The investigation of such problem in short low-voltage arc cesium plasma falls in this gap.

The experiments were performed at plane geometry devices with surface area ~ 1 cm^2 and interelectrode distance d_{ac}=(2-5) mm. The grids with cell dimension $\sim$ (100-200)μm and permeability $\alpha \sim 0.5-0.8$ were utilized. Probe and spectral plasma diagnostic methods were used together with gating integration technique. Time resolution was 50 ns /3/. When a grid is introduced in the gap, the discharge plasma dissolves to two regions with significantly various properties (cathode region and anode region - see Fig.1). In the each region electron temperature T_e , concentration n_e and plasma potential φ change little. But very sharp variation of these parameters takes place in the grid plane. If disharge is developed significantly and the whole emission current flows, the main potential drop occurs in the cathode sheath φ_1 . The electron beam from cathode loses its energy in cathode-grid region. Therefore electron temperature and plasma concentration in cathode region are higher significantly than in anode one ($T_{e1} > T_{e2}$, $n_1 \gg n_2$). Potential drop φ_{12} in the grid plane is negative, i.e. retarding for electron flow from cathode to anode region. Concentration n_2 establishes at the level sufficient for current transfer to anode (point 2 at Fig.1). When anode potential V_a diminishes, cathode potential drop φ_1 , T_{e1} , n_1 and φ_{12} diminish also, plasma parameters in anode region being unchanged (Fig.1, point 1).

When concentrations n_1 and n_2 becomes nearly equal, the grid potential drop φ_{12} changes its sign and the ion generation becomes greater in anode region than in cathode one. Discharge passes into tasitron mode, discovered in /1/. This mode of operation is the most economic because of small value of ion current to cathode ($n_1 < n_2$). Potential drop φ_{12} accelerates electrons and facilitates the current flow in the most narrow space of discharge - between the grid wires.

When V_a increases, enhancement of n_1 ceases when plasma reach the high ionization degree. If V_a continues to increase, the hot electrons penetrate into anode region. Therefore electron temperature T_{e2} and concentration n_2 increase. Concentrations in cathode and anode regions draw together and φ_{12} diminishes (point 3).

The diminution of grid potential V_g causes the enhancement of the pre-electrode layer dimension Δ near the grid wires ($\Delta^2 \sim V_g^{3/2}$). It diminishes the electrical grid permeability α_{el} and causes the enhancement of ion grid current. The pre-electrode layer is sufficiently narrow for discharge conditions that are interesting for practical applications ($n \sim 10^{13}$ cm^{-3}). Therefore permeability diminishes slowly when V_g is depleated. Moreover, if φ_{12} is retarding, α_{el} diminution is compensated by small variation of φ_{12} : $j_a \sim \alpha_{el} \times [exp(\frac{-|\varphi_{12}|}{kT_{e1}}) \cdot n_1 v_{e1} - n_2 v_{e2}]$ Therefore discharge current and plasma parameters are nearly independent of V_g (Fig 2). It must be noticed that the second reason of such independence is often more significant than the first one. This phenomenon (rather than electrostatic screening) prevents grid control in high density plasma.

It is essential that the discharge quenching occurs at negative grid voltage only

Article published online by EDP Sciences and available at http://dx.doi.org/10.1051/jphyscol:19797241

if the potential drop is accelerating for electrons. Near the quenching point main ion generation is concentrated in anode region, grid permeability is small and anode current j_a is diminished appreciably. This result was obtained in experiments as well as in theoretical calculations /4/.

When load resistance R_ℓ is in anode circuit, diminution of j_a causes V_a and φ_1 increasing ($V_a + j_a R_\ell = E_a$ = Const). Therefore concentration n_1 in cathode region increases. It prevents $\alpha_{e\ell}$ diminution and j_a interruption. The load resistance permit to realize the lower branch of voltage-current characteristic-branch with negative resistance. At this branch complicated oscillations occur with frequency ~ 100 kcycles. At Fig.3 the typical results of probe plasma parameters investigation in cathode (1) and anode (2) regions are shown for the conditions when oscillations occur. These are relaxation oscillations with successive ion generation transitions from one region to another.

It was also shawn that grid influences upon discharge when j_a is nearly equal to random current $j_2 = \frac{1}{4} n \bar{v}_e$ and grid potential drop doesn't control discharge. The condition $j_a \simeq j_2$ may be realized by ion concentration diminution or by increasing of anode current. The first situation may be achieved by utilization of a grid with large surface. But such grid causes the grid ion current to increase and quenching anode voltage V_q to increase also. The second situation may be achieved by effective emitter utilization, particulary in discharge with Cs and Ba vapours. Spontaneous current interruptions arise in this situation. Possibility of grid control arises also if the dynamical effects in plasma are utilized. These two possibilities are considered in corresponding reports.

/1/ E.O.Johnson, J.Olmstead, W.H.Webster. Proc.IRE 42, 1950 (1954).

/2/ G.M.Gryaznov, V.B.Kaplan, A.M.Martsinovskiy, V.I.Serbin, V.G.Yuriev, Report on the IV-th Int.Conf.on Thermionic Power Generation (Eindchoven, Netherlands, 1975).

/3/ V.B.Kaplan, A.N.Makarov, A.M.Martsinovskiy a.o. Journ.Techn.Phys.47,247(1977).

/4/ F.G.Baksht, V.B.Kaplan, A.A.Kostin a.o. Journ.Techn. Phys. 48, 2285 (1978).

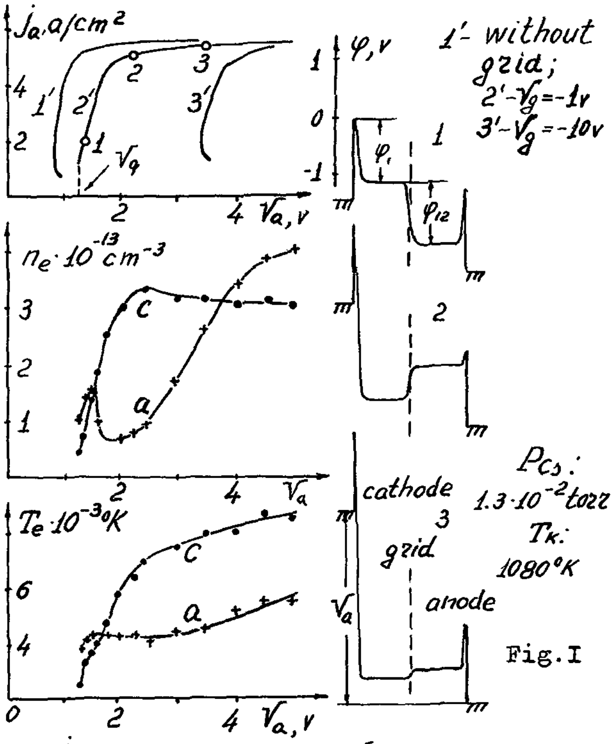

Fig.I

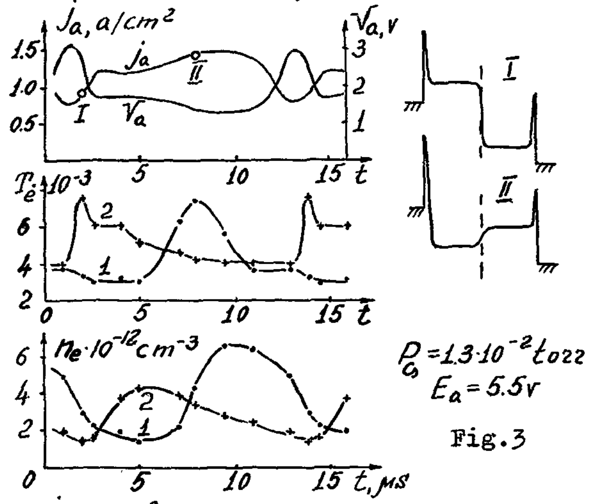

Fig.3

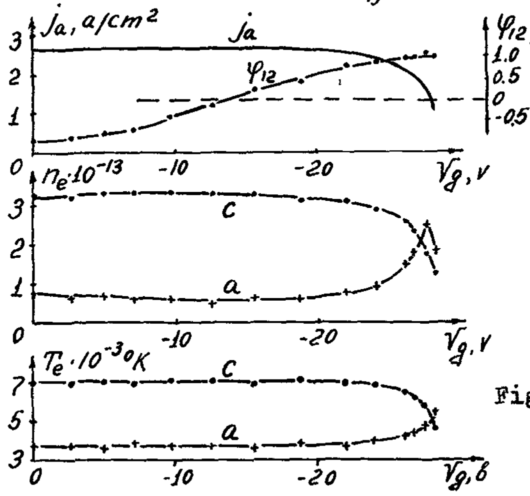

Fig.2