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PECULIARITIES OF ELECTRICAL DISCHARGE IN THE PENNING'S CELL WITH SECTIONAL ANODE

Key words: discharge, Petting's cell, discharge current-voltage characteristic

Ion sputtering can be used for receiving of thin films of high temperature superconductors specifically on the base of YBaCuO ceramics [1]. But there is considerable influence of substrate placement relatively target erosion zone on the properties of films at usage of magnetron discharge of direct current. It can be explained by bombardment of substrate by ions, which appear at target material sputtering [2]. From the target erosion zone the ion stream on the substrate is maximum. To improve the properties of films the substrate is placed from one side of erosion zone but the stochiometric structure and uniformity of the film thickness on the substrate become worse [3].

To eliminate bombardment of substrate by ions, Penning's discharge can be used. In this case two cathodes (targets) are parallel and ion streams from cathodes are moving towards. The substrate is outside discharge what allows to eliminate ion component of stream on the substrate [4].

EXPERIMENTAL SETUP

Penning's cell (Fig. 1) consists of two copper round cathodes 1 of 55mm diameter which are parallel and placed on the distance of 40mm, cylindrical copper anode 2 of five isolated sections of 5mm length. This construction is placed on continuos isolator 3. Magnetic field was applied by samarium-cobalt alloy circular constant magnets 4. The magnetic induction on the surface of cathodes was 0,2T, in the center between cathods under middle section was 0,04T. The magnets with cathodes were included by screen 5 for prevention of discharges on vacuum setup body. The screen and anode were connected with the body, the positive terminal of supply source of discharge current was applied on body.

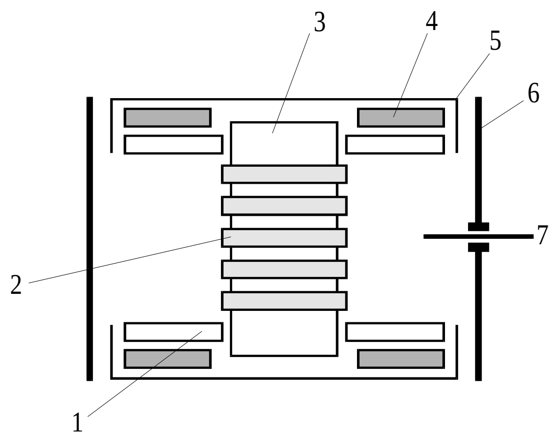


Fig. 1. Petting's cell with sectional anode

The cell was placed in quartz tube 6. In the tube wall the copper probe 7 of 1mm diameter and 5mm length was built-in. Experiments were done on vacuum setup YBP-3M.

EXPERIMENTAL RESULTS AND DISCUSSION

Current-voltage characteristics of Penning's cell were received in discharge in air, oxygen, ammonia in the range of gas pressure P-0,9÷0,72Pa for normal connection of anode sections i.e. the potential is positive on all sections (Fig. 2) and for the case when the middle section is connected with cathodes (Fig. 3).

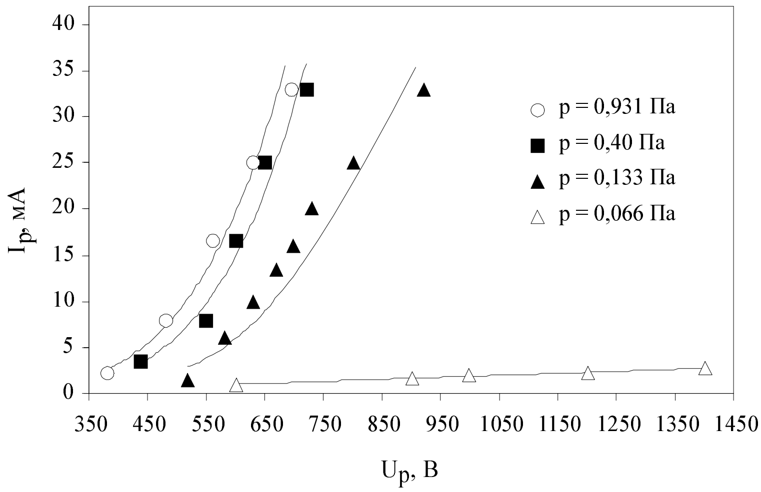


Fig. 2. Current-voltage characteristic of Penning's cell with sectional anode for normal connection of sections

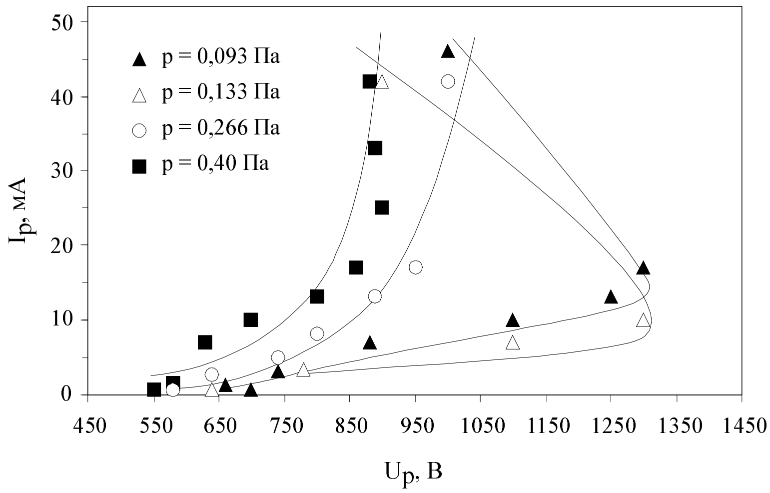


Fig. 3. Current-voltage characteristic of Penning's cell with sectional anode when the middle section is connected with cathodes

Firing potential of discharge is in the limits of 400-700V. At connecting of middle section with cathodes the region of low conductivity is appearing in the range of pressure p<0,133Pa on the current-voltage characteristic. In this region the discharge current is weakly dependent on voltage. Such region is observed at connecting with cathodes of the second and fourth sections. At voltage of 1200V order the current sharply increases and approximately equal to the current at high pressures of gas. The voltage on the discharge region decreases. In the case when all sections are anodes (normal connection) the current jump is not observed.

To understand the processes in the cell the static distribution of potential between electrodes at different connections of anode sections was investigated by simulation method in electrolyte bath (Fig. 4). It can be seen that applying the cathode potential on the middle section causes the formation in the center the region without gradient. This region is limited by equipotentials of 550V (Fig. 4,b) in what longitudinal E_z and radial E_r components of electric field strength are near zero. Field strength near cathodes slightly decreases. At connecting of the second and fourth sections to cathodes (Fig. 4,c) small gradient region is widen, the regions with high gradient by potential are closer to electrodes.

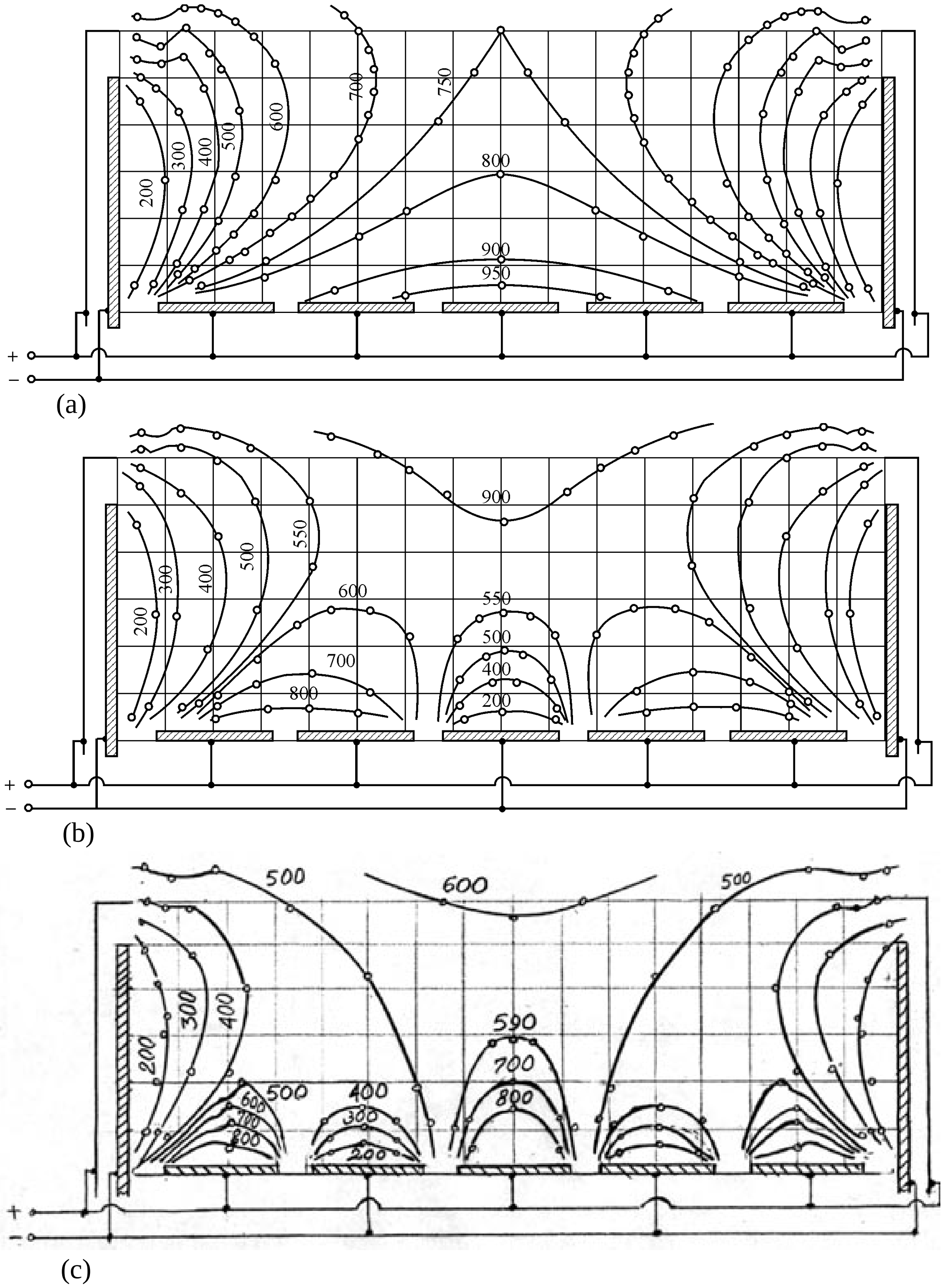


Fig. 4. Potential distribution in Penning's cell with sectional anode:
(a) – all sections under anode potential; (b) – middle section under cathode potential;
(c) – second and fourth sections under cathode potential

The characteristics of electric discharge in Penning's cell are caused by peculiarities of electric field configuration and by influence on charge carriers of quazicathodes - anode sections connected with cathodes. The non-uniformity of magnetic field which is created by constant magnets should be taken into account. It is known that magnetic field induction decrease work as gas pressure decrease that is why the magnetic field influence on ionization intensity in the center of the cell will be weaker.

As a consequence of investigations of Penning's discharge [9] it was shown that there are two regimes which appear in the result of different velocities of electron and ion output from discharge. Not only gas pressure, but also correlation between longitudinal E_z and radial E_r components of electric field strength influence on these velocities. They determine the ion-electron emission factor γ and volume ionization factor α. For ion-dade discharge the distance between cathodes is rather important. It is revealed [10] that there are maximums of the dependence of discharge current on distance between cathodes.

It is obvious that these factors to some extent take place in the Penning's cell with sectional anode. At connecting of all sections the discharge begins in the region of maximum values of electric and magnetic fields near contiguous to cathodes sections. At voltage increase the radial component of field E_r near middle section increases, discharge envelope all anode surface. The following voltage increase causes the appearing of * discharge regime. The ionization region is spread on the volume of discharge gap between cathodes. Increase of gas pressure causes the increase of the number of ionization acts, discharge current increases (Fig.2).

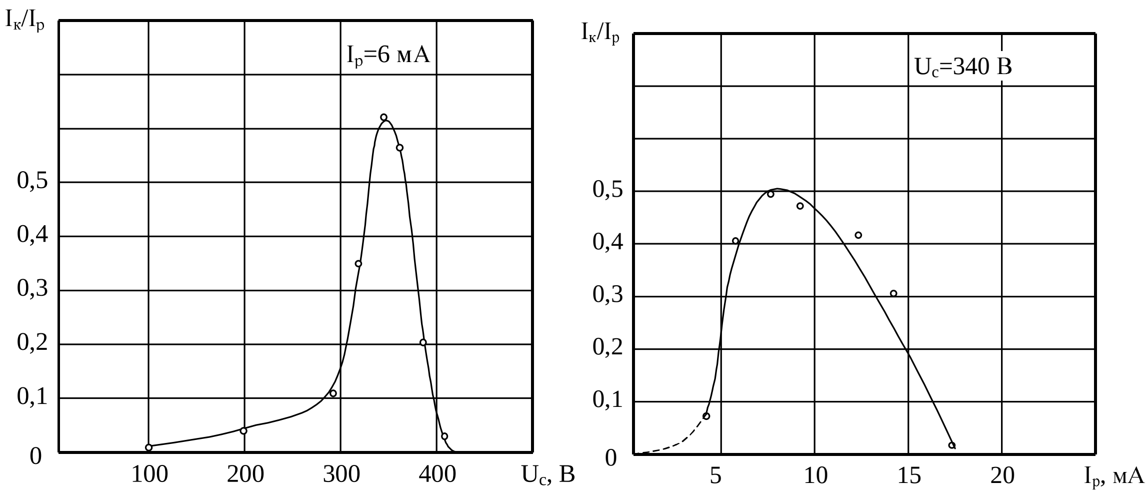
Connecting of middle anode section to cathodes creates the system with intermediate quazicathode causing the electric field deformation. In the center the electrons brake and are ejected on the discharge periphery. This can be the explanation of luminescence round under middle section. Non-gradient region of discharge gap (Fig.6,b) becomes catch for particles which occur in the place where compensated space charge appear. Region in which electrons can receive the energy for ionization is narrow, the ionization intensity is low, current is small. Electrons oscillation in this case is absent or is slight.

At voltage increase the radial component E_r increases, electrons go out from the catch and there is the decrease of current on probe. In the catch the ion charge is accumulated, the round is disappeared, the radial component E_r increases under middle section. Ions accelerate by radial field and bombard this section causing the increase of γ factor in the center and increase of current on probe (Fig.5,b), the discharge current sharply increases. Gas pressure influences on the value of compensated charge in the catch and as a result influences on the voltage of switching to the big current regime.

Oscillations investigations of discharge current confirm these results [6]. Current oscillations are typical for Penning's discharge. Considerable influence of electrodes system especially of distance between cathodes on the oscillation frequency was revealed [7].

At applying of negative potential relatively outer sections (of $(0{,}8\div0{,}9)U_{discharge}$ order) on the middle section the periodical oscillations of 2MHz are observed. The amplitude of oscillations depends on the section potential and discharge current value. The typical current oscillogram is given in Fig.2. The maximum oscillations amplitude corresponds to section potential U_s=-340V for pressure of 1,2Pa. The potential increase on 2÷3V causes the cuenching. It is revealed that such type oscillations appear only at discharge current no more than 14mA. At oscillations the increase of discharge current causes their disappearing. The dependencies of relative oscillations amplitude ($I_{osc}/I_{discharge}$) on middle section potential and on discharge current are given in Fig. 3.

Current cuenching at increase of middle section negative potential or of discharge current can be connected with creation of low gradient region in the center between cathodes. This region is the catch for the particles, which occur in the region. The sizes of this region are determined by action potential. It can accumulate the charge and at some critical value of this charge it can discharge.



а) б)

Fig. 5. The dependence of the amplitude of discharge current oscillations on the middle section voltage (a) and on discharge current (b)

Thus changing the potential of anode sections the configuration of electric field between Penning's cell electrodes can be changed. Respectively the conditions of ignition and luminescence of electrical discharge in gases can be changed. This is the explanation of current-voltage characteristics of Penning's cell with sectional anode.

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