The electrical domains and anomalous phenomenons in plasma

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The anomalous processes include: decrease of plasma conductivity in a strong electric field, enhanced diffusion of plasma across the longitudinal magnetic field and generation of fast ions and electrons. There are a number of mechanisms and models to explain the anomalous processes. They are based on different and often conflicting models. From the virial theorem follows that the plasma as a system of particles always strives to move from a state with high values of energy (potential) to the state with the lowest values of energy (potential). In the process of transition in plasma the distribution of charges and fields adjusted self-consistently so that the work on transition becomes minimal. The process of transition is carried out the next way. It is known that the existence of matter manifests itself in the movement - in the flows of particles and energy. There are flows of directional drift of ions and electrons due to the presence of fields and density gradients in plasma. The electrical domains appear in the plasma due to the inequality flows of directional drift of ions and electrons [1]. Here and hereinafter under the electric domain implied the quasi-neutral in whole system which consists of a region (layer) with surplus negative charge and a region (layer) with surplus positive charge. The distance between these two regions (layers) of the domain exceeds the Debye screening length. Between the regions of the electric domain is always set a strong electric field even for small voltages due to the smallness distance between the regions [1]. The origin of the electric domains in the plasma is accompanied by the generation of transverse electromagnetic waves [2]. The electric domains were first detected in solid-state semiconductor plasma [3]. Later electric domains were detected in the plasma glow discharge [4] and in the cathode plasma in a magnetically insulated diode of the accelerator electron [5]. The domain instability is realized in plasma which is a characteristic state of the plasma at the existing electric and magnetic fields and gradients of density and temperature. The explanation of the anomalous processes in the plasma with one position can be given only on the basis of the theory domain of plasma.

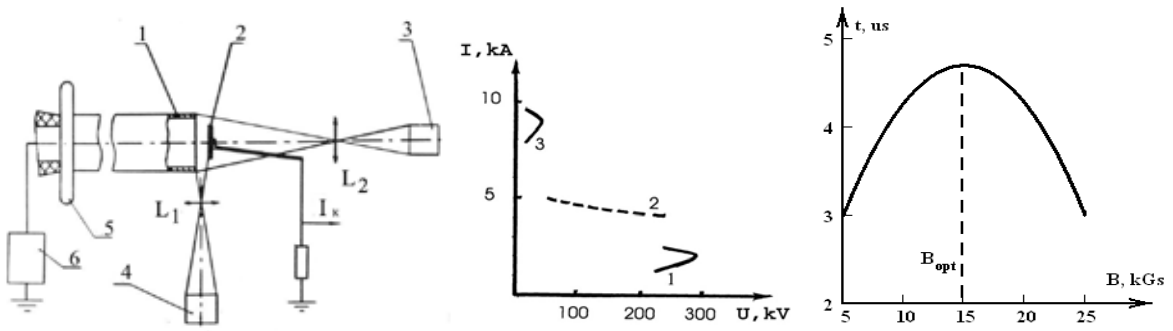
Irregular oscillations of the plasma potential were assumed as basis of the theory of turbulent convection. The explanation that is not related to turbulence can be given to irregular oscillations of the potential. Irregular oscillations of potential are connected with generation of electrical domains in plasma in which the change of temperature and density takes place.

Each subsequent electric domain is born in a less dense and more hotter plasmas. The decreesing of critical value of electric field strength is also takes place that promote the transition of electrons into a state of runaway from collisions. The critical value of intensity is given by Dreicer's formula - $E_k = 10^{-8} nZ^2 / T_e$.

Generation of fast ions and electrons in the plasma is determined by presence of microwave radiation which appears at origin of the electrical domains [2].

In gas discharge plasma, there are generation modes of electric domains which are observed in the plasma of semiconductors. The mode of suppression (destruction) of electric domains is observed in pulses of Trichel. In this mode the domain is destroyed in space - on the way to the electrode. The destruction of domain is accompanied by an electron burst and the emergence of microshock wave. The differential conductance is negative at the presence of a domain in the gap.

An approach on base of electric domain allows giving the explanation to the anomalous resistance of plasma in a strong electric field. The increase of plasma resistance takes place due to the decrease of density of electrons during of its transition from the conductive state to a bound state – to the layers of excess negative charge of electrical domains in the process of their formation. The conductivity of the plasma is given by Spitzer formula in which electron density is a real density – without taking of electrons that run away into the layers of excess negative charge of the electrical domains. The differential conductivity of plasma at the moment of appearance of domain is negative, i.e. $\sigma_d < 0$.



a b c

Fig.1. A scheme of the experiment on registration of electrical domains in the cathode plasma –a; the Ampere-Volt dependence of plasma for the indicated periods of time in Fig.2 (a) – b, and the dependence of pulse duration of magnetic insulated diode from induction of longitudinal isolation magnetic field – c. Designations in **a** : 1 - anode, 2 - cathode, 3 - electron-optical converter "EP-15", 4 - electro-optical camera "Kadr - 2SF", 5 - high-voltage input, 6 - generator of voltage pulse, L1, L2 - optic lenses.

The mode with a delay of the domain appearance was observed in the main stage of work in magnetically insulated diode. A schema of experiments on research of plasma in diode with

magnetic insulation is given in Fig.1 (a). In this mode each next domain appears only when the previous domain reaches the anode and the collapses in its vicinity. Typical wave fronts of the applied voltage and current and also image sweep of plasma luminosity are shown in Fig.2 (*a*,*b*,*c*). Growth of voltage at the moment of appearance of domain is correlated with a shelf on the current waveform due to the transition of part of electrons in the layers of excess negative charge of the electrical domains – see Fig. 2 (*a*). The collapse of the electrical domains near the walls of the anode leads to the formation of plasma channel between the cathode and the anode – Fig. 2 (a-f).

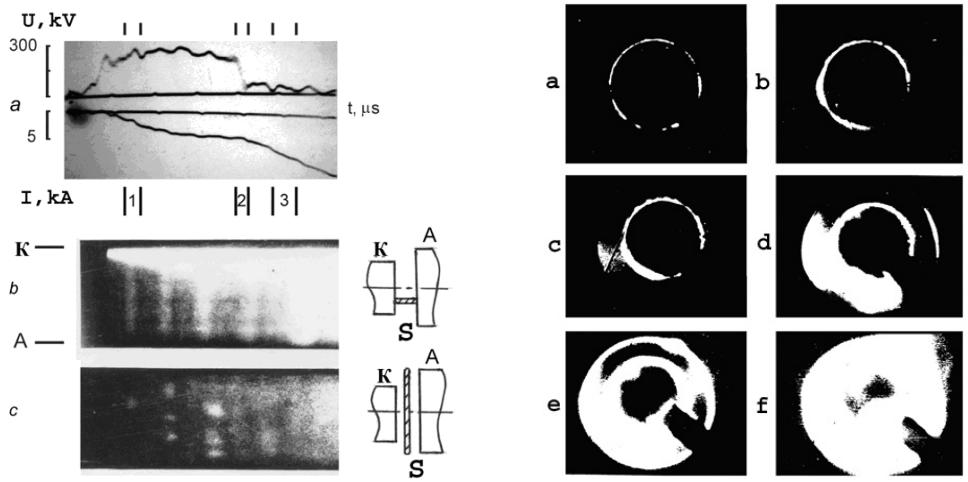


Fig.2. The results of the experiment**: *a*** - the waveform of applied voltage (upper trace), and waveform of current (lower trace); ***b, c*** - sweep of plasma luminosity for positions of slit. Designations: A - anode, K - cathode; S - slit. Time stamps on the oscillograms - 0.5 us. Images of plasma luminosity in the plane which is perpendicular to the axis of the diode. Starting of electrooptical converter relative to the beginning of the voltage growth: a – 0.3 us, b – 0.8 us, c – 1.5 us; d – 2.0 us, e – 2.5 us, f – 2.8 us.

The domain theory allows giving the explanation for the anomalous diffusion of plasma. The main difference between laboratory and space plasma lies in the level of localization energy. Laboratory plasma is created inside a metal chamber. The cylindrical chamber is a hollow resonator from the standpoint of radiophysics. The critical frequency of the resonator is determined by its diameter. The plasma is also an element of the oscillating system. The internal action in the system is carried out by means of the separation of charges in plasma, external – with help of the resonator. The coupling between elements of the oscillating system is realized by electromagnetic waves generated during charge separation. Proofs of this phenomenon are the experiments on the breakdown in air between two electrodes at high voltage [6]. Two cases were studied. In the first case, the electrodes were placed inside a cylindrical chamber, which was also the resonator. In the second case the chamber was absent. Voltage between electrodes was registered by kilovoltmeter. In the experiments it was found that in presence of the chamber the breakdown occurred at a lower voltage than in its

absence. In plasma laboratory, which is located in the chamber the reflected waves appear as a result of electromagnetic waves interaction outgoing from plasma with walls of chamber. Ultimately, as a result of interaction of the incident, reflected, and re-reflected waves in an oscillatory system the resonance of field strength is installed. High-frequency field is established in plasma which leads to decreasing of the effective value induction of longitudinal magnetic field. The plasma goes into the state of anomalous diffusion across of the longitudinal magnetic field [7]. In experiments on the motion of plasma in magnetic insulated diode of the accelerator was revealed that velocity of the plasma in a state of anomalous diffusion increased by the order [7]. The generation of own microwave radiation from the plasma was revealed in the range of wave lengths $(3 < \lambda < 6cm)$ which is comparable to the diameter of the anode $(D_a = 5cm)$.

There is a presence of an extremum on the dependence of pulse duration on the value of the magnetic field [8] due to equality of flow of directed drift of ions and electrons across the longitudinal magnetic field (Fig.1(c)). In area of weak fields (B<Bopt) electrons move faster than ions. In area of strong fields (B>Bopt) ions move faster than electrons. In both cases there is a formation of domains. The most dangerous is the high-frequency hybrid mode, which is implemented in the stage of violation of magnetic insulation. This mode also takes place in the main stage in magnetically insulated diodes with a virtual cathode –vircators

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