# Influence of the alternating electromagnetic field on processes of ionic-plasma burial of the impurity in the surface

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***Abstract*** **Processes of mass transfer and ionic-plasma burial in a surface in the non self-maintained discharge with imposing of a alternating electromagnetic field are considered. Efficiency of imposing of a alternating field in ionic-plasma installations for thermo-chemical processing is shown.**

***Keywords*** **Thermo-chemical processing, ionic-plasma burial, mass transfer, diffusion, electromagnetic field.**

## I. INTRODUCTION

The ionic-plasma method of burial of an impurity in a substrate is widely used at thermo-chemical processing of metals (nitriding, cementation), and also for formation of $SiO_2$, $Si_3N4$ and $Al_2O_3$ dielectric layers on a silicon surface and obtaining p-n transitions in a semi-conductor crystal [1, 2].

Advantages of the method are: uniform burial of an impurity on all surface of a detail, as the discharge is volume; the small expense of technological gas in comparison with gas processing; considerable depth of a diffusive layer. However this method has an essential lack: introduction process is too long (for example, at nitriding – more than 1,5 hours, at obtaining of dielectric layers – 15 hours). Besides, in many cases carrying out of additional operations (for example, tempering or annealing) is required.

To eliminate the specified lacks use of ionic-plasma burial at imposing of a alternating electromagnetic field allows.

## II. PROCESSES OF IONIC-PLASMA BURIAL IN THE PRESENCE OF THE ALTERNATING MAGNETIC FIELD

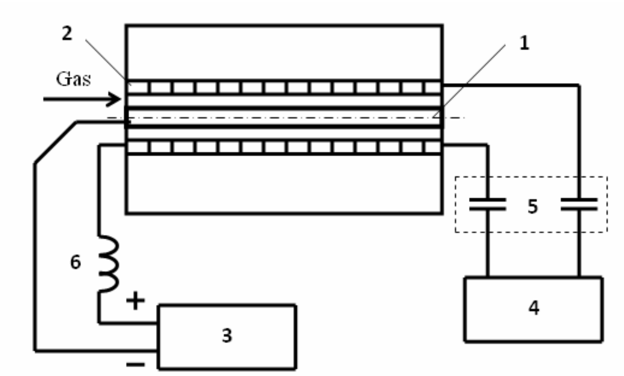
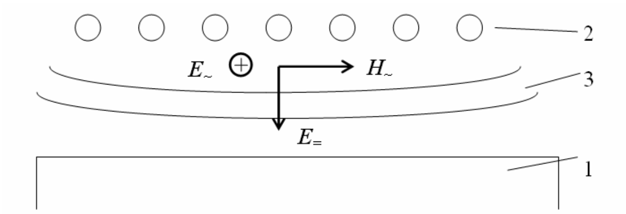



Fig. 1. The electric scheme of installation

The scheme of installation for ionic-plasma burial at alternating field imposing is shown on Fig. 1. The processed detail, pos. 1, heats up in the electromagnetic field generated by an inductor, pos. 2, supplied by sinusoidal current (frequency 1 – 10 kilohertz), received from a source, pos. 4. Between an inductor and a detail the source of a direct current, pos. 3, for creation of the non self-maintained electric discharge is connected. Power sources of the alternating and the direct current are protected from mutual influence by capacitive filter, pos. 5, and inductive filter, pos. 6. Technological gas moves in an interelectrode space, that is in a spase between the inductor and the detail.

The process scheme is shown on Fig. 2.




1 – a processed detail (cathode); 2 – an inductor (anode); 3 – power lines of a magnetic field

Fig. 2. The scheme of process of diffusion-plasma processing with imposing of an electromagnetic field

The current density in an interelectrode space represents the sum of density of a conduction current and a bias current. The density of a current of conductivity is defined under the differential Ohm's law

$$J_c = \sigma(T)E, \qquad (1)$$

where $\sigma(T)$ − conductivity as function of absolute temperature; $E$ – electric field intensity.

The bias current $J_s$ arise in the is low-ionized plasma owing to electronic polarization of atoms. At rather high frequencies currents density of conduction and bias currents in semiconducting mediums are commensurable.

The electron an interelectrode space it will be accelerated by direct electric field $\boldsymbol{E}_=$ and simultaneously to deviate by alternating magnetic field $\boldsymbol{H}_\sim$, which is cross-section concerning a direction of drift of the charged particles. From the decision of the equation of movement of the electron it is visible that through a short time interval movement of the electron gets forward-oscillatory character with the frequency equal to frequency of a alternating magnetic field $\omega$.

At movement in alternating electric field free electrons can receive energy, sufficient for ionization of molecules and atoms of gas.

Considering low-ionized plasma as a dielectric, according to the theory of distribution of an electromagnetic wave in a dielectric we will receive energy increase in volume during time $t$

$$\Delta W = \frac{\omega \cdot E^2 \cdot z^2}{2\pi t\sqrt{\mu_a/\varepsilon_a} \cdot n_a} \quad , \qquad (2)$$

where z – interelectrode distance; $n_a$ – concentration of neutral particles; $\varepsilon_a$, $\mu_a$ – dielectric and magnetic capacity of plasma.

Thus, energy of plasma increases proportionally to frequency and a square of electric field intensity and depends on dielectric and magnetic properties of plasma.

The dominant role in the course of formation of a diffusive layer is played by positive ions of an introduced element. In cathodic area the majority of ions will be neutralized by electrons, emitted by a cathode surface, with formation of neutral atoms.

Under the influence of a alternating magnetic field speed of diffusion of charges changes, and movement of electrons across power lines is described by means of the factor of diffusion $D_{eH}$, connected with factor of diffusion in the absence of alternating magnetic field $D_e$ by a parity [3]

$$D_{eH} = \frac{D_e}{1+\left(\frac{l_e}{r_{Le}}\right)\cdot\left(\frac{l_i}{r_{Li}}\right)}, \qquad (3)$$

where $r_{Le}$, $r_{Li}$ − radius of gyration for electrons and ions; $l_e$, $l_i$ − free length for electrons and ions.

The minimum value of intensity of a alternating magnetic field at which its influence starts to affect considerably, $H_{min}$ is $2 \cdot 10^3$ A/m, thus the minimum concentration of the charged particles on border of cathodic area will be

$$n = 4{,}91 \cdot 10^6 H_{min}^2/T. \qquad (4)$$

Drift of a particle with the speed $V$, proportional $E_=$ and inversely proportional $H_\sim^2$, directed along vector $\boldsymbol{E}_=$, creates a polarizing current (a bias current)

$$J_s = ne_0V. \qquad (5)$$

Calculations show that radius of curvature of a trajectory of electron movement $R_e$ much more extent of cathodic area while for ion $R_i$ it is commensurable with length of cathodic area. At equality $R_i$ and lengths of cathodic area the length of run of an ion increases in $\pi$ times. At imposing of a alternating magnetic field by intensity not less than $2 \cdot 10^3$ A/m according to (2), (3), (4), (5) energy of the ions bombarding the cathode, increases in 1,5 – 3 times.

Thus, imposing of a alternating magnetic field conducts to increase in concentration of ions and their energy at bombardment of a surface of the cathode.

Ionization of technological gas at a surface of a product and mass transfer ions to a surface define concentration of particles of an element of introduction on the given surface and, accordingly, through a concentration gradient, depth of diffusion. Thus, on a metal surface three interconnected processes − adsorption, absorption and chemical sorption – are proceed.

The analysis shows that a major factor defining transition by an ion of a zone “plasma – the processed detail”, is density of a current of the non self-maintained discharge on which depends both cathodic drop, and kinetic energy of ions, and also level of a power barrier. Thus, electric field of the dependent category influences as on the processes occurring in cathodic area (ionization, carrying over of ions to the cathode), and on sorption processes (ion sorption, chemical sorption, absorption), creating thereby a concentration gradient of introduced element and changing the mechanism and kinetics of interactions of the ionized gas with metal. Thermo-chemical processing in the non self-maintained discharge is carried out effectively only at a due combination of such factors in cathodic area, as temperature, electric field intensity, a sort of gas and current density.

## III. Conclusion

Spent theoretical and experimental researches have shown perspectivity of use of imposing of a alternating electromagnetic field at ionic-plasma introduction. The increase in energy of the ions bombarding the cathode, at imposing of a alternating electromagnetic field allows to increase essentially productivity of installation of thermo-chemical processing and depth of a diffusive layer, to lower the expense of the electric power and technological gas.

## IV. References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