CHEMICOTHERMAL TREATMENT

OPTIMIZATION OF THE GASDYNAMIC AND ENERGETIC PARAMETERS OF ION NITRIDING

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One means of speeding up the nitriding process is the use of various electrical gas discharges (glow, corona).

Nitriding in glow discharge plasma has achieved the widest use at the present time.

The increase in the rate of ion nitriding is explained by the effect of glow discharge on all the elementary processes responsible for the formation of the diffusion layer, activation of the gaseous phase, adsorption, and diffusion.

In furnace nitriding the atoms of nitrogen adsorbed on the treated surface diffuse into the lattice, and the shortage of nitrogen is compensated by the arrival of atoms from the adsorption layer.

In this case an \( \alpha \) solid solution with a smooth variation of the nitrogen concentration is formed. A layer of nitrides forms on the surface when the limiting solubility of nitrogen in \( \alpha \) iron is reached.

In ion nitriding in glow discharge the positive ions of the diffusing element (nitrogen, ammonia) [1] acquire a velocity under the influence of the electrostatic field with a vector perpendicular to the treated surface (cathode).

During bombardment of the cathode surface the kinetic energy of the ion \( E_i \) is spent on heating the surface \( E_t \), and on the escape of atoms and electrons from the surface and the transmission of kinetic energy to them, \( E_p \).

Atoms of iron from the cathode surface combine with nitrogen in the plasma of the glow discharge that is in different states of excitation, with formation of iron nitride that is adsorbed on the cathode surface in an even layer. The nitrogen concentration in the nitride layer may reach 5.9-17 wt. % [2]. Under the influence of ion bombardment, the nitride layer decomposes with formation of lower iron nitrides (\( \text{Fe}_2\text{N} \to \text{Fe}_3\text{N} \to \text{Fe}_4\text{N} \)) and an \( \alpha \) solid solution with nitrogen - \( N(\alpha \text{Fe}) \). The nitrogen resulting from the decomposition of the lower nitride diffuses into the surface layer, forming a zone of internal nitriding, while the iron depleted of nitrogen is again discharged into the plasma. The formation of nitrides in the precathode region and their deposition on the cathode are continuously repeated. Thus, the nitride phases condensing on the surface of the cathode are an independent source of nitrogen along with the gaseous phase.

In contrast to furnace nitriding, the formation of \( \alpha \) solid solution of nitrogen begins after formation of nitrides on the surface.

It has been assumed that by controlling the ratio of the processes of cathode sputtering and reverse diffusion (reverse cathode sputtering) one can obtain diffusion layers with and without a nitride zone on the surface, with a base of high-nitrogen \( \alpha \) solid solution.

However, there are no data in the literature concerning the effect of the discharge parameters on the structure of the nitride layer.

Foreign work [3, 4] indicates a broad range of pressures in treating steels in glow discharge plasma (from 1 to 10 mm Hg).

In this connection we investigated the effect of discharge parameters (pressure and composition of the gaseous atmosphere) on the formation rate of the nitride layer. The investigation was conducted on commercial iron and steels 40Kh and 38KhMYuA.
Fig. 1. Depth of diffusion layer on commercial iron and steels in relation to pressure during ion nitriding in ammonia plasma at 520°C (a) and 650°C (b) for 1 h.

Ammonia and mixtures of ammonia and argon and ammonia with propane were used. The mixtures were prepared by means of an automatically controlled regulator with an error of 0.5%.

Nitriding was conducted in laboratory equipment with a power of 2.5 kW, with use of samples 10 mm in diameter and 15 mm long. The process was conducted in two stages – cleaning of the surface by cathode sputtering in the first stage and saturation in the second stage. Cathode sputtering was conducted for 15 min at 1000 V at a pressure of 0.1 mm Hg. The temperature of the sample at the end of the depassivation period was 280°C.

After cathode sputtering, the pressure was varied from 0.3 to 20 mm Hg and the voltage from 1200 to 600 V.

Figure 1 shows the variation of the depth of the nitride layer and the nitride zone with the pressure in ammonia plasma at 520 and 650°C for 1 h.

The variation is of the extremal type, the greatest depth of the layer corresponding to the maximum depth of the nitride zone. During nitriding in glow discharge plasma the maximum density of the vapors of the metal occurs at a distance of several lengths of the free path of ions from the cathode [2]. When the pressure is reduced this distance increases, since the length of the free path of iron atoms from the surface of the cathode increases. The adsorption rate of nitrides on the surface decreases, and the depth of the nitrided case and the nitride zone decrease for this reason.

When the pressure is reduced below the optimal (2 and 6 mm Hg) the voltage must be raised in order to heat the surface of the sample to nitriding temperature. In this case the kinetic energy of the ions bombarding the surface of the cathode increases, and the rate of cathode sputtering probably increases, with reduction of the nitride zone on the surface.

At pressures higher than the optimal the depth of the nitride zone decreases, with hardly any change in the total depth of the nitrided layer.

The smaller depth of the nitride zone is evidently due to the smaller length of the free path of ions, the increase in the recombination rate of ammonia ions, and the lower nitrogen potential of the atmosphere.

It should be noted that the higher the diffusion coefficient of nitrogen in α phase, the smaller the depth of the nitride zone. For example, with nitriding at 520°C for 1 h under optimal conditions the depth of the