Research processing of tool steels surface in low pressure glow discharge

D I Israphilov
Kazan Federal University, 18 Kremlyovskaya street, Kazan, 420008, Russian Federation
diisraphilov@yandex.ru

Abstract. Plasma ion nitriding processing in glow discharge occurs on whole surface of product. Structure and phase composition of the diffusion layer defined by the phase diagram of iron - nitrogen. Low-pressure glow discharge in cross-flow working gas treatment takes place mainly by the working gas stream, which will hold required nitriding surfaces. In addition, low-pressure environment in chamber will reduce the effect of residual gas contaminants on processing surface.

1. Relevance
Plasma nitriding meets environmental requirements and is operated by a large number of equipment for its realization. A feature of the plasma nitriding is that the process can be controlled much easier than other methods.

Process of ion nitriding in hydrogen-containing environments (ammonia, a mixture of nitrogen and hydrogen) is well studied in literature [1 - 3].

A method of forming a wear-resistant coating on a surface of structural steel product includes plasma ion nitriding reactive gas atmosphere - nitrogen, surface cleaning and nitriding. Purification of surface nitriding is carried out at a pressure of reactive gas 5•10-3-2•10-2 Torr, voltage 300-1000 V and ion current density 2 - 8 mA/cm2 for 30-90 min, purification is carried out in a plasma of inert gas - argon at a pressure of 3•10-4 - 7•10-4 Torr and current density of 3-5 mA / cm2. The method allows intensifying process and increasing operational stability of dies, experiencing high specific load in the process of friction.

Structure and properties of hardened layer of nitriding details depend on the following technical factors: the voltage between the electrodes, the gas composition of the environment, degree of vacuum, operating temperature, process time, the mutual arrangement of parts and electrodes. Nitriding details set in the camera by connecting to negative electrode, chamber is sealed and pumped to a pressure near 1 Torr. Camera view is presented in Figure 1.
Figure 1. Vacuum chamber with organization of different particle concentration. RV - rotary vacuum pump, EV - valve, VB - valves box, PK - prev vacuum chamber, DOV - diffusion vacuum pump, ML - oil trap, VL - nitrogen trap, R - vacuum chamber, T1, T2 - thermocouple vacuum gauges, P - high vacuum gauge.

2. Results

Figure 2. shows a glow discharge at low pressure and the results of experimental studies of gas temperature, depending on the length of the discharge chamber at various currents (Fig. 3).

As the chart above shows, gas temperature in the field of supersonic flow drops sharply.

Rational selection of the optimal pressure, which depends on the complexity of configuration and efficient of parts location, since changes in pressure varies with the length of the cathode part of the discharge. With increasing pressure from 1 to 10 Torr cathode area of the discharge is decreased from...
10 to 1 mm. This must be considered to ensure the uniformity of the diffusion layer on the workpiece surface.

Nitriding temperature is usually 470-580 °C, voltage 400-1100 V, vacuum 1-10 Torr. Operating pressure is limited by the properties of glow discharge. At a pressure below 1 Torr ion energy is not enough to heat the workpiece to a working temperature, at a pressure above 10 Torr stability of discharge is disturbed.

Process is carried out for 5-60 minutes at a voltage of 1100-1400 V and pressure of 0.1-0.2 Torr, surface temperature of the parts does not exceed 250 °C. Operating parameters of the process: \( U = 400-1000 \text{ V} \) in electrode gap is fed supersonic flow of working gas - nitrogen.

After surface treatment for 5-60 minutes in a cathode-sputtering mode, voltage is reduced to 1100-1400 V in working. Cathode-sputtering mode can be performed in a hydrogen atmosphere, the use of which is especially useful when nitriding austenitic steels. Working process temperature (470-580 °C) achieving in 15-30 minutes. The heating rate is determined by ratio of details surface and weight [7]. After isothermal holding parts are cooled to room temperature under vacuum. In this cooling rate is above than in heating furnace, since only product heated by ionic treatment and heating walls of the working chamber by convection and radiant heat in a vacuum is light.

Steel X40CrMoV5-1 is basis for a variety of stamps for deformation of steel and non-ferrous metals and injection molding forms of aluminum and magnesium alloys with a diameter of 70-80 mm. Accordingly, resistance of the steel becomes 1.5-2 times higher (Figure 4).

![Figure 4](image_url)

**Figure 4.** - Microstructure details, \( \times 500 \); a) - at a distance of 5 mm from the end of rod; b) - plot of microhardness of the nitrided layer of tool steel X40CrMoV5-1.

Thus, nitrided layer consisting of nitride compounds and internal nitriding zone. Figure 4 shows a photography of the microstructure and a plot of microhardness of nitrided layer steel X40CrMoV5-1. Decomposition of austenite in the pearlite and the intermediate region is preceded by the selection of carbides, occurring at the grain boundaries, which reduces viscosity by 30-40%.

3. **Conclusion**

Change in high current density range (0.5-20 mA/cm²) does not affect the nitriding process.

Increasing the technical efficiency of ion-plasma nitriding by optimizing process parameters depending on weight and geometric characteristics of the parts. This is because the performance depends on the data density distribution uniformity of the ionized gas on the workpiece surface. It is also necessary to consider increasing intensity of glow discharge plasma in a nitrogen atmosphere at sharp edges of parts.

**References**

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