EFRE 2020

Active Screen Plasma Hytrogen Free Plasma Nitriding Steel

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Conventional DC plasma nitriding

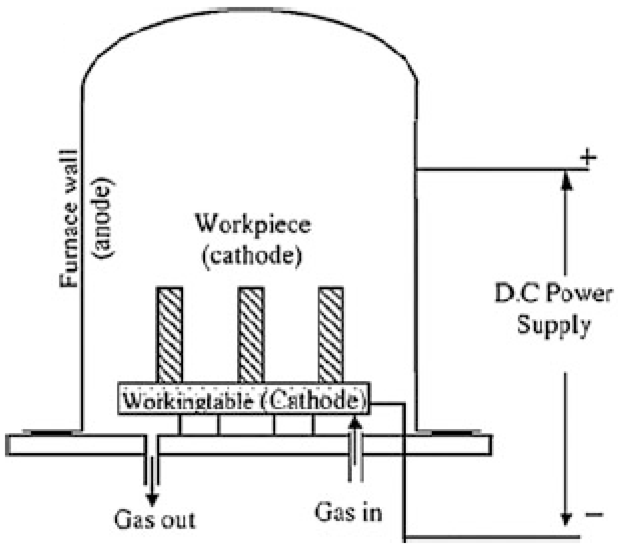

Fig. 1 - Schematic of conventional DC plasma nitriding [Griin R, Giinther H J, (1991) Plasma nitriding in industry-problems, new solutions and limits. Mater Sci Eng A 140:435–441]

Problems

This configuration has a number of significant limitations for the uniform distribution of the hardening effect in the near-surface layers when processing steel parts having a complex surface configuration with holes, cavities or sharp edges. **Edge effects**, as well as the **hollow cathode** effect, lead to a temperature gradient in different areas of the parts and, as a result, an inhomogeneous distribution of the diffusion layer thickness. **Intensive surface sputtering** as a result of ion bombardment together with the inevitable electric **arcs** formation leads to a deterioration in the quality of the surface.

Active Screen Plasma Nitriding - ASPN

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In ASPN, the cathode potential is supplied to a special metal screen, inside of which the nitrided sample is located under a floating potential or a small bias. The screen is heated by energetic particles from plasma and then heats the part with thermal radiation. ASPN allows processing of samples at a speed comparable to traditional plasma nitriding in a glow discharge, but with higher treatment uniformity and less surface roughness

This work presents the results of studying the mechanisms of hardening the surface of structural steel during **hydrogen-free** nitriding in ASPN system at a working pressure of nitrogen of 80 Pa. Samples of **AISI 5140** steel were treated at **different potentials** (cathode or floating potential) inside the active screen, then the depth of the hardened layers was estimated based on the results of microhardness measurements on prepared cross-sections.

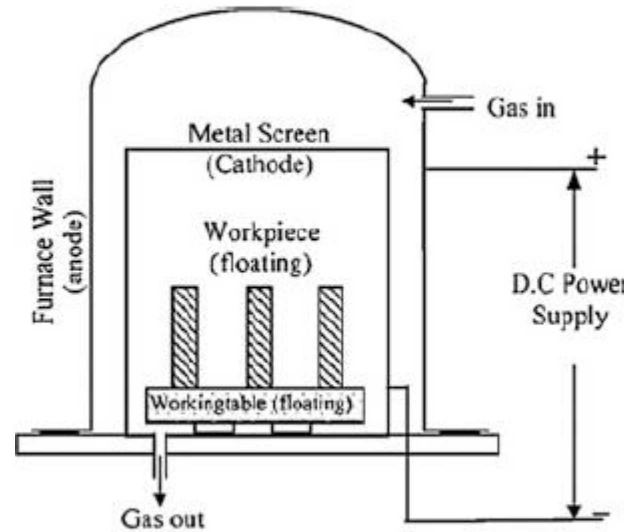

Fig. 2 - Schematic of ASPN [Griin R, Giinther H J, (1991) Plasma nitriding in industry-problems, new solutions and limits. Mater Sci Eng A 140:435–441]

Experimental setup

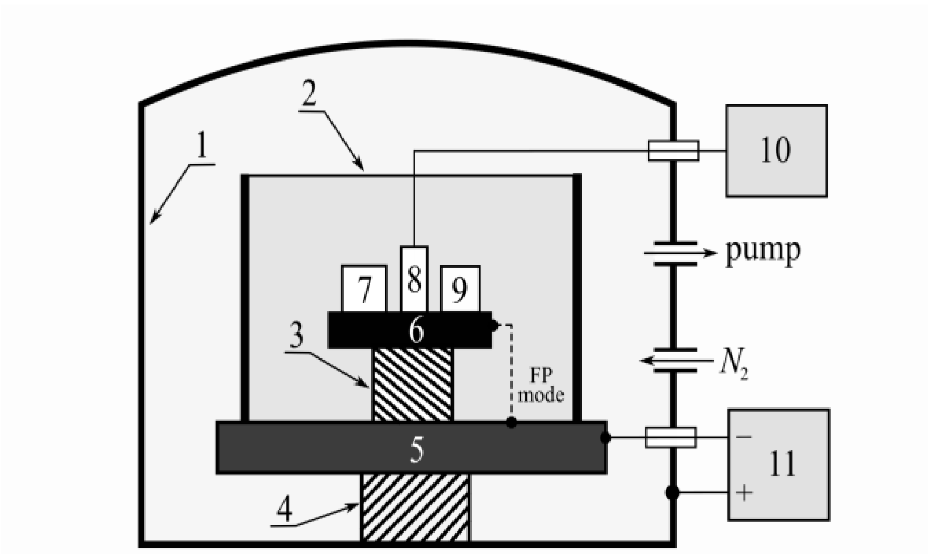

Fig. 3 -ASPN system diagrams in CP mode and FP mode. 1 – vacuum chamber, 2 – active screen, 3, 4 – insulators, 5 – base, 6 – table, 7 – sample (steel AISI 5140), 8 – thermocouple, 9 – glass sample, 10 – temperature display, 11 – power supply.

PLASMA NITRIDING MODES IN ASPN SYSTEM

Parameter	CP mode	FP mode
Pressure	80 Pa	
Discharge voltage	700 V	830 V
Discharge current	12.8 A	15.7 A
Discharge power	9 kW	13 kW
Part temperature	550 ºC	
Heating time	30 min	60 min
Isothermal exposure time	150 min	120 min
Total treatment time	180 min	
Potential applied	cathodic	floating

- **To heat the samples to a temperature of 550 oC, at which the nitriding process is carried out, the CP mode requires a significantly lower value of the glow discharge power than the FP mode.**

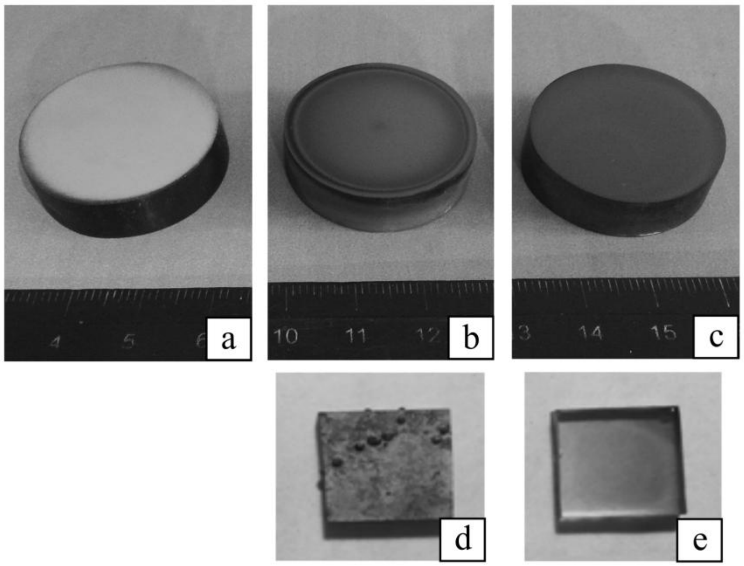

Fig. 4 - The photos of samples: before treating (a), treated in CP mode (b), treated in FP mode (c). The photos of glass samples treated in CP (d), and FP (e) modes.

❑ In FP mode, products of cathode surface sputtering are practically absent on the treated samples. This fact provides unhindered adsorption of atomic nitrogen activated by the discharge and accelerates the diffusion process.

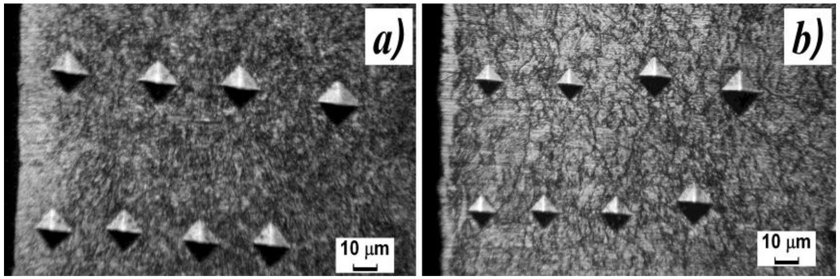

Fig. 5 - Photos of cross-sections of samples treated in CP (a) and FP (b) mode (distance from the edge of the sample is 1500–2000 µm).

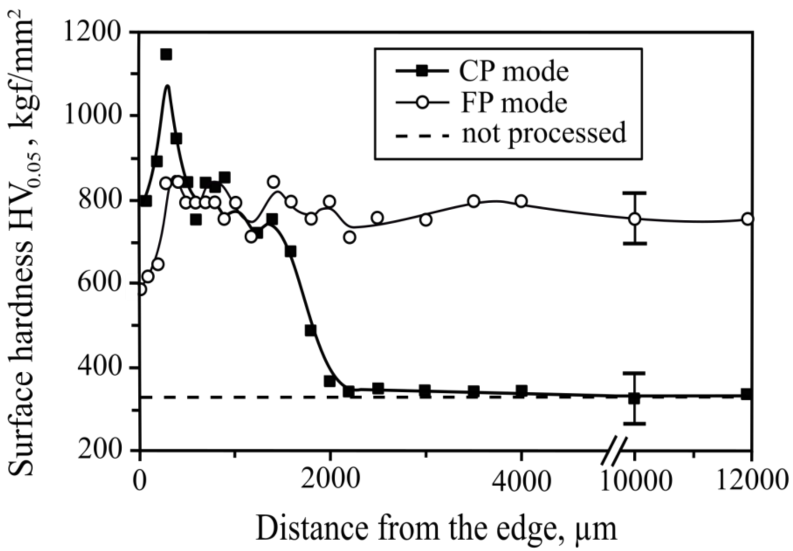

Fig. 6 - Microhardness distribution on the surface of samples (from edge to center of the samples) nitrided in glow discharge with the active screen in pure nitrogen with the pressure of 80 Pa in CP and FP modes.

❑ **The surface of samples treated in the FP mode has a more uniform hardening area compared to the CP mode.**

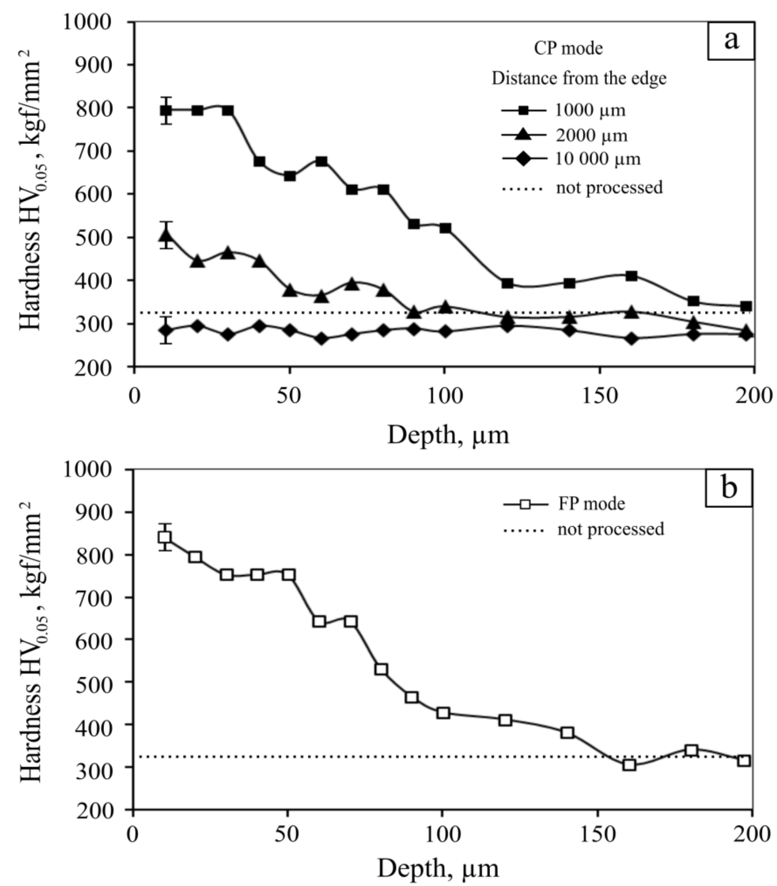

Fig. 7- The microhardness distribution over the depth of samples nitrided in CP (a) and FP (b) mode at a distance of 1000, 2000 and 10000 μm from the edge. The dotted line shows the average hardness of the sample before treatment.

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Conclusion

The experimental data obtained during the study made it possible to formulate the following main conclusions:

1. To heat the samples to a temperature of 550 oC, at which the nitriding process is carried out, the CP mode requires a significantly lower value of the glow discharge power than the FP mode.

2. In FP mode, products of cathode surface sputtering are practically absent on the treated samples. This fact provides unhindered adsorption of atomic nitrogen activated by the discharge and accelerates the diffusion process.

3. The surface of samples treated in the FP mode has a more uniform hardening area compared to the CP mode.

The obtained experimental data indicates a high efficiency of the active screen application in the conditions of hydrogen-free nitriding of steel parts under a floating potential in the glow discharge plasma.