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MODIFYING THE STRUCTURE OF CERTAIN STEEL GRADES BY LOW-TEMPERATURE GLOW DISCHARGE ASSISTED NITRIDING

Keywords

Glow discharge, steel 1H18N9T, steel WCL, nitriding layers.

Abstract

The paper presents the results of studies on the glow discharge assisted nitriding of selected grades of steel (1H18N9T corresponding to EN X6CrNi18-10, and WCL corresponding to EN X37CrMoV51), using the conventional glow discharge nitriding method (the treated parts function as the cathode) and nitriding in the so-called potential of glow discharge plasma. The structure, surface topography, microhardness, phase composition, chemical composition and the residual stress state of the nitrided layers thus produced were examined. The glow discharge nitriding was tested in treating various constructional parts.

Introduction

The technology of glow discharge assisted nitriding is increasingly used in industry, since it is an efficient and economic method of improving the performance properties of machine parts and tools. The advantages of this technology include:

- the possibility of controlling precisely the structure, phase composition and chemical composition of the nitrided layers thus produced,
- the low consumption of electric energy and reactive gases,
- the ease of the masking of the surface prior to the nitriding process,
- the lack of need for work-consuming finishing treatments after the nitriding,
- the possibility of treating steel at low temperatures, beginning from $400^{o}C$ upwards.

These advantages can be achieved, if the process is precisely controlled so that the surface effects that occur at the reactive atmosphere/steel interface and the layer growth kinetics are determined by properly selected process parameters (such as the nitriding temperature, treatment duration, pressure and composition of the atmosphere) and by the surface activation due to the cathode sputtering effect that occur there [1–3].

Great applicative possibilities are opened when the glow discharge nitriding process is accompanied by the surface activation with an electric current of elevated frequency [1, 4], or when the nitriding process is conducted at the so-called plasma potential [5, 6].

1. Experimental procedure

The materials subjected to glow discharge assisted nitriding were 1H18N9T, and WCL steels. The glow discharge assisted process was conducted in a JON-600 apparatus. The steel samples were placed on the cathode or in the plasma region.

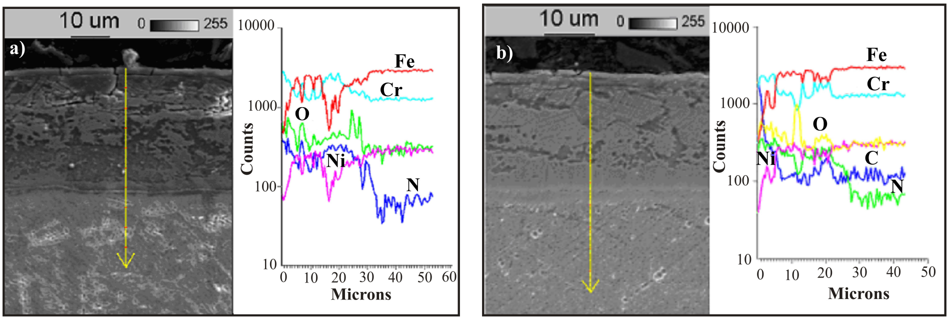
The process parameters were as follows:

- 1H18N9T steel: $T=420^{o}C$, $p=2hPa$ (N_2+H_2), $t=6h$;
- WCL steel: $T=510^{o}C$, $p=1.5hPa$ (N_2+H_2), $t=6h$.

The microstructure was examined in an Olympus IX70 optical microscope and a Hitachi S-3500N scanning electron microscope. The metallographic cross-sections of the 1H18N9T samples were etched in $50\%HCl+25\%HNO_3+25\%H_2$ and those of the WCL samples-in a 2% solution of HNO_3 in ethanol. The chemical composition was determined by the EDS method, and the phase composition was determined using a Philips 1830 X-ray diffractometer with CoKα radiation. The microhardness was measured with a Zwick Materalprufung 3212002 microhardness meter. The residual stress state was determined by the method in the WCL samples, and by in the 1H18N9T samples.

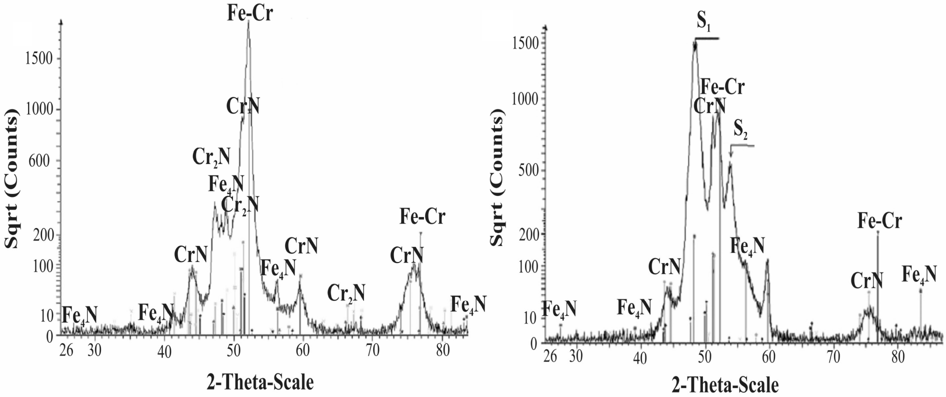
2. Results and discussion

Figs 1, 2 and 3 show the comparative results obtained for nitrided layers produced on 1H18N9T steel by glow discharge assisted nitriding on the cathode and in the plasma region.



a) b)

Fig. 1. Microstructure and atomic distributions of carbon, nitrogen, chromium and iron in the layers nitrided at: a) cathode potential, b) the plasma potential



a) b)

Fig. 2. X-ray diffractogram of the 1H18N9T steel samples glow discharge nitrided: a) on the cathode, b) the plasma region

The surface hardness of the 1H18N9T steel samples nitrided on the cathode was 850 HV0.05, whereas of those nitrided in the plasma region was 770 HV0.05.

Figs. 4, 5 and 6 show the characteristics of the layers produced on WCL steel by nitriding on the cathode and in the plasma region. Fig.7 shows the residual stress distribution in the nitrided layers of the (Fe_4N+Fe_3N)+diffusion layer type, produced on WCL steel.

The results obtained indicate that, when 1H18N9T steel is nitrided at a temperature of 420°C in the plasma region, the nitrided layers are slightly thinner than those produced by conventional glow discharge assisted nitriding, but their primary component is nitrogen austenite, i.e. the phase S. The conventional glow discharge nitriding produces layers with a higher content of chromium nitride (CrN) and iron nitride (Fe_4N) which give a higher surface hardness (nitrided in the plasma region-1170 HV0.05, nitrided on the cathode-1350 HV0.05).

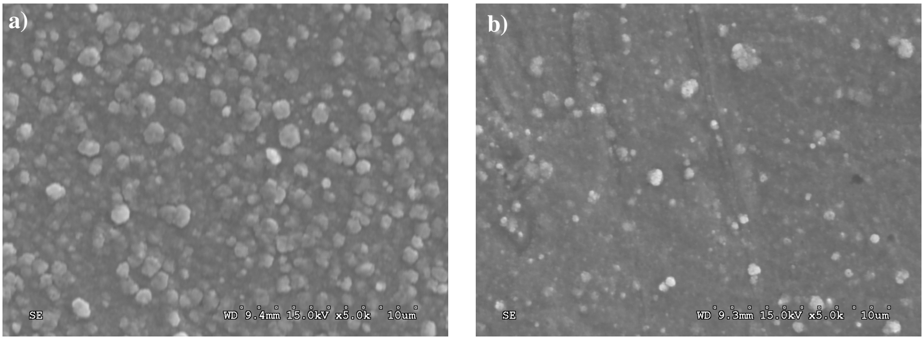


Fig. 3. SEM images of the surface of the layers produced on 1H18N9T steel by nitriding: a) on the cathode, b) and in the plasma region

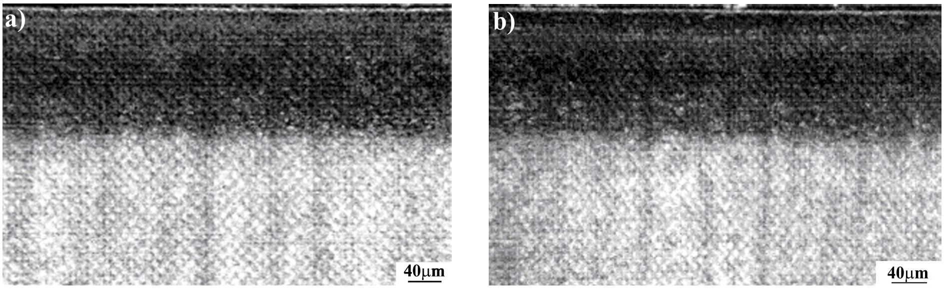


Fig. 4. Microstructure of the nitrided layers produced on WCL steel at a temperature of 510°C: a) on the cathode, b)in the plasma region (b)

It should also be noted that the low-temperature glow discharge nitriding yields uniform layers, without the so-called edge effect, which consists of the layer surface in the near-edge region being more developed (Fig. 8). This is important in many applications, in particular when treating parts of complicated shapes, e.g., precision products, medical instruments, etc. (Fig. 9).

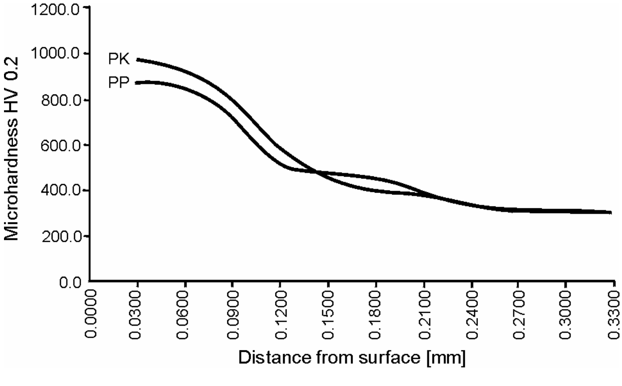


Fig. 5. Distribution of the HV0.2 microhardness in the layers produced on WCL steel by nitriding on the cathode (PK) and in the plasma region (PP)

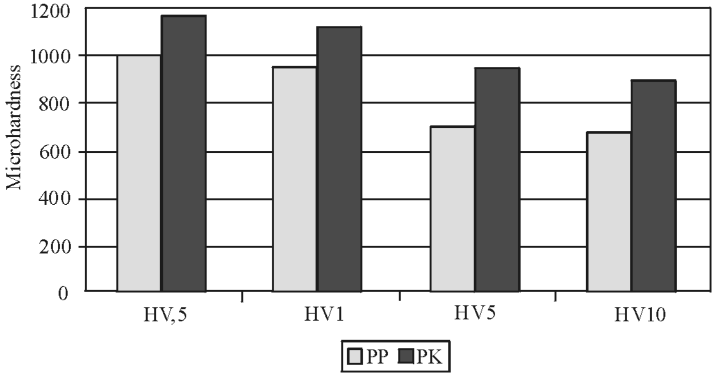


Fig. 6. Surface hardness of the layers produced on WCL steel nitrided on the cathode (PK) and in the plasma region (PP)

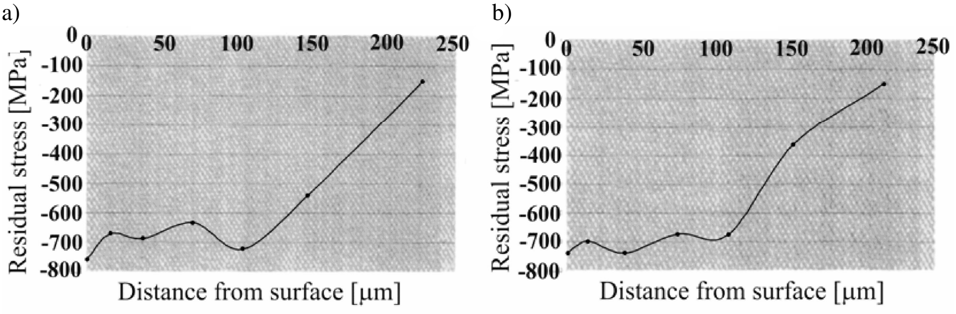


Fig. 7. Residual stress distribution in the nitrided layers produced on WCL steel at the temperature of 510°C: a) on the cathode (PK), b) in the plasma region (PP)

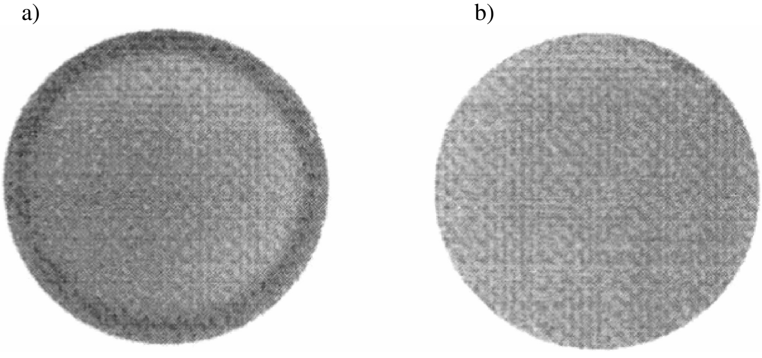


Fig. 8. Appearance of the 1H18N9T steel samples nitrided: s) at the cathode potential (PK) and b) in the plasma region (PP)

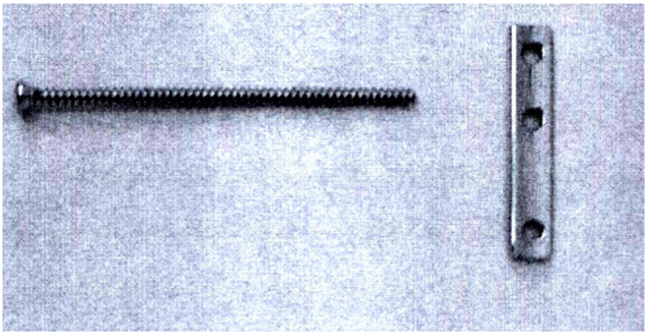


Fig. 9. Examples of biomaterial products (1H18N9T steel) nitrided in the plasma region

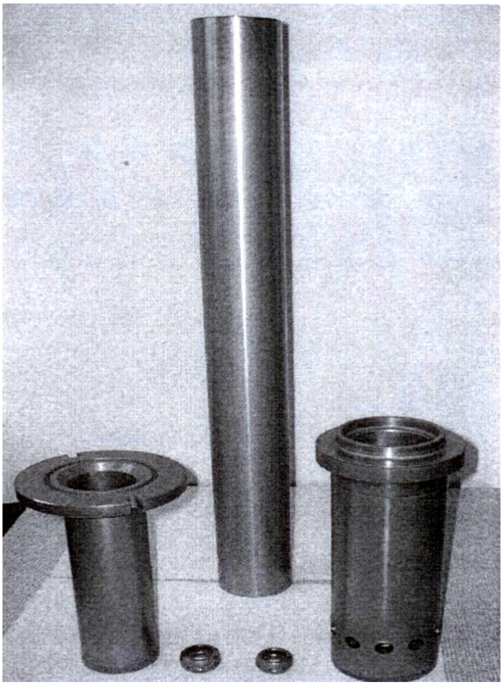


Fig. 10. Examples of products of stainless steel nitrided in the plasma region

In the WCL samples nitrided at a temperature of 510°C, the only difference in the structure between the nitrided layers lies in the thickness of the compound phase and in the contents of the Fe_4N and $Fe_{2.5}N$ phases in the compound zone of the nitrided layer, which result in its surface hardness being varied (Fig. 6).

Conclusions

Glow discharge nitriding at the plasma potential plays the crucial role in the low-temperature treatments of austenitic steel, since it ensures good frictional wear resistance and high corrosion resistance, and permits treating parts of complicated shapes [2, 3, 5]. This technique can thus widen the application range of the glow discharge assisted nitriding to include treating products, such as precision components of various devices, medical instruments, and precision products of complicated shapes made of austenitic steel, H21N4 steel with a high content of chromium used for fabrication of combustion engine valves, or steel of the 3H13 type (X30Cr13) [7].

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Kształtowanie struktury wybranych gatunków stali w procesie niskotemperaturowego azotowania jarzeniowego

Słowa kluczowe

Wyładowanie jarzeniowe, stal 1H18N9T, stal WCL, warstwy azotowane.

Streszczenie

W artykule przedstawiono wyniki badań procesów azotowania jarzeniowego wybranych gatunków stali (1H18N9T odpowiednik EN X6CrNi18-10, WCL odpowiednik EN X37CrMoV51) metodą konwencjonalną (obrabiane detale jako katoda) oraz azotowanych na tzw. potencjale plazmy wyładowania jarzeniowego. Omówiono wyniki badań, struktury, topografii powierzchni, pomiary mikrotwardości, skład fazowy i chemiczny wytworzonych warstw azotowanych oraz stan naprężeń własnych. Proces azotowania jarzeniowego w obszarze plazmy zastosowano do obróbki konstrukcyjnych wyrobów.