Effect of Nitriding Conditions on 304 Stainless-Steel Plasma Nitrided with Ni Screen

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This study investigates the effects of the treatment temperature and time on the S-DCPN (direct current plasma nitriding with screen) treatment using Ni screens. Austenitic stainless steel SUS304 is used as the substrate material, and S-DCPN treatment is performed at treatment temperatures of 673, 723, and 773 K, treatment times of 4 and 16 h, gas pressure of 200 Pa, and treatment gas composition of 75% N_2 and 25% H_2. A Ni mesh is used as the Ni screen. The results of the S-DCPN treatment using a Ni screen on SUS304 after nitridation under each condition confirm that an expanded austenite (S phase) with supersaturated nitrogen solid solution is produced under all conditions, along with a nitrided layer. Ni deposits are formed on the sample surface under all conditions from X-ray diffraction and optical microstructure. The nitrided layer becomes thicker as the treatment temperature and time increase under all conditions. These results indicate that the nitridation efficiency improves upon using the Ni screen.

Keywords: *plasma nitriding, screen, nickel, 304 stainless-steel, nitrogen diffusion layer*

1. Introduction

In the plasma nitriding using a screen (S-DCPN) method, a metal screen and treated material are used as a cathode and voltage is applied. In the plasma generated around the screen, metal atoms sputtered from the screen combine with excited nitrogen species, and the metal nitride formed is deposited on the treated material surface. Nitrogen diffuses into the treated material through decomposition. At this time, a layer of metal nitrides that has not been completely decomposed on the treated material surface (deposits layer) inhibits nitrogen diffusion, but because voltage is also applied to the treated material, sputtering also occurs on the treated material surface, and the deposits layer is removed. This reduces edge effects and arcing, which can lead to defects in the treated material[1)]. Since steel is generally used as the screen material in S-DCPN processing, there have been few reports on the use of nonferrous material screens. In this study, we focused on Ni screens, because nickel nitrides derived from Ni screens are less stable than iron nitrides derived from conventional steel screens, which are reported to be more decomposed on the surface of the treated material, allowing more nitrogen to diffuse into the specimen[2)]. However, much remains unclear about this Ni screen. Based on the above background, this study investigates the effects of treatment temperature and time on S-DCPN treatment using Ni screens.

2. Experiment

The austenitic stainless steel SUS304 was used as the substrate material, and S-DCPN treatment was performed at treatment temperatures of 673 K, 723 K, and 773 K, treatment time of 4 h and 16 h, gas pressure of 200 Pa, and treatment gas composition of N_2:H_2 = 3:1. A Ni mesh material was used as a screen. The treated specimens were subjected to visual observation, X-ray diffraction (XRD) test, grazing incidence X-ray diffraction (GI-XRD) test, surface observation, surface roughness test, hardness test, cross-sectional microstructure observation, glow discharge optical emission spectrometry (GD-OES), and corrosion test to evaluate various properties.

3. Results and Discussion

3.1 X-ray diffraction

Figure 1 shows the results of XRD tests of SUS304 treated with S-DCPN using a Ni screen after nitriding under various conditions. Figure 1 shows that the S-phase, in which nitrogen is supersaturated in the austenite phase, was detected under all conditions. The S-phase shifted to the low-angle side as the treatment temperature and time increased. This is because the austenite phase expands and the interatomic distance increases due to the supersaturated solid solution of more nitrogen in the austenite phase. This is thought to have caused the diffraction peaks to shift to the lower angle side.

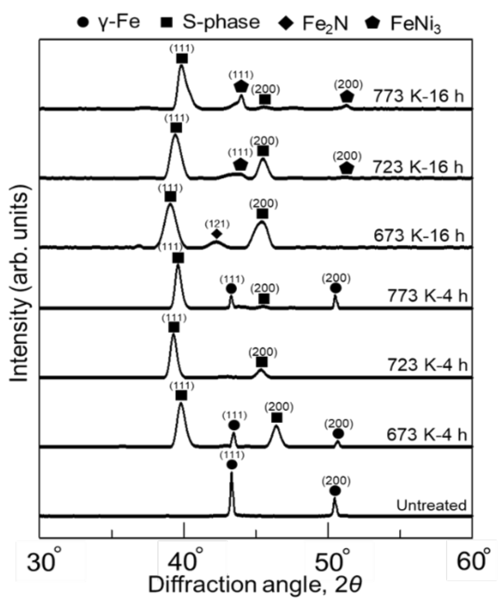

Fig. 1 XRD pattern of SUS304 sample treated by S-DCPN.

3.2 Grazing incidence X-ray diffraction

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Figure 2 shows the results of GI-XRD tests after nitriding, and it can be seen that Ni compounds or Ni were detected in all conditions. This suggests that the deposits layer on the sample surface was formed by screen-derived Ni. The detection of Ni at 723 K for 16 h and at 773 K suggests that the Ni nitride was completely decomposed.

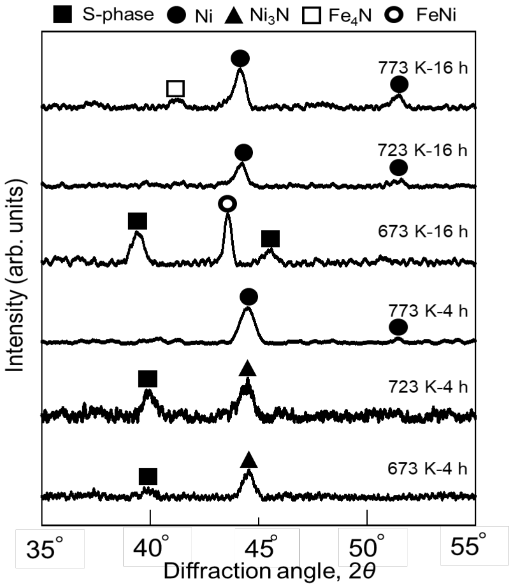

Fig. 2 GI-XRD pattern of SUS304 sample treated by S-DCPN.

3.3 Cross-sectional microstructure observation

Figure 3 shows the results of cross-sectional microstructural observation of the specimens after nitriding treatment. Figure 3 shows that corrosion-resistant S-phase was observed in the cross sections of the 673 K and 723 K 4 h treatments. Black corrosion traces were observed in the nitrided specimens at 723 K for 16 h and at 773 K. This is due to the presence of Cr in the base metal. This is considered to be due to the decrease in the amount of Cr required to form the passivation film and the decrease in corrosion resistance as a result of the precipitation of CrN due to the bonding of Cr with nitrogen in the base metal.

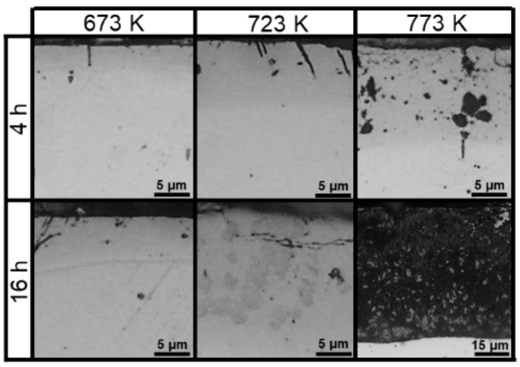

Fig. 3 Cross-sectional microstructure of SUS304 treated by S-DCPN.

3.4 Hardness test

Figure 4 shows the results of the hardness test of the cross section after nitriding treatment. Figure 4 shows that all of the samples were hardened and became harder internally as the treatment temperature and time increased. This is thought to be due to the effect of the Ni deposits layer on the surface and the diffused nitrogen in the interior.

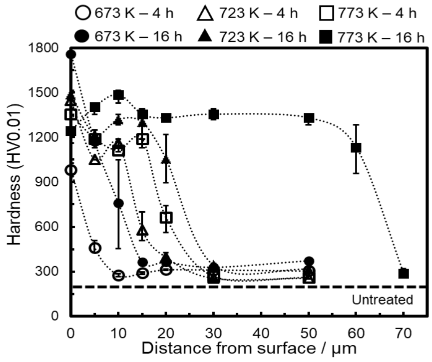

Fig. 4 Surface and cross-sectional hardness of SUS304 treated by S-DCPN.

3.5 Corrosion test

Figure 5 shows a comparison of the pitting potential at 1.0 Am^{-2} (pitting corrosion potential) in the corrosion test results after nitriding. The reasons for the decrease in corrosion resistance are considered to be CrN precipitation, the decrease in N concentration due to Ni diffusion into the interior, and the increase in the grain size of the deposits as the treatment temperature and time increased, resulting in the progression of corrosion due to the increase in the number of gaps. On the other hand, CrN, which improved corrosion resistance, did not precipitate, and the nitrogen diffusing inside prevented a low pH environment, which is thought to have improved corrosion resistance.

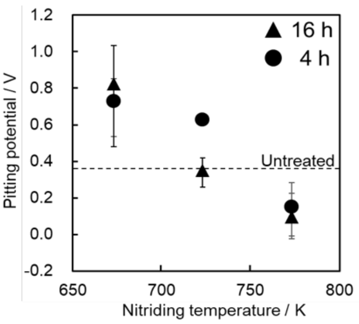

Fig. 5 Corrosion resistance of SUS304 treated by S-DCPN.

4. Conclusions

The results of S-DCPN treatment using a Ni screen on austenitic stainless steel SUS304 and evaluation of the nitriding layer at each treatment temperature and time showed that the nitriding layer became thicker as the treatment temperature and time increased, and that the corrosion resistance was most improved at low temperature and long time.

References

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