Effecte of Nitrogen Ion Implanted on Corrosion Behavior of Aisi 304 Stainless Steel

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Abstract

This work presents the results of a low energy nitrogen ion implantation of AISI 304 type stainless steel (SS) at moderate temperatures of about 500°C. The nitrogen ions are extracted from a Kauffman type ion source at a Energy of 30 keV, and ion current density of 100 µA cm^{-2}. In our study the nitrogen dose of 6×10^{17}, 8×10^{17} and 10^{18} ions cm^{-2}, were selected. The X-ray diffraction results show the formation of CrN polycrystalline phase after nitrogen bombardment and a change of crystallinity degree due to the dose effect the image analysis of implanted samples clearly shows significant changes in surface . Corrosion test has shown that corrosion resistance is enhanced by increasing dose.

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Introduction

Ion implantation has been used to modify the physical and chemical properties of a wide range of metals and super-alloys using different plasma techniques for ion sources and plasma surface treatment [1-2]. High dose ion implantation is also a well-known technique to improve the mechanical properties of metals [3-6]. There have been number of investigations about increasing of microhardness, wear resistance and finally improvement of the corrosion resistance [7-9]. The AISI 304 type stainless steel (SS) which contains high chromium content is a commonly used engineering material mainly because of its corrosion resistance. High dose ion implantation is a possible solution for producing nitride phases layers in a 304 type SS. New phases or structures can be borne enhancing the surface properties of the treated materials.

The microstructure and phase composition of ion implanted surface layers are controlled by the implantation parameters (ions energy, dose rate and processing temperature), which can be maintained easily and precisely. This control was typically performed at high temperature, high doses and different energies under high vacuum conditions.

For the treatment of stainless steel materials, it is important to improve the surface mechanical properties without degrading the corrosion resistance. Therefore, in this work, we have focused on the effects of the ion implantation treatment on the corrosion resistance of the samples.

Materials and experimental techniques

The AISI 304 steel samples of 6×18×0.3 which were ultrasonically cleaned using alcohol and acetone. Implantation of samples was performed using Implanter of Plasma Physics Research Center of I.A.University, which could generate gas ions with maximum 30 keV and elliptic beam size 110×250 mm. The background pressure of $4.8×10^{-6}$ torr decrease to $1.6×10^{-5}$ torr during implantation. Table 1, shows the chemical composition of the AISI 304 steel sample surface which determined by using of Scanning Electron Microscopy (LEO440I) SEM that was equipped with Energy Dispersive X-ray (EDX). The given values are the average of concentrations measured at four different points of samples.

Elements	C*	Fe	Cr	Ni	Ma
Consecration(w%)	0.08	71.06	20.12	7.84	0.89

Table 1: chemical composition of AISI 304 steel (Wt %) determinate by EDX analysis

The implantation parameters were summarized in table 2. X-ray diffraction patterns were recorded at room temperature by SEIFERT XRD PTS 3003 diffractometer using Ni filtered CuKα1 radiation with a step size of 0.05° 2θ.

Sample	1	2	3
Energy(keV)	30	30	30
Ion current($\mu A/cm^2$)	100	100	100
Dose(ions/cm^2)	$6×10^{17}$	$8×10^{17}$	$1×10^{18}$
Time(s)	960	1280	1600
Temperature(°C)	500	500	500

Table 2: The process parameter during implantation

X-ray diffraction analysis was carried out to study micro structural changes and new phases formation induced by the ion implantation. Optical microscopy (Leica Q500) was used to study the samples surface morphology

The potentiodynamic polarization test was performed in 3wt. % NaCl solution made of analytical grade regents and distilled water. The scanning rate was 0.5 mV min^{-1}.The tests performed by EG&G model 273A potentiostat coupled to PC of I.A.University.

Results and discussion

XRD patterns of the ion implanted and untreated samples were shown in Fig. 1.From fig. 1.a, it is clear that the untreated sample presents a single phase γ-Fe with sharp peaks which are typical of annealed materials.

According to the Fig. 1(b), (c) and (d), it can be seen that for the ion implanted sample, all peaks were shifted to lower angles and were broadened considerably. The shift and broadening of the peaks are associated with the 'expanded austenite' (γ_N) phase [10, 11] produced by nitrogen supersaturation and associated stress caused by the nitrogen remaining in solid solution in the fcc lattice. Also it can be concluded that the ion implanted CrN samples produced at 500°C is composed mainly of the CrN phases and the degree of crystallinity change depended on the N doses. It is suggested that CrN would be precipitated during the implantation at 500°C [12]. It should be noted that although the X-ray penetration depth is estimated to be approximately 2.5 μm under our diffraction condition, XRD results can be representative of the whole layers due to the homogeneity of γ phase's constituents of the layers seen from Fig. 1.
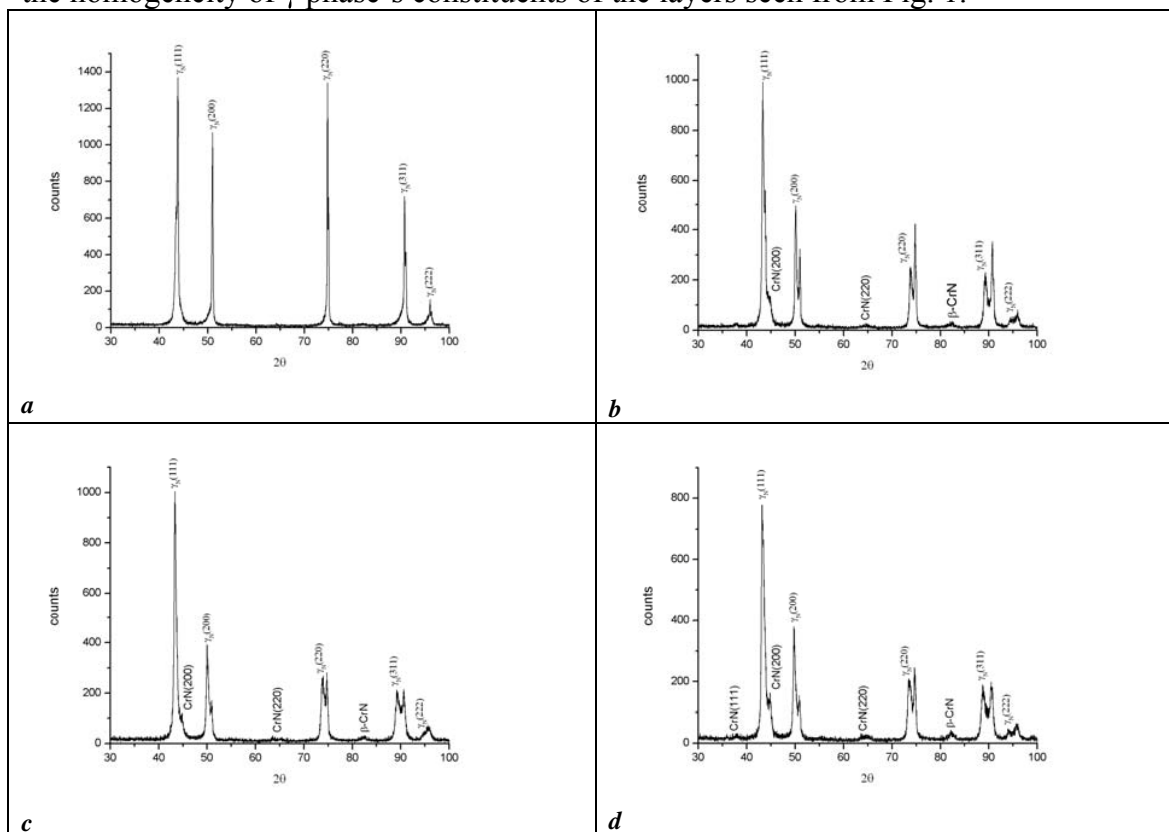

Figure 1. XRD pattern for different doses (a) untreated sample (b) 6×10^{17} ion/cm^2 (c) 8×10^{17} ion/cm^2 (d) with 1×10^{18} ion/cm^2.

Fig. 2.shows optical microscopy images before and after nitrogen implantation which obviously indicate interesting changes as a result of increasing dose.Fig2.(a), was obtained from unimplanted sample for comparison with other implanted samples. Fig2. (b) to (d), show implanted surface at 6×10^{17} , 8×10^{17} , 1×10^{18} ions/cm2 doses respectively . In 6×10^{17} dose (Fig2.b), domain boundaries are starting to appear. By increasing the doses to 8×10^{17} (Fig2.c), it seems that domain boundaries are separated and white area on boundaries due to nitride phases are formed. After further increasing of the dose up to 1×10^{18} (Fig2.d), another behavior was observed that domain boundaries were disappeared or became very smaller.
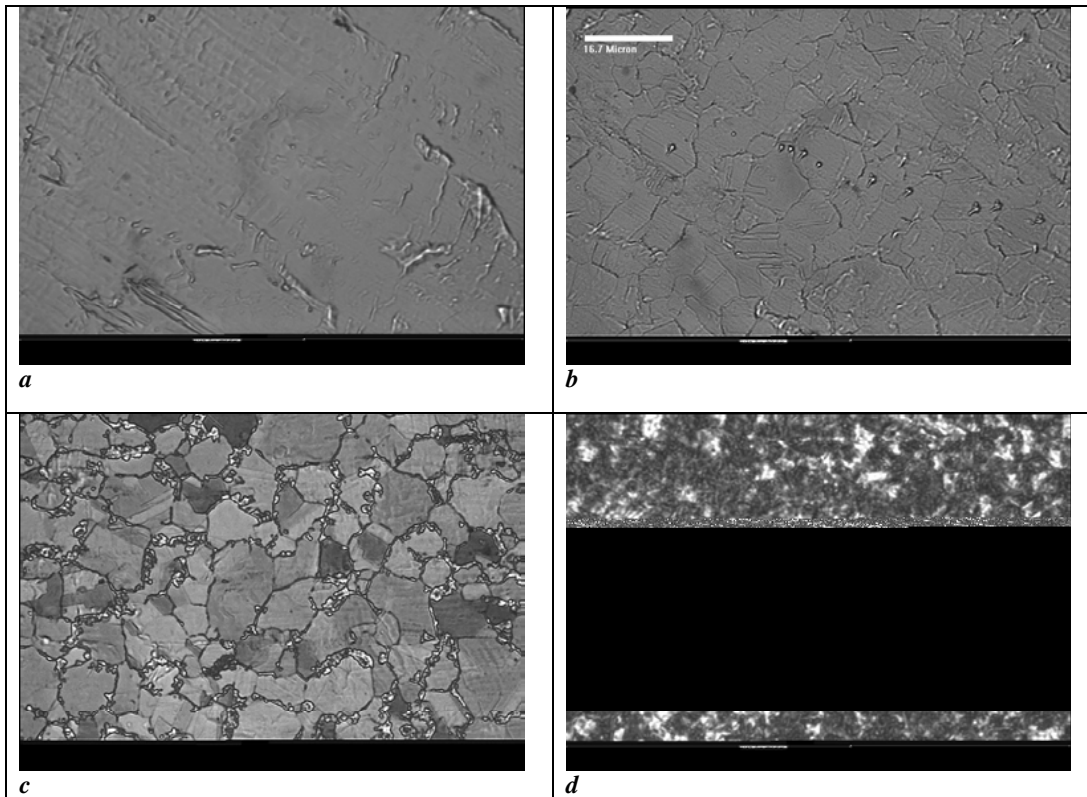

Figure2. Microstructure of the surface layer of nitrogen ionimplanted steels: (a) unimplanted sample (b) sample implanted with 6×10^{17} ion/cm^2 (c) sample implanted with 8×10^{17} ion/cm^2 (d) sample implanted with 1018 ion/cm^2.

The result of the electrochemical corrosion measurement for the sample treated at 1×10^{18} ion cm^{-2} is plotted in Fig. 3.
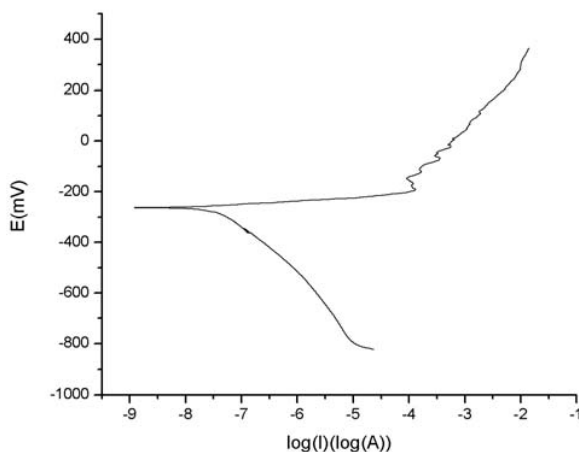
Figure 3. Potentiodynamic polarization curves acquired from the AISI304 in 3 wt. % NaCl solution for dose of 1×10^{18} Ncm^{-2}.

All the treated samples show improved corrosion resistance, a low corrosion current at the equilibrium potential, as well as a very low dissolution current. For example, at -260 mV, the dissolution current is 2.436 µA for the untreated sample, but this current diminishes to about 885.1, 43.75, 31.8 nA for implanted samples at 6×10^{17}, 8×10^{17}, 1×10^{18} ions cm^{-2} doses respectively (Fig. 4). Corrosion testes were performed at 0.5 cm^2 area.
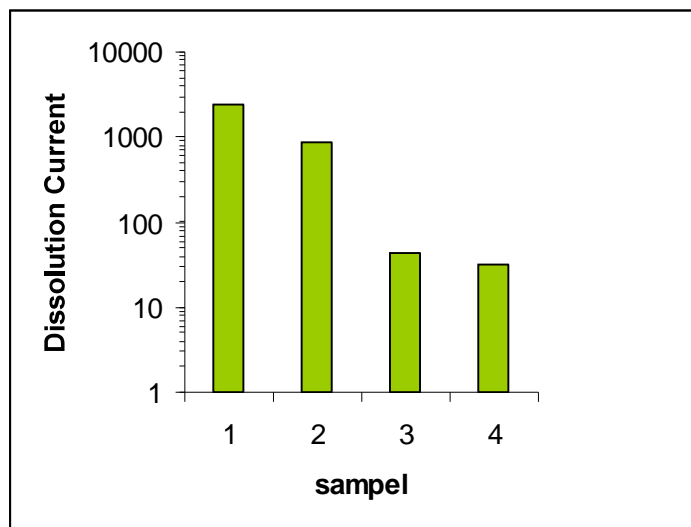

Figure 4. Comparison of dose effect in AISI304 dissolution current in wt. % NaCl solution

Conclusions

It is well known that the corrosion behavior depends on the nitrogen introduced on the steel and composition especially on Cr contents.

As an effort to enhance the corrosion resistance of AISI304, it is suitable to increase the concentration of Cr on its surface. As is well known, anticorrosive effect can be obtained when Cr is in excess of 20% in an iron matrix.

In our experiments electrochemical tests showed that the ion implantation prompted the formation of a stable passive layer probably due to the presence of CrN and γ_N phases shown by XRD resultes.

Acknowledgement

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