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Influence of Ar, Al, and N Ion Implantation on the Surface Properties of the OOH18M2Nb Steel³⁾

By

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By means of potentiokinetic and galvanostatic investigations the effect of Ar, Al, and N ion implantation ($E = 100$ keV, $D_1 = 10^{15}$ cm⁻², $D_2 = 10^{16}$ cm⁻²) on the corrosion resistance of OOH18M2Nb steel is examined. It was found that the irradiation of steel with higher dose of ions generally improves its corrosion resistance. On the base of reflected electron diffraction and X-ray microanalysis data this effect is considered to be connected with the ion-stimulated adsorption of hydrocarbons and amorphisation of the steel surface.

При помощи потенциокинетических и гальваностатических методов исследовано влияние имплантации ионов Ar, Al, N ($E = 100$ keV, $D_1 = 10^{15}$ см⁻², $D_2 = 10^{16}$ см⁻²) на электрохимические свойства стали ООХ18М2Б. Было показано, что облучение большей дозой ионов повышает устойчивость стали к общей коррозии на основе данных дифракции электронов на отражение и рентгеновского микроанализа предполагается, что этот эффект вызван ионно-стимулированной адсорбцией углеводородов и аморфизацией поверхностных слоев стали.

1. Introduction

Ion implantation is a powerful method to change the physico-chemical properties of the surface layer of metals. By means of this method the improvement of corrosion and wear resistance of materials could be achieved [1 to 3]. The results of an investigation of the influence of Ar, Al, and N ions implantation on corrosion properties, structure, and surface layer composition of OOH18M2Nb steel are presented in this paper.

2. Experimental Procedure

2.1 Material

Circular samples, 15 mm in diameter and 1 mm thick, were used in experiments. In Table 1 the chemical composition of the investigated steel is presented.

All samples were polished on abrasive paper number 200 and 400, then etched in 0.05% HNO₃ solution for 3 min. After this they were washed with distilled water and finally dried.

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Table 1
Chemical composition of the steel (in mass %)

C	N	Si	Mn	Cr	Mo	S	D	Nb	Ni
0.02	0.017	0.05	0.29	18	2.1	0.015	0.031	0.05	0

2.2 Ion implantation

Implantations of Ar, Al, and N ions were realised on the ion implanter made in IBJ Świerk. Energy of ions was 100 keV, vacuum about 10^{-5} Torr, density of ion current about $0.3 \mu\text{A}/\text{cm}^2$, and doses 10^{15} and 10^{16} cm^{-2} .

2.3 Measurements

Electro-chemical properties of non-implanted and implanted steel were evaluated by the following parameters: a) polarisation curves recorded in deoxidated solution of acetate buffer (4.35 pH) with the velocity of potential changes 1 mV s^{-1} ; b) galvanostatic curves, potential-time, for anodic dissolution of steel in the solution: 28 g H_2SO_4 (1.84 kg dm^{-3}), 66 g H_3PO_4 (1.7 kg dm^{-3}), and 7 g diethylene glycol monobutyl ether. Density of current was 50 mA cm^{-2} and the rate of dissolution 5 nm s^{-1} .

Composition and structure of the surface layers of steel were studied by electron-probe X-ray microanalysis and reflected electron diffraction. The depth of the layer for the X-ray examination was 1 nm and for the electron diffraction — 2 to 5 nm.

3. Results and Discussion

In Fig. 1 anodic polarisation curves of non-implanted and implanted steel with Ar, Al, N ions with dose 10^{16} cm^{-2} are presented. Implantation with this higher dose in contrast to the dose 10^{15} cm^{-2} , influences visibly the shape of polarisation curves. It leads to a widening of the passivity region of the steel and a marked decrease of anodic current.

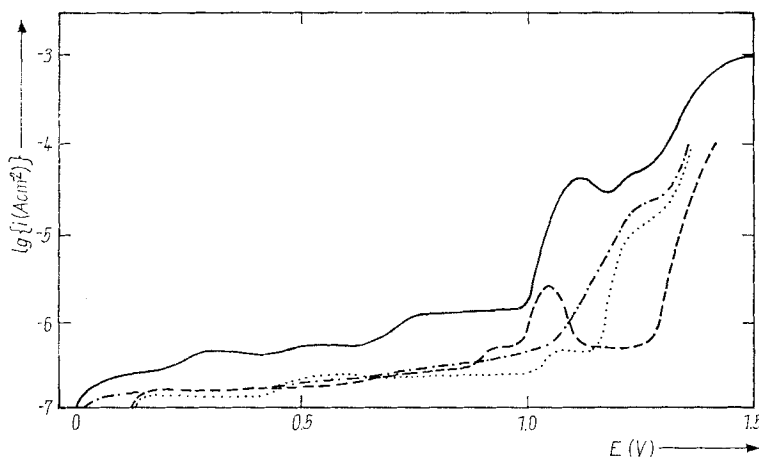


Fig. 1. Anodic polarisation curves of the OOH18M2Nb steel non-implanted (—) and implanted with Ar (---), Al (-.-), N (.....) ions in deoxidated acetate buffer solution (doses $10^{16} \text{ ions/cm}^2$). E at the abscissa means the potential with respect to the saturated calomel electrode

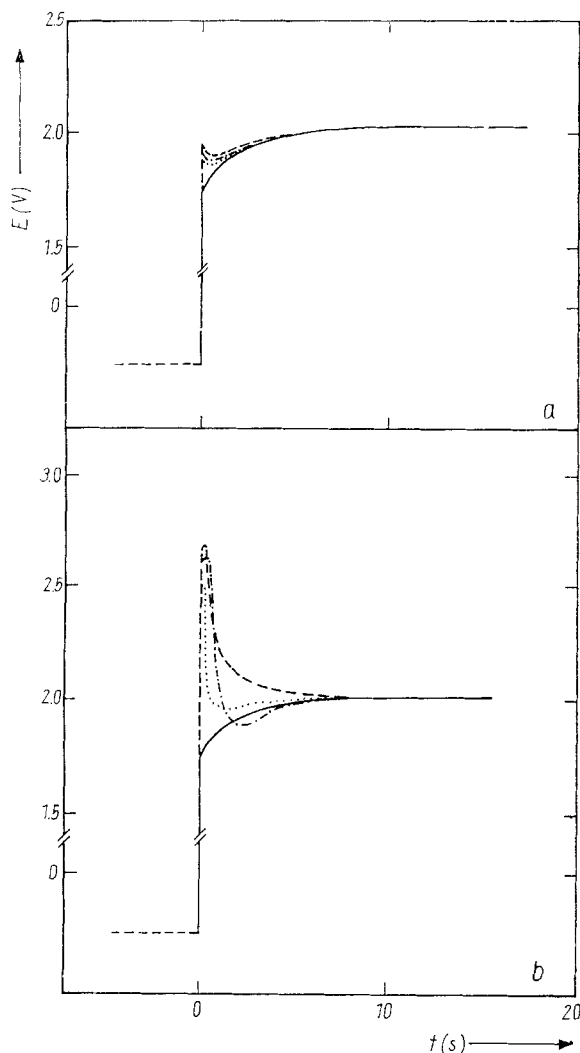


Fig. 2. Influence of Ar, Al, N implantation on the potential of the OOH18M2Nb steel during anodic dissolution (doses: a) 10^{15} and b) 10^{16} cm^{-2}). For symbols see Fig. 1. E at the ordinate means the potential with respect to the saturated calomel electrode

The galvanostatic curves for the implanted steels (Fig. 2) have characteristic maxima indicating the existence of outer layers with higher resistance to the anodic dissolution. The depth of these layers is a few nanometres. The position of these maxima do not coincide with the maxima of theoretical depth distributions of implanted Ar, Al, N into Fe [4] (see Fig. 3).

It is supposed that the improvement of the anodic resistance is not caused by the presence of implanted elements in the surface layer, but with another process occurring during ion implantation. The X-ray microanalysis data show that the amount of C in the surface layer of steel is considerably changing. The X-ray C and O signals from non-implanted steel were 150 and 190. It is seen that the content of O_2 in surface layers of steel is not markedly changed by implantation. The decreased amount of C at implantation with lower dose with respect to implantation with higher dose allows to think that during the implantation two competitive processes are appearing —

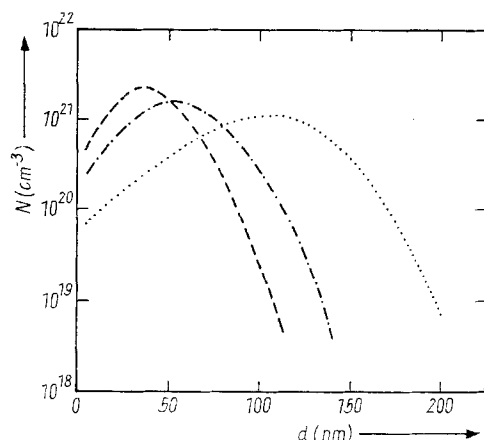


Fig. 3. Theoretical spatial distribution of Ar (---), Al (-.-.), N (.....) implanted into Fe ($E = 100$ keV, $D = 10^{16}$ cm $^{-2}$)

removing and accumulating of carbon. Accumulating of C on the surface of steel is probably caused by ion-stimulated adsorption of hydrocarbons in residual gases [5].

Table 2

X-ray signals of C and O from the irradiated steel samples (pulses s $^{-1}$)

dose (cm $^{-2}$)	Ar		Al		N	
element	10 15	10 16	10 15	10 16	10 15	10 16
C	100	310	100	410	60	170
O	200	200	190	230	220	200

The reflected electron diffraction analysis indicates that the surface layer of the steel is amorphised by implanted ions. It is known that amorphisation of the surface layer favours the creation of more perfect passive layers and usually improves the corrosion resistance.

Potentiokinetic and galvanostatic investigations demonstrate that implantation with 10^{16} cm $^{-2}$ Ar, Al, N ions in the OOH18M2Nb steel improves the corrosion resistance of the steel. This effect, in the light of present results is not connected with the presence of implanted elements in the surface layer of the steel. It is probably connected with the ion stimulated adsorption of hydrocarbons and by the amorphisation of the steel surface.

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