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TEXTURE, MICROHARDNESS AND CORROSION RESISTANCE OF 316L STAINLESS STEEL

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Abstract

The texture, microhardness, and corrosion resistance of cold worked 316L steel were evaluated. The X-ray diffraction analysis in particular permitted to disclose and identify the main textures variations in the structure of the investigated steel after its deformation within the range 10 - 80%. The corrosion resistance was studied using Tafel polarization tests. It was shown that the increase in deformation degree drastically decreases the relative intensity of {111} planes. Besides, with high degree of cold deformation microhardness increases while corrosion resistance deteriorates.
Keywords: Cold deformation, Texture, Microhardness, Corrosion resistance

Introduction

The stainless steels offer excellent ductility, formability, corrosion and creep resistance [1-3]. Stainless steels have greater heat capacity and thermal expansion, with lower thermal conductivity than other steels [2]. These materials are strengthened by work-hardening and cannot be hardened by heat treatment [1, 2, 4]. To obtain corrosion resistance and other characteristics of stainless steels an amount of 12 wt.% or more of chromium is required [2, 4]. Chromium reacts rapidly with oxygen creating a protective layer of chromium oxide on the surface. If the oxide layer get damaged it self-repairs because of the rapidly reaction between chromium and oxygen [2].

Texture is the distribution of crystallographic orientations of a polycrystalline sample. Material properties such as strength, chemical reactivity, corrosion resistance, weldability, can be highly dependent on the material's texture and related changes in microstructure [5-6].

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It is well known the fact that the cold deformation can affect the texture in most alloys [7].

The intention of this study is therefore to investigate the link between the effects of cold rolling deformation on the texture evolution and resulting hardness and corrosion properties of 316L stainless steel.

Material and methods

Chemical composition of stainless steel 316L is shown in Table 1. The initial materials were cold rolled to thickness of 7mm and then by controlled rolling to thickness of 6.3mm, 3.5mm and 1.4mm produced with 10%, 50% and 80% reductions.

Table 1. Chemical composition of stainless steel 316 L (wt.%)

C	Si	Mn	P	S	Cr	Ni	Mo	Fe
0.04	1.00	2.00	0.045	0.030	0.058	10.00-14.00	2.00-3.00	Balance

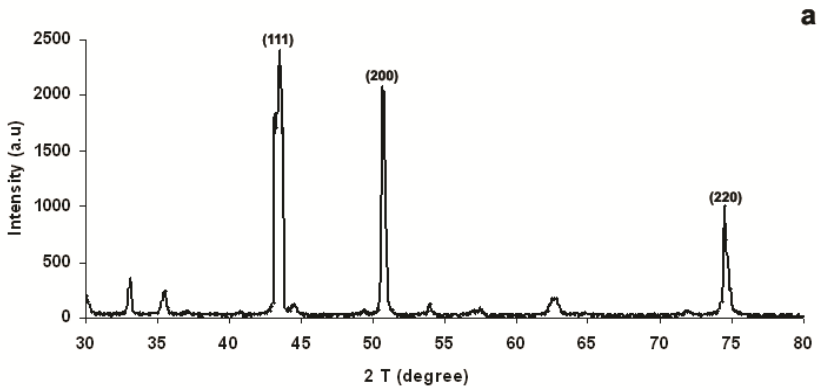
The XRD characterization was performed using a Philips PW 3710 diffractometer, with CuKα (λ=1.5406 Å), in order to determine the phase structure and phase characteristics.

The hardness test was carried out to measure the microhardness of both the virgin and rolled specimens. The Ever One, Model no MH-3 (Germany) microhardness testing machine was used to carry out the test. The hardness profile of the surface layers was measured with varying loads ranging from 10 gms to 100 gms. The Vickers hardness of AISI 316L stainless steel is found to be 185 HV.

The corrosion current density (I_{Corr}), corrosion potentials(E_{Corr}) were estimated by linear fit and Tafel extrapolation to the cathodic part of the polarization curve.

Results and discussion

The corrosion properties depend not only on the microstructure but also on the texture developed. On the other hand, texture may be influenced by the mode and degree of deformation [8]. Figure 1 presents the XRD patterns of the specimens.



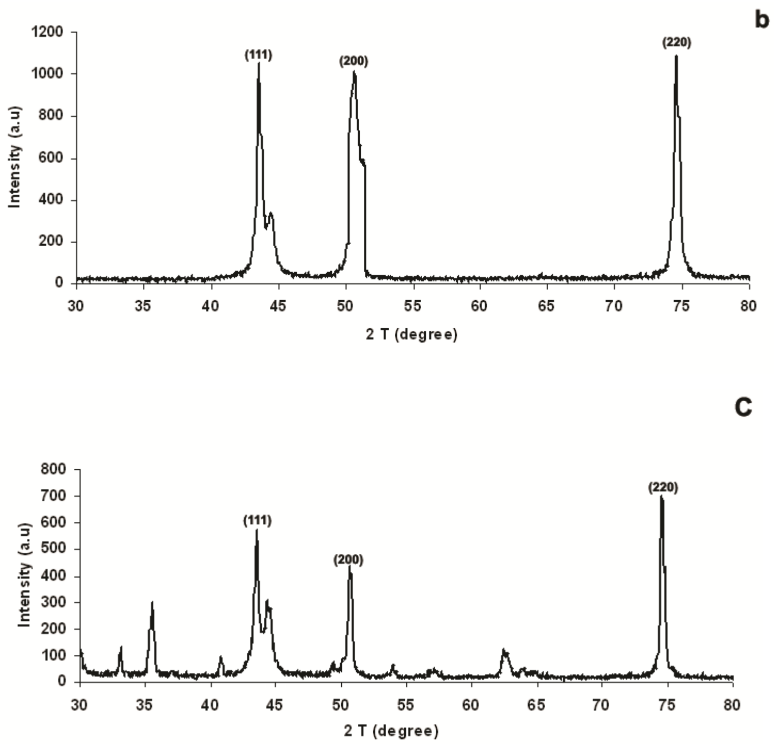


Fig. 1 The XRD patterns of 316L specimens (10% (a), 50% (b), 80% (c)).

Strain hardening of steel after cold working was determined by Vickers hardness measurements (Figure 2). On their ground, a double increase of microhardness was found, from 185 HV1 for the material as-delivered to 390 HV for the material with cold deformation ratio of 80.

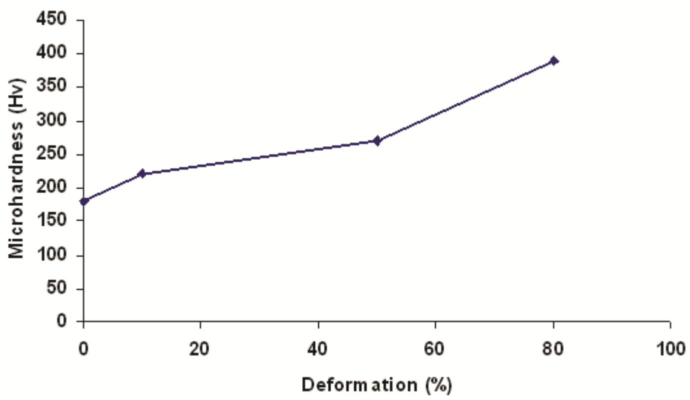


Fig. 2. Effect of cold deformation degree on microhardness of 316L specimens.

For the specimens with various degree of cold deformation, Tafel polarization curves were drawn (Figure 3). Shape of the polarization characteristics was similar for all the examined specimens. The corrosion potential E_{Corr} and I_{Corr} values were determined by extrapolation of the Tafel curves (Table 2).

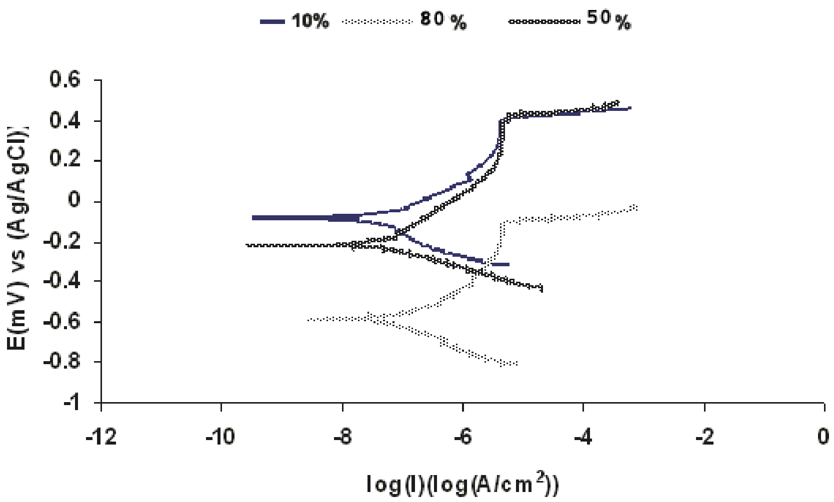


Fig. 3. Tafel polarization curves of 316L specimens.

Table 2. Tafel polarization results for 316L steel.

Deformation (%)	E_{Corr} (mV)	I_{Corr} (nA)
10	-110	42
50	-221	90
80	-590	320

The corrosion potential value was –110 mV for the 10% cold deformation and declined to –590 mV for the specimen with 80% cold deformation. Such a potential difference is sufficient for corrosion occurrence in the case when some places with differentiated cold deformation degree exist in the material. The corrosion current density increased over 7 times from 42 nA/cm^2 for 10% cold deformation to 320 nA/cm^2 for the specimen with the highest cold deformation. The results for all the specimens are shown in Table 3. The results indicate that the corrosion resistance of the 316L steel declines with increasing strain hardening degree.

The increase of dislocation density generated by deformation leads to a higher stored energy, thus increasing the electron activity and consequently the driving force for the electrochemical reactions [9]. In Figure 4 the relationship between deformation, relative intensity of {111} planes and corrosion current density is depicted. As can be seen, increasing the degree of deformation would decrease the relative intensity of {111} planes. The {111} planes, due to highest number of nearest neighbor atoms have strong corrosion resistance. Hence, decreasing relative intensity of {111} planes would result in decreasing corrosion resistance. Moreover, the specimens with the low degree of cold deformation present a high intensity of the (111) plane, while by increasing of cold deformation degree, the relative intensity of (111) plane decreased. The higher density of the (111) plane in FCC structure may contribute for the higher corrosion resistance of the low degree deformation specimens. Indeed, the crystallographic planes with a high number of nearest neighbor atoms require a higher energy for the breaking of the bonds and the subsequent dissolution of atoms [10].

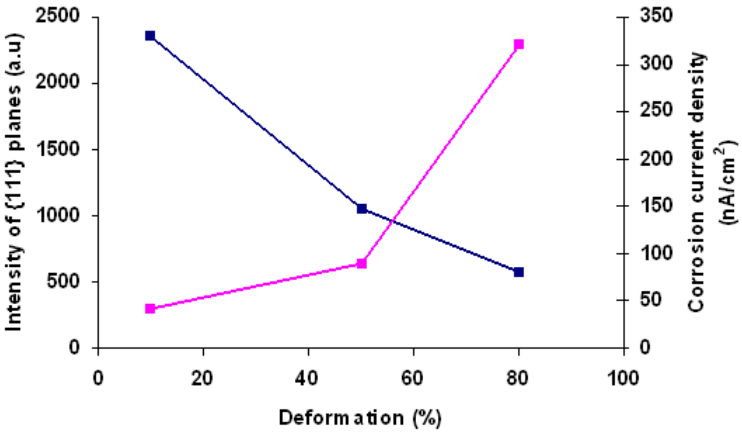


Fig. 4. Relationship between relative intensity, deformation degree and corrosion current density of 316L specimens.

Conclusions

(1) Increasing the cold deformation degree results in the decrease of {111} close pack planes.
(2) Specimens with higher relative intensity of {111} planes have better corrosion resistance than the specimens with lower relative intensity of {111} planes.
(3) The microhardness of specimens increased with increasing the cold deformation degree.

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