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Surface enriched molybdenum enhancing the corrosion resistance of 316L stainless steel

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ABSTRACT

Surface enriched molybdenum 316L stainless steel was obtained by ball milling technique. The electrochemical tests showed surface enriched molybdenum improved the corrosion resistance of the 316L stainless steel. This was attributed to a fact that more molybdenum oxides improved the corrosion resistance of the 316L stainless steel in borate buffer solution. In addition, more chromium oxides in the passive film after ball milling also improved corrosion resistance of the 316L stainless steel.

1. Introduction

Enriched molybdenum on the surface of the stainless steel could affect its corrosion resistance. Electrochemical studies revealed that the molybdenum ion implantation on AISI 316LVM austenitic stainless steel enhanced the pitting corrosion resistance [1]. Laser surface alloying of 304 stainless steel with Mo could be an appropriate technique to enhance the resistance to pitting and erosion–corrosion in NaCl solution [2]. Compared with the uncoated 316L stainless steel, the Ti-Mo-N film coated 316L stainless steel showed enhanced corrosion resistance in simulated polymer electrolyte membrane fuel cell (PEMFC) working condition [3]. The formation of molybdenum insoluble oxides enhanced the corrosion performance of AISI 304 and 316 stainless steels in H_2SO_4 [4]. The compactness of the passive film formed on 316L stainless steel and its corrosion resistance enhanced with increasing of Mo content in the simulated cathodic environment of PEMFC [5]. This was attributed to the fact that Mo could decrease donor and acceptor densities in passive film. In addition, X-ray photoelectron spectroscopy (XPS) results showed that Mo might increase the Cr_2O_3 content in the passive film. The pitting corrosion resistance of the coating on 316L stainless steel fabricated by high-velocity oxyfuel spraying in artificial seawater was improved due to the increasing of Mo content [6]. The passive ability of 316L stainless steel in artificial saliva enhanced with the increasing of Mo content [7]. The stainless steels with higher Mo content retained their high resistance to pitting but underwent an activation [8]. The investigation found that molybdate firstly formed in the passive film and then later partially dissolved into a solution [9]. Compared with unalloyed ferritic stainless steel, the corrosion resistance of molybdenum alloyed ferritic stainless steel increased in 0.1 M H_2SO_4 solution and 0.3 M HCl acid solution [10]. The effect of surface enriched molybdenum on 316L stainless steel by ball milling on corrosion resistance in borate buffer solution was investigated.

2. Experimental

2.1. Material preparation and characterization

The AISI 316L stainless steel with chemical composition (wt%) of C 0.025, Cr 17.01, Ni 12.03, Mn 1.40, P 0.028, S 0.003, Si 0.40, Mo 2.05 and balance Fe was chosen. The as-received samples were annealed at 1050 °C for 1 h, followed by water quenching at room temperature. 316L stainless steel plate was cut to cuboid with a dimension of 10 mm × 10 mm × 1 mm for test. The 316L stainless steel and Mo nanopowders mixtures were loaded into a vacuum ball milling tank with stainless steel balls. The ball to powder weight ratio was 10:1. The ball milling was performed at a

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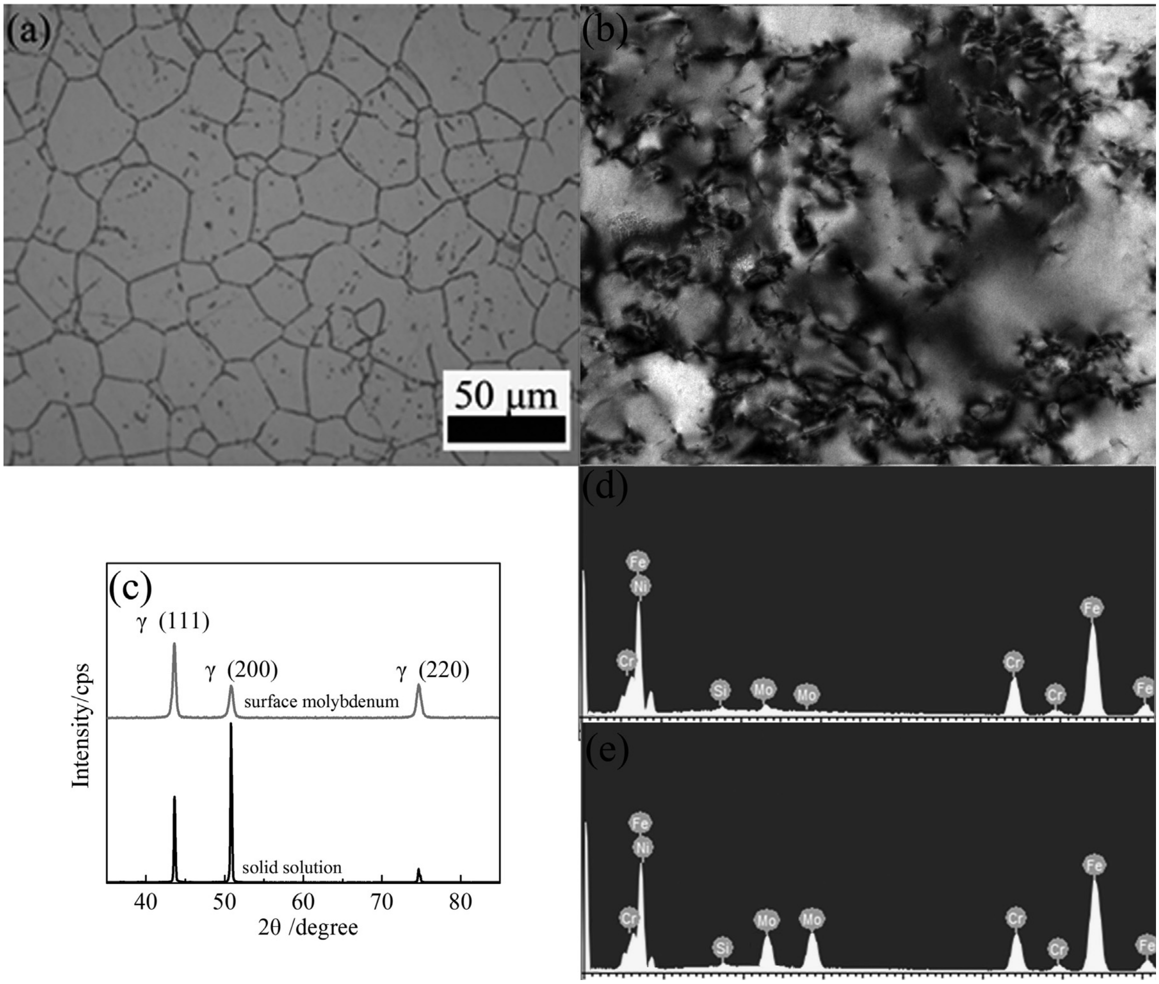

Fig. 1. The microstructures of (a) solid solution and (b) surface enriched molybdenum 316L stainless steels, (c) the XRD results, chemical composition of (d) solid solution and (e) surface enriched molybdenum 316L stainless steels.

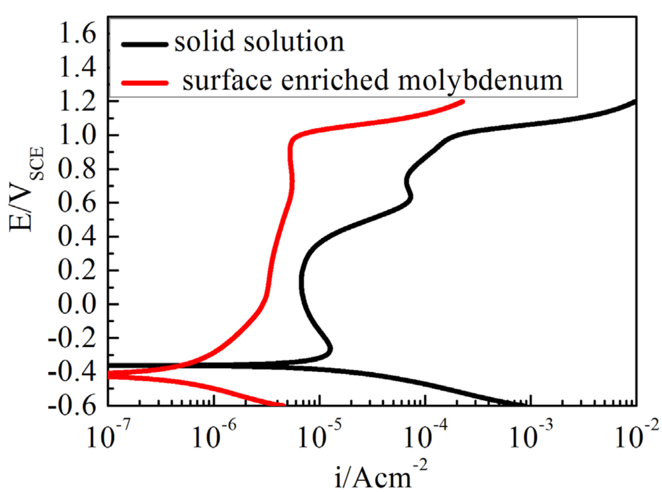

Fig. 2. Potentiodynamic polarization curves of solid solution and surface enriched molybdenum 316L stainless steels in borate buffer solution.

rotational speed of 300 rpm at room temperature. Milling experiments were extended to 300 h. The milling process was periodically interrupted for half an hour every 2 h to avoid excessive heating of the vials. The X-ray diffraction (XRD) measurement was carried out by the Rigaku Ultima IV diffractometer using Cu K_α (0.154056 nm) and radiation at 40 kV and 40 mA.

2.2. Electrochemical test

The electrochemical tests were performed using a CHI Instruments CHI660E electrochemical workstation (Chenhua instrument Co. Shanghai, China) controlled by a computer and software. The electrochemical measurements were conducted using a thin platinum plate as the counter electrode, a saturated calomel electrode (SCE) as the reference electrode and the stainless steel as the working electrode. All the potentials described in the paper were relative to the SCE. The potentiodynamic plot and electrochemical impedance spectroscopy (EIS) measurements were carried out in pH 8.4 borate buffer solution (0.075 M $Na_2B_4O_7$ + 0.3 M H_3BO_3). Before electrochemical experiment the sample was cathodically polarized at $-1.2V_{SCE}$ for 300 s. The samples were firstly passivated at 0.6 V_{SCE} for 1 h, then EIS measurements were carried out using a frequency range of 100 kHz–10 mHz and with a 5 mV amplitude of the AC signal at passivated potential.

2.3. XPS measurement

The surface compositions of the passive film formed at $0.6V_{SCE}$ for 1 h were measured by XPS. The XPS experiments were performed using PHI Quantera SXM (ULVAC-PHI, INC). Photoelectron emission was excited by monochromatic Al Kα radiation. The