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Effect of electrodeposition temperature on grain orientation and corrosion resistance of nanocrystalline pure nickel

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ABSTRACT

The nanocrystalline pure nickels with different grain orientations were fabricated by direct current electrodeposition process. The grain size slightly decreased with the increasing of electrodeposition solution temperature. However, grain orientation was affected significantly. Comparing with samples obtained at 50 °C and 80 °C, sample obtained at 20 °C had the strongest (111) orientation plane which increased electrochemical corrosion resistance of this sample. At the same time, the lowest (111) orientation plane deteriorated electrochemical corrosion resistance of sample obtained at 50 °C.

1. Introduction

The concept of grain refinement has been introduced to improve corrosion resistance of metal. The electrodeposited pure nickel has been used widely studied to improve corrosion resistance [1,2]. The corrosion resistance can be affected by the microstructures, such as grain size, surface morphology and grain orientation. Electrochemical deposition of nickel films has been discussed [3]. However, the microstructures of electrodeposited pure nickel is closely related to the electrodeposited parameters, such as current density [2] electrolyte temperature [4] and additive [1,5]. The morphology of corroded surface of electrodeposited pure nickel revealed that the pits were confined on the pyramids. Moreover, blocky morphology on the surface of the electrodeposited pure nickel was higher resistance to pitting corrosion [6]. The corrosion resistance of metal materials is closely related to the structure and thickness of the surface passive films. The passive film contains point defects. The generation and transmission of point defects affect the performance of the material [7]. The passive film formed nanocrystalline Ni thin films deposited by magnetron sputtering showed a p-type semiconductor characteristic in a pH 8.4 borate buffer solution [8]. Moreover, the passive films formed on industrial electrodeposited nickel in borate buffer solution with NaCl showed a p-type semiconducting behavior. However, the passive films of nano-scale twins nickel showed p-type semi-conductors for the inner layer and an n-type semi-conductor behavior for the outer layer [9]. The study showed that the nickel coating with grain size of 50 nm possessed higher corrosion resistance than that with grain size of 10 nm. This abnormal behavior may be related to the existence of nanoscale twins which induced lower acceptor concentration in the passive films [10]. Moreover, the profound texture effect on the corrosion resistance was related to surface energy scales [11]. The surface energy quantity for face centered cubic (FCC) metal was $(111)<(001)<(110)$ [12]. The samples with the (111) plane parallel to the surface for FCC metals were found to offer the highest corrosion resistance. Sample with the highest atomic density planes parallel to the surface was found to offer the highest corrosion resistance for commercial pure titanium, regardless of its grain size [13]. It has been shown that crystallographic planes with higher atomic density exhibit higher resistance to corrosion for 316LVM stainless steel [14] and aluminum single crystals [15].

However, the effect of grain orientation of nanocrystalline pure nickel on its corrosion resistance was rarely reported. Therefore, an attempt has been made in the present paper to study the effect of grain orientation on corrosion resistance of nanocrystalline pure

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nickel by X-ray diffraction (XRD), transmission electron microscope (TEM) and electrochemical impedance spectroscopy (EIS).

2. Experimental

The nanocrystalline pure nickel was prepared by direct current electrodeposition from an electrolyte containing nickel sulfate (300 g/L), nickel chloride (45 g/L), boric acid (about 45 g/L) and saccharin (about 5 g/L) at 20 °C, 50 °C and 80 °C, respectively. The sample obtained at 20 °C, 50 °C and 80 °C was designated as A, B and C, respectively. High sensitive power source (ZH4231 DC power analyser) was used for electrodeposition. A two-electrode cell system was used for the deposition. The anode was pure Ni plate and the cathode was a AISI 304 stainless steel. The cathode and anode were placed parallel at 5 cm distance during electrodeposition. The 304 stainless steel was successively ground with SiC paper up to a grit of #2000 and polished with alumina slurry down to 0.3 μm. The polished samples were ultrasonically cleaned finally in acetone and ethanol. Mirror polished 304 stainless steel surface was electro-cleaned and then pickled in 0.5 mol/L HCl to activate the surface. The exposed area of the electrode is 10 mm × 10 mm. The electrodeposition process was carried out at a current density of 0.05 A cm^{-2} for 30 min with 300 rpm stirring speed.

Surface morphology and chemical compositions of electrodeposited nanocrystalline samples were examined by Scanning Electron Microscope (SEM JSM5800) with energy-dispersive X-ray spectroscopy, EDX. The grain orientations of all the samples were analyzed by X-ray diffractometry (XRD). The Rigaku Ultima IV X-ray diffractometer was used and the scanning rate was 4°/min. Cu K_α (0.154056 nm) radiation at 40 kV and 40 mA was used. The microstructures was examined in a JEM-2100F transmission electron microscope (TEM). Electrochemical tests were performed in 3.5 wt% sodium chloride solution (mass fraction) and (0.075 M $Na_2B_4O_7 \cdot 10H_2O$ + 0.05 M H_3BO_3, pH = 9.2) in borate buffer solution at ambient temperature. The electrochemical tests were performed with a CHI 660B electrochemical station (Chenhua instrument Co. Shanghai, China) controlled by a computer and software in three-electrode cell. The electrochemical cell was a classical three-electrode system. The reference electrode was a saturated calomel electrode (SCE) and the counter electrode was

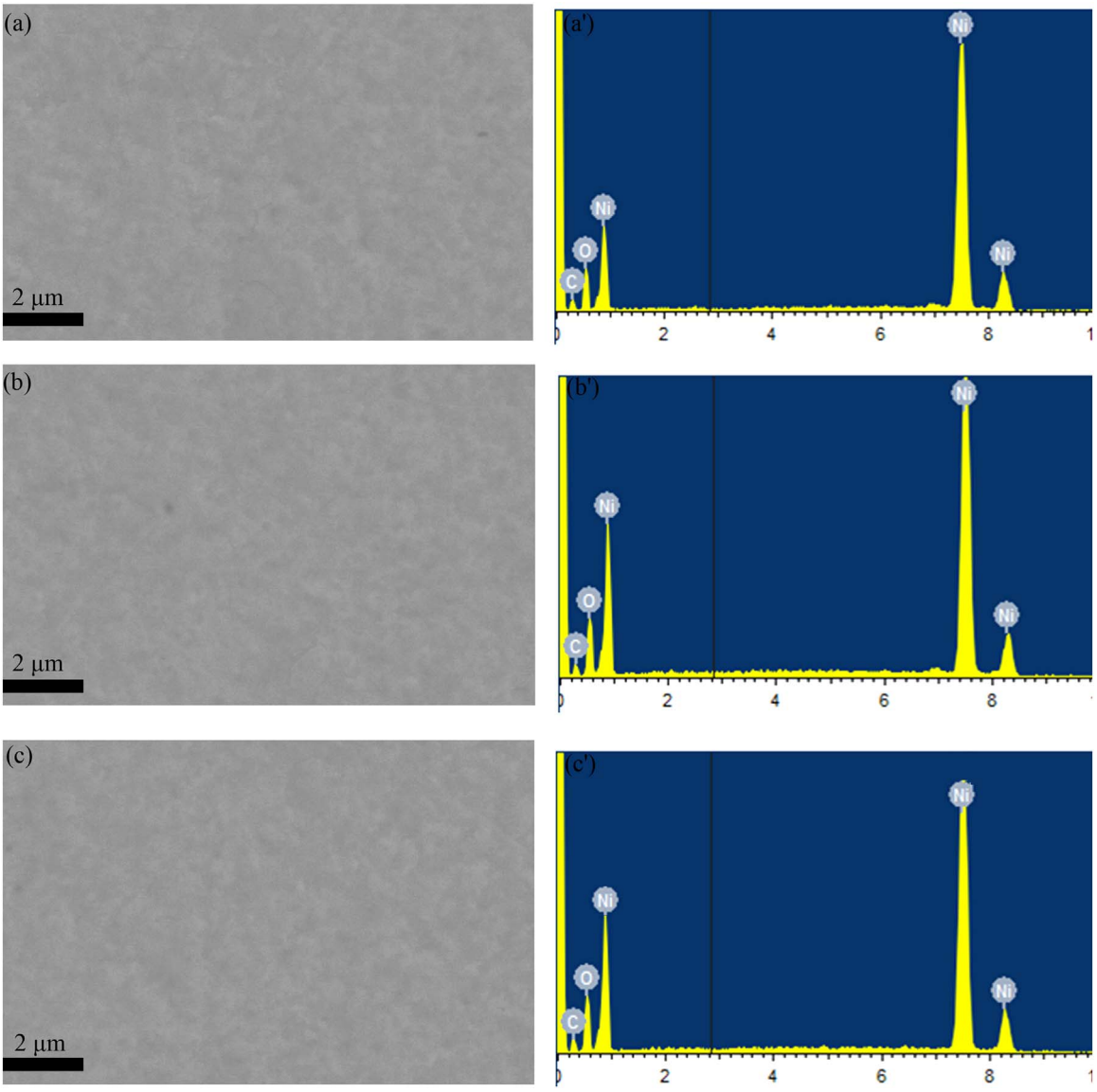

Fig. 1. SEM images of nanocrystalline pure nickel samples of (a) A obtained at 20 °C, (b) B obtained 50 °C and (c) C obtained 80 °C, respectively. The corresponding EDS for samples of (a) A obtained at 20 °C, (b) B obtained 50 °C and (c) C obtained 80 °C.