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EFFECT OF ULTRASONIC POWER ON CORROSION RESISTANCE AND HARDNESS OF Ni-Co-Al_2O_3 NANOCOMPOSITE COATINGS

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The Ni - Co - Al_2O_3 composite coatings were prepared by electroplating under ultrasound condition. The influence of ultrasonic power on micro hardness and corrosion resistance was investigated. Studied by Scanning Electron Microscope (SEM), Energy Disperse Spectroscopy (EDS) and X - Ray Diffraction (XRD), under the cavitation effect of ultrasound condition, the nano Al_2O_3 was dispersed in the coating, and the composite coatings had refiner grains. The surface morphology of coating was uniform and compact. With the increasing of ultrasonic power, the micro hardness of Ni - Co - Al_2O_3 composite coatings increased first and then decreased. When ultrasonic power was 240W, the composite coatings has the highest hardness and the best the corrosion resistance.

Key words: Ni - Co - Al_2O_3 composite coating; ultrasonic electroplating; SEM/EDS/XRD; corrosion resistance; hardness

INTRODUCTION

Ni - Co nano composite coating has higher wear resistance, high temperature oxidation resistance and corrosion resistance than traditional nickel based coating[1,2]. It is widely used in petrochemical industry, aerospace industry, metallurgical industry and other industries[3]. Nano Al_2O_3 has excellent properties such as high hardness, high density and good chemical stability. It can improve the hardness, wear resistance and corrosion resistance of the coating by compounding in the metal coating[4,5]. In this paper, the nano Al_2O_3 particles were compounded to the Ni - Co coating by ultrasonic electrodeposition, and the Ni - Co - Al_2O_3 nanocomposite coating was prepared. The influence of ultrasonic power on the hardness and corrosion resistance of coatings was studied. The Ni - Co - Al_2O_3 nano composite coatings with smooth surface, compact, microhardness and corrosion resistance was prepared.

EXPERIMENTAL MATERIALS AND METHODS

The nickel sulfate bath was used in the experiment. The formula of the plating solution was: $NiSO_4 \cdot 6H_2O$ 300 g/L, $NiCl_2$ $6H_2O$ 80 g/L, $CoSO_4 \cdot 7H_2O$ 3 g/L, H_3BO_3 30 g/L, surface active agent 0,1 g/L, nano Al_2O_3 particle 10 g/L. The cathode was copper plate (25 mm × 25 mm ×3 mm) and nickel plate (50 mm ×25 mm ×2 mm, purity over 99,5 %) was used as anode. Nano Al_2O_3 particle size was 30 nm. The composite coatings were synthetized by DC power supply. The pH value of the plating bath was 4,8, and the temperature was 50 °C. The plating time was 2 h, and the ultrasonic power range was 0 - 400 W. Before plating, 200 # - 2000 # sand paper was used to polish the copper plate. The alkali solution was used to remove the oil from the copper plate, and then activated in 10 wt.% HCl solution. In order to prevent the agglomeration of nanoparticles in the bath, the nano Al_2O_3 particles were dispersed by 150 rpm to disperse for an hour under magnetic stirring.

The surface micromorphology of the nanocomposite coating was observed by SEM (JSM - 6480lv). The chemical composition of the coating surface was analyzed by EDAX . The coating phase structure was analyzed by XRD (X ’ Pert Powder).

The microhardness of the samples was measured by microhardness tester (HVS - 1000)[6]. The hardness values were read out by using applied load of 1,961 N for 15 s. The hardness values of five points in different areas were obtained on each plating piece, and then the average values were calculated.

The polarization curves and AC impedance of nano composite coatings in 3,5 % sodium chloride solution were measured by AutoLab electrochemical workstation (PGSTAT 302), and the corrosion resistance of the nanocomposite coating was analyzed. The three electrode system was adopted. The saturated AgCl electrode is used as the reference electrode. The platinum plate electrode was the counter electrode. The nano composite coating was used as the working electrode. The working area was about 1 cm^2. All the tests were done at room temperature. The polarization curve were studied

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for the scanning potential of -1 ~ 1 V at the scanning rate of 0,1 V/s.

RESULTS AND DISCUSSION

Figure 1 is the surface morphology of the Ni - Co - Al_2O_3 nanocomposite coating prepared under ultrasound condition. As can be seen from Figure 1, the surface of the Ni - Co - Al_2O_3 nanocomposite coating is smooth and dense. Under the condition of ultrasonic field, the cavitation bubbles formed by ultrasonic cavitation will produce huge instantaneous pressure and high temperature when breaking down, which will cause plastic deformation on the surface of the coating , increase the nucleation rate of the coating surface, and make the grain of the nano composite coating refined. Meanwhile, cavitation improves the agglomeration of nano Al_2O_3 particles, and disperse nano Al_2O_3 particles in Ni - Co - Al_2O_3 nanocomposite coatings, resulting in fine grain size.

Figure 2 is the energy spectrum of the Ni - Co - Al_2O_3 nanocomposite coating prepared under ultrasound condition. Figure 2 displays the peak of Al element, indicating that Ni - Co coating contains nano Al_2O_3 particles, that is, Ni - Co - Al_2O_3 nanocomposite coating is successfully prepared under ultrasonic field. The main components of the nanocomposite coating are Ni, Co, Al and O, and their mass fraction is 74,69 %, 4,13 %, 12,01 % and 9,17 %, respectively.

Figure 3 shows the XRD diffraction patterns of Ni-Co-Al_2O_3 nano-composite coatings prepared under ultrasonic condition. It is showed that the peaks at 44 °, 52 °and 76 ° are corresponding to Ni (111), (200) and (220) diffraction peaks. The peaks at 43 °, 50 ° and 74 ° are indexed to Co (111), (002) and (022) diffraction peak. The peaks at 26 ° and 38 ° are the characteristic diffraction peaks of nano Al_2O_3 (012) and (110). It is confirmed that nano Al_2O_3 particles are dispersed in the Ni-Co coating, namely under the ultrasonic condition the Ni - Co - Al_2O_3 nano composite coatings were prepared successfully, and the previous analysis results are consistent.

Figure 4 is the hardness of the Ni-Co-Al_2O_3 nanocomposite coating prepared under different ultrasonic power. As we can see from Figure 4, with the increase of ultrasonic power, the hardness value of the coating increases first and then decreases. When the ultrasonic power is 240 W, the maximum hardness of the coating is 438 HV.

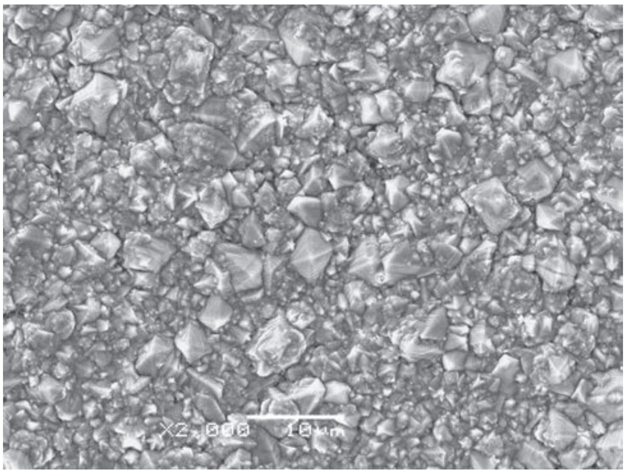

Figure 1 Surface topographies (SEM image) of Ni - Co - Al_2O_3 nanocomposite coatings

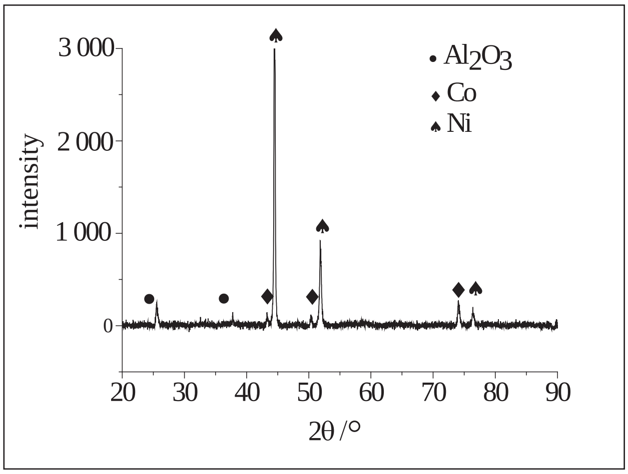

Figure 3 XRD diffraction patterns of Ni-Co-Al_2O_3 nanocomposite coatings

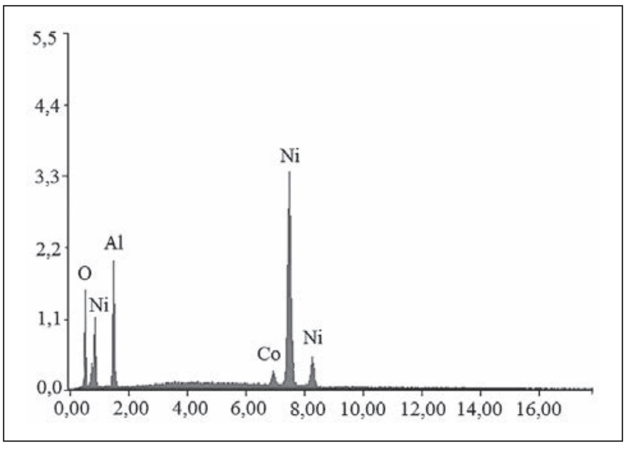

Figure 2 EDS analysis spectrum of the Ni - Co - Al_2O_3 nanocomposite coatings.

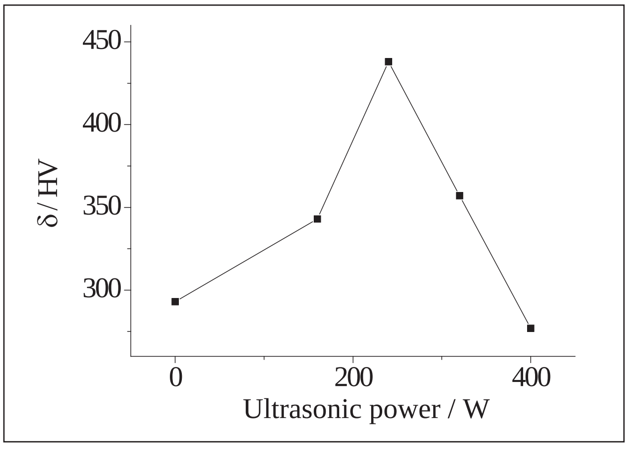

Figure 4 The hardness curve of Ni-Co-Al_2O_3 nanocomposite coating under different ultrasonic power.

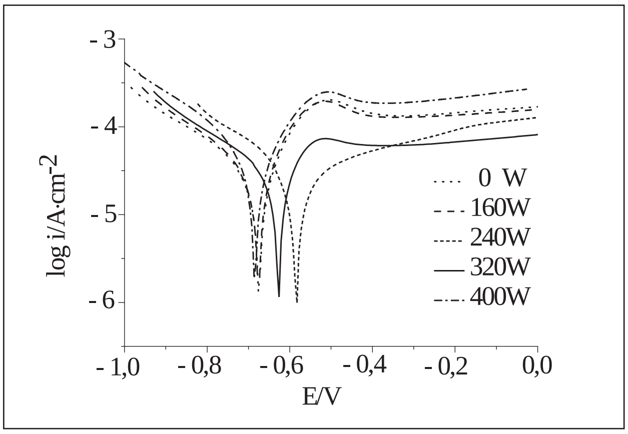

Figure 5 Polarization curves of the Ni-Co-Al_2O_3 nano-composite coatings under different ultrasonic power.

Figure 5 is the polarization curve of the Ni-Co-Al_2O_3 coating prepared under different ultrasonic power in 3,5 % NaCl. The results of the polarization curve are shown in Table 1. From Figure 5 and Table 1, it is known that with the increase of ultrasonic power, the corrosion current density of the coating decreases first and then increases. When the ultrasonic power is 240 W, the corrosion current density of the coating is the smallest, which is 2,17 × 10^{-6} A/cm^2. With the increase of ultrasonic power, the corrosion potential of the coating first shifted positively and then shifted negatively. When the ultrasonic power is 240 W, the corrosion potential is the most positive, which is -0,584 V. According to the second law of Faraday, the smaller the corrosion current density, the lower the corrosion rate; the more the corrosion potential, the smaller the corrosion tendency. Therefore, when the ultrasonic power is 240 W, the coating has the best corrosion resistance.

Table 1 **Results of polarization curves on the coatings deposited under different ultrasonic power.**

Nos.	Ultrasonic power / W	I_{corr} /10^{-6}A/cm^2	E_{corr}/V
1	0	2,942	- 0,675
2	160	2,744	- 0,674
3	240	2,170	- 0,584
4	320	2,206	- 0,627
5	400	3,701	- 0,684

CONCLUSION

(1) By ultrasonic nano composite plating technology, the ultrasonic cavitation effect of ultrasound field, improve the agglomeration of nano Al_2O_3 particles, the enhancement of solution mixing effect, improving the transmission capacity of ion plating solution, nano Al_2O_3 dispersed in the coating. The coating surface is smooth, the compact structure, fine grain size, showing for the ball.

(2) With the increase of the ultrasonic power, the hardness of the Ni-Co-Al_2O_3 nanocomposite coating in the 3,5 % NaCl solution increases first and then decreases. When the ultrasonic power is 240 W, the hardness of the Ni-Co-Al_2O_3 nanocomposite coating is the largest (438 HV).

(3)With the increase of ultrasonic power, the corrosion resistance of Ni-Co-Al_2O_3 nanocomposite coating in 3,5 % NaCl solution increases first and then decreases. When the ultrasonic power is 240 W, the self corrosion current density of Ni-Co-Al_2O_3 nanocomposite coating is the smallest (2,17 × 10^{-6} A/cm^2), the self corrosion potential is the most positive (- 0,584 V), and the corrosion resistance is the best.

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Note: Yi-yong Wang is responsible for English language, Anshan, LiaoNing, China