Electrodeposition of Ni-nanoSiO_2 Composite Coating under Ultrasound Conditions

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***Abstract*—Ni-nanoSiO_2 composite coating was electrodeposited under ultrasound conditions, and the effect of ultrasound power on its microstructure, microhardness and acid resistance was investigated. SEM and XRD characterization show that ultrasound power has evident influence on the morphology, while shows hardly any effect on the diffraction pattern. Experimental test reveal that microhardness and acid resistance of the ultrasound electrodeposited composite coating are better than those of conventional Ni-nanoSiO_2 coating, and they are both improved first and then weakened with the increasing of ultrasound power.**

Keywords-composite coating; Ni-nanoSiO_2; electrodeposition; ultrasound

I. INTRODUCTION

Metal matrix composite material has been widely applied in many fields, such as aerospace, weaponry, mould and automobile, etc, due to its excellent comprehensive performance. Electrodeposition is a low-cost and good-flexibility process to fabricate metal composites, and nickel-based, copper-based as well as zinc-based coatings with well morphology have been successfully prepared using this technique [1-3]. However, low particle content in the composites, especially to the codeposition of nanoscale particles, is a bottleneck problem which restricts the enhancement of coating properties to a large extent.

For this reason, numerous studies have been done around the theme of optimizing the process conditions and then improving the comprehensive performance of composite coatings. The investigation results showed that ultrasound agitation is advantageous to the homogeneous dispersion and distribution of nanoparticles, thus create good conditions for the preparation of composite coatings possessing good physicochemical properties [4,5]. In recent years, electrodeposition of metal matrix composites under ultrasound conditions has become a hot topic in surface engineering field, while little literatures on the microstructure and properties of the ultrasound electrodeposited Ni-nanoSiO_2 coating was available. This paper carried out the research on this aspect.

II. EXPERIMENTAL

A. Materials

Fig. 1 illustrates the schematic diagram of ultrasound composite electrodeposition. The compositions of electrolyte are: $Ni(NH_2SO_3)_2$ 430ml/L, $NiCl_2{\cdot}6H_2O$ 8g/L, H_3BO_3 35g/L, $CH_3(CH_2)_{11}OSO_3Na$ (wetter) 0.05g/L, particle: SiO_2 (about 70nm in diameter and 10g/L in concentration). An electrolytic nickel plate and a red copper wafer with a thickness of 1mm were respectively used as the anode and the cathode. The cathode (substrate) was pretreated before deposition. The electrodeposition process parameters are: cathode current density 7A/dm^2, ultrasound power 0-600W, temperature 40℃. During electrodeposition, the electrolyte was auxiliarily agitated with compressed air in order to ensure that the nanoparticles were suspension and evenly distribution. The thickness of composite coating was kept about 70μm by controlling the deposition time.

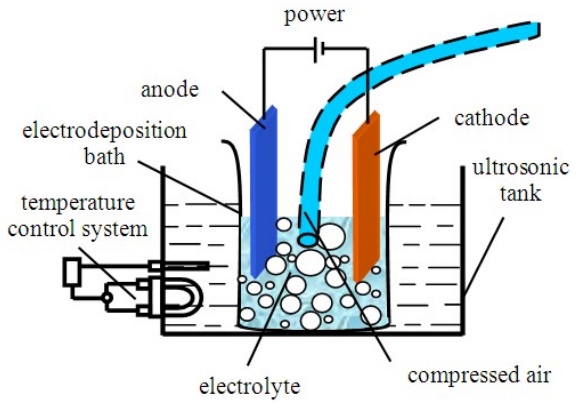

Figure 1. Schematic diagram of the ultrasound composite electrodeposition

B. Characterization and Test

The topographical morphology and phase structure were separately characterized by scanning electron microscopy (JSM-5610LV, Japan) as well as X-ray diffracmeter (Rigaku D/max-2500, Japan). Microhardness test was performed at room temperature using a microhardness tester (HXS-1000A, China) under a load of 980mN exerted for 10s. The microhardness value presented is the average of seven measurements in different places. Acid resistance is reflected by the corrosion rate which is expressed by the formula: $v=(m_{before}-m_{after})/s\times t$ ($g/mm^2{\cdot}d$), where ($m_{before}-m_{after}$) is the quality loss, s is the corrosion area ($5\times6mm$) and t is the corrosion time (9 *day*). The corrosion medium is 15% wt. HCl solution, and the quality of composites before and after corrosion was weighed by precision electronic balance (PL303, Switzerland).

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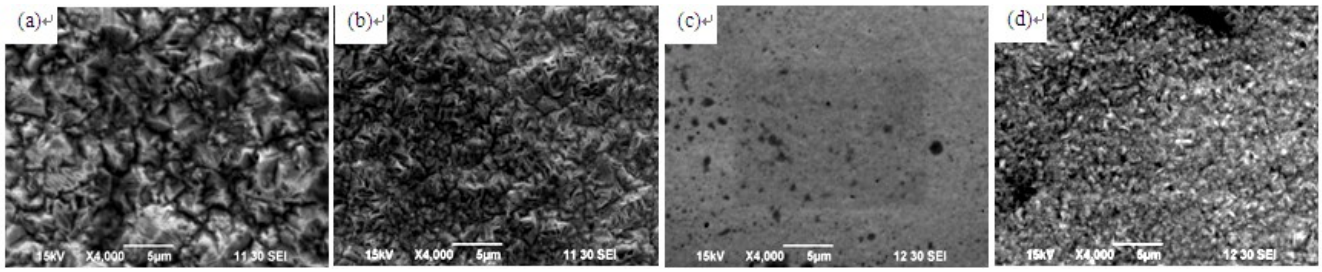
III. RESULTS AND DISCUSSION

A. Morphology and Microstructure

As shown in Fig.2, compared with the Ni-nanoSiO_2 composite coating obtained with conventional electrodeposition process (0W, without ultrasound agitation)at 7A/dm^2, see Fig.2(a), the one prepared under ultrasound conditions (200W) with the same cathode current density presents finer grains and compacter morphology. Which indicates that ultrasound agitation is beneficial to raise the nanoparticle content in the composites, thus refines the grain and improves the structure. And it can be seen that, the effect was strengthened as the ultrasound power increases, showed in Fig.2(c). However, when the power raised to 600W, a Ni-nanoSiO_2 coating featuring rough surface and coarse structure was electrodeposited. It is likely that higher power has adverse effect on the mosaic of nanoparticles in the composites because of the strong cavitation impact effect, resulting in weaker cathode polarization and faster grain growth speed [6].



(a) 0W; (b) 200W; (c) 400W; (d) 600W

Figure 2. SEM morphology of the Ni-nanoSiO_2 composite coatings electrodeposited with different ultrasound power

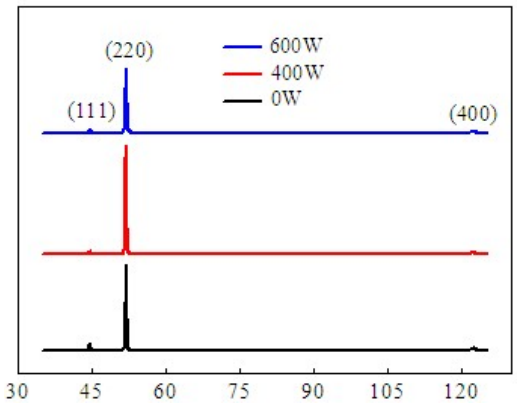


Figure 3. XRD patterns of the composites prepared with different electrodeposition process

Take the three coatings that were separately prepared under the conditions of 0W, 400W and 600W as an example, further analyze the phase structure using X-ray found that, all the composites are of face-centered cubic structure and presents a (220) preferential orientation, see Fig.3. Moreover, the crystal plane index as well as the number of diffraction peak shows almost no change with the varying of ultrasound power from 0 to 600W, which reflects that power has no significant influence on the texture of Ni-nanoSiO_2 coatings achieved under ultrasound conditions.

B. Microhardness

The relation curve of microhardness and ultrasound power is shown in Fig.4. As illustrated, in contrast with the Ni-nanoSiO_2 composite coating prepared based on conventional electrodeposition process, the ultrasound electrodeposited composites show higher microhardness. And the value increases with the raising of ultrasound power from 100 to 400W. It can be concluded that the primary reason for the increase of microhardness is grain refinement and grain boundary strengthening effect caused by ultrasound power lowers. However, in the interval of [400W, 600W], an increase in ultrasound power was accompanied by a lower microhardness. Combining with the mentioned above and according to the Hall-Petch empirical relationship [7], the bigger the grain size is, the lower the microhardness value is.

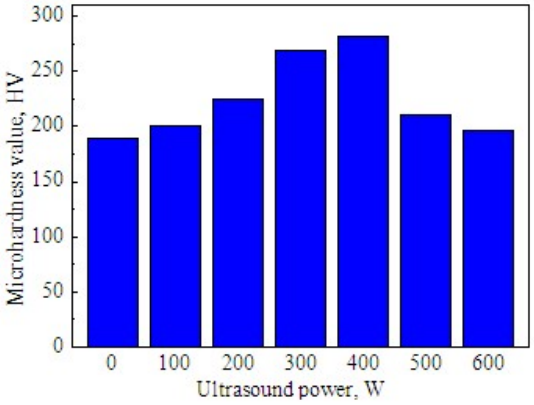


Figure 4. Microhardness of Ni-NanoSiO_2 coatings electrodeposited under ultrasound conditions

C. Acid Resistance

Fig.5 shows the corrosion rate of Ni-nanoSiO_2 composites. The result indicates that the acid resistance of Ni-nanoSiO_2 coating prepared based on ultrasound electrodeposition is better than that of conventional Ni-nanoSiO_2 coating. Also, a similar variation trend as expressed in Fig.4, that is, the acid resistance enhanced first and then weakened as the power increases (100-600W), is observed. In conclusion, the composite coating electrodeposited with 400W (ultrasound power) presents excellent acid resistance, its corrosion rate in HCl solution is only 0.0067 mg/mm^2·d, about one-third of the conventional coating whose corrosion rate is up to 0.018 mg/mm^2·d.

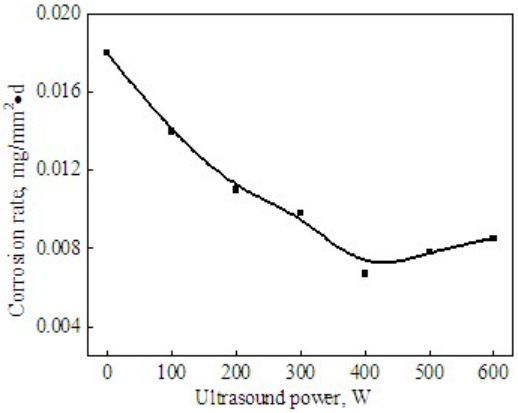


Figure 5. Relationship of corrosion rate and ultrasound power

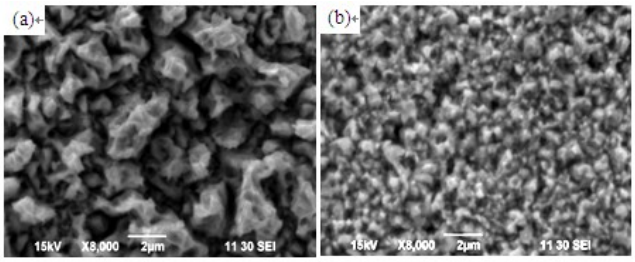


Figure 6. Morphology of two typical Ni-nanoSiO_2 composites after corrosion in HCl solution: (a) conventional coating; (b) ultrasound electrodeposited coating at 400W

Comparing with the morphology (shown in Fig.6) of two typical Ni-nanoSiO_2 coatings after corrosion in HCl solution, the former shows coarse structure featuring big hollow and salient due to severe and uneven pitting, while the latter presents slight honeycomb texture because the pitting is significantly inhibited.

IV. CONCLUSIONS

1) Compared with conventional Ni-nanoSiO_2 coating, the composite coating prepared based on ultrasound electrodeposition presents denser surface morphology, higher microhardness and better acid resistance.

2) Ultrasound power has evident influence on the morphology, microhardness and acid resistance of the ultrasound electrodeposited Ni-nanoSiO_2 coating, while shows hardly any effect on the phase structure.

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