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Corrosion resistance of electrodeposited RE-Ni-W-P-SiC composite coating^①

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[Abstract] Immersion experiment results show that corrosion rate of the as-deposited RE-Ni-W-P-SiC composite coating in HCl solutions increases with the rise of HCl concentration. On the contrary, the corrosion rate of the composite coating after heat treatment decreases with increasing HCl concentration. The corrosion rates of the composite coatings in as-deposited state and after heat treatment in H₂SO₄ and H₃PO₄ solutions respectively decrease with the rise of H₂SO₄ and H₃PO₄ concentrations. The corrosion rate of the composite coating as-deposited in FeCl₃ solutions decreases with increasing FeCl₃ concentration, while the rate of the composite coating after heat treatment increases with the rise of FeCl₃ concentration. The corrosion rate of 316L stainless steel in the corrosion media of H₂SO₄, HCl, H₃PO₄ and FeCl₃ solutions at different concentrations increases with rising concentration. In addition, the corrosion rate of 316L stainless steel in the corrosion media of H₂SO₄, HCl, H₃PO₄ and FeCl₃ solutions respectively is much greater than that of the RE-Ni-W-P-SiC composite coating as-deposited and after heat treatment in the same corrosion media.

[Key words] corrosion resistance; RE-Ni-W-P-SiC composite coating; electrodeposition

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1 INTRODUCTION

Making use of composite materials is the developing trend in the current materials science. It means obtaining a new composite material by combining the best properties of several different materials so as to meet people's demands. Composite electroplating is one of the most useful way to obtain such composite materials.

Because of many better properties of the composite coatings, they can meet some special requirements in a way. The processes and techniques of the composite coatings have made great development in recent years. Series of practical coatings are developed, including Ni-SiC, Ni-Fe-Al₂O₃, Ni-W-P-SiC and Cu-SiC composite coatings^[1~4]. The wear and corrosion resistance or other special function needed can be well established by making protection films on the surface of spare, which increases the using life-span of the machines. Rare earth has many special physical and chemical properties, and negligible amount can bring remarkable effects^[5~7], it can raise wear resistance and high temperature oxidation resistance of the composite coatings^[8~10]. Many papers about the wear resistance of the composite coatings have been published^[11~13], while researches on the corrosion resistance of the composite coatings has been not put forward in details up to now. Here the RE-Ni-W-P-SiC composite coating will be made out by use of the composite electrodeposition and its corrosion resistance will be studied.

2 EXPERIMENTAL

2.1 Bath composition and deposition conditions

The bath composition and deposition condition are as

NiSO ₄ •6H ₂ O	10~ 50 g/L;
Na ₂ WO ₄ •2H ₂ O	60~ 90 g/L;
NaH ₂ PO ₂ •H ₂ O	5~ 20 g/L;
SiC(3.0~ 3.5 μm)	50~ 70 g/L;
Complex agent	100~ 150 g/L;
Additive	20~ 30ml/L;
Rare earth(RE)	3~ 9 g/L;
pH	6.0~ 6.5;
Cathodic density(Dk)	10~ 15 A/dm ² ;
Temperature	50~ 60 °C

2.2 Experiments

Specimens of corrosion experiment including as-deposited RE-Ni-W-P-SiC composite coatings, 400 °C and 1 h heat-treated RE-Ni-W-P-SiC composite coatings, 316 L stainless steel. Corrosive media are shown in Table 1.

Table 1 Corrosive media and mass fraction of corrosive media

Corrosive media	Mass fraction of media/ %			
HCl	5	10	15	20
H ₂ SO ₄	5	10	20	30
H ₃ PO ₄	30	40	50	60
FeCl ₃	10	15	20	

Immersion experiments were carried out in beakers. Anodic polarization curves were obtained by DHZ-1 electrochemical synthetic tester and HDV-7 transistor constant potentiometer at room temperature.

3 RESULTS AND DISCUSSION

3.1 Corrosion resistance in HCl solutions

Corrosion rates of the specimens in various concentrations of HCl solutions are given in Table 2.

Table 2 Corrosion rates of specimens at various concentrations of HCl solutions ($\text{mg} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$)

Specimen	$w(\text{HCl})$			
	5%	10%	15%	20%
RE-Ni-W-P-SiC	0.029 8	0.047 0	0.043 8	0.063 6
RE-Ni-W-P-SiC*	0.070 5	0.026 3	0.007 7	0.010 6
316L stainless steel	0.104 9	0.166 4	0.301 6	1.868 5

* Heated at 400 °C for 1 h

Results show that corrosion rate of RE-Ni-W-P-SiC composite coatings in as-deposited state in HCl solutions increases with increasing HCl concentrations. The corrosion rate of 316L stainless steel in HCl solutions represents the same tendency as the RE-Ni-W-P-SiC composite coatings as-deposited, but its tendency is very clear. On the contrary, the corrosion rate of the composite coatings after heat treatment decreases with increasing HCl concentrations. Corrosion resistance of the coatings after the heat treatment in HCl solutions is much better than that of the coatings as-deposited, and both of them are better than that of 316L stainless steel.

Fig. 1 gives anodic polarization curves of RE-Ni-W-P-SiC composite coatings after heat treated at 400 °C in the media of HCl. It is shown that corrosion current density of the heat-treated RE-Ni-W-P-

SiC coating in 15% HCl solutions is the minimum in the four HCl concentrations. So the corrosion resistance is the best.

3.2 Corrosion resistance in H₂SO₄ solutions

Corrosion rates of specimens in H₂SO₄ solutions with various concentrations are given in Table 3.

Table 3 Corrosion rates of specimens at various concentrations of H₂SO₄ solutions ($\text{mg} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$)

Specimen	$w(\text{H}_2\text{SO}_4)$			
	5%	10%	20%	30%
RE-Ni-W-P-SiC	0.050 1	0.024 3	0.001 1	0.001 0
RE-Ni-W-P-SiC*	0.022 1	0.084 7	0.001 6	0.008 5
316L stainless steel	0.048 8	0.408 2	0.011 3	2.250 8

* Heated at 400 °C for 1 h

It is shown that corrosion rate of RE-Ni-W-P-SiC coating in as-deposited state in H₂SO₄ solutions decreases with increasing H₂SO₄ concentration, and it is minus in 30% H₂SO₄ solution. The reason is that there has an oxidation layer in the surface of the RE-Ni-W-P-SiC composite coating, which makes the corrosion more difficult. In the range of low concentration, corrosion rate is less than that in the high concentration, and the corrosion resistance is better than that in as-deposited state. In the ranges of 5% to 30% H₂SO₄ concentration, the corrosion resistance of RE-Ni-W-P-SiC composite coating is much better than that of 316L stainless steel, and the anodic polarization curves of this coating in H₂SO₄ solutions are shown in Fig. 2.

3.3 Corrosion resistance in H₃PO₄ solutions

Table 4 shows that the corrosion resistances of both RE-Ni-W-P-SiC composite coatings in as-deposited state or after heat treatment are inferior to that of 316L stainless steel respectively. All of the RE-Ni-W-P-SiC composite coatings gain mass, except

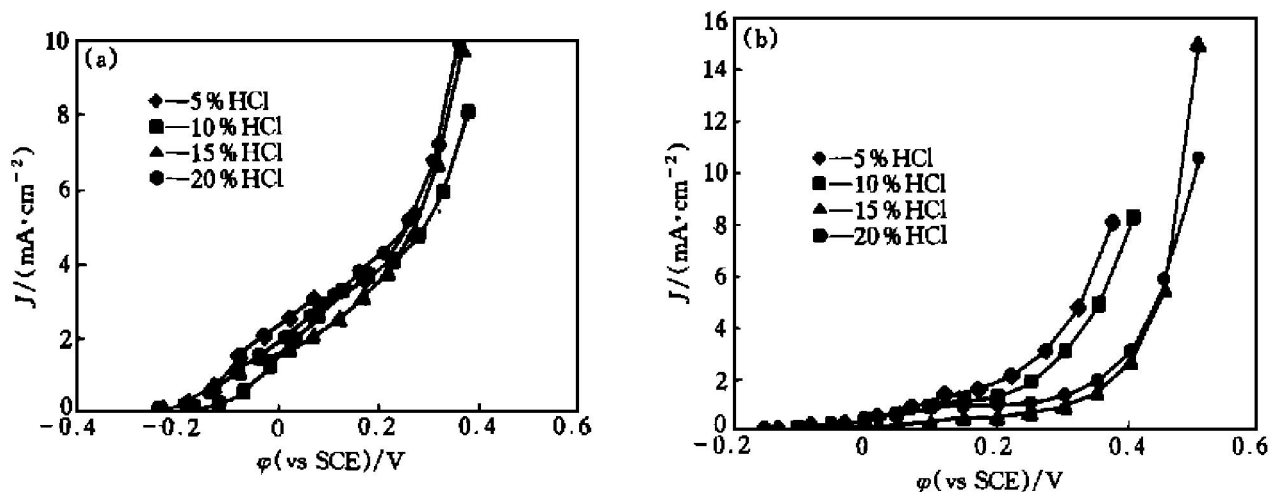


Fig. 1 Anodic polarization curves of RE-Ni-W-P-SiC composite coating in HCl solutions

(a) —As-deposited; (b) —Heat treated at 400 °C for 1 h

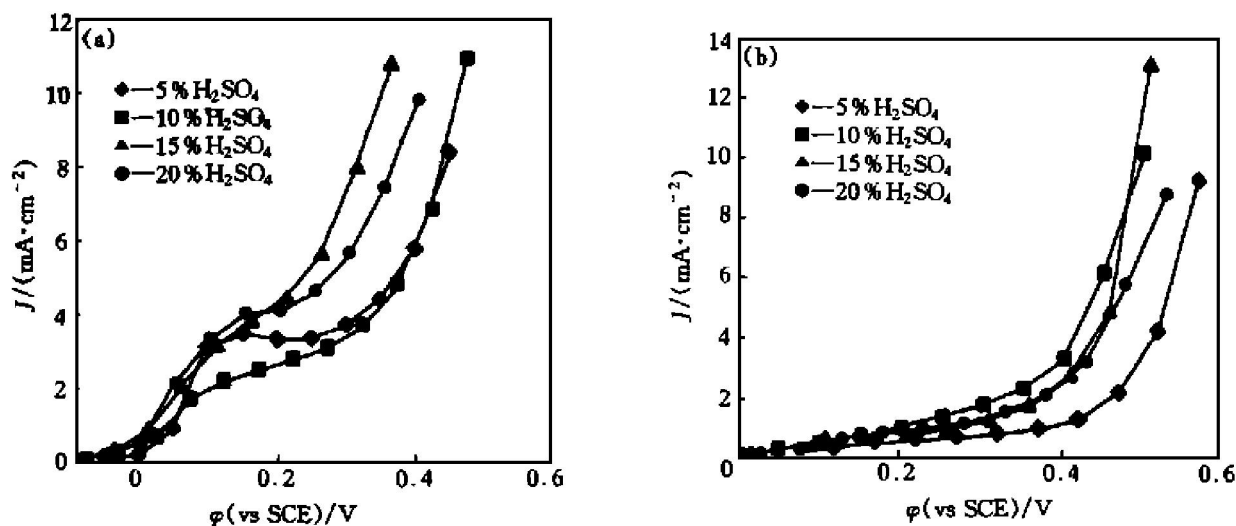


Fig. 2 Anodic polarization curves of RE-Ni-W-P-SiC composite coating in H_2SO_4 solutions

(a) —As deposited; (b) —Heat treated at 400 °C for 1 h

Table 4 Corrosion rates of specimens at various densities of H_3PO_4 solutions ($\text{mg} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$)

Specimen	$w(\text{H}_3\text{PO}_4)$			
	30%	40%	50%	60%
RE-Ni-W-P-SiC	0.0264	0.0408	0.0463	0.0328
RE-Ni-W-P-SiC*	0.0230	0.0178	0.0399	0.0209
316L stainless steel	0.0087	0.0070	0.0119	0.0089

* heated at 400 °C for 1 h

for the RE-Ni-W-P-SiC composite coating after heat treatment in 40% H_3PO_4 solution.

Anodic polarization curves of RE-Ni-W-P-SiC composite coatings in as-deposited state show that the passivation-maintaining current density is almost zero when the electric potential of anodic polarization is in the range of -0.2 V to 0 V, i. e. the corrosion doesn't occur. With increasing H_3PO_4 concentration, the passivation phenomenon occurs in the anodic polarization curves of H_3PO_4 solutions of 40%, 50% and 60%, and the corrosion decreases (see Fig. 3).

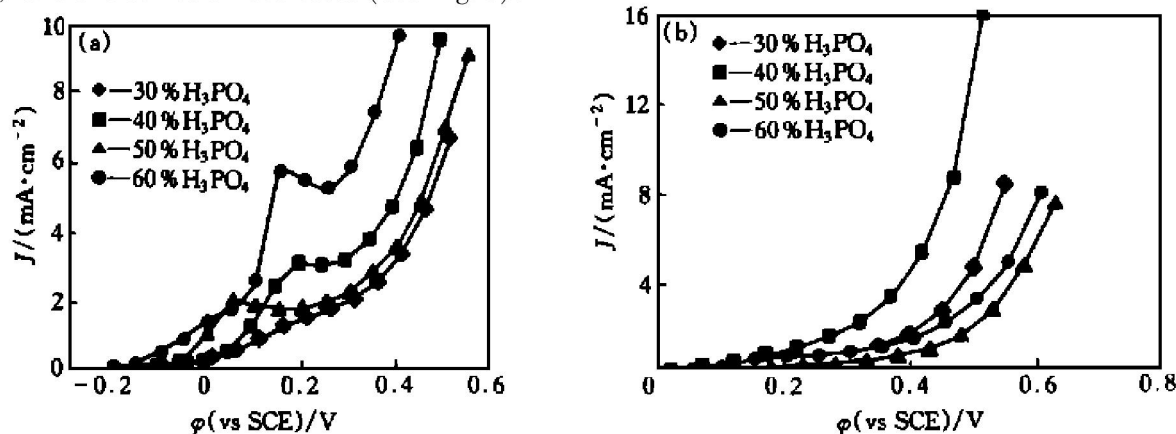


Fig. 3 Anodic polarization curves of RE-Ni-W-P-SiC composite coating in H_3PO_4 solutions

(a) —As deposited; (b) —Heat treated at 400 °C for 1 h

On the contrary, under the condition of heat treatment, when the electric potential of anodic polarization is in the range of 0 V to 0.2 V, the passivation-maintaining current density is almost zero, and the corrosion doesn't occur. With the rising of electric potential, the corrosion increases.

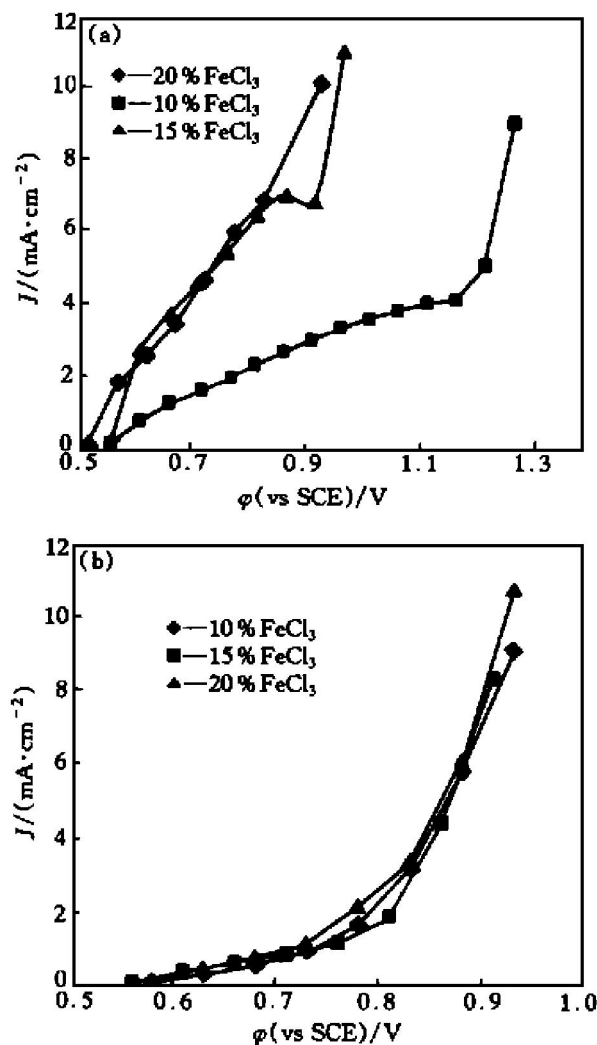
3.4 Corrosion resistance in FeCl_3 solutions

Table 5 shows that with the rising of FeCl_3 concentration, the corrosion rate of RE-Ni-W-P-SiC composite coating as-deposited decreases, and the corrosion rate of the coating after heat-treated increases but it is inferior to that of the as-deposited composite coating. Both the coatings are superior to that of 316L stainless steel, especially the heat-treated coating, which is the best. Anodic polarization curves show that the passivation phenomenon occurs in the curve of the as-deposited coating in 20% FeCl_3 solutions, and the corrosion resistance of the heat treated composite coating is superior to that of the as-deposited coating (see Fig. 4).

Table 5 Corrosion rates of specimens at various densities of FeCl_3 solutions ($\text{mg} \cdot \text{cm}^{-2} \cdot \text{h}^{-1}$)

Specimen	Concentration of FeCl_3		
	10%	15%	20%
RE-Ni-W-P-SiC	1.831 5	1.253 2	1.182 4
RE-Ni-W-P-SiC*	0.021 5	0.041 3	0.176 5
316L stainless steel	1.568 4	3.394 7	2.873 6

* heated at 400 °C for 1 h

**Fig. 4** Anodic polarization curves of RE-Ni-W-P-SiC composite coating in FeCl_3 solutions

(a) —As deposited; (b) —Heat treated at 400 °C for 1 h

4 CONCLUSIONS

1) The corrosion resistance of RE-Ni-W-P-SiC composite coatings in as-deposited state and after heat treatment in HCl, H_2SO_4 , H_3PO_4 and FeCl_3 solutions of some concentration ranges is superior to that of

316L stainless steel.

2) One of the merits of RE-Ni-W-P-SiC composite coatings is its corrosion resistance to H_3PO_4 solutions.

3) Corrosion resistance of heat-treated RE-Ni-W-P-SiC composite coatings is superior to that of the coatings in as-deposited state.

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