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Microstructure of electrodeposited RE-Ni-W-P-SiC composite coating①

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Abstract: The components and microstructure of the RE-Ni-W-P-SiC composite coating were analyzed by means of EPXDS, SEM and XRD. The results showed that the composite coating containing 5% ~ 14% RE, 4% ~ 7% SiC, 12% ~ 15% P and 5% ~ 6% W was obtained by use of appropriate bath composition and plating conditions. The as-deposited composite coating is amorphous and it becomes mixture when the temperature is raised from 200 ℃ to 400 ℃. However, the composite coating is crystal when the temperature is over 400 ℃. Scanning electron microscopy indicates that the heat treatment temperature has no effect on the surface morphologies of the RE-Ni-W-P-SiC composite coating. This is to say that the composite coating has a better heat stability of microstructure and high temperature oxidation.

Key words: electrodeposition; RE-Ni-W-P-SiC composite coating; microstructure **Document code:** A

1 INTRODUCTION

The composite electroplating technique as a new functional plating method is attracting people's attentions, especially there has been a rapid development in the recent tens of years. Furthermore, most composite techniques have been used in industries[1~6]. Rare earth(RE) elements are noted for their unique physical and chemical characters and producing considerable effectiveness with a little amount, so they are widely used in the fields of materials science. RE has been applied in the surface technologies such as plating chromium, chemical heat treatment and transforming films[7, 8]. However, the application of RE in composite plating is very small[9~12]. Moreover, the relationship among the amount of RE, structure, microstructure and properties of the composite are not studied systematically and deeply. Therefore, a new composite coating containing RE is prepared by means of electrochemistry; and the structure, microstructure and properties of the coating are investigated systematically in this paper.

2 EXPERIMENTAL

Bath composition and plating conditions are as follows:

$NiSO_4 \cdot 6H_2O$	10~ 50 g/L
$Na_2WO_4 \cdot 2H_2O$	60~ 90 g/L
$NaH_2PO_2 \cdot H_2O$	5~ 20 g/L
Complex agent	100~ 150 g/L
Additive	20~ 30 mL/L
SiC	50~ 70 g/L
RE	0~ 9 g/L
Current density(Dk)	10~ 15 A/dm^2
pH	6.0~ 6.5
Temperature	50~ 60 ℃
Time	2~ 3 h

45# steel(40 mm × 35 mm × 3 mm) was used in this study.

The components of RE-Ni-W-P-SiC composite coating were measured quantitatively by means of EDAX 9100 electron probe X-ray spectrum and chemical analytical methods. The average value of five-point measured values was used.

The structures of the coatings were analyzed by use of 3015 X-ray diffraction, and surface morphologies of the coatings and distribution conditions of the elements in the coatings were analyzed by means of ASM-SX scanning electron microscopy.

3 RESULTS AND DISCUSSION

3.1 Effects of amount of RE on deposition rate, SiC and CeO_2 contents in coatings

It is known from Table 1 that the content of SiC particles increases with the rise of addition of RE in the bath, and it reaches peak value when the amount of RE is 7 g/L. The content of SiC particles in the deposits, however, decreases gradually with increa-

Table 1 Effects of RE concentrations in bath on contents of SiC and CeO_2 in deposits and rate of deposition

c(RE)/(g·L^{-1})	w(SiC)/%	w(CeO_2)/%	v/(g·dm^{-2}·h^{-1})
0	3.85	0	2.05
3	4.10	5.60	2.38
5	5.17	5.74	2.75
7	6.16	5.96	2.86
9	4.56	14.24	3.07

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sing amount of RE. On the other hand, the content of CeO_2 in the deposits and deposition rate increase with the rise of the amount of RE in the bath. Because the RE in the bath accelerates the cathodic polarization of the bath and enables SiC colloidal particles in the bath to obtain much more positive charge[9, 10], it is useful for SiC particles to co-deposit with Ni-W-P alloy under the effectiveness of the electrical field force.

3.2 Effects of amount of RE and heat treatment temperature on surface morphologies of composite coatings

It is clear from Fig. 1 and Fig. 2 that the amount of RE in the bath and the temperature of heat treatment have little effect on the surface morphologies of the RE-Ni-W-P-SiC composite coating. It is shown that the addition of RE in the composite coatings has no effect on the microstructure and structure. Besides, it is known from Fig. 2 that the composite coatings have higher heat stability of microstructure and oxidation resistance at high temperatures[11, 12].

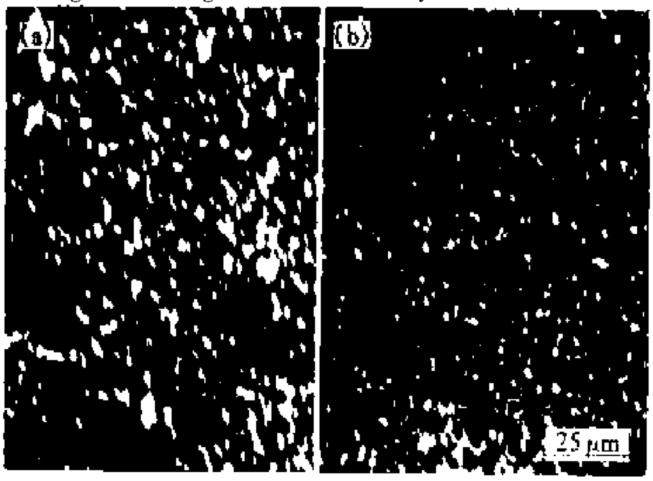

Fig. 1 Effects of RE concentrations in bath on surface morphologies (SEM) of RE-Ni-W-P-SiC composite coatings
(a) —3 g/L RE; (b) —9 g/L RE

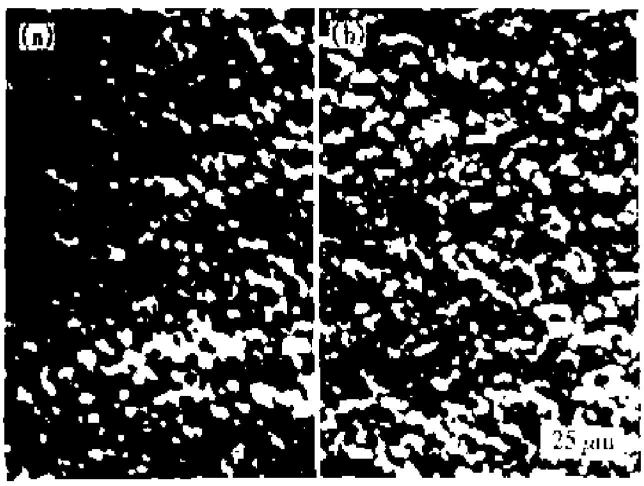

Fig. 2 Effects of holding temperature on surface morphologies (SEM) of RE-Ni-W-P-SiC composite coatings
(a) —200 ℃, 1 h; (b) —500 ℃, 1 h

3.3 Distribution of elements in composite coatings

Distribution of elements in the RE-Ni-W-P-SiC composite coatings is shown in Fig. 3. It is known from Fig. 3 that the distribution of the elements in the deposits is much more uniform, without segregation. It is displayed clearly that the composite coatings as-deposited are amorphous, because the obvious character of amorphous materials is that the components of the materials have no segregation. Besides, XRD indicates that Si and Ce exist in the form of SiC and CeO_2 in the coatings.

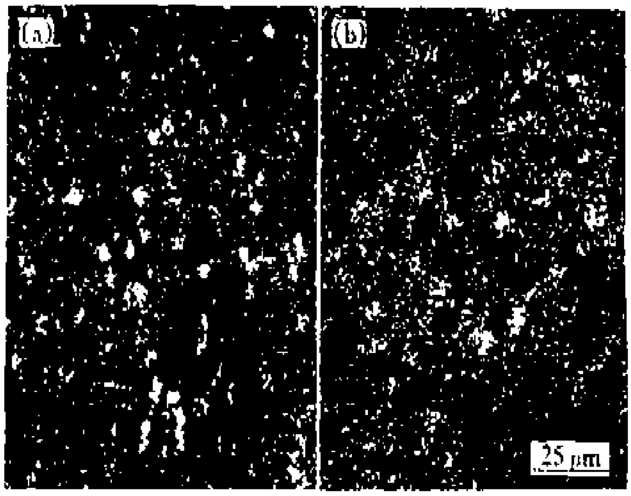

Fig. 3 Distribution patterns of electron of elements in deposits (SEM)
(a) —Distributive pattern of Ce element;
(b) —Distributive pattern of Si element

3.4 Effects of heat treatment temperature on the structure of RE-Ni-W-P-SiC composite coatings

X-ray diffraction patterns of RE-Ni-W-P-SiC composite coatings at different heat temperatures are shown in Fig. 4. It is clear that there is a "bread" peak in the diffraction pattern of RE-Ni-P-SiC composite coating as-deposited, which indicates that the coating as-deposited is amorphous. Besides, there are some sharp peaks of diffraction in the pattern, and the measurements show that they are diffraction peaks of α-SiC and CeO_2 particles. Moreover, the results of component analysis of the coatings also demonstrate that there are about 4% ~ 7% SiC and 5% ~ 14% CeO_2 particles in the deposits.

The composite coatings become crystal and precipitate Ni_3P and W phases, besides there are α-SiC and CeO_2 phases, but the width of diffraction peak keeps unchanged when the temperature of heat treatment rises to 200 ℃. There are not any new phases in the pattern, but the width of the diffraction is reduced when the temperature is raised to 400 ℃. However, the width is obviously reduced and Ni(111), Ni(200) and Ni(220) peaks rise in the pat-

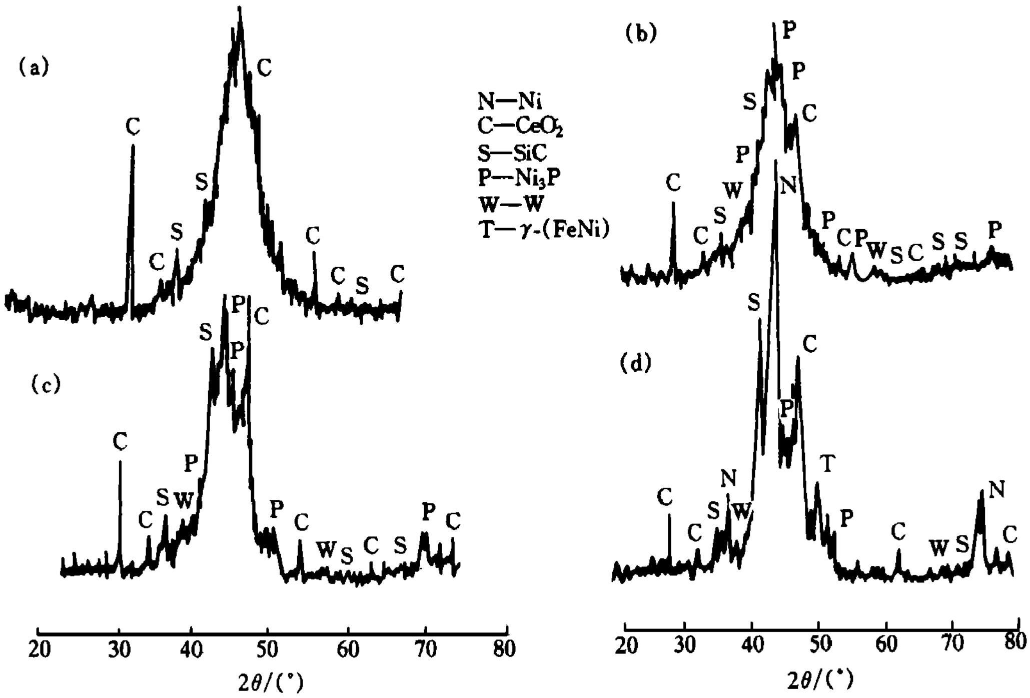

Fig. 4 X-ray diffraction patterns of RE-Ni-W-P-SiC composite coatings at different temperatures
(a) —As-deposited; (b) —200 ℃; (c) —400 ℃; (d) —500 ℃

tern when the temperature of heat treatment is increased to 500 ℃. It is shown that the composite coating has been transformed into crystal. Besides, appearance of γ-(FeNi) phases indicates that nickel atoms in the coating and Fe atoms in the matrix diffuse mutually, and form transition phase γ-(FeNi). In this way, the joint force between the composite coating and matrix is raised greatly.

4 CONCLUSIONS

1) RE-Ni-W-P-SiC composite coating containing 5% ~ 14% RE, 12% ~ 15% P, 5% ~ 6% W and 4% ~ 7% SiC was obtained by means of appropriate bath composition and plating conditions.

2) The as-deposited composite coating is amorphous and it becomes crystal and precipitates Ni_3P phases when heated at 200 ℃; the coating finishes crystallization and produces a new phases —γ-(FeNi) when the temperature is raised to 500 ℃.

3) Rear earth(RE) element has no effect on the microstructure of the composite coating, but it raises the contents of SiC particles in the deposits.

REFERENCES

[1] Thoma M. Electroless plating Ni-P-SiC composite coating [J]. Plating and Surface Finishing, 1984(9): 42.
[2] Vest G E. Electroplating Ni-SiC composite coating and its application [J]. Metal Finishing, 1967(11): 43.
[3] YE Yi-zhong, JIN Zong-de, CHEN Pei-lu, *et al*. Electrodeposited Au-Al_2O_3 composite coating [J]. Plating and Finishing, (in Chinese), 1992, 14(4): 3.
[4] GUO Zhong-cheng, LIU Hong-kang, YANG Xian-wan, *et al*. Process of electrodeposited Ni-W-P-SiC composite coatings [J]. Nonferrous Metal, (in Chinese), 1994, 46 (4): 44.
[5] GUO Zhong-cheng, LIU Hong-kang, YANG Xian-wan, *et al*. Properties of electrodeposited Ni-W-P-SiC composite coatings [J]. Acta Metallurgica Sinica, 1996, 9(1): 47.
[6] MA Ke-yi, GUO Zhong-cheng, WEN Ming-fen, *et al*. Combination strengthening process of Ni-W-Ti-SiC composite coating and nitrocarburization [J]. Trans Nonferrous Met Soc China, 1997, 7(4): 148.
[7] FANG Guo-xin, *et al*. Preparation of organic RE additives for Cr plating [J]. Materials Protection, (in Chinese), 1993, 26(5): 26.
[8] QIAN Da-ren. Application of RE in electroplating [J]. Plating and Finishing, (in Chinese), 1992, 14(3): 19.
[9] GUO Zhong-cheng. Effects of rare earth process and properties of composite plating [J]. Acta Metallurgica Sinica, (in Chinese), 1996, 32(5): 516.
[10] GUO Zhong-cheng, LIU Hong-kang, WANG Zhi-yin, *et al*. Process and properties of electroless RE-Ni-B-SiC composite coatings [J]. Acta Metallurgica Sinica, (in Chinese), 1995, 8(2): 118.
[11] GUO Zhong-cheng, YANG Xian-wan and LIU Hong-kang. Characteristic of Ni-B-Al_2O_3 coating material [J]. Trans Nonferrous Met Soc China, 1996, 6(2): 33.
[12] GUO Zhong-cheng, YANG Xian-wan and LIU Hong-kang. Structure and microstructure of electrodeposited Ni-W-P-SiC composite coatings [J]. Trans Nonferrous Met Soc China, 1997, 7(1): 22.

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