COMBINATION STRENTHENING PROCESS OF Ni-W-Ti-SiC COMPOSITE COATING AND NITROCARBURIZATION ①

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ABSTRACT The significance and theoretical basis of the combination strengthening process of electroplating Ni-W-Ti-SiC composite coating and nitrocarburization were expounded briefly with the emphasis on the technical conditions of the process and the structure and properties of the coating. The results showed that satisfactory Ni-W-Ti-SiC composite coating can be obtained on the steel when some appropriate complex reagent and additive were selected and the process parameters were controlled. The hardness and wear resistance of the nitrocarburized composite coating are much higher than those of the composite coating without nitrocarburization. Scanning electron microscope investigation indicated that Fe in the matrix diffuses into the coating during nitrocarburization to produce the "nailing-up effect" and to increase the joining force between the coating and the matrix remarkably.

Key words composite electroplating nitrocarburizing combination strengthening

1 INTRODUCTION

Coating and heat diffusion treatment is one of the modern surface combination strengthening techniques. After heat treatment the coating atoms diffuse into the matrix, and the joining force between the coating and the matrix is changed from simple mechanical joint to metallurgical binding and intensified. In addition, the composition and structure of the composite coating can be adjusted to obtain better surface properties.

The main components of hard alloy are Co and WC, or Co, WC and TiC, and the high hardness of hard alloy is attributed to WC (2400 HV) and TiC(3200 HV). Since the composite coating has higher hardness and wear resistance[1-4], if carbon steel or alloy steel is electroplated with Ni-W-Ti-SiC composite coating and followed by nitrocarburization to form the nitride or carbide of tungsten and titanium, the microstructure and property of the steel surface can be rendered similar to those of hard alloy. This process can save a large amount of precious metals, prolong the service life of the steel workpieces, simplify the technological procedures and lower the operating costs.

2 EXPERIMENTAL

The bath composition and process conditions are shown in Table 1.

Although the standard electrode potentials of tungsten and titanium differ greatly from that of nickel, their codeposition may be effected by use of the "induction codeposition effect" of nickel to obtain satisfactory ternary alloy coating if some appropriate complex reagent and additive are selected and the process parameters are controlled. The surface morphology of the ternary alloy coating can be improved effectively when SiC particles are inserted.

The nitrocarburization of the Ni-W-Ti-SiC composite coating was carried out in 1Cr18Ni9Ti

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Table 1 Bath composition and process conditions

Chemical composition	$Ti(SO_4)_2$	Na_2WO_4	$NiSO_4$	Complex reagent	SiC	NaCl	NH_4AC
Concentration / $g \cdot L^{-1}$	80~120	60~90	10~30	170~210	40~100	10~15	15~20

Conditions: current density= 3~ 8 $A \cdot dm^{-2}$, temperature= 30~ 60 ℃, pH= 4~ 6

stainless steel crucible heated by electric resistance wire. The heating temperature was 570 ± 10 ℃, and the heating duration was 2 hours. The salt bath solution contained 34% ~ 36% CNO^- [5], and the specimen matrix was 40Cr steel.

The composition of the composite coating was analyzed by EDAX9100 electron spectrometer, the coating thickness was measured with electron microscope, and the coating hardness was determined by means of HX-1 microhardometer under a load of 100 g. The surface morphology and cross-section of the coating and the diffused layer were examined by scanning electron microscope, and the structure of the diffused layer was analyzed by GX-3B X-ray diffractometer. The wear resistance was determined by abrasion test, and the test device included a roll was made of GCr15 (HRC60), which was pressed against the coated specimen with a force of 300 N and rotated at 400 r/mim for 2 h.

3 RESULTS AND DISCUSSION

3.1 Analysis of spectrum of Ni-W-Ti-SiC composite coating

The qualitative analysis of the coating spectrum confirmed that the composite coating contained nickel, tungsten, titanium and silicon. The quantitative analysis indicated that the coating contained (%, in mass): Ni 50~ 65, W 30 ~ 40, Ti 2~ 5 and SiC 3~ 9.

3.2 Morphology and microstructure of Ni-W-Ti-SiC coating and diffused layer

The surface morphologies of Ni-W-Ti alloy and Ni-W-Ti-SiC composite coating are shown in Fig. 1(a) and Fig. 1(b), respectively. It can be seen that the crystal grains of Ni-W-Ti-SiC composite coating are much finer than those of Ni-W-Ti alloy. This proved that SiC particles inserted can obstruct the crystal growth of Ni-W-Ti alloy and make the grains finer and uniform, which contribute to higher hardness and wear resistance of Ni-W-Ti-SiC composite coating.

Fig. 2(a) shows the microstructure of Ni-W-Ti alloy coating, and indicates that the hardness of Ni-W-Ti alloy coating, the white and bright layer in this Fig., is much higher than that of the matrix. Fig. 2(b) shows the microstructure of nitrocarburized Ni-W-Ti-SiC composite coating, and indicates that the hardness of the coating decreases gradually from external part to internal part while the hardness of the matrix keeps constant. This suggested that nitrogen and carbon ions dose not penetrate the composite coating to permeate into the matrix. If it is necessary for nitrogen and carbon ions to permeate into the matrix, the nitrocarburizing duration should be extended or the coating thickness reduced. In addition, it can be seen from Fig. 2(b) that some phases (black points) exist in the nitrocarburized composite coating, and these phases act as strengthener. Electron micro-

Fig. 1 Surface morphology of Ni-W-Ti ternary alloy(a) and Ni-W-Ti-SiC composite coating(b)

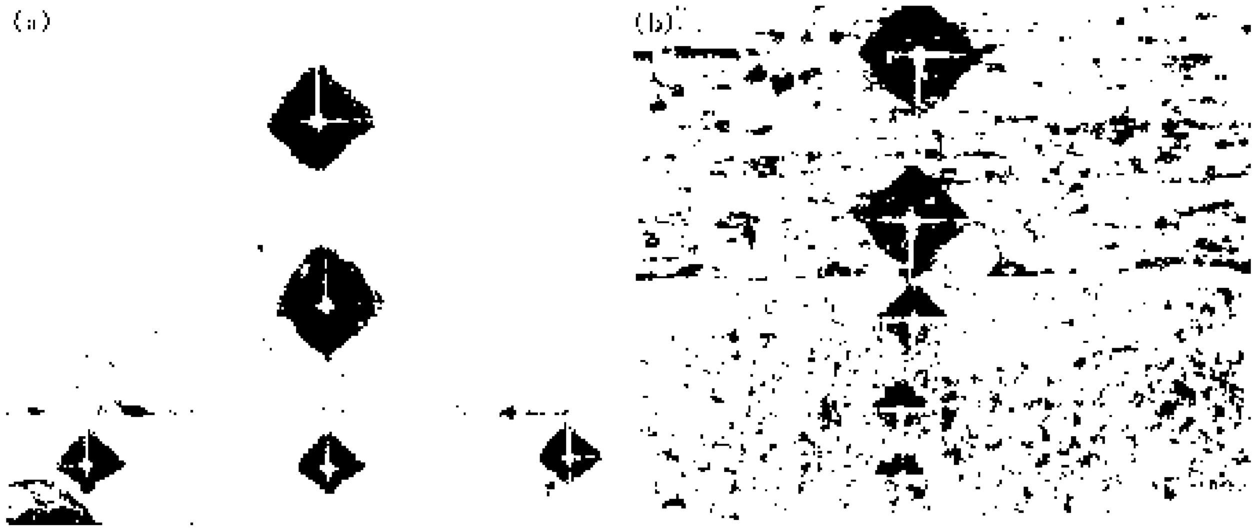

Fig. 2 Microstructure of Ni-W-Ti coating(400×)(a) and nitrocarburized Ni-W-Ti-SiC composite coating(400×)(b)

scope identified these strengthener-phases are W(C,N), Ti(C,N) and SiC particles.

3.3 X-ray diffraction pattern of Ni-W-Ti-SiC composite coating after nitrocarburization

As shown in Fig. 3 the nitrocarburized coating contains solid solution of nickel, as well as titanium carbide, titanium nitride, tungsten carbide, tungsten nitride and a small amount of γ-(FeNi). This indicates that nitrocarburization results in diffusion of Fe in the matrix into the coating to form γ-(FeNi) transition phase, which increases the joining force between the coating and the matrix.

3.4 Hardness of Ni-W-Ti-SiC composite coating after nitrocarburization

The hardness-variation curve of the nitrocarburized composite coating is shown in Fig. 4. Obviously, the hardness of the surface layer is the highest (1 370 HV), and the coating hardness decreases gradually from the surface to internal part. However, the hardness changes unremarkably after the distance from the surface exceeds 80 μm, which suggests that the hardness of the matrix metal keeps constant.

The hardness data of some materials are given in Table 2. The values point out that the hardness of the nitrocarburized Ni-W-Ti-SiC composite coating is the highest, and it is over twice as high as that of the coating without nitrocarburization. The reason is that the nitrocarburized composite coating contains some strengthening-phases such as tungsten carbide, titanium nitride, titanium carbide and silicon carbide, and these phases modify the microstructure and functional characteristics of Ni-W-Ti-SiC composite coating.

3.5 Wear resistance of Ni-W-Ti-SiC composite coating after nitrocarburization

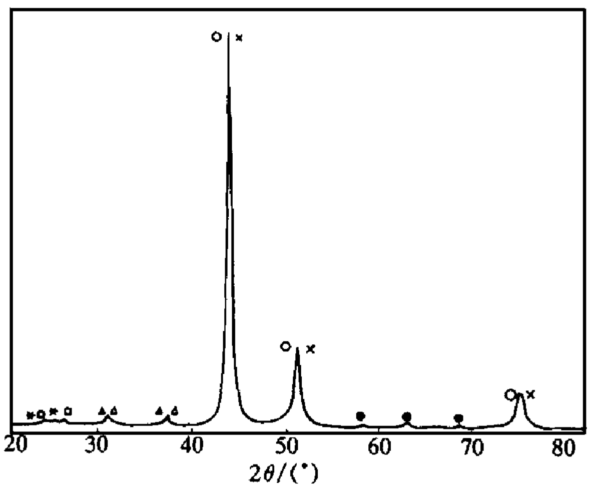

Fig. 3 XRD pattern of Ni-W-Ti-SiC coating after nitrocarburization

○—Ni; ×—γ-(FeNi); ●—Si; △—WC; ▲—WN; *—TiC; □—TiN

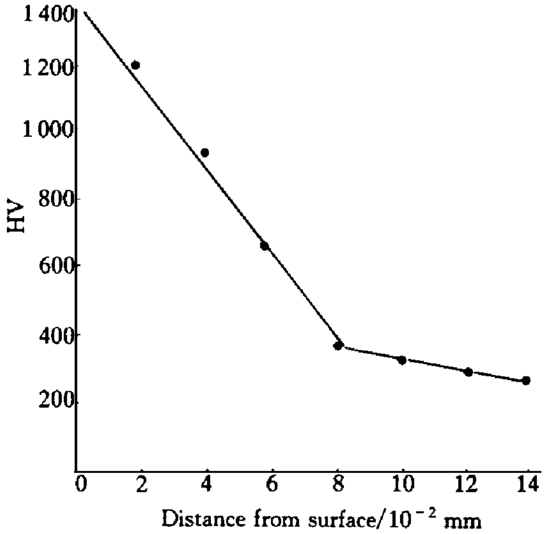

Fig. 4 Hardness-distance curve for nitrocarburized composition coating

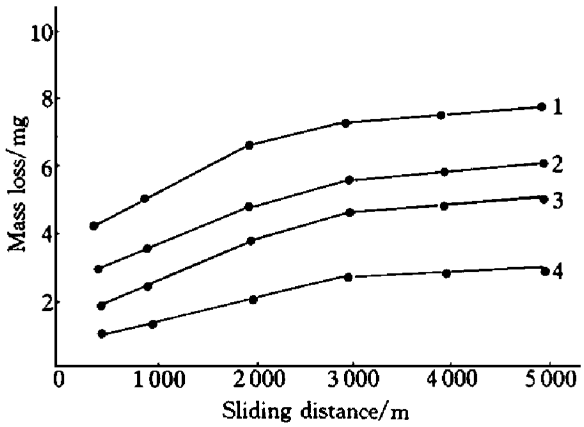

Fig. 5 Comparison of wear resistances of some materials

1 —40 Cr steel; 2 —20 CrMnTi steel;
3 —Ni-W-Ti-SiC (plating only);
4 —Ni-W-Ti-SiC (nitrocarburized)

Table 2 Hardness data of some materials

Material	Treatment	Hardness(HV)
40 Cr steel	Nitrocarburizing	400~ 500
20 CrMnTi steel	Nitrocarburizing	600~ 650
Ni-W-Ti-SiC coating	Plating only	500~ 600
Ni-W-Ti-SiC coating	Nitrocarburizing	1 300~ 1 350

The mass loss *vs* sliding distance curves of some materials in abrasion test are shown in Fig. 5. At the early stage of abrasion the mass loss of these materials rises straightly with an increase in sliding distance, but these curves become gentle after a certain sliding distance. This is because that at the early stage the top softer ash layer was worn out first, and the abrasion rate was higher; at the later stage the friction surface was polished and lubricated, so the abrasion rate was reduced. Fig. 5 also shows that the mass loss of the nitrocarburized Ni-W-Ti-SiC composite coating is the lowest. Evidently, the nitrocarburized composite coating contains WC, TiC, WN and TiN besides SiC, and these hard particles play dispersing and strengthening role and are the main contact points with the frictional auxiliary contact in friction process.

4 CONCLUSIONS

(1) Under appropriate conditions tungsten and titanium can be coplated with nickel by the "induction codeposition effect". SiC particles can improve the surface morphology of Ni-W-Ti alloy coating.

(2) The joining force between Ni-W-Ti-SiC composite coating and matrix is strengthened remarkably after the coating is heated and nitrocarburized, and it is changed from mechanical joint to metallurgical binding.

(3) The hardness and wear resistance of the matrix surface can be increased effectively after the matrix metal is plated with Ni-W-Ti-SiC composite coating and followed by nitrocarburization.

The equipment used in this process is simple, its operation is easy and stable, and the production cost is low. So this process shows broad prospects for industrial application.

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