CHARACTERISTICS OF RE-Ni-B-Al_2O_3 COATING MATERIAL ①

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ABSTRACT The effect of heat treatment on the hardness, wear resistance and structure of a coating material of 0.45% RE-Ni-4.8% B-6.2% Al_2O_3 has been discussed. Results showed that the hardness and wear resistance of the composite material reached their optimal values when heating temperature rose to 350 and 500 ℃ respectively. The crystalline process of the RE-Ni-B-Al_2O_3 composite was: amorphous $\xrightarrow{300\sim 400\ ℃}$ mixture $\xrightarrow{\text{over } 400\ ℃}$ crystalline. X-ray diffraction and scanning electron microscopy indicated that the composite material was amorphous at the as-coated status. Sharp diffraction peaks of Al_2O_3 particles appeared on the diffraction pattern, but the diffraction peaks of RE did not appear because of its low content. The crystalline temperature of Ni-B alloy increased when RE and Al_2O_3 particles were inserted. The hardness and wear resistance of the composite increased obviously with the addition of RE and Al_2O_3 particles.

Key words RE-Ni-B-Al_2O_3 composite material coating material amorphous crystalline

1 INTRODUCTION

It is well known that diamond, carbide, boride, and nitride have high hardness, low friction coefficient and good wear resistance, yet their applications are limited because of their low tensile strength, weak capacity of pounding and machining difficulty[1]. If insoluble solid particles are added in the electroless bath, and enabled to codeposit with metals on a plate to form a uniform composite layer, then the plate would possess better characteristics[2-6] than the bare metals or alloys. In this paper, the stabilizer and active agent for the bath were developed by a lot of experiments on the basis of electroless Ni-B alloy and a new type of composite material (RE-Ni-B-Al_2O_3) was prepared successfully.

2 EXPERIMENTAL METHOD

The plating solution of Ni-B alloy recommended by literature[7] was used as electroless composite bath shown in Table 1. The stability of the bath was deteriorated and could cause spontaneous decomposition because of addition of Al_2O_3 particles, so some stabilizers must be added, and a few active agents should be added to improve the affinity between the bath and Al_2O_3 particles because Al_2O_3 are inactive.

The content of boron was measured by AES, and Al_2O_3 particles were measured by

Table 1 Bath composition and its operation conditions

Agent	Concentration/ $g \cdot L^{-1}$
$NiCl_2 \cdot 6H_2O$	30
$H_2N(CH_2)_2NH_2$	60
$NaBH_4$	0.9
NaOH	40
Al_2O_3(1 um)	12
RE	8
Stabilizer	0.8
Active agent	a little
Temperature	80 ±2 ℃
pH	13 ±0.2
Agitating speed	400 r/min

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weight, i. e., the coatings were dissolved in heated nitric acid solution; after the solutions was filtrated, precipitate was rinsed with distilled water for several times, then dried at 120 ℃ for 2 h and weighed with analytical balance. The content of Al_2O_3 in the coating was calculated as follows:

$$C(Al_2O_3) = \frac{W_{Al_2O_3}}{W_{coating}} \times 100\%$$

The content of RE (rare earth) was measured by electron spectrum.

Microhardness was measured under a load of 100 g wear resistance and the rate of abrasion were determined by the weight difference before and after abrasion. The wear testing device included a roll made of steel (GCr15, HRC59). The force acting on the coating was 300 N at 400 r/min for 3 h.

Phase structure of the coatings was analysed by GX-3B X-ray diffraction, and the morphology of the surface and cross section were examined by ASM-SX scanning electron microscope.

3 RESULTS AND DISCUSSION

3.1 *Structure of the Coatings*

X-ray diffraction patterns of Ni-B alloy and RE-Ni-B-Al_2O_3 composite with the same B content are shown in Fig. 1 and Fig. 2, respectively. Their X-ray profiles are very similar. Both of them show broad diffraction peak at $\theta = 22.5$, and the strength of diffraction reduces slowly within a wide extent, which is the mark of amorphous status. Some small sharp diffraction peaks appear in Fig. 2, indicating the existence of α-Al_2O_3 particles, and that RE and Al_2O_3 particles are inserted in the Ni-B alloy and have no effect on the alloy's structure.

Fig. 1 Diffraction pattern of Ni-4.8%B alloy, as-coated

Fig. 2 Diffraction pattern of 0.45% RE-Ni-4.8%B-6.2% Al_2O_3 coating, as-coated

3.2 *The Effect of Temperature on the Structure of the Coatings*

Fig. 3 and Fig. 4 show the effects of heat treatment temperature on the structure of coatings. The effects of temperature on the structure of Ni-B and RE-Ni-B-Al_2O_3 coatings are basically the same. The structure of the coatings is amorphous with crystalline α-Al_2O_3 particles. While at 300~400 ℃ there are peaks of α-Al_2O_3 particles and Ni_3B on the patterns, yet there is no peak of nickel of RE-Ni-B-Al_2O_3 composite coating, which appears only in the case of Ni-B alloy. This demonstrates that the composite coating is a mixture material and Ni-B alloy is crystalline at 300~400 ℃. The diffraction peaks of nickel show up on the pattern of the composite coating when the temperature is over 400 ℃, indicating that the composite coating has changed into crystal. On the other hand, the diffraction peaks of Al_2O_3 particles maintain unchanged in the process of crystallization. Therefore, the final stable phases of RE-Ni-B-Al_2O_3 composite coating are Ni+ Ni_3B+ Al_2O_3, in addition, the crystalline temperature of Ni-B alloy is raised when RE and Al_2O_3 particles are inserted in the alloy.

Fig. 3 Effect of temperature on microstructure of Ni-B alloy

(● —Ni; ○—Ni_3B)

1 —500 ℃; 2 —400 ℃; 3 —300 ℃;
4 —200 ℃; 5 —25 ℃

3. 3 *The Effect of Temperature on Hardness and Wear Resistance of the Coatings*

The effects of temperature on hardness and wear resistance of the coatings are shown in Fig. 5 and Fig. 6, respectively. The hardness and wear resistance of RE-Ni-B-Al_2O_3 coating are much better than those of the other two coatings, because it contains RE and Al_2O_3 particles, which play the role of dispersion strengthening.

In addition, the hardness and wear resistance of the coatings increase with increasing temperature, and the hardness reaches peak value at 350 ℃ and then decreases, yet the wear resistance is not good at 350 ℃. Only when temperature rises to 500 ℃ does the wear resistance of the coatings reach its best. At 350 ℃, there is a lot of hydrogen inducing high internal stress and great frangibility in the coatings, so part of the coatings peel off under the effect of alternating stress in the process of relative friction, and the abrasion rate of the coatings increases. On the other hand, at higher temperature gases release, the stress relaxes and frangibility is lower. However, at this condition the grains grow up, Ni_3B particles coarsen and the coatings are softened. Therefore the coatings are easy to be cut and the rate of abrasion increases. At about 500 ℃, the coatings with higher hardness and mild frangibility possess the best wear resistance.

Fig. 4 Effect of temperature on microstructure of RE-Ni-B-Al_2O_3 coating

● —Ni; ○—Ni_3B; △ —Al_2O_3;

1 —600 ℃; 2 —500 ℃; 3 —400 ℃;
4 —300 ℃; 5 —200 ℃; 6 —25 ℃

3. 4 *Comparison of Wear Resistances of Several Coatings*

The standard specimen is plated with RE-

Ni-B-Al_2O_3 coating, and tested in the MM-200 wearing device. For comparison, hard-chromium, electroless Ni-B alloy, ion nitriding coating and Ni-B-Al_2O_3 composite coating are used. The results are shown in Fig. 7. The amount of abrasion of RE-Ni-B-Al_2O_3 composite coating is the smallest and is only about 67% of Ni-B-Al_2O_3 coating, 18% of hard-chromium and 4.5% of nitriding coating, respectively.

3.5 *Microstructure and Morphology of Coatings*

Fig. 5 Effect of temperature on hardness of the coatings

1 —0.45% RE-Ni-4.8% B-6.2% Al_2O_3; 2 —Ni-4.8% B-3.8% Al_2O_3; 3 —Ni-4.8% B

Fig. 6 Effect of temperature on wear resistance of the coatings

(v —rate of of abrasion)

1 —0.45% RE-Ni-4.8% B-6.2% Al_2O_3; 2 —Ni-4.8% B-3.8% Al_2O_3; 3 —Ni-4.8% B

Fig. 7 Results of abrasion testing on coatings

(ΔW —amount of abrasion)

1 —RE-Ni-B-Al_2O_3; 2 —Ni-B-Al_2O_3; 3 —hard-chromium; 4 —Ni-B; 5 —ion nitriding coating

Microstructure of the cross section of Ni-B alloy free of Al_2O_3 particles shows a white band, while the RE-Ni-B-Al_2O_3 coating with some Al_2O_3 particles scattered as black fine particles in the white band. Surface morphology of the composite coating was observed by SEM, which shows clearly that the dispersion of Al_2O_3 particles is uniform.

REFERENCES

1 Wu Yichen. Plating & Finishing, 1990, 12(5): 11 - 14.

2 Guo Zhongcheng. Materials Protection, 1991, 24 (11): 15- 17.

3 Zhao Guopeng. Electroplating & Pollution Control, 1987, 7(3): 24- 26.

4 Guo Huotong. Plating & Finishing, 1991, 13(2): 3 - 7.

5 Guo Zhongcheng. Materials Protection, 1993, 26 (5): 19- 22.

6 Yi Xianhai. Surface Technology, 1991, 20(1): 22- 24.

7 Guo Zhongcheng. Materials Protection, 1992, 25 (5): 34- 36.

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