Structure & Properties Of Electroless Ni-P-B_4C Composite Coatings

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The surface image and inner structure of electroless Ni-P-B_4C deposit layers were observed and analyzed by SEM, optical microscope and X-ray diffractometer. The results showed that with increase of the amount of B_4C particles in the plating solution, the number of the surface nodular protrusions increased. The particles of B_4C evenly dispersed on the Ni-P matrix and adhered well in the coatings. The presence of the B_4C particles does not change the phase composition. The mechanical properties of composite coatings were measured. The results indicated that with increase of the content of B_4C, the hardness and wear resistance were obviously improved, but the critical load was decreased.

It is well known that there are three types of material failure: corrosion, wear and fatigue. Wear is the main failure mode for many machine components. Improving surface hardness is one method to upgrade the wear resistance of materials. At present, to improve surface hardness and wear resistance, many treatment methods are adopted; for example, electroplating, carbon case hardening, nitrogen hardening, PVD, CVD, ion implantation, etc. Every technology has its limitations, however. Some have poor feasibility, and some are expensive. Electroless Ni-P composite plating is one of the new technical metal surface treatments. It offers excellent technical feasibility (good throwing power, uniform coating thickness, good surface smoothness, etc.), as well as other functional properties.

Many reports have been published worldwide that are mainly focused on electroless Ni-P composite plating.[1-7] Although there are a few reports concerning Ni-P-B_4C deposits, little data was given. In this paper, the authors emphasize study of the structure and mechanical properties of Ni-P-B_4C deposit coatings.

Experimental Procedure

Electroless Composite Plating Solution

In the plating solution, sodium butanate and amino acetic acid are used as complexing agents, with sodium hypophosphite as reducing agent. Solution pH, 4.5 to 5.0, temp 85 °C. The particle size of the B_4C is W5. Mechanical agitation is employed at the rate of 750 rpm.

Pre-cleaned Substrates of Gray Cast Iron

The preparation and plating sequence for the substrates was chemical de-oiling and rust removal —> washing with deionized water —> chemical activation (15% H_2SO_4 solution), 25 °C , 8 sec) —> pre-plating Ni —> electroless plating.

Assessment of Coatings

The surface images before and after the wear test were observed by SEM, and the phase was analyzed by X-ray diffractometer. A scratch test was adopted to measure the adhesive force. The critical load, *Lc*, which first causes stripping during the scratch test is regarded as the adhesive force. Hardness was measured by a microhardness tester. The thickness of the deposit was 25 µm, and the load was 1 N. The wear test was conducted on a wear tester. The top sample was measured with sample rotation rate of 200 rpm; the bottom sample was compared, having rotated at 180 rpm. The weight loss method was adopted, with a test load of 300 N, time 20 min. The wearability was expressed by the loss of weight of the sample before and after the test.

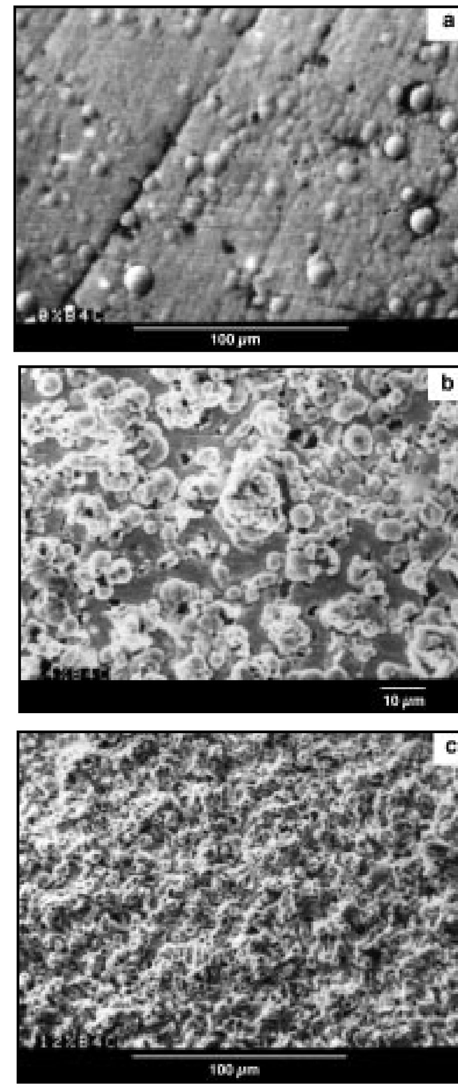

Fig. 1—SEM micrographs of composite coatings: (a) Ni-P; (b) Ni-P-19%B_4C; (c) Ni-P-32%B_4C.

Results & Discussion

Surface Image & Inner Structure

Figures 1(a)(b)(c) are SEM micrographs of Ni-P, Ni-P-19%B_4C and Ni-P-32%B_4C composite coatings, respectively. It can be seen from the figures that there are a few nodular protrusions and pores in the surface of the Ni-P deposit; more in the surface of the Ni-P-19%B_4C coating, but the surface of the Ni-P-32%B_4C deposit is almost covered with nodular protrusions. The micrographs indicate that, with increase of the content of B_4C particles, the surface nodular protrusions increase, but their size gets smaller. In addition, they show that the B_4C particles are partly exposed or wholly embed-

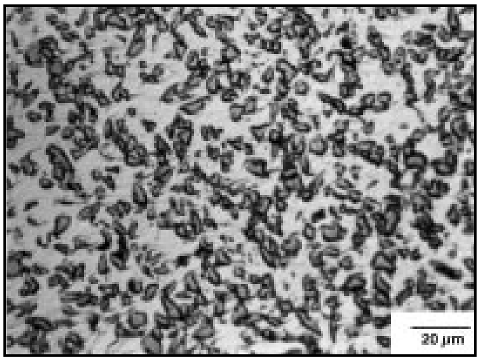

Fig. 2—Optical micrograph of composite coating.

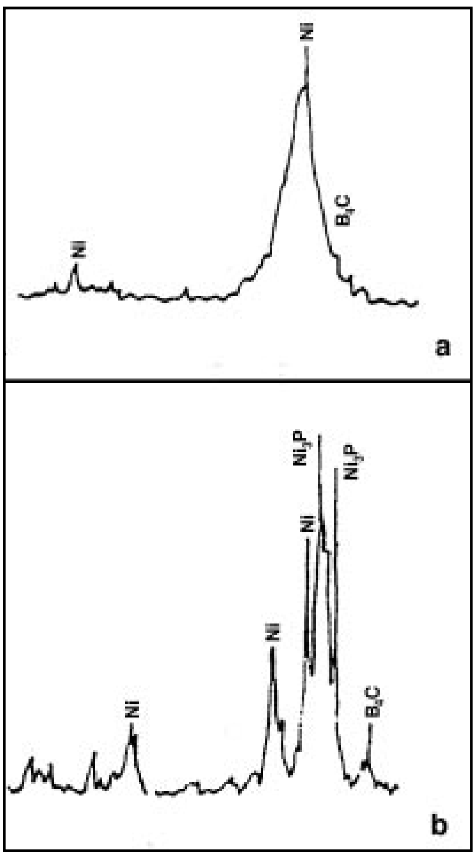

Fig. 3—X-ray diffraction curve of Ni-P-26%B_4C coatings: (a) as deposited; (b) after heat treatment for one hr at 350 °C.

ded in the Ni-P matrix. Figure 2 is an optical micrograph of the surface-polished Ni-P-26%B_4C composite coating. It can be seen that B_4C particles are evenly dispersed in the coatings.

The amount of particles in coatings depends on the amount of the particles added to the plating solution, the agitation rate and particle diameter. After the latter two factors were determined in the experiment, it was found that the amount of B_4C particles in the coatings increases with increase of particles in the plating solution.

Figure 3a shows the X-ray diffraction curve of Ni-P-26%B_4C in the deposit. The curve shows that there are B_4C particles in the amorphous Ni-P matrix. Figure 3b shows the X-ray diffraction curve of Ni-P-26%B_4C plating layer after heat treatment for one hr at 350 °C. The curve shows that the coating consists of Ni, Ni_3P and B_4C.

Figure 3c reveals that the B_4C content in the plating layer affected the diffraction intensity of Ni and Ni_3P. The increase of the B_4C particle content caused a decrease of the Ni and Ni_3P diffraction intensity attributable to the change in quantities of the constituents.

In the X-ray diffraction curve of the Ni-P deposit,[7] it can be seen that the B_4C particles only strengthen the intensity of diffraction. From these results, it is clear that the presence of B_4C particles doesn't change the structure and phase composition of the Ni-P matrix.

Mechanical Properties

Hardness

The hardness test of electroless Ni-P-SiC composite coatings indicated that the hardness depends on the hardness of the Ni-P matrix and the content of SiC. Accordingly, we first examined the relationship between the hardness of the Ni-P alloy and heat treatment technology. The results indicated that the greatest hardness of the Ni-P deposit coatings is HV 912 after one hr heat treatment at 350 °C.

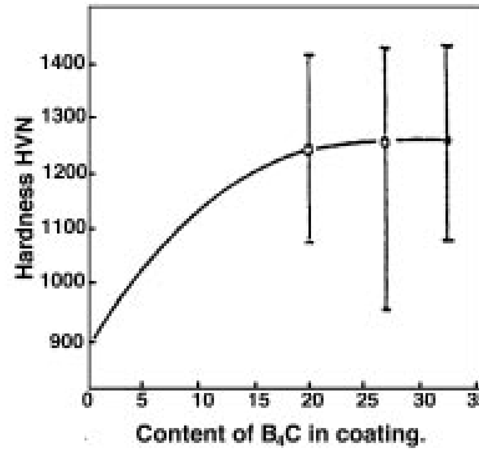

Fig. 4—Relationship between hardness and B_4C content.

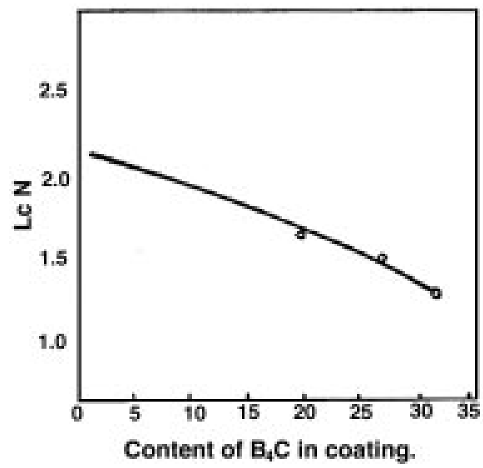

Fig. 5—Adhesive force variation with B_4C content.

Figure 4 shows the relationship between B_4C content and the hardness of Ni-P-B_4C at one hr heat treatment at 350 °C. The results show that the hardness increased considerably when the coatings contained B_4C particles, but the test data have some scattering, which may be because the load is so small that the indentation can only impinge partially on B_4C particle, or wholly on the Ni-P matrix. The real hardness of composite coatings cannot, therefore, be obtained, but it is nevertheless true that with increase of the B_4C content in the deposit coatings, the entire hardness increased.

Adhesive Force

A scratching test was adopted to measure the adhesive force of composite coatings. The results are shown in Fig. 5. The curve indicates that the higher the content of B_4C, the poorer the adhesive force.

Figure 6 shows the micrograph of the spot where the coatings strip during scratching. With the load on the Ni-P layer increasing (direction of arrow), it first appeared as a crack, then stripped large lumps, but on the Ni-P-32%B_4C coatings, only small lumps were stripped. It indicates that adding B_4C particles destroys the continuity of the Ni-P matrix and that *Lc* cannot be used to evaluate exactly the real adhesive force of composite coatings. Obviously, the force needed to cause stripping of large lumps is larger than the force to cause stripping of small lumps. Indentation and file tests qualitatively indicated that the Ni-P-B_4C composite coating has excellent adhesion to cast substrates.