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The Dispersion of Nanometer SiC on Electroless Ni-P-nano SiC Composite Plating

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***Abstract*—In recent years, along with the development of nanometer material and technology, it is raising the upsurge of researching the craft of electroless composite plating with nanometer particles in domestic and foreign. However the nanometer material because its big relative surface proportion, the increase of superficial atomicity, insufficient of atomic coordinate, and the high surface energy, make these superficial atoms to have the higher activeness, they are extremely unstable and very easy to reunite with each other and become the big reunion body with some connection interfaces. Therefore, in order to make the nanometer particles suspend evenly in the bath to obtain the composite coating of symmetrical distribution of nanometer particles, the question of dispersion of nanometer particles appears important especially. The orthogonal test method has been used to study the effects of the concentration of SiC, the speed of mixing, the temperature and the surfactants on depositing rate and micro-hardness, and obtained the optimized technological scheme and fine Ni-P-SiC composite coating. The results showed that using citric acid-acetic acid as complexing agents can obtain high speed of depositing and homogeneous coating with SiC well-distributed. Among the technological parameters, the effects of temperature on depositing rate is biggest, and the surfactants is next; the effects of the concentration of SiC particles on micro-hardness is biggest, and the surfactants is next. Give consideration to depositing rate and stability of the liquid, the temperature should be controlled at 82±2°C, the concentration of SiC particles and surfactants should be controlled in 4g/L and 60mg/L. The influence to micro-hardness value of coating with ultrasonic disperser craft also has been studied.**

Keywords—electroless composite plating; nanometer SiC; disperser; ultrasonic; surfactant; speed of mixing

I. INTRODUCTION

With the rapid development of aviation, aerospace, electronic, mechanical, chemical and nuclear energy, a variety of new functional and structural materials are becoming urgent need, and some single material can not meet some special requirements, therefore, composite materials have been developed rapidly. Composite plating, also known as spread-plated, composite coatings with wear and corrosion resistance were deposited on the surface of metal matrix layer by electroplating or electroless composite plating to achieve longer life, saving material, reducing costs and improving economic efficiency.

Electroless composite plating is a more convenient and economical way for preparation of composite coating, easy to operate, less investment in equipment, easy to control, low energy consumption. This paper uses a way of adding single SiC wear particles to the Ni-P alloy bath, deposites wear and corrosion Ni-P-SiC composite coating on the surface of 45 steel by electroless composite plating that can be used for piston rings, cylinder liners, molds, bearings, crankshaft and other mechanical parts, extending its life.

II. EXPERIMENT

A. Experimental Instrument and Materials

Experimental instrument is shown in Table I.

TABLE I. EXPERIMENTAL INSTRUMENT

Instrument name	Specification
Collector constant temperature heating magnetic stirrer	DF-101S
Desktop CNC ultrasonic cleaner	KQ5200DB
PH meter	FE20K
Electronic Analytical Balance	AR423CN
Vickers Hardness Tester	HVS-10

Use the ordinary carbon structural steel plate Q235 as sample, Size (L×W×H) is 15 mm×15mm×2mm, producted by Weifang red flag Machinery Factory. Before plating pretreatment of the sample must be carried out whose process is described below.

Chemical degreasing→ Rinse with distilled water→ Ultrasonic cleaning → Rinse with distilled water→10%HCl Activating (1-2min)→Rinse with distilled water.

Bath components are selected according to the results of a large number of single-factor test, The composition of plating solution is shown in Table II.

The physics performance of nano-SiC particles used in this study is indicated in Table III.

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TABLE II. THE COMPOSITION OF PLATING SOLN

Composition	$NiSO_4 \cdot 6H_2O$ [g/L]	$NaH_2PO_2 \cdot H_2O$ [g/L]	$Na_3C_{it} \cdot H_2O$ [g/L]	CH_3COONa [g/L]	Accelerant [g/L]	Stabilizer [mg/L]	Nano SiC [g/L]
Content	25	30	35	5	5	5	

TABLE III. PHYSICS PERFORMANCE OF THE NANOMETER PARTICLE OF SIC

Average size [nm]	Surface area [m^2/g]	Crystal	Color	Free silicon [%]	Total oxygen content [%]	Purity [%]	Bulk density [g/cm^3]
40	90	Cubic structure	Gray-green	<0.2	<0.61	>99.09	0.05

B. Test Method

The plating speed is indicated by the coating weight gain per unit area and per unit time. First, clean degrease the substrate, and then weigh on analytical balance in the parts per million, record the quality m_1. After plating, clean degrease the sample, and then weigh on analytical balance in the parts per million again and record the quality m_2. Plating rate is calculated by equation 1.

$$V = \frac{m_2 - m_1}{S \times t} \quad (1)$$

Formula S-Plating area (m^2)

t-Plating time (h)

Experiments load applied is 100g, loading time is 15s. Select three different locations in the coating surface to test their hardness, calculate the average hardness by the online system using Equation 2.

$$HV=1854.5 \times F \div D2 \quad (2)$$

Formula HV-Vickers microhardness symbol(Kgf/mm^2)

F-The load applied to the specimen (g)

D-Diagonal(μm)

The L_9^3 orthogonal table has been used to study the effects of the concentration of SiC, the speed of mixing, the temperature and the surfactants on depositing rate and micro-hardness. Each factor is tested by three levels, experimental factors and levels are shown in Table IV.

TABLE IV. ORTHOGONAL FACTORS AND LEVEL

Factors level	Concentration of SiC [g/L]	Speed of mixing [r/min]	Surfactant [mg/L]	Temperature [°C]
1	6	200	30	77
2	4	250	60	82
3	2	300	90	87

The surface and cross-section morphology of composite coatings were identified by QUANTA200 environmental scanning electron microscopy (SEM) under the test condition of accelerating voltage 3.0kV. Elements of composite coatings were determined by their micro-scanning using INCA ENERGY 300 X-ray energy dispersive spectroscopy (EDS) under the test condition of accelerating voltage of 25kV.

III. TEST RESULTS AND DISCUSSION

A. The Influence of Factor on Depositing Rate and Analysis

The influence of factor on depositing rate and analysis is shown in Table V.

Table V shows the the analysis results that within the scope of this experiment, temperature is a major factor in the coating deposition rate, surfactant concentration is a secondary factor affecting the plating rate, stirring speed and amount of SiC is little effect to plating rate.

TABLE V. THE INFLUENCE OF FACTOR ON DEPOSITING RATE AND ANALYSIS

Factor Level	Concentration of SiC [g/L]	Speed of mixing [r/min]	Surfactant [mg/L]	Temperature [°C]	Depositing rate [g/m^2h]
1	1	1	1	1	46.667
2	1	2	2	2	47.222
3	1	3	3	3	49.060
4	2	3	2	1	37.778
5	2	1	3	2	53.333
6	2	2	1	3	60.556
7	3	2	3	1	29.445
8	3	3	1	2	94.445
9	3	1	2	3	78.472
R1	47.650	59.491	67.223	37.964	
R2	50.556	45.741	54.491	65.000	
R3	67.454	60.428	43.946	62.696	
Differential	19.804	14.687	23.277	27.036	

B. The Influence of Factor on Micro-hardness and Analysis

The influence of factor on micro-hardness and analysis is shown in Table VI.

Table VI shows the the analysis results that within the scope of this experiment, the amount of SiC is the main factors impacting coating microhardness, the content of surfactant is the secondary factor affecting coating microhardness.

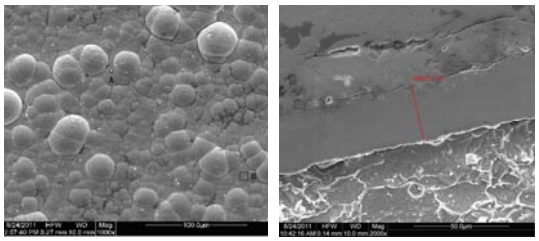
TABLE VI. THE INFLUENCE OF FACTOR ON MICRO-HARDNESS AND ANALYSIS

Factor Level No.	Concentration of SiC[g/L]	Speed of mixing [r/min]	Surfactant [mg/L]	Temperature [°C]	Micro-hardness [$HV_{0.1}$]
1	1	1	1	1	268
2	1	2	2	2	600
3	1	3	3	3	390
4	2	3	2	1	460

C. Surface Morphologres and Composition Analysis

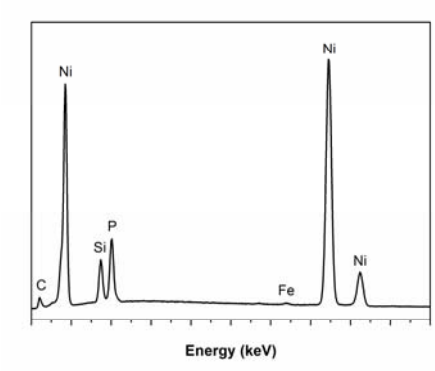
It can be seen from Figure I, composite coating with uniform and dense dispersed small SiC particles.

Figure II and Table VII showed that the Chemical Constituents were different between the region A and B of composite coatings. The element contents of C and Si in the place of A were significantly higher than B. There were small SiC particles in the region A.

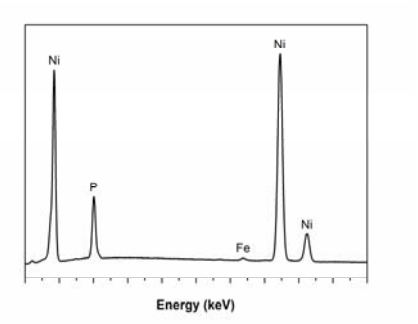


(A) (B)

FIGURE I. CROSS-SECTION AND SURFACE MORPHOLOGY OF COMPOSITE COATINGS (A) SURFACE MORPHOLOGY (B) CROSS-SECTION MORPHOLOGY



(A)



(B)

FIGURE II. EDS PATTERNS OF DIFFERENT POSITIONS ON COMPOSITE COATINGS IN FIGURE I

TABLE VII. THE INFLUENCE OF FACTOR ON MICRO-HARDNESS AND ANALYSIS

Element		Ni	P	Si	C
Position A	Weight%	73.94	12.48	4.02	9.56
	Atomic%	48.41	15.49	5.50	30.59
Position B	Weight%	85.77	14.23		
	Atomic%	76.07	23.93		

IV. SUMMARY

The results showed that using citric acid-acetic acid as complexing agents can obtain high speed of depositing and homogeneous coating with SiC well-distributed. Among the technological parameters, the effects of temperature on depositing rate is biggest, and the mixing speed is next; the effects of the concentration of SiC particles on micro-hardness is biggest, and the mixing speed is next. Give consideration to depositing rate and stability of the liquid, the temperature should be controlled at 82±2°C, the concentration of SiC particles and surfactants should be controlled in 4g/L and 60mg/L.

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