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ARTICLE

Effects of n-Al_2O_3 Particles Content on Structure and Performance of Electro-Brush Plating Ni-Co Alloy Composite Coatings

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Abstract: The composite electronic brush plating technique was used to prepare alloy nanocomposite coatings with different nano-Al_2O_3 particles contents. The effects of nanoparticles content in the electrolyte on the deposition rate, nanoparticles content in coating, microhardness and tribological property of composite coatings were investigated by scanning electron microscopy, microhardness tester and attrition testing machine. It is found that with the increase of nano-Al_2O_3 particles content in the electrolyte, the deposition rate of coatings drops, the surface morphology of the coating becomes flat, the microhardness first increases and then decreases, and wear scar depth and friction coefficient decrease first and then increase. When the nano-Al_2O_3 particles concentration in the electrolyte is 20 g/L, the coating reaches its optimized structure and performance.

Key words: nanocomposite plating technique; nanoparticle; hardness; tribological property

The nanomaterials, due to their small size effect, have unique physical, chemical, electrical, and magnetic properties, and belong to the research field of the materials science leading frontier[1]. The nanocomposite coatings refers to a special metal matrix composite, formed by mixing one or more insoluble nanosized solid particle (s), inert particle (s), fibers, etc., uniformly to the metal deposition layer by the method of electrodeposition[2-4]. The electronic brush plating technique, a significant innovation in the electrodeposition field, is an advanced technique of surface engineering and equipment remanufacturing, and widely applied to equipment surface reinforcement and repairing[5,6]. The nanoparticle composite coatings prepared by the electronic brush plating technique have higher hardness[7,8], excellent abrasion resistance[9,10], corrosion resistance[11] and higher anti-fatigue properties[12,13], which attracts more and more attention. However, the studies are focused more on the nickel base composite plating by the electronic brush plating, and there are fewer studies on the alloy nanocomposite plating, which is far from developing the advantages of the nanocomposite electronic brush plating technology.

In the present investigation the composite electronic brush plating technique was adopted to prepare the alloy nano-composite coatings using Ni-Co alloy coatings as matrix, nano-Al_2O_3 particles as the reinforcing phase. The effects of nanoparticles content in the electrolyte on the deposition rate, nanoparticles content, microhardness and tribological property of composite coatings were discussed.

1 Experiment

The technical principles of nanocomposite electronic brush plating are basically consistent with the technique of electronic brush plating, employing a dedicated constant voltage DC power device, a plating pen engaging positive electrode of powered source as the anode of brush plating, and a workpiece engaging the negative electrode of the power source as the cathode of brush plating. The anode of the plating pen uses highly pure graphite blocks with the anode

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outside surrounded by lots of cotton immersed in the electrolyte and wearable polyester cotton sleeve. The plating pen moves on workpiece surface at a relative moving speed after the plating pen is fully immersed in the electrolyte upon brushing plating. Under the influence of electrical force, metal ions in the electrolyte obtain the electrons, reducing to give the metal plating on cathode surface, forming a matrix phase of the nanocomposite plating; at the same time, nanoparticles in the electrolyte are carried to co-deposit into the metal coating, forming a nanocomposite coating reinforcing phase, and the nanocomposite electronic brush coatings become thickening gradually as the electronic brush plating time is passing by.

The nano-Al_2O_3 particles were selected as the reinforcing phase in the test with the main specifications as shown in Table 1.

Table 2 lists the main components and the content of the Ni-Co electrolyte employed in the tests. The electrolyte was dark green and would smell acetic acid.

During the process of n-Al_2O_3/Ni-Co composite electronic brush electrolyte prepared by the high energy ball milling, firstly, Ni-Co alloy electrolyte was formulated according to Table 2, and then nano-Al_2O_3 particles were gradually added to the formulated electrolyte, simply stirred with a glass rod, at this time, the agglomerated nanoparticles could not decompose, and the nanoparticles were adsorbed one another. In order to disperse the agglomerated nanoparticles, the electrolyte with the nanoparticles was poured into a high energy ball mill to conduct a sufficient ball milling dispersion (24 h). Hard agate balls in the ball mill will mill and disperse the agglomerated nanoparticles, greatly reducing the grain size of the nanoparticles. The nanoparticles could adsorb metal ions and functional groups in the electrolyte. The metal ions and functional groups mutually generate an electrostatic force resistance effect, so that the nanoparticles cannot be close to each other, and then n-Al_2O_3/Ni-Co composite electronic brush electrolyte was obtained.

The process of electronic brush plating was as follows: preplating surface preparation, electronic cleaning, washing with deionized water, 2# activating with activate fluid, washing with deionized water, 3# activating with activate fluid, washing with deionized water, wiping without electricity, plating the base coating, washing with deionized water, wiping without electricity, brush plating the working plating.

Table 1 Index of nano-Al_2O_3 particles

Nano-particle	Particle size/nm	Specific surface area/$m^2 \cdot g^{-1}$	Purity/%	Apparent density/$g \cdot cm^{-3}$
Al_2O_3	50	≤10	≥99	1.6

Table 2 Main components and the content of Ni-Co electrolyte (g/L)

Nickel sulfate	Cobalt sulfate	Nickel chloride	Formic acid	Acetic acid	Hydrochloric acid
100~125	0~50	40~60	18	48	150

With Nova NanoSEM 450/650-type environmental scanning electron microscope, the surface topography of the coatings was tested, and Feature Max-type X-ray spectrometer was used to test and get the element distribution of the coating surface. The microhardness was measured by HVS-1000 digital display microhardness tester, at load 0.49 N, for loading time 15 s.

The tribological properties of the coatings were tested by CETR-UTM-3-type ultra-functional attrition testing machine. Fig.1 is a schematic diagram of the test principles. The milled sample of the coating test-piece is a Si_3N_4 ball with a diameter of 4 mm, HV hardness of 17 GPa. To ensure the relative property, 1000# abrasive paper was used to polish the coating surface before the test. Before each test, the upper and lower samples must be cleaned with ultrasonic and alcohol and 3 trials were run under the same conditions. After finishing the test, the wear rates were calculated by the wear scar depth recorded by the tester. Dry friction test was conducted at room temperature. Test parameters were as follows: load 10 N, amplitude 5 mm, frequency 5 Hz, and time 20 min.

2 Results and Discussion

2.1 Deposition rate

Fig.2 shows how the addition amount of the nanoparticles in the electrolyte affects the coating deposition rate. As can be seen from the figure, with the increase of nanoparticles in the electrolyte, the coating deposition rate becomes slow, and the dependence of the drop of the coating deposition rate on the increase of the nanoparticles content in the electrolyte approximately exhibits a linear relationship. Ni-Co alloy coating deposition rate is 4.8 μm/min. When the nanoparticles content in the electrolyte is 25 g/L, the deposition rate is reduced to 2.067 μm/min, which is about 43% of Ni-Co alloy coating deposition rate.

There are three reasons for the reducing of the coating deposition rate when the nanoparticles are added to the electrolyte. Firstly, for the added nano-Al_2O_3 particles in the electrolyte are non-conductive particles, they act as a shield, reduce the conductivity of the electrolyte, and thus reduce the deposition rate. Secondly, nano-Al_2O_3 particles are co-deposited

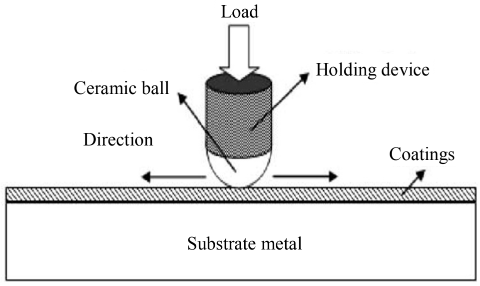

Fig.1 Schematic diagram of CETR test rig

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