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MoS_2 coated with Al_2O_3 for Ni–MoS_2/Al_2O_3 composite coatings by pulse electrodeposition☆

Zhong-jia Huang *, Dang-sheng Xiong

Department of Materials Science and Engineering, Nanjing University of Science and Technology, Nanjing 210094, China

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Abstract

The MoS_2 powders were coated with Al_2O_3 (5 wt.%) through controlling hydrolysis of Al $(NO_3)_3 \cdot 9H_2O$. MoS_2 powder coated with Al_2O_3 was written as MoS_2/Al_2O_3 hereinafter. MoS_2/Al_2O_3 powders were put into Ni plating electrolyte bath. Cetyltrimethylammonium bromide (CTAB) — the surfactant was also put into the bath. The experiment proves that MoS_2/Al_2O_3 particles were absorbed onto the Ni plate. The amount of MoS_2/Al_2O_3 deposited on Ni plate rises with the increasing concentration of MoS_2/Al_2O_3 in the bath. The microhardness, micro-surface, phase and the tribological property of the MoS_2/Al_2O_3 multi-plating coating were measured and analyzed. The performances of microhardness and wear resistance of the Ni–MoS_2/Al_2O_3 composite are better than those of Ni–MoS_2 composite.

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Keywords: MoS_2 coated with Al_2O_3; Electrodeposition; Dendrite growth; Ni–MoS_2/Al_2O_3 coating; Tribological property

1. Introduction

The combination of different materials could produce the improved mechanical, chemical, electrical, magnetic and optical properties. However, these properties depend upon the distribution of phase and the composition of basic phase in the composite.

One type of composite in which ceramic particles were distributed in the metal matrix has been applied widely, especially in machinery for anti-wear and anti-friction. Various cationic surfactants had been added into the plating bath in order to increase the ceramic particles in the composite since the ceramic particles in a particle-dispersed metal matrix composite can share most of the load.

Electroplating has typically been used in the surface treatment industry [1]. It is reported that the composites with ultrafine particles have been made successfully over the past decades. These composites are combined with metallic powders, silicon carbide powders, oxide powers, diamond powders, polymers and the multi-plating of metal or alloy. The structures and properties of the mentioned composites have been studied and confirmed [2–4].

It is well known that pulse electroplating is more effective than the traditional DC electroplating to make composite and alloy due to its independent, controllable parameters and the high instant current [5]. The structure of materials or alloys can be changed through adjusting the pulse current and the properties of materials or alloys can be controlled or improved accordingly. Electroplating is one of the most important surfaces coating technology. When there are particles among the plating bath, the particles will be absorbed onto the plate. Such kind of coating plate is called composite plating. Many researchers have confirmed that the multi coating possess of many specific properties due to the different particles in the coating [6–12].

It has been reported that low-friction composite materials such as Ni-polyethylene [13], graphite-brass [14], Ni-PTFE [15], graphite-bronze [16], Ni–P-carbon-nanotube [17] and good wear resistance composite materials such as Ni–Al_2O_3 [18], Ni–P–SiC [19], Ni–ZrO_2 [20]can be obtained via the electroplating technique.

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* Corresponding author. Tel.: +86 25 8431 5325; fax: +86 25 8431 5325.
E-mail address: jiajiahua@gmail.com (D. Xiong).

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Table 1
Bath composition and operating conditions

Composition and operating conditions	
Nickel sulfate	330 g/l
Nickel chloride	10 g/l
Boric acid	40 g/l
Cetyltrimethylammonium bromide (CTAB)	50 ppm/l
MoS_2 or MoS_2/Al_2O_3 respectively	0, 5, 15, 20, 25, 30 g/l
Temperature	60 °C
PH	4.5
Pulse current condition density	15 Adm^{-2}
Duty cycle	2/3
Frequency	50 Hz
Magnetic stirring speed	600 rpm

MoS_2 has the specific property of self-lubricate. Ni–MoS_2 composite plating is obtained by adding MoS_2 particles into the Ni bath. Such kind of composite plating is called functional plating in industry. Ni–Al_2O_3 composite plating can be used as anti-friction material due to the good harness performance of Al_2O_3. The composite plating will have self-lubricate and anti-friction properties if MoS_2/Al_2O_3 was absorbed onto the plate. In this experiment, we will show you the procedure of making Ni–MoS_2/Al_2O_3 composite plating and analyze its friction property.

2. Experiment

Commercial MoS_2 powder was used in this study. The MoS_2 powder was suspended in a mixed mineral acid (H_2SO_4+HCl),

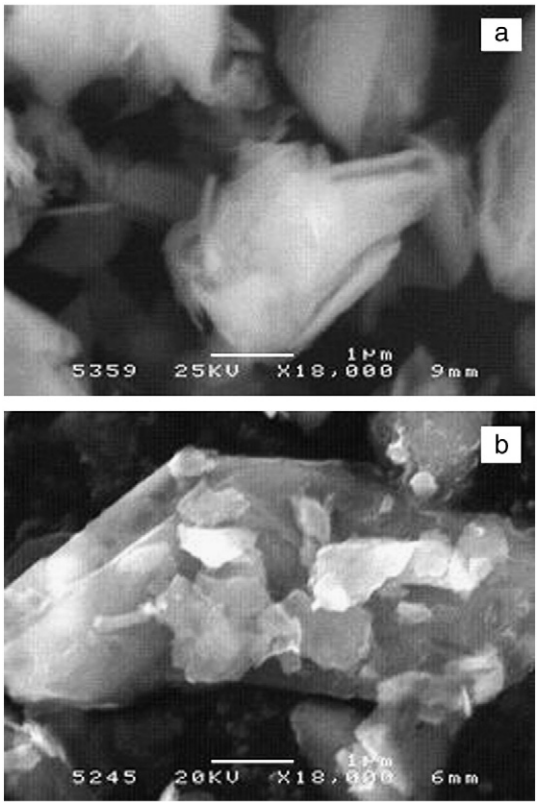

Fig. 1. SEM of powder: (a) pristine MoS_2 powder (b) 5 wt.% Al_2O_3 coated MoS_2.

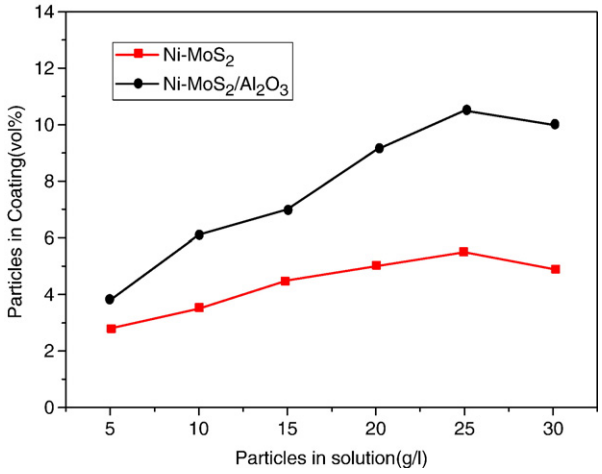

Fig. 2. Comparison of Ni–MoS_2 and Ni–MoS_2/Al_2O_3 coating.

and the acid solution was refluxed for 4 h. The MoS_2 powder treated with the mineral acid was repeatedly washed with water to remove the acid solution, and then the washed MoS_2 powder was dried in a drying oven. The MoS_2 powder 40 g, was suspended in 500 ml distilled water for experiments. Sodium acetate which was used to amortize pH of solution was added to the solution. And pH of the solution was maintained at 6. The beaker was set in a heating mantle on a magnetic stirrer to avoid settling of the MoS_2 powders during the process and subsequently by ultrasonic agitation for 20 min just prior to coating. The solution containing MoS_2 powder was heated at 80± °C for experiments. 32 g of Al $(NO_3)_3 \cdot 9H_2O$ was dissolved in 5 ml distilled water and added to the MoS_2 solution slowly. After completion of the experiment, the powder was collected by filtering and washed with hot distilled water repeatedly until the supernatant showed neutral pH. And then the powder was washed with ethanol and was collected by filtering. The MoS_2 powder treated with the $Al(NO_3)_3 \cdot 9H_2O$ reagent was heated at 300 °C for 3 h.

The MoS_2 and MoS_2/Al_2O_3 powders respectively, were suspended in the plating electrolyte bath, and CTAB, which is a surfactant. Surfactant CTAB was added to reduce the particles particle agglomeration [21]. Additionally, the adsorption of surfactant CTAB on the particles has been proven to enhance the adhesion force to the cathode, enabling larger particles to be embedded [21]. The plating electrolyte was a nickel sulfate bath. The compositions and the range of experimental operating conditions are shown in Table 1. A nickel plate of 120 mm × 60 mm was used as the anode, and a low carbon steel disk of about half

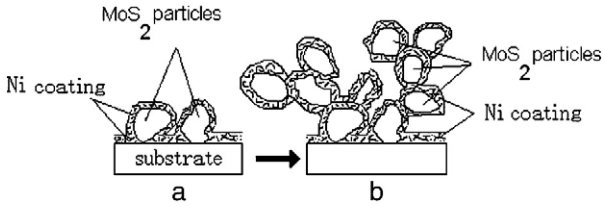

Fig. 3. Schematic of the diacritic growth of the Ni–MoS_2 coating. (a) MoS_2 was incorporated into the deposited Ni. (b)MoS_2 was adsorbed onto the protruding of the MoS_2 resulting in dendrite growth.