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Preparation and tribological behavior of Ni-graphene composite coating under room temperature

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ABSTRACT

In this paper, Ni-graphene composite coatings with different graphene addition amounts were prepared on 45 steel disk by using dipulse composite electrodeposition technology. Meanwhile, the influence of plating time, bath temperature and load on friction and wear of the coating was studied. The tribological behavior of composite coating was tested against a Si_3N_4 ceramic ball under dry condition. Cross-sectional morphologies showed that Ni-graphene coating was successfully coated on the substrate with an average thickness of $85 \pm 5\,\mu m$. XRD analysis concluded that with the increase of addition amount of graphene, the average crystallite size of coating decreased. EDS analyses and Raman spectra proved the presence of graphene. Friction coefficient of composite coating decreased with the increase of graphene addition amounts, while the hardness increased. Meanwhile, the wear resistance of composite coating improved. The optimum experimental conditions were obtained.

1. Introduction

Metal matrix composite coatings containing nano-sized particles of reinforcing phase can be effectively deposited by electrodeposition to enhance the corrosion and wear performance of materials [1]. The problem of stable suspension of nanoparticles in the plating solution is usually overcome by addition of suitable surfactant. The particles reach the surface of the substrate by stirring and get deposited on the substrate metal resulting in composite coating having thickness from tens to hundreds of micrometers. It has already been reported that inclusion of nanoparticles in composite coatings enhances the hardness, corrosion resistance, lubrication and antifriction properties of steel [2]. Also, these properties are reported to be dependent on the experimental parameters like current density, pH, bath constituent's concentrations and the nature of particle [3]. Amongst many metal-based composite coatings, Ni matrix composite coatings are of great importance because of their high hardness and wear resistance.

He et al. [4] prepared Ni-diamond composite coatings containing 1.47–15.6 wt% diamond particle by composite electrodeposition. They reported that Ni-diamond composite coating had a completely different structure from pure nickel coating and the presence of diamond particles provided better corrosion resistance than pure nickel coating. Carpenter et al. [5] prepared nickel-carbon nanotube (Ni-CNT) composite coatings having different CNT volume fractions by electrodeposition and examined their friction and wear properties under dry sliding reciprocating motion. The results indicated that Ni-CNT coatings had higher and more consistent hardness as well as improved wear resistance.

Since, the successful preparation of graphene from exfoliation of graphite by Geim and Novoselov in 2004 [6], it has attracted a lot of attention from scientists due to its excellent properties. Because of smaller shear force between its layers, it has lower friction coefficient than graphite in theory, thus we hope it can make contributions to antifriction and lubrication. Kim et al. [7] prepared graphene films on the surface of SiO_2/Si by chemical vapor deposition (CVD), used Cu and Ni as catalyst. Then they evaluated the friction performance by atomic force microscope (AFM), finding that the friction coefficient of Ni-graphene was only 0.03. Venkatesha et al. [8] successfully prepared Ni-graphene composite coatings on mild steel specimens by electrodeposition and analyzed their corrosion behavior. They reported a change in the surface morphology of graphene resulting in fine grained structure with higher

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Table 1
Bath composition and operating conditions.

Component	
$NiSO_4 \cdot 6H_2O$	240 g/L
$NiCl_2 \cdot 6H_2O$	45 g/L
H_3BO_3	30 g/L
Na_2SO_4	20 g/L
SDBS	0.05 g
Graphene	0.1 g/L, 0.2 g/L, 0.3 g/L, 0.4 g/L
Temperature	50–80 °C
Time	2 h, 4 h, 6 h, 8 h
Current density	1 A dm^{-2}
Stirring rate	750 rpm

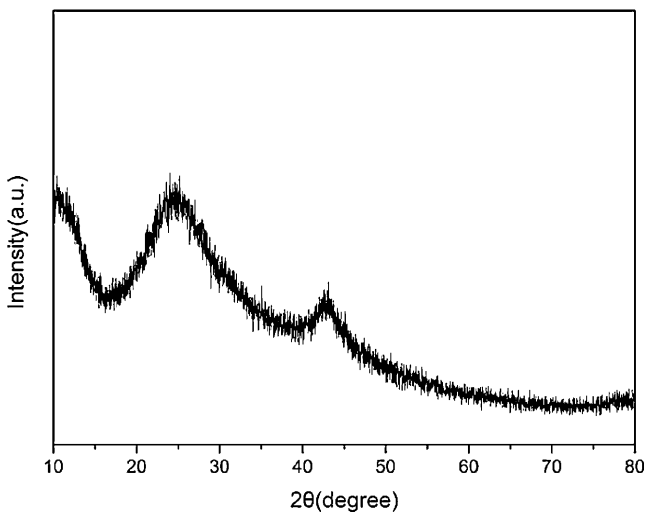

Fig. 1. XRD pattern of graphene.

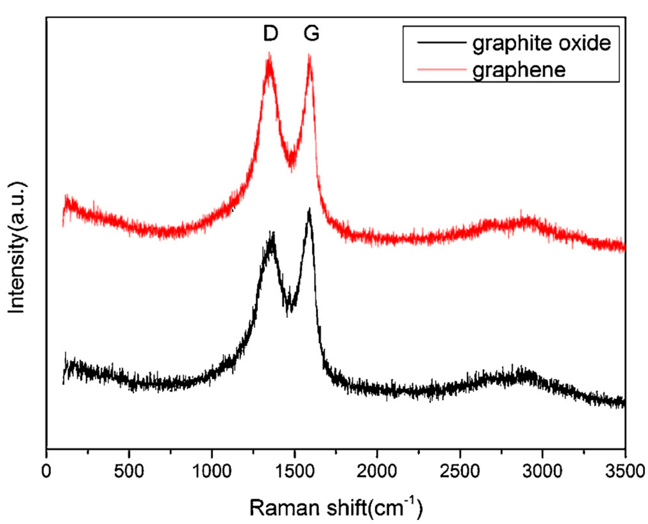

Fig. 2. Raman spectra of graphite oxide and graphene.

hardness and an improvement in corrosion resistance in comparison to the pure Ni coating.

In the present work, Ni-graphene composite coatings with different additions of graphene have been prepared by electrodeposition and the effect of experimental parameters such as plating time, bath temperature and composition on the mechanical properties of composite coatings has been examined. The friction and wear characteristics of the composite coatings under dry sliding contact have also been determined to understand the influence of graphene on the tribological behavior of Ni graphene coatings.

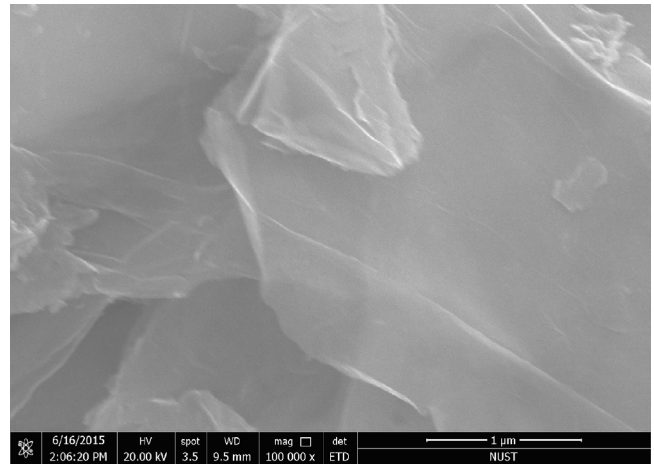

Fig. 3. SEM photomicrographs of graphene.

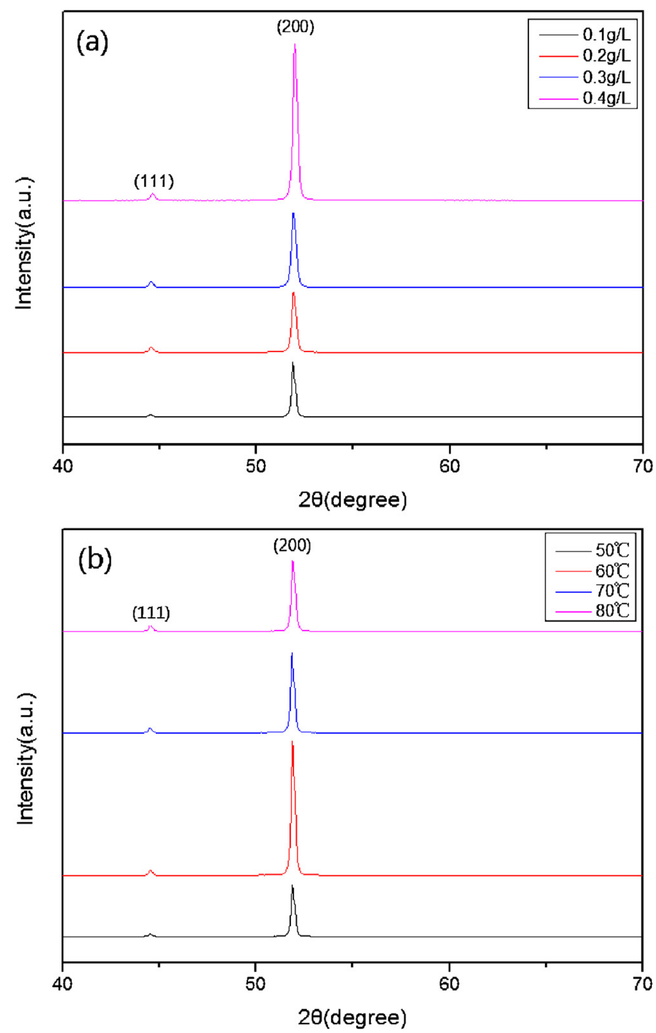

Fig. 4. XRD patterns of composite coatings with different addition amounts of graphene (a) and under different bath temperature with 0.1 g/L graphene (b).