Tribological properties of tertiary Al_2O_3/CNT/nanodiamond pulsed electrodeposited Ni–W nanocomposite

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Wear resistance of electrodeposited tertiary alumina/carbon nanotube/nanodiamond nanocomposite using pulsed current has been studied in Ni–W binary alloy matrix. Electroplating process was performed in citrate based Ni–W bath, and the nanostructure of obtained compound layer was examined by AFM. The effects of process variables, i.e. tungsten concentration in electrolyte, treatment time, frequency and duty cycle, were experimentally studied. Statistical methods were used in order to provide the minimised wear rate. Finally, the contribution percentage of different effective factors was calculated and confirmation run revealed the validity of obtained results. Nanocomposite layers with higher density of nanoparticles will show better tribological properties.

Keywords: Alumina, Electrodeposition, Tertiary nanocomposite coatings, Wear, Nanodiamond

Introduction

Over the past decade, many researchers have tried on dc electroplating, pulse plating and electroless plating as well as simultaneous deposition processes to fabricate nanocrystalline coatings.[1–6] The desired material can be produced as foil, sheet and irregular shapes depending on the process time and substrate geometry.

Fundamentally, electroplating fabricates nanostructured layers when its effective parameters, e.g. bath composition, pH, temperature, overpotential, etc., are chosen such that electrocrystallisation results in massive nucleation and reduced grain growth. Also the pulsed plating permits considerably higher current densities than the limiting dc current density.[7–11]

In the present study, for possible improvement of wear resistance, tertiary nanocomposite coatings consisting of nanometric sized Al_2O_3/carbon nanotube (CNT)/nanodiamond particles were embedded in a Ni–W matrix by pulsed electrodeposition method. The nanostructure and wear resistance of obtained nanocomposites were investigated with respect to the different effective factors of the coating process. Ni–W matrix composite coatings containing nanosized Al_2O_3/CNT/nanodiamond fine particles with different average sizes of nanoparticles were prepared from a Ni–W sulphate/citrate based bath. The wear performance of these coatings has been analysed in a systematic way.

The design of the experiment (Taguchi method)[12,13] took into account the influencing extent of individual process parameters. This consideration led to the selection of four influential factors, i.e. tungsten concentration in electrolyte, time, frequency and duty cycle with three different levels (1–3). The results of the factor response analysis were used to derive the optimal level of combination. Confirmation experiments were conducted to evaluate the validity of the analytical results. The percentage contribution of each factor was determined by variance analysis.

Experimental

Materials and treatments

Electrodeposition of Ni–W compound layers were carried out in an electrolyte as follows: pure 0·14 mol dm^{-3} nickel sulphate ($NiSO_4.6H_2O$), 0·44 mol dm^{-3} trisodium citrate ($Na_3C_6H_5O_7$) as the complexing agent, 0·1–0·3 mol dm^{-3} sodium tungstate ($Na_2WO_4.2H_2O$) with 0·01 g L^{-1} saccharin ($C_7H_5NO_3S$), 0·01 g L^{-1} sodium dodecyl sulphate ($C_{12}H_{25}NaO_4S$), 10 g L^{-1} CNT and also nanodiamond nanoparticles and 50 g L^{-1} Al_2O_3 nanopowder (with the size among 20–50 nm). The pH of all solutions which were measured with Mettler MP230 was adjusted to 8·0 by the addition of sulphuric acid or sodium hydroxide at room temperature. Pure copper sheets ($50 \times 10 \times 1$ mm) were used as cathodic electrodes. The preparation of all specimens was as follows: first, they were mechanically polished with different grade emery papers up to no. 4000 and then degreased in sodium hydroxide solution; then, they were put in 10% HCl solution for activation; and finally, they were rinsed with acetone. The operating conditions for plating were average current density equal to 10 A dm^{-2}, stirring rate of 200 rev min^{-1} and frequency and duty cycle of monopolar pulsed current adjusted at their relative levels.

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