

Electrodeposition of nickel-zirconia composites

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Composite coatings of nickel-zirconia (Ni-ZrO₂) were produced by conventional electrodeposition from a nickel fluoborate plating bath. The effect of current density (C.D.) and concentration of ZrO₂ powder in the electrolyte on its incorporation within the Ni matrix was studied. Properties of the composite coatings such as hardness, wear resistance and oxidation resistance were assessed by comparison with electrodeposited nickel coatings.

Key words: Composite coatings, nickel-zirconia, electrodeposition

INTRODUCTION

A significant amount of work has been directed towards developing new engineering coatings that display improved mechanical and/or chemical properties. One technique for achieving such improvements is by incorporation of inert particles within metal matrices thus forming composite coatings. These may be produced by many methods among which, electrodeposition has proved to be more flexible and economical than the others [1].

In electrodeposited Ni-ZrO₂ composites, particles of ZrO₂ to be dispersed in a Ni matrix were kept in suspension in the bath by mechanical agitation and during plating become incorporated in the deposit. In this work, the possibility of incorporating fine ZrO₂ powder in Ni matrix was investigated systematically. The plating conditions were optimised in order to improve the performance of Ni coatings and hopefully enlarge the scope for industrial applications.

EXPERIMENTAL

ZrO₂ powder of density 5.70 g.cm⁻³ and an average particle size of 8.1 μm was kept in suspension in the nickel fluoborate bath of the composition 280 g.dm⁻³ Ni(BF₄)₂, 40 g.dm⁻³ H₃BO₃, 5 g.dm⁻³ free HBF₄ and 0.1 g.dm⁻³ lauryl sulphate. pH of the bath was maintained at 3.0 and the plating was carried out at 323K with a fully regulated DC power supply. The experimental set up and procedure were the same as reported earlier [2], except that the powder concentration and the range of current density varied from 5.0-12.5 g.dm⁻³ and 2-10 A.dm⁻² respectively. The plating was carried out for a duration of 2 hours in each run and the resultant deposit was analysed chemically to determine the volume per cent (vol. %) inclusion of ZrO₂ in the deposit. The effect of current

density and concentration of ZrO₂ in the electrolyte on its incorporation within the Ni matrix was studied.

Hardness of the deposit was measured with a Vickers hardness tester at a load of 50 g. The abrasion wear resistance was measured using a Taber abraser employing CS-10 calibre wheel and applying 750 g load in each arm. A thermogravimetric technique was employed to measure the oxidation rate of the Ni-9.9 vol. % ZrO₂ deposit. The sample (2.5 × 2.5 × 0.015 cm) was kept in the reaction tube and the oxidation runs were carried out at 1070 and 1170K. The readings were continuously noted and from the weight gain per unit area the oxidation rate (k) constant was calculated.

RESULTS AND DISCUSSION

Effect of ZrO₂ inclusion on hardness and wear resistance

The improvement in hardness and wear resistance against varying vol. % ZrO₂ inclusion in the Ni matrix is shown in Figs. 1 and 2. This favourable effect was not entirely due to the dispersion hardening effect of the ZrO₂ particle, but also due to the fine grained structure of the deposit. From Fig. 3 it could be seen that the vol. % inclusion of ZrO₂ in deposit increases sharply with their concentration in the solution and attains a steady value of 11-13% from 75 g.dm⁻³ ZrO₂ concentration. Due to insufficient stirring and formation of agglomerates at higher ZrO₂ concentration there was no noticeable effect after 75 g.dm⁻³ addition.

For a given particle concentration 50 g.dm⁻³, the current density had a more remarkable effect than pH or temperature. Up to 6 A.dm⁻² the deposit was fine grained and the vol. % inclusion increased (Fig. 4). But beyond this limit the inclusion decreased and a rough and dark

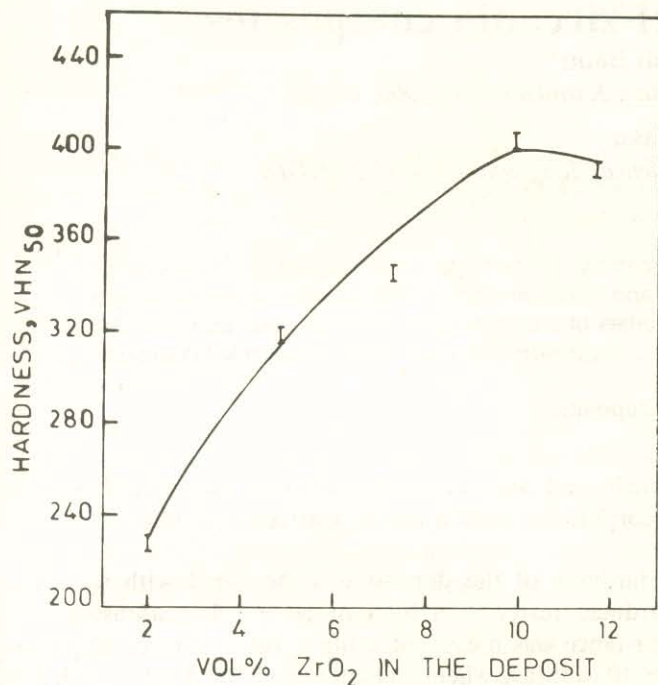


Fig. 1: Effect of ZrO₂ inclusion on hardness

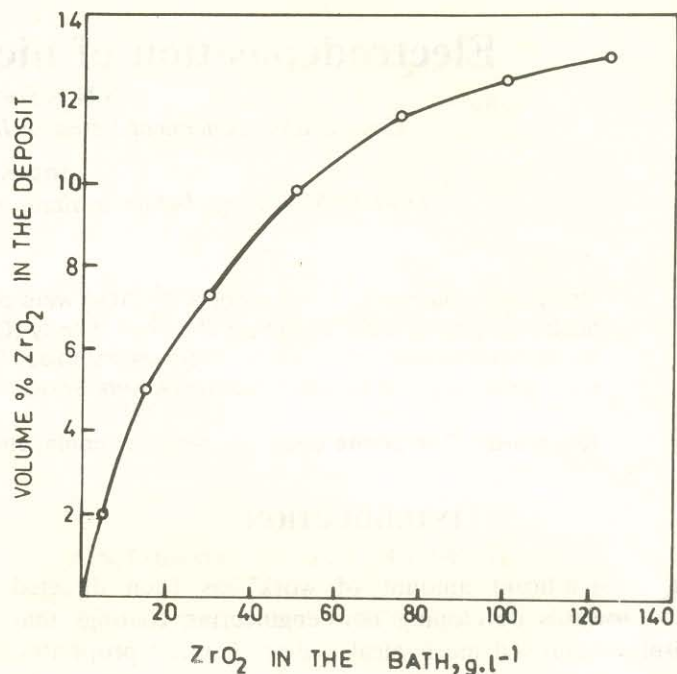


Fig. 3: Effect of ZrO₂ in the bath on the vol% inclusion in the deposit (C. D. 6 A.dm⁻²)

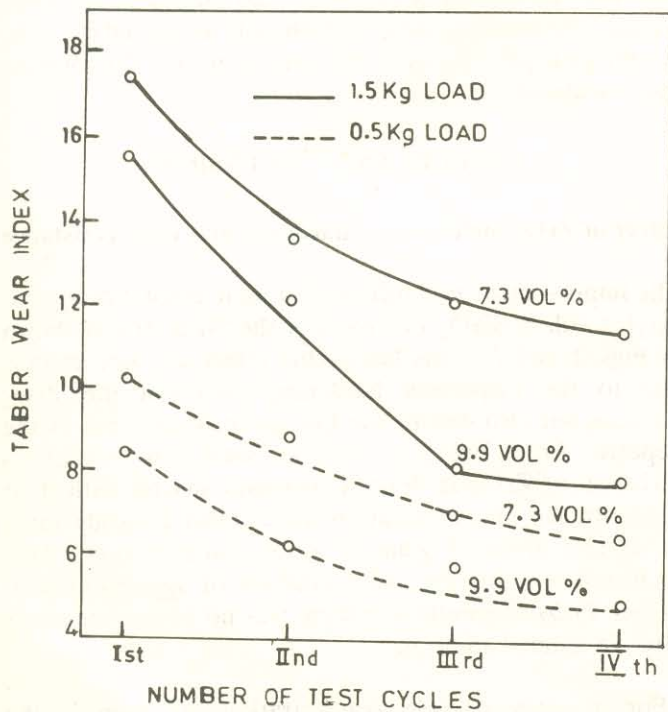


Fig. 2: Effect of ZrO₂ inclusion in the deposit on wear resistance
grey deposit resulted.

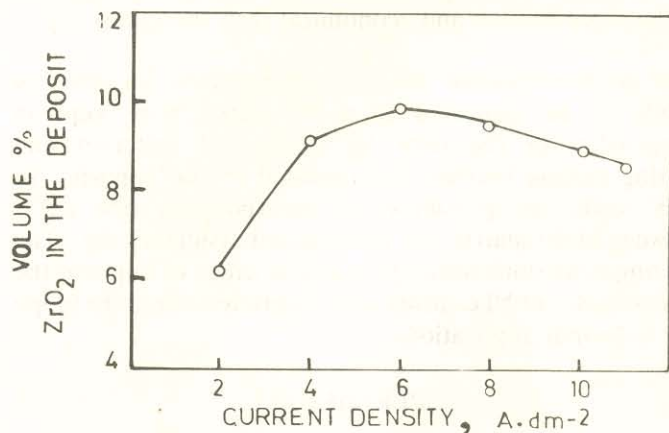


Fig. 4: Effect of current density on ZrO₂ inclusion in the deposit (ZrO₂ Conc'n 50 g.dm⁻³)

Oxidation behaviour of Ni-ZrO₂

The results shown in Fig. 5 obeyed the parabolic rate law, $w^2 = K_p \cdot t$ where w is the weight gain per unit area, K_p is the parabolic rate constant and t is the time which would suggest that the oxidation process is under diffusion control.

Comparison of the rate constants (K_p for Ni 3.5×10^{-10} and Ni-ZrO₂ 3.5×10^{-11}) showed that Ni-9.9 vol. % ZrO₂ is more resistant to oxidation than the electrodeposited

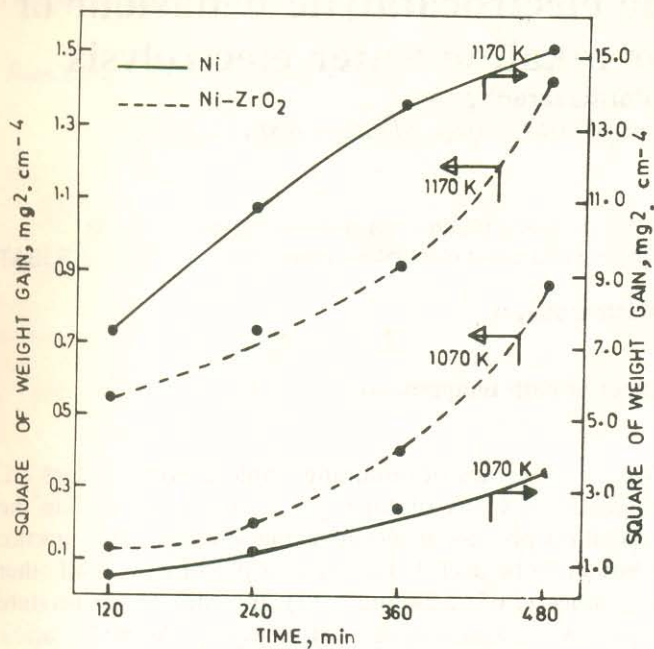


Fig. 5: Parabolic oxidation plot for the oxidation of Ni and Ni-ZrO₂ (9.9 vol%)

nickel.

CONCLUSION

ZrO₂ could be readily codeposited (up to 13 vol. %) with nickel and the composite showed improved mechanical properties and good performance in high temperature environments.

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