ELECTROFORMING OF NICKEL-TUNGSTEN ALLOY FOR HIGH TEMPERATURE APPLICATIONS

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ABSTRACT

Electroforming process is growing as production process for the fabrication of critical components which are used by aerospace and nuclear areas. Mainly nickel alloys like nickel-cobalt, nickel-molybdenum are currently electroformed for functional applications, In some of the critical components in nuclear applications nickel tungsten electroforming is required. Interest in nickel-tungsten alloys has increased in recent years due to their unique combination of tribological, magnetic, electrical and electrochemical properties (such as tensile strength. improved hardness & good wear resistance) and good resistance to strong oxidizing acids and high melting temperature. Possible future applications of nickel-tungsten alloys include barrier- layers or capping layers in copper metallization for ultra large scale integration devices (ULSI) or micro electromechanical systems (MEMS), mould inserts. magnetic heads and relays etc. The present investigation explained binary alloy deposition by induced co-deposition technique in nickel sulphamate electrolyte. The effect of temperature and current density on the percentage incorporation of tungsten was analyzed. Some of the properties like hardness and wear resistance were studied on these deposits.

KEYWORDS: Electroforming, alloy deposition. nickel- tungsten plating.

INTRODUCTION

Alloy electroforming process is gaining momentum nowadays because of improved mechanical properties of the deposit preferably in nuclear field. Tungsten alloys are known for their excellent mechanical and tri-biological properties. Lowe et al [1] found that hardness of this alloy is two or three times higher than that of pure electroformed nickel. Nickel-tungsten layer with 10 weight percentage of tungsten resulted in micro hardness of 600HV; the annealed layer to a temperature of 650°C gives a good value of 800 HV. The authors also reported that nickel-tungsten alloy can also be employed for the production of micro-structured tools due to their excellent mechanical properties regarding wear and mechanical durability [2-8]. Generally mold inserts for hot embossing and injection moulding requires hard and wear resistant materials in order to achieve an exact replication of poly carbonates and ceramics. Younes et al [9] indicated that the concentration of tungsten in plated alloy has a major effect on the mechanical and chemical properties such as hardness. abrasion resistance and improved corrosion resistance at even high temperatures. It is also reported that the micro-hardness of nickel-tungsten alloy increased with percentage of tungsten in the deposit. It has been reported that nickel-tungsten alloys exhibit enhanced properties such as corrosion resistance, wear resistance and catalytic activity for hydrogen useful in practical applications [10]. X-ray diffraction studies conducted by Frantsevich-Zabludovskaya et al. [11] indicated homogeneity. ascribable to a solid solution of tungsten in nickel, in spite of the fact that some layered structure was observed in the deposit microstructure. Tungsten alloys with iron group elements are of interest in scientific and industrial applications in compositionally modulated multilayer

(CMM) coatings. This alloy is of interest because of its magnetic properties for high speed and high density magnetic recordings in both theoretical and applied aspects for their specific applications.

Nickel-tungsten alloy deposition can be used in copper metallization for ultra large scale integration devices (ULSI) or micro electromechanical system (MEMS) [12]. Moreover its good wear resistant property is suitable for magnetic heads. bearings, tool inserts. and electrodes for hydrogen production process. This alloy is also suitable for high hardness applications and may be replaced hard chromium plating in erospace industries.

EXPERIMENTAL

Various baths have been tried based on sulphate, tartrate, acetate and suphamate. Among these the sulphamate based one produces lower stress compared with others. Alloy deposits were prepared on copper panels by using the following bath.

Nickel sulphamate	50-100 g/L
Nickel chloride	1—3 g/L
Boric acid	10 g/L
Sodium Citrate	10-150 g/L
Sodium tungstate	120—15 g/L
Temperature	40 to 60"C
pH	5-8
Current density	2-3 A/dm^2

Copper panels of size 75 x 50 mm^2 were pretreated and then deposition was carried out. The deposition was produced on 50 x 25 mm^2 area. Various current densities of 2, 2.5 and 3 A/dm^2 were employed for alloy deposition process. Similarly pH of the electrolyte was varied in the range of 5 to 8. The bath temperature was also varied from 40 to 60^0C and then alloy deposit was produced The alloy composition was analyzed by using XRF X-ray analytical microscope model Horiba XGT-2700.

Vickers hardness of the alloy deposit was measured with a Micro hardness tester SHIMADZU of model 341-00622. The load applied was 100g for all the tests.

Taber Abrader test method was employed to measure the wear resistance of the alloy deposit. The weight loss in gram per 1000 cycles per load of 1000 gm was measured and expressed as Taber wear index. The lower the Taber wear index, the better is the wear resistance of the coating. Brass panels of size 100 x 100 x 2 mm^3 were taken and 8 mm diameter hole was made at the center to fix the specimen in the Abrader unit.

RESULTS AND DISCUSSION

Alloy deposition was carried out with various pH values and temperature by maintaining the current density at 2.5A/dm^2. The effect of pH & temperature on hardness and wear resistance on the deposit are shown in the following tables

Table-1 : Effect of pH on tungsten content

pH	Nickel content	Tungsten content
	& weight	% weight
5	97 3	2.7
6	83	17
8	95.5	4.5

It is observed from these data that there is no correlation of pH with tungsten content in the deposit. The electrolyte operated at a pH value of 6 produces a Nickel-Tungsten alloy deposit which contains 17% of tungsten in the deposit.

Table-2 : Effect of temperature on tungsten content

Temperature ^0C	Nickel content % of weight	Tungsten content % of weight
40	85	15
50	83	17
60	73	27

The hike in temperature of the electrolyte shows a linear increase of tungsten content in tile deposit.

Table 3 : Effect of pH on Hardness and Wear

pH	Hardness Vickers	Wear index
5	233	2.8
6	393	1.9
8	265	2.5

It is observed from these data that a definite correlation between the pH of the electrolyte and hardness of the deposit could not be arrived at. By varying the pH of the bath, wear resistance of the deposit is also varied but it is very difficult to predict a definite correlation with these data. The optimum pH value of 6 produced a good wear resistant deposit.

Table - 4 : Effect of Temperature on Hardness and Wear

Temperature ^0C	Hardness Vickers	Wear index
40	393	1.7
50	395	1.9
60	387	1.7

The hardness of the deposit is not at all affected by varying the operating temperature of the bath as the change of hardness value is of a marginal one. From these data there is no significant change in the wear index of the deposit with respect to temperature of the electrolyte.

CONCLUSION

For some of the nuclear components. 10 to 20 % by weight of tungsten is preferable with improved hardness: a good wear resistant deposit is desirable for engineering, components. This study reveals that desirable nickel-tungsten alloy deposit can be obtained at a pH value of 6, at a temperature of 50°C from the nickel sulphamate based electrolyte.

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