ELECTRODEPOSITION OF COPPER-TIN-PTFE COMPOSITE COATINGS

R.Balaji,* Maiathy Pushpavanarm#, K.Yogesh Kumar@ K.Subramanian@
*Central Electrochemical Research Institute, Karaikudi 630 006 TamilNadu, India.
@ A.C. College of Engineering and Technology, Karaikudi 630 006 TamilNadu, India.
# Author for correspondence, e-mail : malathypush@yahoo.com

ABSTRACT

The aim of this research is to obtain lubricant composite coatings of bronze (90% copper and 10% Tin) with PTFE (polytetrafluoroethylene particles over mild steel substrate. The electrodeposition was carried out from an alkaline bath containing cyanide. The composite coatings were prepared hy means of CECD (Conventional Electrochemical deposition) and SCD (Sediment Codeposition) techniques. The PTFE particles involved were of the average size of 3-5 μm. The incorporation of PTFE in the composite coatings was investigated with respect to the PTFE concentration in bath, cathode current density. and mode of deposition. The cathode efficiency of the coating was calculated. The morphology of the eleetrodeposited composites was studied using Scanning Electron Microscope (SEM) The PTFE distributions in the composite coatings are uniform at low concentration of PTFE in the bath but at high concentration the PTFE particles were agglomerated. The PTFE incorporation in SCD technique is higher than that of CECD technique. Physical properties of the composites including hardness, wear resistance and coefficient of friction, were measured.

Keywords: Electroplating. bronze-PTFE, hardness, wear resistance, roughness

INTRODUCTION

Extensive research work has been carried out in the past in composite coatings produced by chemical or electrochemical deposition techniques. Different metal matrix composites containing second phase particles have been electrodeposited to improve mechanical and physiochemical properties of the material. A different approach to improve wear characteristics is based on the reduction of coefficient of friction between relatively moving surfaces by the introduction of a dry lubricant in the metal matrix [1]. Polymers, especially PTFE, with their nonstick properties are used mainly for dry lubrication. Research on electrodeposition of Ni/PTFE has been carried out during the past one decade and it is also compared with the electroless coating [2]. Research on Au-PTFE composite coating has also been carried out by Rezrazi et al [3]. Addition of PTFE particles in the deposition baths decreases the coating's hardness but gives good self-lubrication properties [3-5]. Occlusion plating of a second phase particle with a metal matrix has been carried out by both CECD and SCD techniques [5]. Particles were kept in suspension by continuous agitation in CECD technique whereas particles are suspended intermittently in the electrolyte and allowed to settle onto the horizontal cathode as sediment and co-deposited in SCD technique [6,7]. Co-deposition of particles in a metal matrix is the result of adsorption of metal ions on the particle surface thus making them attracted to the cathode [8].

For bearing applications the coating selected must possess high ultimate tensile strength, hardness and low dry coefficient of friction. Since bronze, which is an alloy of 90% copper and 10% tin, has the above properties, it is widely used in the automotive industry mainly as a bearing material. PTFE is a material that possesses non-stick and sliding properties, chemical inertness etc., Hence, co-deposition of PTFE along with should provide an excellent load carrying capacity and solid lubrication. Reports are available on electro-co-deposition of $A1_2O_3$, CaF_2, talc particles and graphite along with bronze (Cu-Sn) alloy [9,10]. In this paper electro deposition of bronze-PTFE composite coatings on a mild steel substrate and its characterization are discussed.

EXPERIMENTAL

The electrolyte used in this study adopts a cyanide-stannate system, containing PTFE suspension with the average particle size of 3-5 μm. The composition of the bath and operating parameters for electrodeposition are as given in Table 1. PTFE concentration in the electrolyte was varied between 10-60 g/L. Electrodes were positioned, in horizontal plane (SCD) and vertical plane (CECD) with dual anodes. The distance between anode and cathode was maintained as 7 cm. Steel specimens of 6.25 dm^2 were used for studies. Cathode was consecutively polished, degreased with trichloroethylene, and cathodically cleaned in alkaline solution before each experiment. Experiments were performed in a beaker with magnetic stirring in order to keep the PTFE particles in suspension. Stirring speed was up to 200 rev/min. Experiments were conducted with and without PTFE addition. Cathode efficiency of the deposits was calculated knowing the mass of the deposit and

Table 1 - Composition and Deposition Parameters of Cu-Sn Bath used

Deposition Concentration Parameters	Concentration
CuCN	30g/L
NaCN	45g/L
Na_2SnO;	42g/L
NaOH	10g/L
Temperature	40° C to 60° C
pH	12.5
Current Density	1-5 A/dm^2

Table 2 - Hardness of the Deposits at Different PTFE Concentrations

Volume percent of PTFE in deposit	Hardness of the deposits (Hv) 20g. load
0	408
15.35	383
23.64	365
35,64	354
42.79	332
52.87	307
57.51	296

the composition of the alloy. The copper, tin and PTFE content of the composite coating were determined by using XRF and AAS methods. The PTFE content was estimated gravimetrically. Structural examination of the deposits was made using SEM.

Hardness of the deposits was determined using Mitutoyo micro hardness tester at a load of 25 g. Wear was determined using pin on disc machine in dry conditions. The pin used was SAE 200 high-speed steel with 5% cobalt and with 6mm diameter. The track diameter was 14mm. The wear resistance of the coating was assessed in the form of weight loss. Surface roughness of the composite was determined by means of Mitutoyo Roughness testing instrument

RESULTS AND DISCUSSION

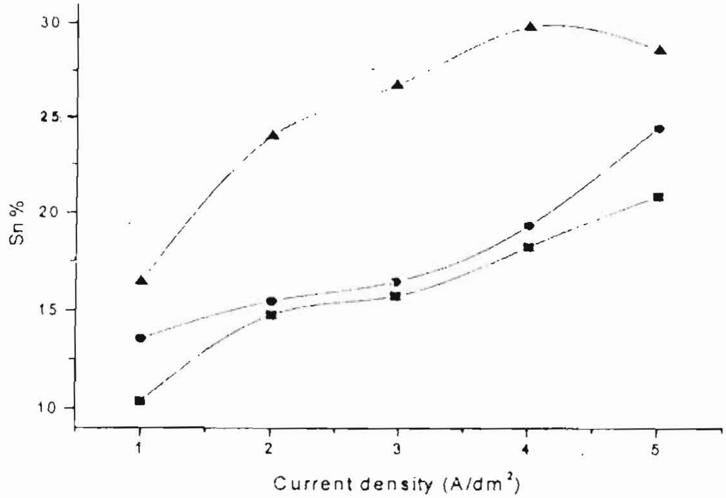

Fig 1 - Chemical Composition of Matrix as a function of Current Density

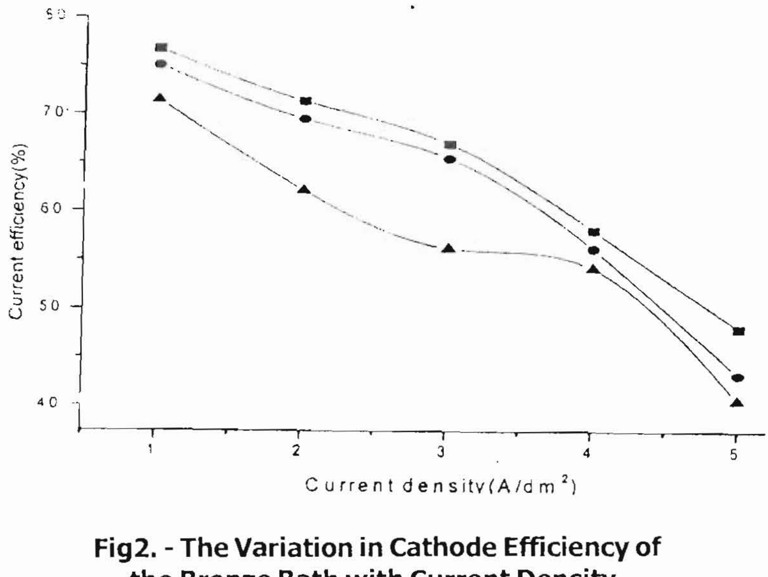

Fig2. - The Variation in Cathode Efficiency of the Bronze Bath with Current Density.

and temperature. Decrease in cathode efficiency with increasing operating current density can be attributed to increased cathode polarization due to mass transfer limitations. Normally, deposition from complex baths result in lower efficiency due to increase in activation overpotential. Tin deposition from stannate bath occurs through tetravalent tin and associated with poor efficiency. This could be the reason for the above behavior.

PTFE Incorporation in Coating

The volume fraction of particles in composite coatings was determined by gravimetric analysis, Electroplating of the bronze-PTFE was carried out by both CECD and SCD techniques. The PTFE volume percent in deposit as a function of PTFE concentration in the bath is shown in Fig-4.

At constant stirring rate, an increased concentration of particles in the bath corresponded to an increased incorporation of particles. In Fig. 3, it can be seen that with increase of PTFE concentration above 50 g/L in bath, the PTFE percent in composite coating becomes almost constant similar to that observed for graphite-bronze composites [10,11]. This is because of the agglomeration of particles in bath; the effective particles concentration is constant, thus resulting in constant PTFE in composite coating.

Fig. 3 also shows that the amount PTFE in composite coating is higher in the SCD compared to the CECD technique at constant PTFE concentration is similar to that observed by Ghouse for Cu-graphite, and Cu-SiC composite coatings [8,12]. In sedimentation technique. the horizontal cathode allows codeposition of particles easily due to the positive Influence of gravity of the PTFE particles. In CECD method, this is not possible and hence, the particles should function against gravity to adhered to the substrate till they are engulfed in the growing metal deposit.

Percentage of Tin in Matrix

The dependence of the tin composition in the composite with the mode of deposition at cathode current density of $2A/dm^2$ is shown Fig.4. It is clear that the tin content decreases with increase in concentration of PTFE in the bath. As the concentration of particles in the bath increases. more of electrode area is covered by the particles and hence the area available for metal deposition is less. This makes the current density applied to be considerably higher than what is expected from the geometrical of the substrate. So, at such higher current densities, as already noted in Fig. 1, tin content decreases. However. the tin content obtained with the SED technique falls within limits and hence considering higher particle incorporation and the desired tin content in the alloy, SED deposition appears to be more preferable than SCECD method.

Morphology of Bronze PTFE

The morphology of the bronze - PTFE composite coating without PTFE and with 30g/L and 40-gL concentration of PTFE in solution are shown in Fig. 5-7. PTFE is fairly uniformly distributed in the deposit.

CONCLUSION

The composition of matrix depends on current density and temperature. Coatings with 90%Cu-10% Sn can be obtained from cyanide bath at 40-60° C The current density, and

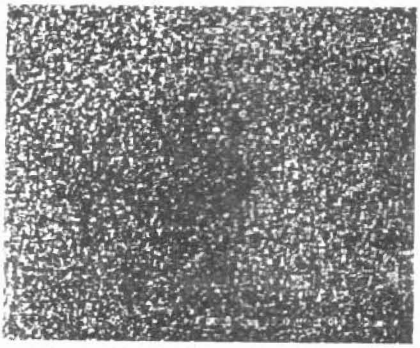

Fig.5 - Micrograph of Bronze without PTFE

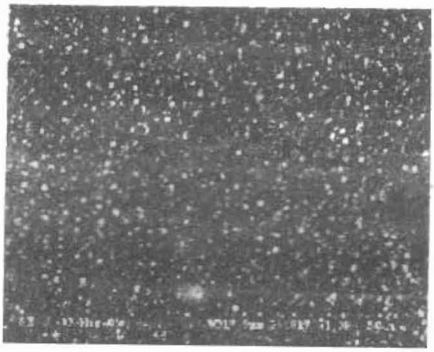

Fig.6. Micrograph of Bronze with 30g/l PTFE (SCD)

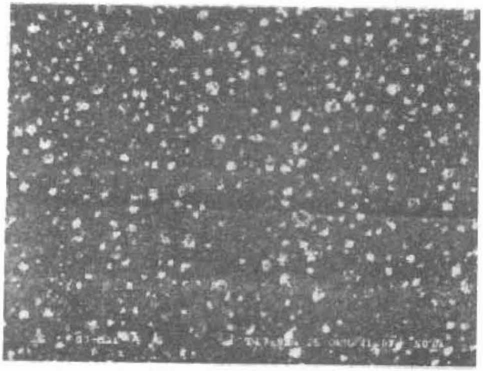

Fig.7. Micrograph of Bronze with 40g/l PTFE (SCD)

PTFE content in bath influence the cathode efficiency and deposition rate. PTFE particle can be sucessfully co-deposited with bronze alloy by both the CECD and SCD technique.

The PTFE content of the composite coating depends on the particle concentration in bath,

Table 3 - Weight Loss As a Function of PTFE Contents in Deposit

PTFE percent in deposit	Weight loss/mg	
	CECD	SED
15.35	8.5	6.1
23.54	6.99	4.5
35.64	5.2	3.8
42.79	4.0	3.0
52.87	3.5	2.2
57.51	3	1.8

Table 4 - Surface Roughness Measured at Different PTFE Contents in Deposit

PTFE percent in deposit	Surface roughness, Microns
15.35	0.02
23.64	1.2
35.64	1.3
42.79	1.8
52.87	2.2
57.51	2.4

current density, and method of deposition (CECD and SCD). The amount of PTFE obtained by the SCD technique is greater than that obtained by CECD technique.

REFERENCES

1. Pushpavanam.M, N.Arivalagan, N.Srinivasan, P. Santhkumar, and S.Suresh (1996) Plating and Surface Finishing 83 72.
2. P.Berot, A.Grosjean, M.Rezrazi and J.Pageti, (1998) Surface and Coating Technology 107 85. .
3. Z.Serhal, P.Bercot, J.Morvan, M.Rezrazi and J.Pagetti (2002) Surface and Coating Technology 150 290.
4. Nishira M Takanao (1994) Plating and Surface Finishing 81 48.
5. Ghouse M Viswanathan M(1980), Metal Finishing 7 57.
6. Ghouse M Viswanathan M Ramachandran E G (1980) Metal Finishing 3 31.
7. Ghouse N1 Ramachandran E G (1981) Metal Finishing 6 85.
8. Tomaszewki T W (1976) Trans. Inst. Meta1 Finishing 54 45.
9. M. Ghorbani. M.Mazaheri, K.Khanghc. and Y.Kharazi. (2001) Surface and Coating Technology. 148 71.
10. Afshar A Ghorbani M Mazaheri M. (2004) Surface and Coatings Technology 187 293.
11. Foster J Cameron 13 (1976) Trans. Inst.. Metal Finishing, 54 178.
12. Celis J P Roos J R (1977) J. Electrochemical Society 124 1508.