Bulletin of Electrochemistry 20 (3) March 2004, pp 115-118

0256-1654/2004/$ 3-50

CHARACTERIZATION OF ZINC-IRON ALLOY ELECTRODEPOSITS FOR CORROSION RESISTANCE

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[Received: 30 June 2000 Accepted: 22 August 2003]

Zinc alloy plating is a high performance coating. Compared to pure zinc plating, zinc alloys provide several advantages. A zinc alloy will generally provide superior sacrificial protection to steel. The degree of protection and rate of corrosion depends on the alloy metal and composition. The demand for higher-quality, longer-lasting, more corrosion-resistant coatings in industries such as aerospace, fastener, electrical component and particularly, automotive has played a large role in the development and use of zinc alloy coatings. Zinc-iron alloy has good weldability and ductility. In this paper the corrosion resistance properties of zinc-iron deposited from a sulphate bath are evaluated by electrochemical methods and the results are discussed.

Keywords: Zinc alloy, plating, corrosion resistant coating

INTRODUCTION

Over two decades zinc and electrodeposited zinc alloys achieved an important position in the protection of ferrous materials against corrosion [1]. Zinc-iron alloy exhibited good corrosion resistance and its protection was better than zinc [2-3]. Hence, the replacement of zinc by zinc-iron alloy deposit is being tried presently in an industrial level.

EXPERIMENTAL

Cold-rolled steel plates were degreased with trichloroethylene and alkaline electrocleaned cathodically for two minutes and anodically for 30 seconds in a solution consisting of 35 g/l NaOH and 25 g/l Na_2CO_3 at 343 K. They were washed in running water and then dipped for 10 seconds in 5% H_2SO_4 solutions. The composition of zinc-alloy plating bath employed is given in Table I. Electrodeposition of zinc-iron from the bath at current density 0.5 $A.dm^{-2}$ resulted in an alloy with 6% Fe. At lower than that current density the deposit obtained was very poor in quality, with very poor in quality, with very low coverage. At a current density of 1 $A.dm^2$ a deposit with 2.5% Fe was obtained. Above that current density, deposit had zero iron content. This may probably be due to the high hydrogen overvoltage of zinc.

Electrochemical polarization studies were carried out for various zinc-iron alloy deposits of 1 cm^2 area in 5% NaCl solution at 303 K at 5 mV/sec. A large platinum foil was used as auxiliary and saturated calomel electrode (SCE) as reference electrodes respectively. Potentidoynamic polarization studies were carried out using EG & G applied research electrochemical system at 5 mV/sec from OCP for various zinc-iron electrodeposits of 1 cm^2 area in 5% NaCl solution at 343 K. Galvanic current flowing between zinc-iron alloy electrodeposits and freshly polished and cleaned mild steel panels of 1 cm^2 area each in 5% NaCl solution was measured using a zero resistance ammeter (home made). The inter-electrode distance was maintained at 5 cm. Galvanic voltage mild

TABLE I: Composition and conditions of plating

$ZnSO_4$	0.05 *M*
Ferrous ammonium sulphate	0.01 *M*
Na_2SO_4	20 g/l
H_3BO_3	30 g/l
CH_3OH	5 ml/l
Triethanolamine	0.2 *M*
Sodium lauryl sulphate	0.025 g/l
Ascorbic acid	0.0025 *M*
Temperature	343 K
*p*H	4
Current density	2-4 $A.dm^{-2}$

TABLE II: Parameters derived for various alloy electrodeposis (6 μm) from E-Log i curves in 5% Nacl solutins at 303 K - 5 mV/sec

Iron-zinc alloy deposit (% of Fe)	Corrosion potential mV vs SCE	Tafel slopes ± 5 mV/decade		Corrosion current densities ($\mu A/cm^2$)	
		Anodic	Cathodic	Anodic	Cathodic
0.0	-1065	40	30	15	15
2.5	-1040	40	30	28	28
6.0	-1025	40	30	60	60

steel was measured using high impedance voltmeter.

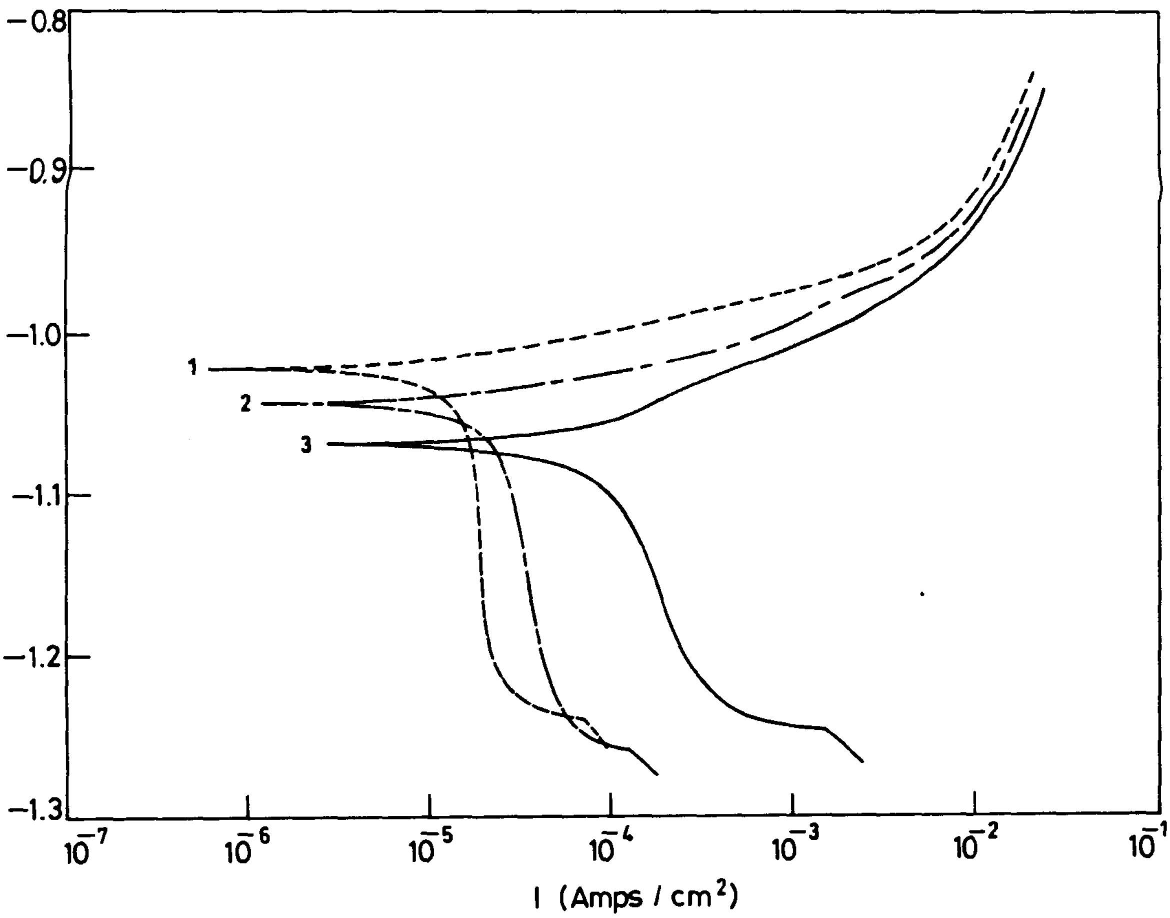

Fig. 1: Typical polarization curves for zinc and zinc-iron alloy electrodeposits in 5% NaCl
(1) Zinc (2) Zinc + 2.5% Fe (3) Zinc + 6% Fe

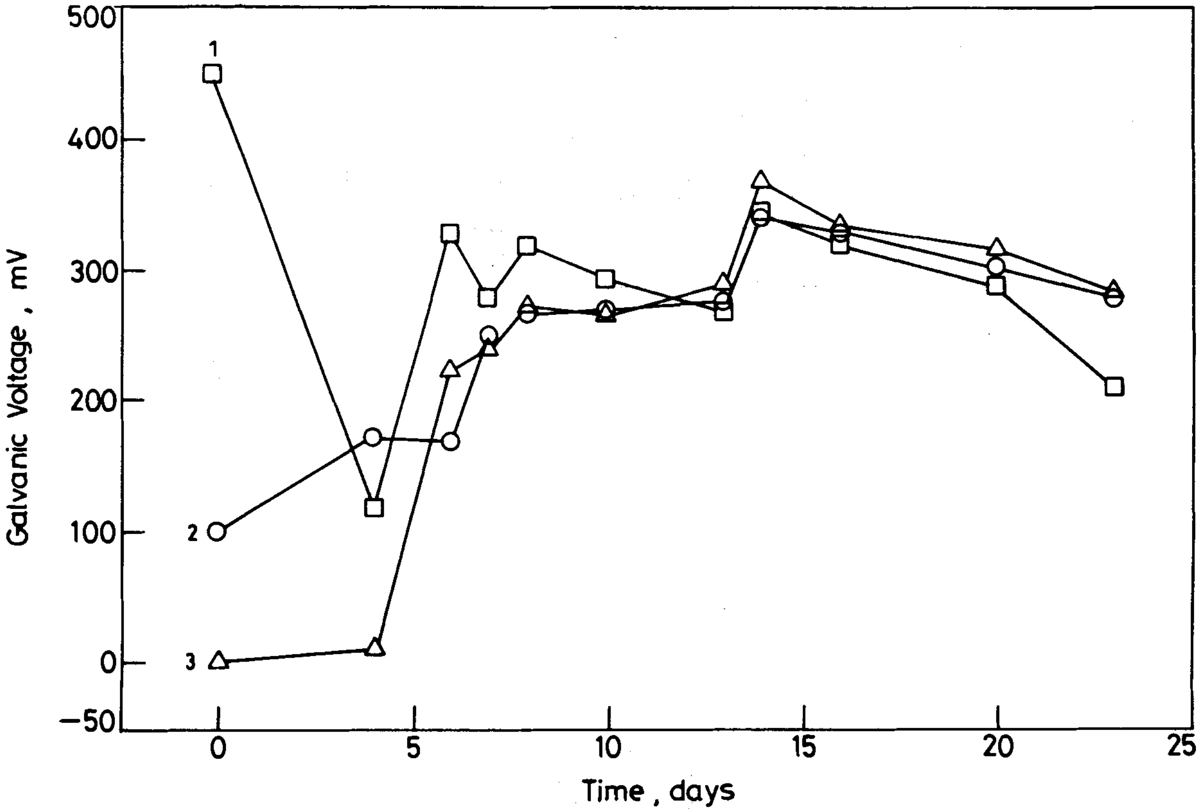

Fig. 2: Variation of galvanic voltage with time
(1) Zinc (2) Zinc + 2.5% Fe (3) Zinc + 6% Fe

RESULTS AND DISCUSSION

From the electrochemical theory of corrosion [4] corrosion current densities can be obtained by extrapolating the linear segments of anodic and cathodic (E - log i) curves. The slopes of the linear segments of anodic and cathodic branches give the anodic and cathodic Tafel slopes.

$$b_a = \text{Anodic Tafel slope} = RT/\alpha_a F \quad (1)$$

$$b_c = \text{Cathodic Tafel slope} = RT/-\alpha_c F \quad (2)$$

where α_a, α_c are transfer coefficients. Three typical polarization curves for zinc and zinc-iron alloy electrodeposits are given in Fig. 1.

The steady state corrosion potentials obtained for various electrodeposits revealed that introduction of iron in zinc shifted the potential to active values (Table II) and the corrosion current densities increased with the increase of iron content in the zinc-iron alloy deposit.

Fig. 2 presents the variation of galvanic voltage with time. At the start of the experiment 6% Fe alloy exhibited more voltage followed by 2.5% Fe alloy. But at the end of 24 days, the galvanic voltage was least for 6% Fe alloy.

Fig. 3 presents the variation of galvanic current densities with time. 6% Fe alloy exhibited higher current densities at the beginning of the experiment. At the end of 24 days galvanic current densities were least. The oscillations in galvanic voltage and current densities are due to the formation and subsequent dissolution of corrosion products of zinc alloy surfaces.

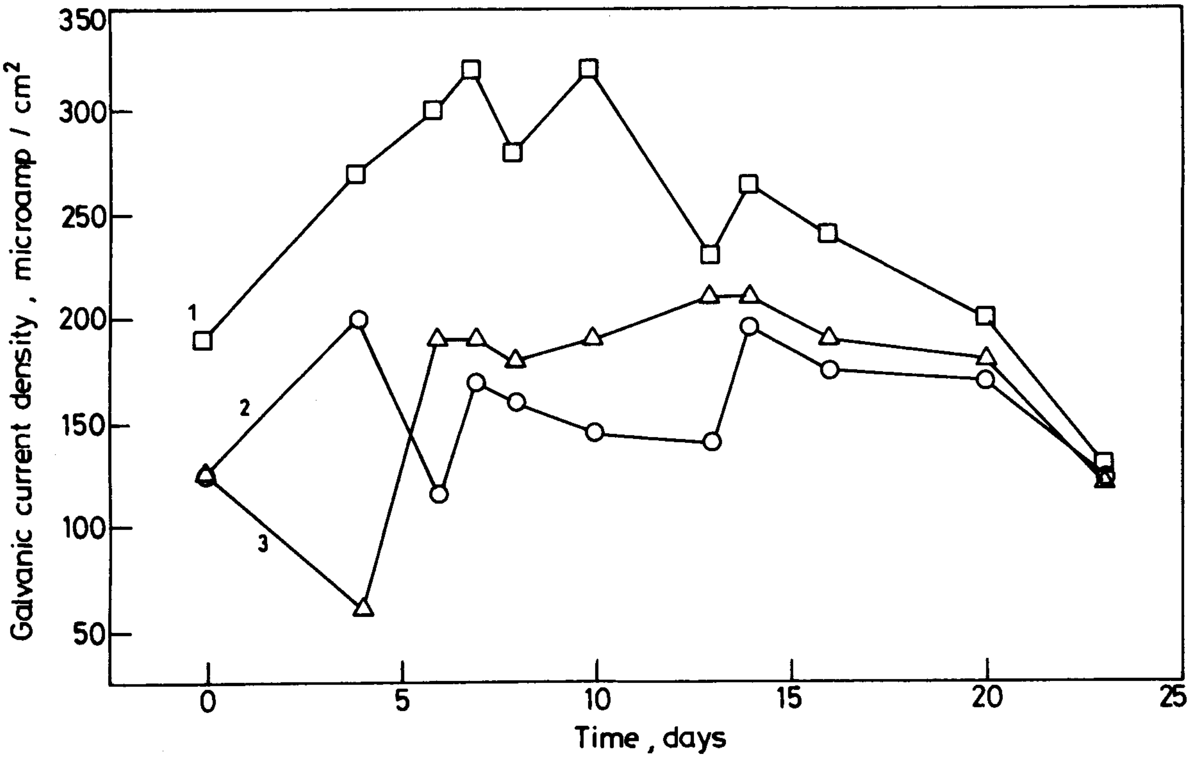

Fig. 3: Variation of galvanic voltage with time
(1) Zinc (2) Zinc + 2.5% Fe (3) Zinc + 6% Fe

CONCLUSIONS

Electrochemical studies on zinc-iron alloy electrodeposits revealed that zinc with 6% Fe alloy deposit exhibit least corrosion resistance and offer sacrificial protection to steel.

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