

Polarization Functions of Pb-Sn-Cd Alloys Treated with Sulfuric Acid

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Abstract

The study is conducted to investigate the polarization functions of different lead alloys including impurities of 0.6-2% tin and 0.03-0.09% cadmium metals. Alloys were immersed in sulfuric acid with density of 1.20, 1.25, 1.30, and 1.40 g cm⁻³ at temperature of 298K. Highest corrosion rate occurred at 1.20 and 1.25 g cm⁻³ densities, while the density of 1.30 g cm⁻³ showed the lowest corrosion rate especially for alloys containing more than 0.6% Sn and 0.03% Cd. Polarization studies showed that corrosion current density was reduce by increasing acid density from 1.20 to 1.30 g cm⁻³ with positive elevation in corrosion potential. The evolution of hydrogen was the main cathodic reaction, as deduced from Tafel slopes and the corresponding transfer coefficients, while metal dissolution was the main anodic reaction. The values of polarization resistance, critical current density and passive current density were decreased in alloys of very low levels of impurities and increased with high levels of Sn and Cd.

Keywords: polarization, lead, tin, cadmium alloys

1.0 Introduction

Corrosion is classified as uniform, galvanic, inter-granular, crevice, pitting, selective leaching and erosion. All these types can be affected by one or more than of the following factors such as; oxygen, oxidizers, velocity, temperature and corrosive concentration [1 – 3]. Meanwhile, the electrochemical aspects of corrosion are electrochemical reactions and polarization.

The polarization is a deviation of equilibrium potential of reaction due to the formation of current [1]. The following description showed the relation between potential and current density, this description is representing the polarization named as an over-voltage (η) and can be expressed by following equation, $\eta = E - E_c$,

Where:

E= potential of polarization

E_c= equilibrium potential.

The corrosion rate can be estimated from intersection of anodic and cathodic lines with corrosion potential which is called Tafel area [4]. However, the following derivation of electrochemical reactions for corrosion is important [5].

$i = i_{\text{corr}} [\exp \{ \alpha_a F \eta / RT \} - \exp \{ \alpha_c F \eta / RT \}]$, this equation has the same form of Butler-Volmer,

$i = i_o [\exp \{ (1-\beta) F \eta / RT \} - \exp \{ -\beta F \eta / RT \}]$

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where,

i = current density,
 i_0 = equilibrium exchange current density,
 i_{corr} = corrosion current density, β = symmetry factor

However, symmetry factor is replaced by transfer coefficients (α_a or α_c)

$$\alpha_a = (1 - \beta)$$

$$\alpha_c = \beta, \text{ then}$$

$$i = i_0 e^{\alpha_a F \eta / RT} \text{ for anode}$$

$$i = i_0 e^{-\alpha_c F \eta / RT} \text{ for cathode}$$

At large values of η , the second part of Butler-Volmer equation is much less than first one and can be ignored, and then; $i = i_0 e^{\alpha_a F \eta / RT}$ when the value of η is about 0.12V or less, Butler-Volmer equation can be reduced to: $i = i_0 F \eta / RT$, from re-arrangement, the polarization resistance (R_p) can be obtained by following equation:

$\eta/i = RT/i_0 F = R_p$, which is represented by Stern-Geary equation [6].

Meanwhile, there are many types of polarization can be identified such as activation [2], concentration [7,8], combined [9] and I.R. drop [10,11].

This research is conducted to establish a corrosion protection of lead alloys by addition of Sn and Cd metals through calculations of some polarization functions.

2.0 Materials and Methods

Twelve lead alloys were prepared by additions of tin and cadmium (Table 1), using typical sampler of 1 cm in diameter and 2 cm as height. The characteristics of these alloys were determined and are shown in previous work [12]. Identification of polarization curves were obtained by using the polarization apparatus [13]. The apparatus consists from potentiostat with three electrodes (working electrode, reference electrode and auxiliary electrode), voltmeter and ampere meter (Fig. 1).

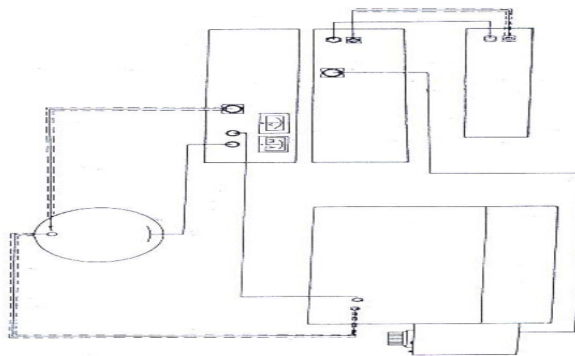


Fig. 1 Diagram of electrical circle used in polarization measurements

Table 1 Compositions of alloys

Alloy no.	Alloy composition
1	Pb only
2	Pb-0.6%Sn
3	Pb-0.6%Sn -0.03%Cd
4	Pb-1.2%Sn
5	Pb-1.2%Sn -0.03%Cd
6	Pb-2%Sn
7	Pb-2%Sn -0.03%Cd
8	Pb-2%Sn -0.06%Cd
9	Pb-1.2%Sn -0.06%Cd
10	Pb-2%Sn -0.09%Cd
11	Pb-1.2%Sn -0.09%Cd
12	Pb-0.6%Sn -0.06%Cd
13	Pb-0.6%Sn -0.09%Cd

The alloys were immersed in four different sulfuric acid densities (1.20, 1.25, 1.30, 1.40 g cm⁻³). Then, the alloys were connected to the polarization apparatus and working at the voltage of -120 to +120 mV. The records of current, current density and relation between potential and current density were obtained. At the same time, the corrosion potential (E_{corr}) for all samples were measured at open circuit

3.0 Results and Discussion

Polarization functions of pure and lead alloys were shown in Fig. 2 to 4. The results pointed out that the lowest values of corrosion were occurred in sulfuric acid with density of 1.30 g cm⁻³. However, the passive layer was stable for very short time at limited potential values for pure lead due to the formation of lead sulfate layers (Fig.2).

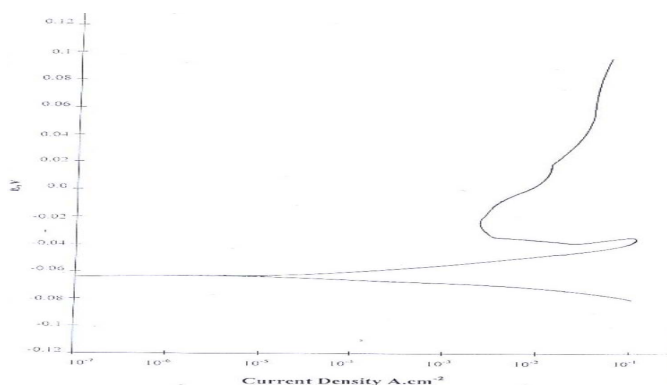


Fig. 2 Polarization curve for pure Pb at acid density of 1.3 g cm⁻³

The corrosion decreased by addition of tin due to the formation of two passive layers one is of PbO and the other of PbSnO₃ (Fig.3), while the addition of cadmium gave a highest protection to alloys due to the formation of PbSnO₃ and CdSnSO₄ which causing a decrease in corrosion current density and a high corrosion potential (Fig.4).

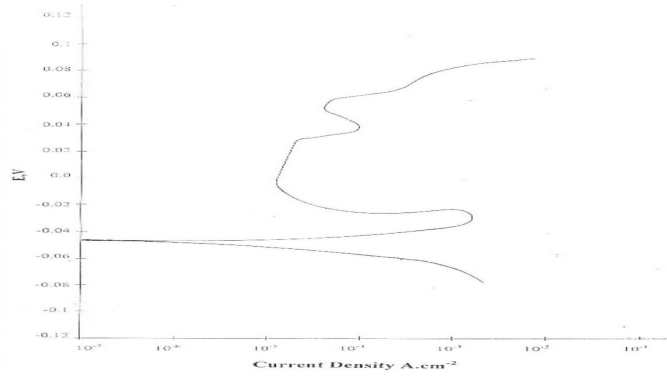


Fig. 3 Polarization curve for Pb-2%Sn alloy at acid density of 1.3 g cm⁻³

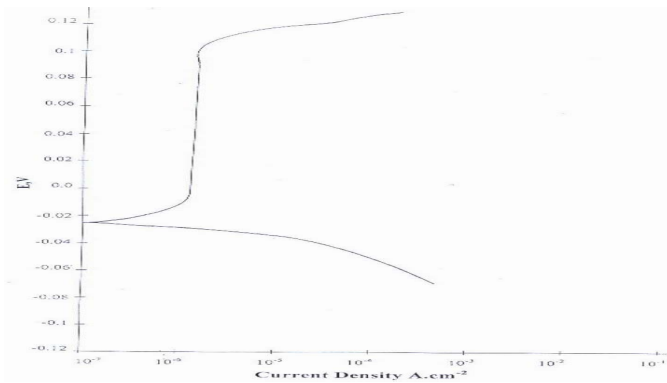


Fig. 4 Polarization curve for Pb-0.6%Sn-0.09%Cd alloy at acid density of 1.3 g cm⁻³

Meanwhile, electrochemical functions for corrosion were obtained through the relations exist in the figures. One of the most important function is corrosion current density (I_c) parallel to that of corrosion potential. The I_c values were varied with acid density and the alloys type for example a lead and alloys of low tin and cadmium showed an increase in I_c values with density (Table 2 and 3). The polarization curve of lead at considered potential showed a formation of passive layer which is stable for very short time, then the corrosion increased and pointed out a break down in the passive layer, this process is might be due to the formation of lead oxides [14,15] and its happening even with addition of very small amounts of tin [16,17]. While the addition of high percentage of tin causing a formation of a passive layer consisting almost PbO [18]. Then a second layer of PbSnO₃ was occurred which is increasing the oxidation rate of PbO to PbO₂ and establish a layer of PbSO₄ under the layer of PbSnO₃ [19]. The formation of PbSnO₃ and CdSO₄ layers was occurred by increasing the amounts of cadmium in alloys. This formation is reducing the values of I_c with acid density due to a nemours porues at the layers [20]. The lowest I_c value was occurred at alloy no.13 while there was shifting the potential to more noble values especially at acid density of 1.30 g cm⁻³ due to the formation of CdSnO₃ and PbSnO₃ (Table 2 and 3).

Table 2 The values of corrosion current density(Ic) and corrosion potential(Ec) at different densities of sulfuric acid for the first seven alloys.

Alloy no.	Alloy content	Acid density g cm-3	Ic A.cm-2	-Ec V
1	Pb	1.20	2.35×10^{-5}	0.060
		1.25	2.37×10^{-5}	0.062
		1.30	2.50×10^{-5}	0.063
		1.40	2.61×10^{-5}	0.065
2	Pb-0.6%Sn	1.20	2.21×10^{-5}	0.060
		1.25	2.23×10^{-5}	0.062
		1.30	2.35×10^{-5}	0.061
		1.40	2.48×10^{-5}	0.064
3	Pb-0.6% Sn-0.03% Cd	1.20	2.16×10^{-5}	0.055
		1.25	2.19×10^{-5}	0.056
		1.30	2.15×10^{-5}	0.056
		1.40	2.37×10^{-5}	0.064
4	Pb-1.2%Sn	1.20	2.15×10^{-5}	0.054
		1.25	2.13×10^{-5}	0.053
		1.30	1.99×10^{-5}	0.052
		1.40	2.12×10^{-5}	0.053
5	Pb-1.2% Sn-0.03% Cd	1.20	2.14×10^{-5}	0.053
		1.25	2.13×10^{-6}	0.051
		1.30	1.85×10^{-6}	0.047
		1.40	2.10×10^{-6}	0.051
6	Pb-2%Sn	1.20	2.12×10^{-6}	0.053
		1.25	2.11×10^{-6}	0.050
		1.30	1.79×10^{-6}	0.046
		1.40	2.00×10^{-6}	0.047
7	Pb-2% Sn-0.03% Cd	1.20	2.10×10^{-6}	0.052
		1.25	1.96×10^{-6}	0.048
		1.30	1.68×10^{-6}	0.045
		1.40	1.97×10^{-6}	0.047

Table 3 The values of corrosion current density(Ic) and corrosion potential (Ec) at different densities of sulfuric acid for the last six alloys.

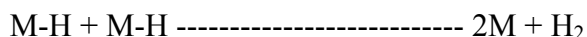
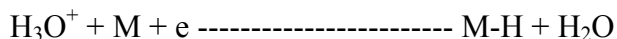
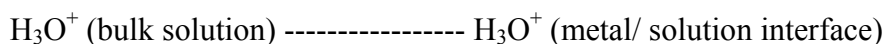
Alloy no.	Alloy content	Acid density g cm-3	Ic A.cm-2	-Ec V
8	Pb-2% Sn-0.06% Cd	1.20	1.93×10^{-6}	0.052
		1.25	1.86×10^{-6}	0.047
		1.30	1.37×10^{-6}	0.042
		1.40	1.56×10^{-6}	0.045
9	Pb-1.2% Sn-0.06% Cd	1.20	1.84×10^{-6}	0.052
		1.25	1.78×10^{-6}	0.046
		1.30	1.30×10^{-6}	0.040
		1.40	1.45×10^{-6}	0.045
10	Pb-2% Sn-0.09% Cd	1.20	1.24×10^{-6}	0.051
		1.25	1.10×10^{-6}	0.042
		1.30	1.04×10^{-6}	0.038
		1.40	1.14×10^{-6}	0.044
11	Pb-1.2% Sn-0.09% Cd	1.20	1.21×10^{-6}	0.050
		1.25	1.11×10^{-6}	0.042
		1.30	1.02×10^{-6}	0.037
		1.40	1.14×10^{-6}	0.043
12	Pb-0.6% Sn-0.06% Cd	1.20	1.12×10^{-6}	0.048
		1.25	1.03×10^{-6}	0.041
		1.30	1.00×10^{-6}	0.035

		1.40	0.99×10^{-6}	0.042
13	Pb-0.6% Sn-0.09% Cd	1.20	0.99×10^{-7}	0.043
		1.25	0.51×10^{-7}	0.032
		1.30	0.32×10^{-7}	0.025
		1.40	0.47×10^{-7}	0.032

Little changes in cathodic and anodic Tafel slopes b_c and b_a with acid densities (Table 4 and 5). These slopes were leading to calculate the transfer coefficients of cathodic and anodic α_c and α_a by using following equations [1,4]:

$$\alpha_c = 2.303 RT/b_c F \quad \text{and} \quad \alpha_a = 2.303 RT/b_a F$$

These calculations are leading to identify the discharge-chemical desorption for hydrogen evolution reaction through following processes; diffusion



Where, M = metal and M-H = hydrogen atom adsorbed on metal surface. Actually, the changes in b_c and b_a are depend on reaction-determine step of the metal dissolution reaction.

Table 4 The values of Tafel slopes and transfer coefficients at different densities of sulfuric acid for the first seven alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	b_a v.decade ⁻¹	$-b_c$ v.decade ⁻¹	α_a	α_c
1	Pb	1.20	0.131	0.131	0.451	0.451
		1.25	0.129	0.130	0.458	0.454
		1.30	0.128	0.129	0.461	0.459
		1.40	0.127	0.128	0.465	0.461
2	Pb-0.6%Sn	1.20	0.125	0.131	0.473	0.451
		1.25	0.123	0.130	0.445	0.454
		1.30	0.141	0.126	0.419	0.468
		1.40	0.125	0.125	0.397	0.472
3	Pb-0.6% Sn-0.03% Cd	1.20	0.123	0.129	0.481	0.457
		1.25	0.131	0.127	0.451	0.465
		1.30	0.125	0.125	0.473	0.472
		1.40	0.131	0.126	0.413	0.468
4	Pb-1.2%Sn	1.20	0.124	0.127	0.477	0.465
		1.25	0.126	0.124	0.469	0.476
		1.30	0.127	0.123	0.466	0.479
		1.40	0.129	0.122	0.458	0.474
5	Pb-1.2% Sn-0.03% Cd	1.20	0.121	0.124	0.481	0.476
		1.25	0.122	0.123	0.485	0.479
		1.30	0.123	0.124	0.485	0.476
		1.40	0.124	0.122	0.466	0.474
6	Pb-2%Sn	1.20	0.119	0.125	0.481	0.472
		1.25	0.118	0.126	0.505	0.468
		1.30	0.116	0.125	0.509	0.472
		1.40	0.117	0.142	0.505	0.416
7	Pb-2% Sn-0.03% Cd	1.20	0.112	0.122	0.528	0.484
		1.25	0.112	0.122	0.528	0.484
		1.30	0.116	0.123	0.509	0.479

		1.40	0.132	0.142	0.447	0.416
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Table 5 The values of Tafel slopes and transfer coefficients at different densities of sulfuric acid for the last six alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	ba v.decade ⁻¹	-bc v.decade ⁻¹	αa	αc
8	Pb-2% Sn-0.06% Cd	1.20	0.119	0.119	0.496	0.496
		1.25	0.108	0.124	0.547	0.476
		1.30	0.101	0.134	0.584	0.441
		1.40	0.110	0.135	0.537	0.437
9	Pb-1.2% Sn-0.06% Cd	1.20	0.115	0.122	0.513	0.484
		1.25	0.114	0.123	0.518	0.480
		1.30	0.119	0.116	0.497	0.509
		1.40	0.110	0.125	0.537	0.481
10	Pb-2% Sn-0.09% Cd	1.20	0.138	0.129	0.429	0.458
		1.25	0.110	0.117	0.536	0.506
		1.30	0.120	0.119	0.528	0.497
		1.40	0.127	0.132	0.467	0.448
11	Pb-1.2% Sn-0.09% Cd	1.20	0.138	0.125	0.429	0.474
		1.25	0.127	0.132	0.467	0.448
		1.30	0.111	0.118	0.533	0.586
		1.40	0.127	0.132	0.466	0.448
12	Pb-0.6% Sn-0.06% Cd	1.20	0.123	0.137	0.481	0.432
		1.25	0.127	0.125	0.466	0.473
		1.30	0.098	0.067	0.603	0.883
		1.40	0.124	0.121	0.481	0.489
13	Pb-0.6% Sn-0.09% Cd	1.20	0.122	0.120	0.485	0.493
		1.25	0.064	0.062	0.924	0.954
		1.30	0.055	0.065	1.075	0.909
		1.40	0.062	0.059	0.954	1.002

Tables 6 and 7 showed the values of the exchange current density (I_0) and the polarization resistance (R_p) for all acid densities. The estimation of these parameters were gotten from following equations:

$$\eta = [RT/ I_0 F] i = E - E_c ,$$

where,

η =over-voltage,

E = polarization potential,

E_c =corrosion polarization

plot $E - E_c$ vs. i gives a slope of $RT/ I_0 F$

while, $R_p = [d(\Delta E)/di]_{\Delta E \rightarrow 0} = b_c b_a / 2.303 (b_c b_a) i_c$

Table 6 The values of polarization resistance and the exchange current at different densities of sulfuric acid for the first seven alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	R_p Ω cm ⁻²	i_0 A.cm ⁻²
1	Pb	1.20	1210.3	2.12×10^{-5}
		1.25	1186.3	2.16×10^{-5}
		1.30	1115.1	2.29×10^{-5}
		1.40	1060.6	2.42×10^{-5}
2	Pb-0.6%Sn	1.20	1254.5	2.04×10^{-5}
		1.25	1228.5	2.09×10^{-5}

		1.30	1229.5	2.08×10^{-5}
		1.40	1094.3	2.34×10^{-5}
3	Pb-0.6% Sn-0.03% Cd	1.20	1263.5	2.03×10^{-5}
		1.25	1277.4	2.01×10^{-5}
		1.30	1262.3	2.03×10^{-5}
		1.40	1176.7	2.18×10^{-5}
4	Pb-1.2%Sn	1.20	1266.6	2.02×10^{-5}
		1.25	1358.3	1.89×10^{-5}
		1.30	1363.5	1.88×10^{-5}
		1.40	1283.7	1.99×10^{-5}
5	Pb-1.2% Sn-0.03% Cd	1.20	1245.1	2.10×10^{-6}
		1.25	1248.4	2.05×10^{-6}
		1.30	1250.8	1.77×10^{-6}
		1.40	1271.3	2.02×10^{-6}
6	Pb-2%Sn	1.20	124.9	2.05×10^{-6}
		1.25	1253.6	2.04×10^{-6}
		1.30	1460.2	1.76×10^{-6}
		1.40	1393.8	1.48×10^{-6}
7	Pb-2% Sn-0.03% Cd	1.20	1268.7	2.02×10^{-6}
		1.25	1269.8	2.02×10^{-6}
		1.30	1544.2	1.66×10^{-6}
		1.40	1508.0	1.69×10^{-6}

Table 7 The values of polarization resistance and the exchange current at different densities of sulfuric acid for the last six alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	Rp Ω cm ⁻²	i _o A.cm ⁻²
8	Pb-2% Sn-0.06% Cd	1.20	1339.7	1.91×10^{-6}
		1.25	1348.6	1.90×10^{-6}
		1.30	1906.8	1.34×10^{-6}
		1.40	1687.5	1.52×10^{-6}
9	Pb-1.2% Sn-0.06% Cd	1.20	1397.4	1.83×10^{-6}
		1.25	1444.1	1.77×10^{-6}
		1.30	1960.8	1.31×10^{-6}
		1.40	1753.8	1.46×10^{-6}
10	Pb-2% Sn-0.09% Cd	1.20	2334.0	1.09×10^{-6}
		1.25	1461.8	1.04×10^{-6}
		1.30	2481.9	1.04×10^{-6}
		1.40	2468.9	1.04×10^{-6}
11	Pb-1.2% Sn-0.09% Cd	1.20	2347.9	1.09×10^{-6}
		1.25	2468.9	1.04×10^{-6}
		1.30	2485.3	1.03×10^{-6}
		1.40	2472.6	1.04×10^{-6}
12	Pb-0.6% Sn-0.06% Cd	1.20	2524.0	1.02×10^{-6}
		1.25	2681.1	0.96×10^{-6}
		1.30	2690.9	0.95×10^{-6}
		1.40	2678.0	0.96×10^{-6}
13	Pb-0.6% Sn-0.09% Cd	1.20	2653.4	0.97×10^{-7}
		1.25	2681.2	0.95×10^{-7}
		1.30	4067.9	0.63×10^{-7}
		1.40	2793.0	0.91×10^{-7}

The values of Rp decreased with acid densities at alloys of nos. 1, 2 and 3, while alloys of nos. 4,5,6,7,8 and 9 showed an increase at density of 1.30 g cm⁻³. Meanwhile, there was an elevation in Rp values for alloys 10, 11 and 12 with dramatic increase at alloy no. 13.

However, there was an increase in I_o for the first three alloys and a reduction started at alloy no. 4 continuously until alloy no. 13 [21,22]. These results are indicated that a reduction in corrosion is occurred with high values of R_p and low values with I_o .

The results are indicated that prepared samples can be classified to be transferred from active to passive behavior with potential increases. This process occurred when potential at passive area (E_{pp}) is less than reserved reaction potential of H_2/H^+ . And to do so, this process should be happened at I_p values greater than that of exchange current density. However, the low values of critical current density (I_c) indicated that a metal is forming a passive area easily [1,23 – 25] as shown in Tables 8 and 9. At the same time, there was a decrease in passive primary current (I_{pp}) and passive primary potential (E_{pp}) should be less than hydrogen potential to create a passive area at samples.

Table 8 The values of critical current density, passive primary current and passive primary potential at different densities of sulfuric acid for the first seven alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	I_{cr} A.cm ⁻²	I_{pp} A.cm ⁻²	- E_{pp} V
1	Pb	1.20	5.43×10^{-2}	3.96×10^{-4}	0.037
		1.25	5.68×10^{-2}	4.14×10^{-3}	0.039
		1.30	6.17×10^{-1}	4.50×10^{-3}	0.039
		1.40	694×10^{-1}	5.04×10^{-2}	0.040
2	Pb-0.6%Sn	1.20	5.36×10^{-2}	3.66×10^{-4}	0.032
		1.25	5.75×10^{-2}	4.12×10^{-3}	0.033
		1.30	6.00×10^{-1}	4.35×10^{-3}	0.033
		1.40	6.91×10^{-1}	5.00×10^{-2}	0.035
3	Pb-0.6% Sn-0.03% Cd	1.20	5.35×10^{-2}	3.30×10^{-4}	0.019
		1.25	5.43×10^{-2}	3.70×10^{-4}	0.020
		1.30	5.60×10^{-2}	3.48×10^{-4}	0.020
		1.40	7.19×10^{-2}	4.46×10^{-3}	0.023
4	Pb-1.2%Sn	1.20	5.31×10^{-3}	3.27×10^{-4}	0.026
		1.25	5.25×10^{-3}	3.66×10^{-4}	0.026
		1.30	5.00×10^{-3}	3.30×10^{-4}	0.025
		1.40	5.55×10^{-3}	3.31×10^{-4}	0.025
5	Pb-1.2% Sn-0.03% Cd	1.20	4.98×10^{-3}	2.83×10^{-5}	0.024
		1.25	4.85×10^{-3}	2.79×10^{-5}	0.023
		1.30	4.50×10^{-3}	2.60×10^{-5}	0.021
		1.40	4.88×10^{-3}	2.81×10^{-5}	0.023
6	Pb-2%Sn	1.20	4.94×10^{-3}	2.50×10^{-5}	0.025
		1.25	4.54×10^{-3}	2.29×10^{-5}	0.024
		1.30	4.21×10^{-3}	2.13×10^{-5}	0.022
		1.40	4.35×10^{-3}	2.20×10^{-5}	0.023
7	Pb-2% Sn-0.03% Cd	1.20	4.76×10^{-3}	2.49×10^{-5}	0.020
		1.25	4.53×10^{-3}	2.37×10^{-5}	0.027
		1.30	4.00×10^{-3}	2.09×10^{-5}	0.025
		1.40	4.15×10^{-3}	2.16×10^{-5}	0.026

Table 9 The values of critical current density, passive primary current and passive primary potential at different densities of sulfuric acid for the last six alloys.

Alloy no.	Alloy content	Acid density g cm ⁻³	I _c A.cm ⁻²	I _{pp} A.cm ⁻²	-E _{pp} V
8	Pb-2% Sn-0.06% Cd	1.20	4.14x10 ⁻³	2.41x10 ⁻⁵	0.028
		1.25	3.72x10 ⁻⁴	2.17x10 ⁻⁵	0.026
		1.30	3.33x10 ⁻⁴	1.94x10 ⁻⁵	0.023
		1.40	3.58x10 ⁻⁴	2.08x10 ⁻⁵	0.025
9	Pb-1.2% Sn-0.06% Cd	1.20	3.17x10 ⁻⁴	2.26x10 ⁻⁵	0.026
		1.25	3.10x10 ⁻⁴	2.20x10 ⁻⁵	0.023
		1.30	2.50x10 ⁻⁵	1.78x10 ⁻⁵	0.020
		1.40	2.89x10 ⁻⁵	2.06x10 ⁻⁵	0.022
10	Pb-2% Sn-0.09% Cd	1.20	2.75x10 ⁻⁵	2.12x10 ⁻⁵	0.031
		1.25	2.22x10 ⁻⁵	1.71x10 ⁻⁶	0.026
		1.30	2.00x10 ⁻⁵	1.54x10 ⁻⁶	0.023
		1.40	2.44x10 ⁻⁵	1.88x10 ⁻⁶	0.027
11	Pb-1.2% Sn-0.09% Cd	1.20	2.65x10 ⁻⁵	2.13x10 ⁻⁵	0.035
		1.25	2.19x10 ⁻⁵	1.75x10 ⁻⁶	0.030
		1.30	1.90x10 ⁻⁶	1.53x10 ⁻⁶	0.026
		1.40	2.29x10 ⁻⁵	1.84x10 ⁻⁶	0.031
12	Pb-0.6% Sn-0.06% Cd	1.20	2.26x10 ⁻⁵	1.81x10 ⁻⁶	0.035
		1.25	2.01x10 ⁻⁵	1.61x10 ⁻⁶	0.030
		1.30	1.66x10 ⁻⁶	1.33x10 ⁻⁶	0.026
		1.40	1.99x10 ⁻⁶	1.60x10 ⁻⁶	0.031
13	Pb-0.6% Sn-0.09% Cd	1.20	1.75x10 ⁻⁶	1.73x10 ⁻⁷	0.051
		1.25	1.65x10 ⁻⁶	1.63x10 ⁻⁷	0.039
		1.30	1.15x10 ⁻⁶	1.15x10 ⁻⁷	0.033
		1.40	1.36x10 ⁻⁶	1.34x10 ⁻⁷	0.038

4.0 Conclusion

1. The corrosion rate was affected by addition of tin and cadmium which showed a maximum rate at pure lead and a minimum with tin and cadmium additions.
2. Sulfuric acid density showed various effects on corrosion rate of alloys.
3. The results obtained for corrosion rate were completely matching the values of corrosion current density (I_c), corrosion potential (E_c), passive primary current (I_{pp}) and critical current density (I_{cr}).
4. The cathodic reaction as concluded from Tafel slopes was a hydrogen evolution reaction.

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