Effect of Chloride Ions on the Corrosion Behavior of Al – Zn Alloy in NaOH Solution at Four Different Temperatures

Rana A. Majed, Hanaa A. Al-Kaisy and Hind B. Al-Atrakchy

Department of Materials Engineering/ University of Technology

(Received 5 September 2007; accepted 13 May 2008)

Abstract

This research involves study effect of chloride ions in concentration range (0.01 – 0.50 mol.dm⁻³) on the corrosion behavior of Al-Zn alloy in basic media of 1x10⁻³ mol.dm⁻³ NaOH at pH=11 and four different temperatures in the range (298-313 K). Cathodic and anodic Tafel slopes (βc & βa) and transfer coefficients (αc & αa) were calculated and the results interprets according to the variation of the rate – determining steps. The results also indicate that the chloride ions are bonded chemically in the interface as an initial step of formation of different mixed oxohydroxy – and chloro complexes. Polarization resistance (Rp) is calculates and interprets the different polarization behavior because of addition of chloride ions to the basic media.

Keywords: Al-Zn alloy, Effect of chloride ion, Corrosion behavior in basic medium.

1. Introduction:

Corrosion of aluminum has been a subject of numerous studies due to the importance of this material in contemporary civilization. It is well known that there is a potential region in which the rate of corrosion, even in such aggressive media as chlorides. The relatively complex corrosion mechanism of aluminium has been studies by several authors.

Corrosion of aluminium occurs only when the metal protective oxide layer is damaged and when the repair mechanism is prevented by chemical dissolution[1].

Polarization methods have been extensively used to investigate the mechanism of localized corrosion and processes that lead to localized corrosion. In using potentiostatic techniques, the potential variable[2]. Potentiostatic and potentiodynamic techniques have been applied by several authors to study the corrosion of aluminium in different environment[3-8].

The exceptional corrosion resistance of aluminium in many environments is due to its protective oxide film which is relatively inert chemically and so provides the passive behavior of aluminium.

However in aggressive environments, particularly in the presence of halide ions, aluminium suffers from localized corrosion by local breakdown of the passive film. Various theories are postulated to explain the mechanism of passivity breakdown in halide solutions but the most common and accepted ones are as follows:

a- Penetration theory.
b- Flaws and crack/heal theory.
c- Localized acidification theory.
d- Complex formation theory.

2. Experimental Work:

Al – Zn alloy was cut into cylinder shape with (1.2 cm) diameter, and made into electrode by pressing a copper wire into a hole on one side and then insulating all but one side with an epoxy resin. The open side was polished mechanically to a mirror finish, rinsed in distilled water and stored in a desiccator.

The analytical composition of alloy was shown in Table (1) which was obtained by chemical analysis in Naser Company.
The electrochemical glass cell was of the usual type with provision for working electrode (Al-Zn alloy), auxiliary electrode (Pt electrode), and a Luggin capillary for connection with an saturated calomel electrode (reference electrode SCE). The basic solution was 1x10^{-3} mol.dm^{-3} NaOH (obtained by Ferak with M.wt 40 g.mol^{-1} and purity >99.5%) and distilled water (specific conductivity 1x10^{-6} S.m^{-1}). To study the effect of chloride ions uses NaCl (obtained by Fluka with M.wt 58.44 g.mol^{-1} and purity 99.5%) was prepared with seven concentrations (0.01, 0.10, 0.15,0.20,0.25,0.35, and 0.50 mol.dm^{-3}).

Electrochemical measurements were performed with a potentiostat (Corroscript) which was obtained from Tacussel (France) at a scan rate of 0.3 Volt per minute.

The Tafel extrapolation and Linear-polarization techniques are uses to determine the rate of corrosion. The Tafel extrapolation method for determining corrosion rate was used by Wagner and Traud to verify the mixed-potential theory, the method was shown in figure (1). Tangents to the anodic and cathodic Tafel regions were extrapolated to the point of intersection, from which both the corrosion potentials (E_{corr}) and corrosion current density (i_{corr}) were determined using the four-point method [9].

Thus metals like aluminium and zinc, whose oxides are amphoteric, are thermodynamically unstable in alkaline solutions and will react with water at high pHs with consequent hydrogen evolution and formation of metal anions as shown below:

\[ \text{Al}^{3+} + 3e \rightarrow \text{Al} \]
\[ \text{O}_2 + 2\text{H}_2\text{O} + 4e \leftrightarrow 4\text{OH}^- \]
\[ \text{H}_2\text{O} + e \rightarrow 1/2 \text{H}_2 + \text{OH}^- \]

3. Results and Discussion:

Figure (2) represent the polarization curve of Al – Zn alloy in 1x10^{-3} NaOH solution (pH=11) in the absence of chloride ions (Cl^-) at 298 K, the section (abc) represented the cathodic polarization region which occur on the metals presumably by migration of electrons through the surface oxide films and subsequent interaction of those electrons with water molecules and dissolved oxygen at the film/solution interface, so the corrosion process is complicated with mass transfer. Corrosion of Al-Zn alloy proceeds similarly by reduction of oxygen and the water molecules will act as the electron acceptor and the rate of corrosion is controlled by the diffusion limited current density for cathodic reduction, the probable reactions are:

\[ \text{Al}^{3+} + 3e \rightarrow \text{Al} \]
\[ \text{O}_2 + 2\text{H}_2\text{O} + 4e \leftrightarrow 4\text{OH}^- \]
\[ \text{H}_2\text{O} + e \rightarrow 1/2 \text{H}_2 + \text{OH}^- \]

Along the section (cde), the metal hydroxide is expected to be formed. The hydroxide soon dissociates into metal oxide (Al_2O_3) on a surface which behaves as a passive layer (protective film) according to the reaction:

\[ \text{Al}^{3+} + 3\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 + 6\text{H}^+ \]

The breakdown of passivity began at point (e) and continued along (ef) and this section represent the anodic Tafel region.

The presence of Cl^- effects mainly on anodic polarization. Fig. (3) show the effect addition of 0.01mol.dm^{-3} Cl^- on the corrosion behavior, since addition Cl^- with this concentration penetrates the passive layer but partially destroyed and shifts passive potential (E_{pass}) to more negative values and corrosion current density to lower values.

Table 1
The Analytical Compositions of Al-Zn Alloy Which Useful in This Search.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Zn</th>
<th>Mg</th>
<th>Cu</th>
<th>Cr</th>
<th>Ni</th>
<th>Ti</th>
<th>Mn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt %</td>
<td>5.70</td>
<td>2.50</td>
<td>1.330</td>
<td>0.22</td>
<td>0.01</td>
<td>0.08</td>
<td>0.06</td>
<td>Bal.</td>
</tr>
</tbody>
</table>
Fig. 2. Polarization Curve for Corrosion of Al-Zn alloy in 1x10^-3 mol.dm^-3 NaOH Solution in the Absence of Chloride Ion at 298K.

Fig. 3. Polarization Curve for Corrosion of Al-Zn Alloy in 1x10^-3 mol.dm^-3 NaOH Solution in the Presence of 0.01 mol.dm^-3 Chloride Ion at 298K.
When add a higher concentration of chloride ion, the passive layer was breakdown and \((i_{corr})\) value increases with increasing the concentration of Cl\(^-\) in solution as shown in Figs.(4) to (9) where the polarization curve, in general, consist of the cathodic (abc) and anodic (cde) Tafel regions.

![Fig.4. Polarization Curve for Corrosion of Al-Zn Alloy in 1x10\(^{-3}\) mol.dm\(^{-3}\) NaOH Solution in the Presence of 0.10 mol.dm\(^{-3}\) Chloride Ion at 298K.](image)

![Fig.5. Polarization Curve for Corrosion of Al-Zn Alloy in 1x10\(^{-3}\) mol.dm\(^{-3}\) NaOH Solution in the Presence of 0.15 mol.dm\(^{-3}\) Chloride Ion at 298K.](image)
Fig. 6. Polarization Curve for Corrosion of Al-Zn Alloy in $1 \times 10^{-3}$ mol.dm$^{-3}$ NaOH Solution in the Presence of 0.20 mol.dm$^{-3}$ Chloride Ion at 298K.

Fig. 7. Polarization Curve for Corrosion of Al-Zn Alloy in $1 \times 10^{-3}$ mol.dm$^{-3}$ NaOH Solution in the Presence of 0.25 mol.dm$^{-3}$ Chloride Ion at 298K.
Fig. 8. Polarization Curve for Corrosion of Al-Zn Alloy in $1\times10^{-3}$ mol.dm$^{-3}$ NaOH Solution in the Presence of 0.35 mol.dm$^{-3}$ Chloride Ion at 298K.

Fig. 9. Polarization Curve for Corrosion of Al-Zn Alloy in $1\times10^{-3}$ mol.dm$^{-3}$ NaOH Solution in the Presence of 0.50 mol.dm$^{-3}$ Chloride Ion at 298K.
When only hydroxide ions (OH\(^{-}\)) exists in solution (NaOH without additive), aluminium hydroxide Al(OH)\(_3\) will be formed and so repairing the passive film on the anode. Moreover the electrolyte at the anode will be replenished again with (OH\(^{-}\)) by migration. But when Cl\(^{-}\) exists in solution (NaOH with additive), then part of the current will be transported by these ions and since the anode products in alkaline chloride solution is still Al(OH)\(_3\), therefore the concentration of chloride ions at the anode will be increased rapidly while the concentration of hydroxide ions decreases to values corresponding to pH values less than (7), solid Al(OH)\(_3\) is still formed, but finally the electrolyte becomes so acid that it leads to the formation of soluble anode products rather than solids.

This process leads to the breakdown of passivity, the reactions may be given by:

\[
\text{Al} \rightarrow \text{Al}^{3+} + 3e
\]

\[
\text{Al} + 3\text{H}_2\text{O} \leftrightarrow \text{Al(OH)}_3 + 3\text{H}^+
\]

Under equilibrium condition the rates of production and consuming of protons will be equal. The proton can be consumed by direct reduction:

\[
2\text{H}^+ + 2e \leftrightarrow \text{H}_2
\]

Or by diffusion to the bulk solution:

\[
\text{H}^+ \text{ (anode)} \xrightarrow{\text{Diffusion}} \text{H}^+ \text{ (bulk solution)}
\]

The results of \(E_{\text{corr}}, i_{\text{corr}}, b_c, b_a, \alpha_c, \alpha_a, R_p,\) and \(i_b\) for Al – Zn alloy in the absence and presence of chloride ions in NaOH solution at four different temperatures have been given in Table (2).

From deep analysis of the cathodic and anodic regions of the polarization curves, it was possible to derive data concerning:

a- The cathodic (\(b_c\)) and anodic (\(b_a\)) Tafel slopes.

b- The cathodic (\(\alpha_c\)) and anodic (\(\alpha_a\)) transfer coefficients. Values of (\(\alpha\)) have been calculated from the corresponding values of the Tafel slope (\(b\)) using the relation [10,11]:

\[
\alpha = \frac{2.303RT}{bF} \quad \ldots(1)
\]

where:

R: gas constant (8.314 J.mol\(^{-1}\).K\(^{-1}\)).
T: temperature in Kelvin scale.

\(F\): Faraday constant (96500).

\(c\)- The polarization resistance (\(R_p\)) may be defined as [12,13, 14]:

\[
R_p = \frac{d(E - E_{\text{corr}})}{di} \quad \ldots(2)
\]

where \(E\) and \(E_{\text{corr}}\) are the applied corrosion potential (Volt) respectively, \(I\) is the current density (A.cm\(^{-2}\)). For small polarization, one may write approximation [13,14]:

\[
R_p = \frac{d(E - E_{\text{corr}})}{di} = \frac{E_{\text{corr}}}{i_{\text{corr}}} \quad \ldots(3)
\]

where \(E_{\text{corr}}\) and \(i_{\text{corr}}\) are the corrosion potential (V) and corrosion current density (A.cm\(^{-2}\)). The ratio \((E_{\text{corr}}/i_{\text{corr}})\) thus corresponds to the resistance of the metal/solution interface to charge-transfer reaction. It is also a measure of the resistance of the metal to corrosion in the solution in which the metal is immersed.

For low-field polarization [15]:

\[
\frac{\eta}{i} = \frac{RT}{F_i} \quad \ldots(4)
\]

and

\[
\frac{E_{\text{corr}}}{i_{\text{corr}}} = \frac{RT}{F_i} = R_p \quad \ldots(5)
\]

where \(\eta=E-E_{\text{corr}}\) and \(i_b\) is the equilibrium exchange current density (A.cm\(^{-2}\)). The reaction resistance (\(R_p\)), which mainly depends upon the equilibrium exchange current density \((i_b)\) determines what may be termed the polarizability, i.e., what overpotential \((\eta=E-E_{\text{corr}})\) a particular current density needs or produces since:

\[
R_p = \frac{d\eta}{di} = \frac{d(E - E_{\text{corr}})}{di} = \frac{E_{\text{corr}}}{i_{\text{corr}}} = \frac{RT}{F_i} \quad \ldots(6)
\]

The polarization resistance (\(R_p\)) was also determined in another way from Stern-Geary equation [16,17,18], where:

\[
R_p = \left(\frac{dE}{di}\right)_{i=0} = \frac{b_b}{2.303(b_a - b_c)i_{\text{corr}}} \quad \ldots(7)
\]
The values of $R_p$ have been calculated from equation (7), which is presented in table (2).

The results of Table (2) indicates that the lowest value of ($b$ =0.026 or $\alpha$=2.4) and the highest value is ($b$=0.120 or $\alpha$=0.5). A cathodic Tafel slope of 0.120 (or $\alpha$=0.5) may be diagnostic of discharge-chemical desorption mechanism for hydrogen evolution reaction of the cathode in which the proton discharge is the rate-determining step. If chemical desorption is the rate-determining step, the rate will then be independent on the overpotential since no charge transfer occur in such step and the rate becomes directly proportional to the concentration or the coverage ($\theta$) of the adsorbed hydrogen atoms, and may occur at coverage ranging from very small values to almost full surface layer formation [19].

### Table 2

<table>
<thead>
<tr>
<th>Medium (mol.dm$^{-3}$)</th>
<th>$T$ (K)</th>
<th>Corrosion $E_{corr}$ (Vol)</th>
<th>$i_{corr}/10^3$ (A.cm$^{-2}$)</th>
<th>$b$ (V.decade$^{-1}$)</th>
<th>$a$</th>
<th>Passivity $E_{pass}$ (Volt)</th>
<th>$i_{pass}/10^3$ (A.cm$^{-2}$)</th>
<th>$R_p/10^{-4}$ (A.cm$^{-2}$)</th>
<th>$i_d/10^{-6}$ (A.cm$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x10$^{-3}$ NaOH (pH=11) only</td>
<td>298</td>
<td>1.66</td>
<td>2.916</td>
<td>0.107</td>
<td>-</td>
<td>0.55</td>
<td>0.99</td>
<td>0.301</td>
<td>14.910</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.61</td>
<td>3.125</td>
<td>0.100</td>
<td>-</td>
<td>0.60</td>
<td>1.20</td>
<td>0.542</td>
<td>13.913</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.56</td>
<td>3.333</td>
<td>0.095</td>
<td>-</td>
<td>0.64</td>
<td>1.22</td>
<td>0.581</td>
<td>13.044</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.50</td>
<td>3.750</td>
<td>0.091</td>
<td>-</td>
<td>0.68</td>
<td>1.24</td>
<td>0.622</td>
<td>11.594</td>
</tr>
<tr>
<td>pH=11 + 0.01 Cl$^-$</td>
<td>298</td>
<td>1.44</td>
<td>0.416</td>
<td>0.061</td>
<td>-</td>
<td>0.97</td>
<td>1.21</td>
<td>0.063</td>
<td>104.52</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.39</td>
<td>0.500</td>
<td>0.058</td>
<td>-</td>
<td>1.04</td>
<td>1.24</td>
<td>0.071</td>
<td>86.956</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.36</td>
<td>0.541</td>
<td>0.052</td>
<td>-</td>
<td>1.17</td>
<td>1.28</td>
<td>0.088</td>
<td>80.366</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.33</td>
<td>0.625</td>
<td>0.042</td>
<td>-</td>
<td>1.45</td>
<td>1.30</td>
<td>0.010</td>
<td>69.565</td>
</tr>
<tr>
<td>pH=11 + 0.10 Cl$^-$</td>
<td>298</td>
<td>1.39</td>
<td>0.541</td>
<td>0.044</td>
<td>0.120</td>
<td>1.34</td>
<td>0.41</td>
<td>-</td>
<td>2.584</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.36</td>
<td>0.583</td>
<td>0.034</td>
<td>0.111</td>
<td>1.76</td>
<td>0.55</td>
<td>-</td>
<td>1.938</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.33</td>
<td>0.625</td>
<td>0.031</td>
<td>0.081</td>
<td>1.97</td>
<td>0.75</td>
<td>-</td>
<td>1.557</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.31</td>
<td>0.666</td>
<td>0.029</td>
<td>0.062</td>
<td>2.14</td>
<td>1.00</td>
<td>-</td>
<td>1.288</td>
</tr>
<tr>
<td>pH=11 + 0.15 Cl$^-$</td>
<td>298</td>
<td>1.38</td>
<td>0.541</td>
<td>0.054</td>
<td>0.115</td>
<td>1.09</td>
<td>0.51</td>
<td>-</td>
<td>2.949</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.33</td>
<td>0.583</td>
<td>0.047</td>
<td>0.100</td>
<td>1.27</td>
<td>0.60</td>
<td>-</td>
<td>2.381</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.32</td>
<td>0.708</td>
<td>0.029</td>
<td>0.071</td>
<td>2.11</td>
<td>0.86</td>
<td>-</td>
<td>1.262</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.31</td>
<td>0.958</td>
<td>0.026</td>
<td>0.051</td>
<td>2.38</td>
<td>1.21</td>
<td>-</td>
<td>0.780</td>
</tr>
<tr>
<td>pH=11 + 0.20 Cl$^-$</td>
<td>298</td>
<td>1.39</td>
<td>0.666</td>
<td>0.060</td>
<td>0.120</td>
<td>0.98</td>
<td>0.49</td>
<td>-</td>
<td>2.607</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.37</td>
<td>0.833</td>
<td>0.049</td>
<td>0.093</td>
<td>1.22</td>
<td>0.64</td>
<td>-</td>
<td>1.672</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.34</td>
<td>0.916</td>
<td>0.042</td>
<td>0.083</td>
<td>1.45</td>
<td>0.73</td>
<td>-</td>
<td>1.321</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.32</td>
<td>1.416</td>
<td>0.027</td>
<td>0.068</td>
<td>2.29</td>
<td>0.91</td>
<td>-</td>
<td>0.592</td>
</tr>
<tr>
<td>pH=11 + 0.25 Cl$^-$</td>
<td>298</td>
<td>1.39</td>
<td>1.458</td>
<td>0.055</td>
<td>0.100</td>
<td>1.07</td>
<td>0.59</td>
<td>-</td>
<td>1.056</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.38</td>
<td>2.000</td>
<td>0.049</td>
<td>0.096</td>
<td>1.22</td>
<td>0.62</td>
<td>-</td>
<td>0.704</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.34</td>
<td>2.083</td>
<td>0.045</td>
<td>0.049</td>
<td>1.35</td>
<td>1.24</td>
<td>-</td>
<td>0.488</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.33</td>
<td>2.500</td>
<td>0.031</td>
<td>0.036</td>
<td>2.00</td>
<td>1.72</td>
<td>-</td>
<td>0.289</td>
</tr>
<tr>
<td>pH=11 + 0.35 Cl$^-$</td>
<td>298</td>
<td>1.38</td>
<td>1.666</td>
<td>0.052</td>
<td>0.057</td>
<td>1.13</td>
<td>1.03</td>
<td>-</td>
<td>0.708</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.35</td>
<td>1.875</td>
<td>0.047</td>
<td>0.055</td>
<td>1.27</td>
<td>1.09</td>
<td>-</td>
<td>0.586</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.33</td>
<td>3.333</td>
<td>0.046</td>
<td>0.050</td>
<td>1.32</td>
<td>1.22</td>
<td>-</td>
<td>0.312</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.32</td>
<td>3.750</td>
<td>0.042</td>
<td>0.042</td>
<td>1.47</td>
<td>1.47</td>
<td>-</td>
<td>0.243</td>
</tr>
<tr>
<td>pH=11 + 0.50 Cl$^-$</td>
<td>298</td>
<td>1.39</td>
<td>1.875</td>
<td>0.065</td>
<td>0.091</td>
<td>0.91</td>
<td>0.65</td>
<td>-</td>
<td>0.878</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1.38</td>
<td>2.242</td>
<td>0.058</td>
<td>0.081</td>
<td>1.03</td>
<td>0.74</td>
<td>-</td>
<td>0.654</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>1.37</td>
<td>3.513</td>
<td>0.051</td>
<td>0.058</td>
<td>1.19</td>
<td>1.05</td>
<td>-</td>
<td>0.335</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1.36</td>
<td>4.445</td>
<td>0.043</td>
<td>0.037</td>
<td>1.44</td>
<td>1.67</td>
<td>-</td>
<td>0.194</td>
</tr>
</tbody>
</table>
The expected Tafel slope in such step would then be -0.03 V. decade\(^{-1}\) (or =2.0).

When electrochemical desorption becomes the rate-determining step for the hydrogen evolution reaction on the cathode, the expected value of \(b_e\) is -0.05 V. decade\(^{-1}\) (or =1.5).

The variation of the cathodic and anodic Tafel slopes or transfer coefficients may be attributed to variation of the rate-determining step in the metals dissolution reaction.

Another approach to the problem of the electrochemical corrosion rate measurement is to apply only a small potential difference to the specimen and then measure the current density.

The measurement of polarization resistance has very similar requirements to the measurement of full polarization curves and it is particularly useful as a method to rapid identifying corrosion, up-setting and initiating a remedial action[20].

The results of Table (2) indicates that the values of \(R_p\) obtained for the solution at pH=11 and in the (pH=11+0.01 mol.dm\(^{-3}\) Cl\(^-\)) system were higher than other media.

Generally, the polarization resistance \(R_p\) in the other media decreases with increasing the concentration of chloride ion in solution because of increases the attack on the bare surface. The higher values of \(R_p\) enhanced by presence the passive layer as shown in the polarization curves which attribute to produce aluminium hydroxide Al(OH)\(_3\) which transform to protective film (Al\(_2\)O\(_3\)) and reduces the expected attack on the surface alloy and lead to more resistance to corrosion as shown in Fig.(2), and to the equilibrium states between Al\(_2\)O\(_3\) and AlCl\(_3\) in addition to form Al(OH)\(_3\) in (1x10\(^{-3}\)NaOH + 0.01Cl\(^-\)) system as shown in Fig.(3), but when add higher concentrations of Cl\(^-\) there are many soluble complexes to be form according to the following reactions:

\[
\begin{align*}
\text{Al} + 3\text{OH}^- & \rightarrow \text{Al(OH)}_3^- + 3e \\
\text{Al(OH)}_3^- + \text{OH}^- & \rightarrow \text{Al(OH)}_4^- \\
\text{Al(OH)}_3 + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}^- + \text{OH}^- \\
\text{Al(OH)}_2\text{Cl}^- + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}_2^- + \text{OH}^- \\
\text{Al(OH)}_2\text{Cl}_2^- + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}_3^- + \text{OH}^- \\
\text{Al(OH)}_2\text{Cl}_3^- + \text{Cl}^- & \rightarrow \text{AlCl}_4^- + \text{OH}^- \\
\end{align*}
\]

4. Conclusion:

From the present measurements the conclusion indicates that the polarization behavior of Al-Zn alloy in 1x10\(^{-3}\) mol.dm\(^{-3}\) NaOH solution (pH=11) gives special case in the presence of 1x10\(^{-2}\) mol.dm\(^{-3}\) Cl\(^-\) and this phenomena may be attributed to occur the equilibrium state between the Al\(_2\)O\(_3\) and AlCl\(_3\) in addition to produce Al(OH)\(_3\), while the addition of higher concentrations of Cl\(^-\) leads to increase the rate of corrosion of Al-Zn alloy in the basic media.

Chloride ion is bonded chemically in the interface as an initial step of the formation of different mixed oxohydrox- and chloro-complexes according to the following formula[21]:

\[
\begin{align*}
\text{Al[O}_3\text{(OH)}_2\text{(H}_2\text{O)}_x]\text{Cl}^- & \rightarrow \text{Al[O}_3\text{(OH)}_4\text{(H}_2\text{O)}_x]\text{Cl}^- + 3\text{OH}^- \\
\text{AlO(OH)}_4\text{Cl}_2\text{H}_2\text{O}^- & \rightarrow \text{AlO(OH)}_4\text{Cl}_2\text{H}_2\text{O}^- + 2\text{OH}^- \\
\text{AlO(OH)}_3 + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}_2^- + \text{OH}^- \\
\text{Al(OH)}_3 + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}_2^- + \text{OH}^- \\
\text{Al(OH)}_2\text{Cl}_2^- + \text{Cl}^- & \rightarrow \text{Al(OH)}_2\text{Cl}_3^- + \text{OH}^- \\
\end{align*}
\]

Finally the [AlCl\(_3\)]\(^-\) complex is produced.

The effect of Cl\(^-\) on the polarization curves be more significant in the anodic regions, where can be observe in Figures (5), (6), and (8) anodic polarization observably is marked by two important regions, (A) and (B). The region (A) show a gradual increase in the current density with applied potential [22]. As soon as region (A) is crossed, a sharp rise in the current density is observed. This is characteristic of region (B).

The break in the curve is due to the onset of pitting as consequence of breakdown of the oxide layer. But in Figures (4), (7) and (9), decease this phenomena and the increasing in current density is sudden.

5. List of Symbols:

- \(b\) Tafel slope (V.decade\(^{-1}\))
- \(E\) Potential (Volt)
- \(F\) Faraday constant (96500 C.mol\(^{-1}\))
- \(i\) current density (A.cm\(^{-2}\))
- \(R\) gas constant (8.314 J.mol\(^{-1}\).K\(^{-1}\))
- \(R_p\) polarization resistance (Ω.cm\(^{-2}\))
- \(T\) temperature (K)

6. Greek letters:

- \(\alpha\) transfer coefficient
- \(\eta\) overpotential (Volt)
7. Sub/superscripts:

a         anodic
b         cathodic
corr       corrosion
corr      passivity

d. References:

تأثير أيونات الكلوريد على سلوك التآكل لسبيكة المنيوم-زنك في محلول هيدروكسيد الصوديوم عند اربع درجات حرارية

رنا عفيف ماجد    هناء عرير القبيسي
قسم المواد/الجامعة التكنولوجية

الخلاصة

يهدف البحث إلى تصميم ومحاكاة مرحلة نشاط 
بالمواصفات التالية: مدى الترددات الخارجة (9.9 - 900.4) ميكرو هرتز، نسبة تدفق المعلومات (150kb/s)، مدى الفصل بين الفوات (500kHz)، زمن تحويل 1 ميكرو ثانية ومستوى ضوضاء طوري (85) دبسيل عند 1000 هرتز من التردد الخارجي. تقييمات الدوائر الحديثة ساهمت بشكل فعال في زيادة التكامل للمرسلات والمستقبلات للاشارات الراديوية. خواص أفضل قلة استبداد القدرة، صغر الحجم وقلة الكفاءة هي التي تعتبر المقياس الخاص بالتصميم والتي تشملها يتم الحكم على أداء النظام. أن التصميم المبكر بواسطة مرحلة ترددات من نوع 
(ΣΔ modulator fractional-N) مرحلة نشاط GaussianFSK للتحويل من قلة استخدام مرحلة ترددات وصغر الحجم وقلة الكفاءة. عملية التصميم من نوع 
(ΣΔ) وضعت في دوراً قللت الطور الرقمي للسيطرة على القيمة الكسرية لقسم التردد وبواسطةه تم استخدامه للحصول على
كفاءة طفيفة عالية في الإشارة المضمنة. ان التطبيقات لهذه المرسلة هي قلة كفاءة أقل المعلومات اللاسلكية، أنظمة الأمن، السيطرة عن بعد بواسطة إشارات 
(RF) والعادات اللاسلكية.