Corrosion and inhibition Behaviour of Aluminium in Alkaline Medium and Sodium Silicate.

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Abstract

A number of metals and alloys in various forms are used in electronic industry. Also new materials and technology are introduced all the time for increased performance. Thus electronic components become increasingly complex. Presently corrosion of electronic components has been a very big problem. Multiplicity of materials used is one reason limiting the corrosion reliability, aluminum is used mostly in electronic units. Looking at the wide applicability of aluminum in different fields, Corrosion rate and inhibition efficiency has been studied for corrosion of aluminum in alkaline media( NaOH) using a new voltammetric method. Corrosion rate has been determined as a function of time, using gravimetric PIT method and some electrochemical methods i.e. Potentiodynamic polarization measurement and
voltammetric methods. The corrosion inhibition efficiency of sodium silicate is found to be 92% after 24 h.

**Key words**: Corrosion, Inhibition Efficiency, Aluminum, Sodium Silicate.

**Introduction**

Amongst several corrosive media the alkaline medium is the most dangerous [1] for the corrosion of aluminum. However corrosion data are less readily available in this environment. It is therefore desire to study the corrosive effect of NaOH on aluminum.

The authors have therefore undertaken the present study, which report the inhibitive effect of alkali silicate, on corrosion of aluminum in NaOH solution. The corrosion and inhabitation processes were examined at 25°C by gravimetric simple weight loss and some electrochemical viz. Galvanostatic and potentiodynamic polarization measurements.

The above mentioned methods prevalent in the field of corrosion rate determination, furnish only an average value for a long time interval [2,3] However, looking at the sensitivity and minimum detection limits [4] of voltammetric and polarographic techniques, we have developed polarographic and voltammetric differential pulse polarographic (DPP) and differential pulse anodic stripping voltammetric (DPASV) methods for the determinations of corrosion rates at short
time intervals, the results of which have also been discussed in the paper.

**Experimental**

All the chemicals used were of Anal-R /BDH grade. The experiments were carried out in 1 % NaOH solution. The rectangular specimens of Al – B 265 were used in the experiment. The specimens were polished to a mirror like finish, followed by Tripoli composition and were degreased with carbon tetrachloride (sulphur free).

**Weight loss method**

The rectangular specimens of 30*20*8 mm size having surface area 21.37 cm² with a small hole of about 2mm diameter at the top of the specimen of Al – B 265 were used in the experiment.

Precisely weighed aluminum test specimens were immersed in the test solution (NaOH) with and without additives) for 24h at room temp. (25°C). Duplicate tests were performed. At the end of the measurements, the specimens were cleaned and reweighed for the determination of corrosion rates, calculated using eq.-

\[
\begin{align*}
    n &= \frac{m_o - m_n}{m_o} \times 100%
\end{align*}
\]

Where n is the inhibition efficiency, mo and mn are weight losses Uninhibited and inhibited samples respectively.
Potentiodynamic polarization measurements

The specimen was molded in to epoxy resin in order to cover the sides of the rod, while the circular cross-section area at cylinder was exposed to the solution. The specimen was used as cathode and a saturated calomel electrode (SCE) as a reference electrode. A platinum electrode was used as auxiliary electrode.

The potential scan path was 50mv/5 min. The current was recorded with the change in potential. A Tinsely (UK) electronic model VT 85016 potentiometer was used for potentiometric observation and the current was recorded on a polyflex galvanometer. The observed current was plotted against the applied potential[4].

Polarographic method and Voltammometric methods

An Elico (India) micro processor based Polarograph model CL - 362 attached with hp DeskJet printer model 640 c was used for the studies. A cell consisting of three electrodes viz. saturated calomel as reference electrode, a coiled platinum wire as an auxiliary and dropping mercury electrode (DME) as working electrode, were used. The pulse amplitude used for the measurements was 25 mV.

The test specimens were polished, as discussed earlier, and one specimen was suspended in one liter. NaOH solution at room temperature (25°C). Nitrogen gas was bubbled through the solution throughout the experiment to avoid oxidation of dissolved species. A definite aliquot of solution was withdrawn from the test solution at short time intervals i.e. 5, 10, 20 min, 1, 2 and 24 h etc.

Polarograms/ Voltammograms of the test solution were recorded in deaerated...
0.1 M KCl and 0.001 % gelatin at pH 9.0 ± 0.1. The pH was adjusted using HCl/NaOH solution. A similar experiment was performed using sodium silicate (0.5 g/l) inhibitor in 1% NaOH solution.

Results and discussion

Weight Loss method

The maximum inhibition efficiency of sodium Silicate (0.5 g/l) in NaOH solution is 92% after 24h. Above this concentration inhibitive efficiency does not increase for the corrosion and inhibition of B-265 aluminum weight losses are 16.8 mg and 0.71 mg and respective corrosion rates are 3.27 and 0.13 mg cm$^{-2}$ h$^{-1}$ x $10^2$ after 24h with and without sodium silicate inhibitor respectively.

Potentiodynamic Polarization measurements

Potentiodynamic polarization curves are shown in Fig. 1 in the absence and presence of an inhibitor. It is seen that the inhibitor increases the polarization resistance.

A specimen of B-265 aluminum in 1 % NaOH solution developed a corrosion potential of - 600 mV Vs SCE, while in the presence of sodium silicate this potential is found to be 520 mV and the corrosion currents are shortened.

Voltammetric and Polarographic methods

Fig. 3A, 3B, and 3C are the direct current Polarogram (DCP), differential pulse polarogram (DPP) and differential pulse anodic stripping voltamogram (DPASV) respectively, for the corrosion sample after 5 min. at pH 9.0 ± 0.1. The
half wave potential (El/2) / Peak Potential (Ep) for aluminum is - 1.70/ - 1.72 V vs SCE in DCP/DPP mode and Ep value is - 1.18 V vs SCE in DPASV mode [5]. Fig. 4 shows the DPP curves of corrosion mixture of B. 265 aluminum in NaOH. The peak height (ip) for Al (Ill) over the whole of the working concentration range in DCP, DPP and DPASV modes is proportional to its concentrations. The corrosion rates at different time intervals with and without inhibitor with respect to Al (III) are reported in Table-I. A shift in the El/2 / Ep value of Al (III) indicates a metal: sodium silicate complex formation in the solution [6].

A perusal of the data in Table -1 clearly shows that the rate of corrosion is very fast in the beginning of the experiment, which decreases with time. The corrosion inhibition efficiency of sodium silicate are 50%, 65%, 76%, 86%, 89% after 5 min. , 10 min, 20 min, 1 and 2 h and it becomes 92% after 24h.

A comparison of the corrosion rate data as calculated by gravimetric, and potentiodynamic polarization measurements clearly indicates that sodium silicate is a good inhibitor for corrosion of B 265 aluminium in basic medium i.e. 1% NaOH . It could also be concluded that Polarography and Voltammetry give dependable data for corrosion rates of Al (III) at short time intervals too which is other not possible using methods prevalent in the field of corrosion rate determination [7-9] and also in the field of trace analysis.
Acknowledgement

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REFERENCES


Fig. 1 Potentiodynamic Polarization curves of B-265 Al in 1% NaOH solution.

Fig. 2 A. Direct current polarogram

B. Differential pulse polarogram

C. Differential puls Anodic stripping voltamogram of corrosion sample (after 5 minutes) of B-265 Al 1% NaOH in ammonium tartrate supporting electrolyte + 0.00% gelatine (ph.9)
Table-1

Concentration and Corrosion rates of B-265 Aluminium in 1% NaOH solution and different time interval with and without inhibitor (sodium silicate 0.5g/l) using voltammetric methods.

<table>
<thead>
<tr>
<th></th>
<th>Without Inhibitor</th>
<th></th>
<th>With Inhibitor</th>
<th></th>
<th>Inhibition efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conc. (mg/l)</td>
<td>C.R.x10^2 mg cm^2 h^-1</td>
<td>Conc. (mg/l)</td>
<td>C.R.x10^2 mg cm^2 h^-1</td>
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<tr>
<td>DP ASV mode</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1) 5 min.</td>
<td>1.00</td>
<td>56.23</td>
<td>0.5</td>
<td>28.11</td>
<td>55.7%</td>
</tr>
<tr>
<td>2) 10 min.</td>
<td>1.85</td>
<td>51.98</td>
<td>0.64</td>
<td>18.02</td>
<td>65.3%</td>
</tr>
<tr>
<td>3) 20 min.</td>
<td>2.77</td>
<td>38.99</td>
<td>0.65</td>
<td>9.23</td>
<td>76.3%</td>
</tr>
<tr>
<td>4) 1 hr.</td>
<td>6.00</td>
<td>28.12</td>
<td>0.83</td>
<td>3.93</td>
<td>86.0%</td>
</tr>
<tr>
<td>5) 2 hr.</td>
<td>6.65</td>
<td>15.56</td>
<td>0.84</td>
<td>1.75</td>
<td>88.7%</td>
</tr>
<tr>
<td>6) 24 hr.</td>
<td>15.69</td>
<td>3.06</td>
<td>1.49</td>
<td>0.29</td>
<td>90.5%</td>
</tr>
<tr>
<td>DPP mode</td>
<td></td>
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</tr>
<tr>
<td>1) 5 min.</td>
<td>1.00</td>
<td>56.23</td>
<td>5.05</td>
<td>28.11</td>
<td>55.7%</td>
</tr>
<tr>
<td>2) 10 min.</td>
<td>1.81</td>
<td>50.08</td>
<td>0.64</td>
<td>17.97</td>
<td>64.0%</td>
</tr>
<tr>
<td>3) 20 min.</td>
<td>2.78</td>
<td>39.02</td>
<td>0.65</td>
<td>9.23</td>
<td>76.3%</td>
</tr>
<tr>
<td>4) 1 hr.</td>
<td>6.01</td>
<td>28.12</td>
<td>0.83</td>
<td>3.93</td>
<td>86.0%</td>
</tr>
<tr>
<td>5) 2 hr.</td>
<td>6.65</td>
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<td>0.84</td>
<td>1.77</td>
<td>88.6%</td>
</tr>
<tr>
<td>6) 24 hrs.</td>
<td>15.70</td>
<td>3.06</td>
<td>1.49</td>
<td>0.29</td>
<td>90.5%</td>
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