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Electrochemical Behavior of Chemical Conversion Coated Aluminum ASA6061 in Chromic Acid

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Abstract

The corrosion behavior of bare and chemical conversion coated (through anodizing) aluminum ASA 6061 in stagnant chromic acid solutions. Solutions of 2, 6 & 10 wt. % CrO_3 *at 45°C, have been investigated using polarization technique. The anodizing experiments were conducted under fixed conditions of 35 minute exposure time and 30 volt supplied voltage. The most important feature achieved was the great difference in behavior between the anodic polarization curves for bare and anodized aluminum in different concentrations of chromic acid solutions.*

Keywords: coated aluminum, chromic acid.

Introduction

Chromate coatings on aluminum alloys have the advantage that they are easy to apply and that commercial information are readily available. However, the environmental and health risks associated with the use of chromate ions will restrict the use of such coating in the future.

The corrosion behavior of aluminum and its alloys is quite good in many aqueous solutions in the pH range of 4-9 due to the formation of an insoluble and protective aluminum hydroxide layer [1].

Nevertheless, the corrosion resistance decreases noticeably when the pH value changes away from the near neutral conditions as a consequence of the Al $(OH)_3$ layer dissolution.

Aluminum alloys are extensively employed as structural components in the industrial practice, and some surface treatments like anodizing; chromating and painting are used to improve their corrosion behavior. However, no substantial improvement was obtained in the most severe conditions.

Anodizing may be used to enhance the corrosion resistance of aluminum and its alloys. An electrolytic process is used to thicken the surface film and produces a hard, compact strong and highly adherent layer.

The chromic acid process is employed where a high resistance to corrosion is required with a minimum loss of metal section [2].

Sealing has a great effect on the corrosion resistance of the oxide coating. If the coating is not completely sealed, corrosion as well as staining may take place very rapidly. Conversely, properly sealed anodic coatings are being successfully used in the architectural field. In general, the alloys with higher aluminum contents are more resistance to corrosion [3].

This work is aimed to study the electrochemical behavior of aluminum ASA 6061 surfaces covered by a chemical conversion coating obtained by anodizing process in different CrO_3 acid concentrations and compared with that of the same aluminum alloy surface not anodized.

Experimental Work

Passivation of aluminum ASA 6061 was carried out by immersion in (2, 6 and 10 wt.%) CrO_3 acid solution, through anodizing process for 35 minute exposure time and 30 volt supplied voltage at 45°C. Usually the corrosion behavior of resulting surface layer is tested by immersion in NaCl solutions of certain normalities (i.e., 0.1 or 0.5 N NaCl solution).

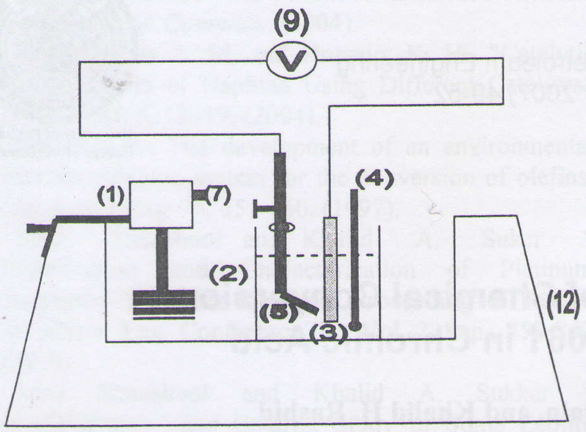

Fig. 1 Schematic diagram for the whole assembly of open circuit potential work

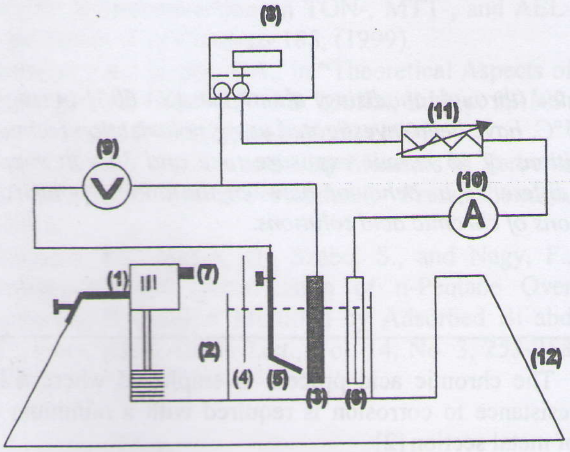

Fig. 2 Schematic diagram for the whole assembly of electric circuit for polarization work

1-Heater – stirrer
2- Corrosion cell.
3- Working electrode.
4- Thermometer.
5- SCE reference electrode.
6- Counter electrode (platinum).
7- Thermostat
8- DC power supply.
9- Voltmeter.
10- Ammeter.
11- Resistance box.
12- Water bath.

In this investigation, the corrosion behavior of resulting coating layer due to anodizing process and of the non-anodizing aluminum alloy was monitored in solutions of (2, 6 and 10 wt.%) CrO_3 and using potential/current relationship recorded through polarization curves and potential as E_{corr} vs exposure time during the corrosion test. Aluminum specimens before anodizing and corrosion tests were abraded in sequence on 220, 320, 400 and 600 grades of emery paper under running tap water on a Metasern hand grinder tray washed with tap water followed by distilled water, dried with a clean tissue, degreased by immersing them in acetone & benzene, then dried with paper tissue and kept in a dissector over a silica gel bed.

Open circuit potential (E_{corr}) was carried out in a cell described in Fig. 1 and polarization was carried out in a cell with electrical circuit shown in Fig. 2.

The working electrode was (1x3cm) aluminum ASA6061. It was supported by means of PVC racks to hold it stable in the cell. The counter electrode was a platinum electrode of (1.5x3.5cm), hold by a plastic plate setted directly opposite to the working electrode. The reference electrode was a saturated calomel electrode bridged by a Luggin-Haber probe. The distance between the electrode surface and the Laggin-Haber capillary was set to 1 mm to minimize the experimental error due to IR drop. The temperature was maintained within 45±1°C by a thermometer.

Results and Discussion

The corrosion resistance of aluminum ASA 6061 before anodizing was evaluated by following its corrosion potential. Fig. 3 show's the open circuit potential of bare or not anodized aluminum alloy in 2, 6 and 10 wt. % CrO_3 acid solutions at 45°C and duration time of about 3 hours. It is clear that:

1. The electrode potential, generally shifts to more positive direction in all acid solutions studied, and this shift in potential is more pronounced in the order: 10 wt. % CrO_3 > 6 wt. % CrO_3 > 2 wt. % CrO_3
2. It is believed that this gradual increase in corrosion potential is most likely the result of the formation of an insoluble and protective aluminum hydroxide layer according to the anodic reactions takes place on the metal surface.

$$Al \rightarrow Al^{+3} + 3e^{-} \quad (1)$$

$$Al + 3OH^{-} \rightarrow Al(OH)_3 + 3e^{-} \quad (2)$$

The published data reveal a scatter of values for the open circuit potential of aluminum ranging over several volts under identical experimental conditions [4, 5, 6].

It can be concluded that the variation of electrode potential with time depends and affected by material or alloy purity, surface treatment of the alloy and oxygen contact of the electrolyte… etc.).

Figures 4-6 show the anodic and cathodic polarization curves of unprotected and anodized aluminum ASA 6061 in (2, 6 & 10wt. %) CrO_3 acid solutions at 45°C.

In these figures it seems that:

1. At potentials more positive than E_{corr} for unprotected (not anodized), aluminum alloy in all CrO_3 concentrations the current density rises sharply indicating the chemical dissolution of natural oxide film.

2. At potentials more negative than $E_{corr.}$, the 1st region of all cathodic curves of unprotected is almost horizontal, characterized by a current density increasing rapidly with small variation in the applied potential. This is followed by an almost vertical region where the current density is practically independent on the potential, as also reported by Dibari and Read [7].
3. The cathodic arm of the polarization curves generally represents the cathodic reaction complicated with mass transfer due to oxygen reduction reaction & its effect on the rate of dissolution reaction of the aluminum alloy.
4. $E_{corr.}$ for anodized aluminum ASA 6061 appears a shift to more noble direction by about 50 mV compared to $E_{corr.}$ of unprotected one due to sharp anodic kinetic change because of anodized film formation.
5. Suppressing the kinetics of anodic polarization curves at anodic sites on the surface are more pronounced in 10 wt. % CrO_3 anodized samples than (6 & 2) wt. % CrO_3 anodized samples (i.e., at certain potential more positive than $E_{corr.}$, the anodic current density was reduced 90-95 % for anodized compared with the unprotected one).

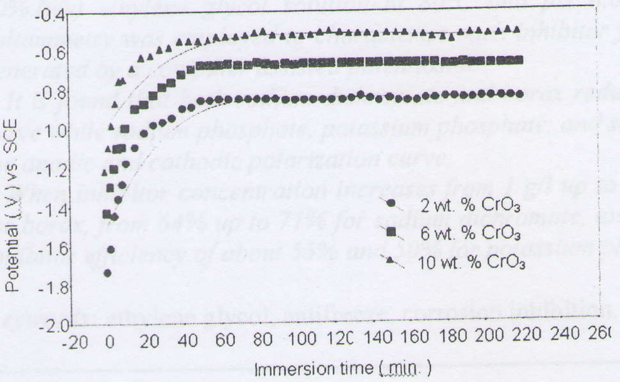

Fig. 3 Open circuit potential of protected aluminum ASA 6061 in different chromic acid concentrations and 45°C as a function of immersion time.

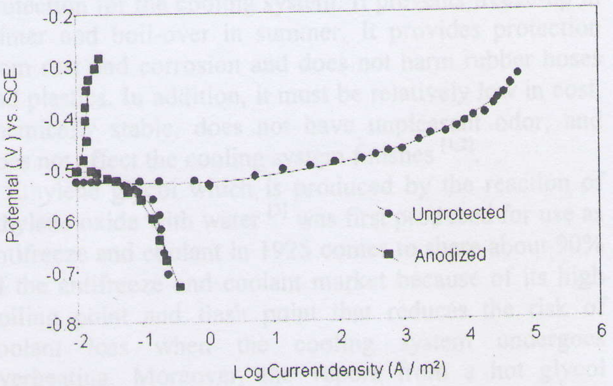

Fig. 4 Polarization curves of anodized & unprotected aluminum alloy in 10 wt. % CrO_3 acid solution.

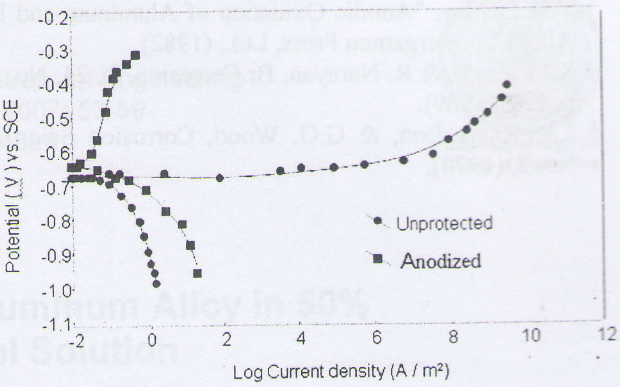

Fig. 5 Polarization curves of anodized & unprotected aluminum alloy in 6 wt. % CrO_3 acid solution

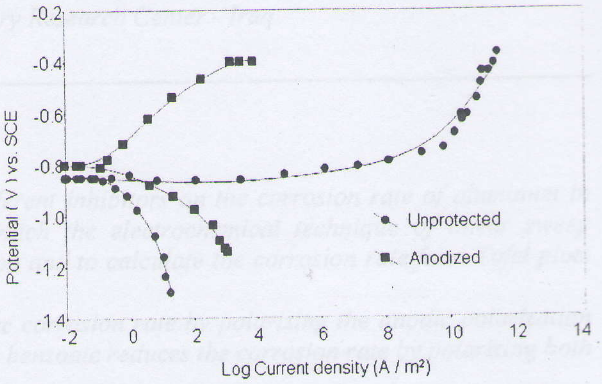

Fig. 6 Polarization curves of anodized & unprotected aluminum alloy in 2 wt. % CrO_3 acid solution

Conclusions

1. The polarization data reveals that the final chemical conversion coated oxide films formed under the mentioned operationg conditions is believed to behave as an insulating layer and has pronounced rectifing property.
2. the steady state corrosion potentilal values depend on the electrolyte concentration.
3. generally, the cathodic branch of polarization curves show over a wide potential range that indicates of anodized aluminum alloy, the coated surface is more catalytic to hydeogen evolution reaction than the unprotected surface. That is the anodized coating has an electronic resistivity of order CrO_3 (anodized)> unprotected one.

References

1. W.C. Moshier, G.D. Davis, J.S. Ahear, Corr. Sci., 27, 785, (1987).
2. E. W. Turns, R.E. Forrester, "Universal Chromic Acid Anodizing Method ", US Pat. 4,256,547, (1981).

3. V.F. Henley, "Anodic Oxidation of Aluminum and Its Alloys", Pergamon Press, Ltd., (1982).
4. K.P. Sherif, & R. Narayan, Br.Corrosion, J., 24, No. 3, p. 199, (1989).
5. J.A. Richardson, & G.G. Wood, Corrosion Sci., 10, No. 3, (1970).
6. R.I. Groover, , J.J. J.J.Hnnox, & M. Peterson, Mater. Prot., 25, No. 11, (1969).
7. G.A. Dibari, & H.J. Read, Corrosion, 27, No. 11, December, (1971).