

Studying of Aluminum corrosion in citric acid and NaCl solution

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Abstract

The object of this research is to study the effect of citric acid that present in Tomato baste and the Nacl as a salt these use in cooking on the Aluiminuim as kitchen utensils. Different temperatures (30,50,70 °C) and different percentages of baste (1%,3%,5%) solutions without and with (1%) of salt (Nacl) on corrosion behavior of Aluiminuim by electrochemical technique.

Results show that the increasing adding of baste lead to increase currents density . On the other hands When adding salt that lead to increase current density more rapidly. The increasing in temperature had strong effect on corrosion behavior of Aluiminuim.

Keywords: Aluiminuim, kitchen utensils, Nacl , Tomato baste, citric acid.

1. Introduction

Corrosion is degradation of materials' properties because of interactions with their environments all material types are susceptible to degradation.

Pure metal and alloys react chemically / electrochemically with corrosive medium to form a stable compound, in which the loss of metal occurs. The compound so formed is called corrosion product and metal surface becomes corroded. The movement of metal ions into the solution at active areas (anode), passage of electrons from the metal to an acceptor at less active areas (cathode), an ionic current in the solution and an electronic current in the metal. (Barbara A. and et al 2006) (Nimmo B. & Gareth H. 2003)(El-Etre A 2006) (El-Etre A 2007) (El-Etre A 2010)(Desail M. and Shah 1972)(Martinez S. and at el2002)

The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal. Failures of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small. (Goel R. and at el 2010)

Aluminum and its alloys have excellent durability and corrosion resistance, but, like most materials, their behavior can be influenced by the way in which they are used. Aluminum is commercially important metal and its .alloys are widely used in many industries such as reaction vessels, pipes, machinery and chemical batteries because of their advantages. Aluminum has been used in major project all over the world. It is used in offshore application including structures, plat forms ,pipelines, jetties and power plants , airspace and kitchen utensils. (Sastri V. and et al 2007) (Szklarska-Smialowska Z. 1999)

Corrosion in aluminium alloys is generally of a local nature, because of the separation of anodic and cathodic reactions and solution resistance limiting the galvanic cell size. The basic anodic reaction is metal dissolution: (Ahmad Z.2012)

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

While the cathodic reactions are oxygen reduction:

$O_2+2H_2O + 4e^- \rightarrow 4OH^-$ (2)

or hydrogen reduction in acidified solution such as in a pit environment as a result of aluminium ion hydrolysis:

$2H^+ + 2e \rightarrow H^2$ (3)

Al and its alloys are resistant towards corrosion in mildly aggressive aqueous environments. The protective oxide layer represents the thermodynamic stability of Al alloys in corrosive environment. While the passive layer breakdown mechanism by chloride ions is still in debate due to the complexity of the process, the general consensus is that localized attack starts by adsorption of aggressive anions and formation of soluble transitional complexes with the cations at the oxide surface. (Sato N. 1990)(Szklarska Z. 2002)
The results of corrosion Aluiminuim alloys in citric acid and show that they resist a dilute solution of citric acid at room temperature whether agitated or not. The rate of corrosion was approximately doubled per 10 °C. rise in temperature; the life of equipment would be very short at boiling temperature. In the presence of salt, the corrosion rates of the two alloys and of all the grades of aluminium tested. (Bryan J. 1950)
Study case:
This study will show the corrosive effect of citric acid came from local markets baste on the Aluminums kitchen utensils. Different weight of baste would used beside the different temperatures . Salt (NaCl) would used with the baste to reach to the cooking condition.

2. Experimental work

2.1.Aluminum samples preparation

Aluminum alloy cut from a plate which is already used as kitchen utensils from local markets. Dimensions of sample is 1cmx1cm as square and 1mm thickness. Components of alloy as in table (1).

2.2.Solution preparation

Baste of tomato (Zer) which use for cooking from the local market to prepare the test solutions. Test solution was prepared by dissolving (10,30,50g) of baste in one liter of tap water with and without using Nacl salt (1g) from local markets also. Each test solution is jest like the cooking solution that used in kitchen.

2.3.Electrochemical measurements

The electrochemical tests have been done by polarization method .the apparatus and equipments used in this work which include 1.Ammeter 2.Power supply 3.Variac resistance 4.Voltmeter 5. The test cell. The test cell consist Aluminum specimen as a working electrode , corrosive solution , saturated calomel electrode as a reference electrode and Platinum electrode as an auxiliary electrode.

3. Results and Discussion

The electrochemical behavior of Aluminum alloy in three test solutions (1%,3%,5wt %) with and without Nacl (1wt%) in three different temperatures (30,50,70° C)
Tables (2,3,4) represent the abstracted data from experiments .Figures (1-9) and tables (1-3) show the effect of changing the concentration of baste on the current density .From these results, it is clearly increased in the baste concentration(which is contain citric acid and low concentration of salt) would leads to increase the corrosion current density and higher corrosive effect .In spite of Aluminum is corrosive-resistant to citric acid but the consist salt in baste leads to this corrosion.

On the other hand ,In figures (9-18) when the salt (Nacl) (1wt%) had been added to the solution the current density would increased also. In spite of the small weight of salt is added but the effect would be more observed. When salt is present, the chloride (Cl^-) ions attack the oxidized layer, penetrating and exposing fresh Aluminum.

Aluminum corrodes more rapidly in acids and in alkalis compared to distilled water, with rates in acids depending on the nature of anion. Corrosion of Aluminum in alkaline region greatly increase with PH, unlike iron and steel, which remain corrosion- resistance. (Uhilg H. 2008)

In figure (19-20) demonstrated the effect of temperature on corrosion of Aluminum very clearly .

Higher temperature leads to higher tendency to corrode with adding or not adding salt and higher corrosion rate according to Arrhenius : (perez P. et al 2004)

$$R=Ae^{-E/RT} \quad (4)$$

4. Conclusions

The effect of citric acid and Nacl on Aluminum at different temperatures was studied.

following conclusions are:

1. Corrosion currents of Aluminum are increased with increased both citric acid and Nacl.
2. Corrosion currents of Aluminum with increased temperatures.
3. Using the Aluminum as kitchen utensils is unhealthy and if necessary use them most not adding the baste or Nacl in first cooking or high temperature.

Acknowledgements The authors wish to acknowledge the Department of Chemical Engineering, Babylon University , Iraq for providing the equipment used for the electrochemical corrosion test.

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Table(1) Aluminum alloy (A92017) compositions limit.

Component	Percentage %
silicon	13.5%
iron	2%
copper	0.6%
manganese	4%
magnesium	11%
chromium	0.35%
nickel	3%
zinc	0.25%
antimony	0.2%
tin	0.1%
strontium	0.3%
zirconium	0.3%
titanium	0.3%
other elements	less than 0.15% in total

Table (2): weight baste in one liter of tap water at T=30 ^{0}C without and with NaCl (10g).

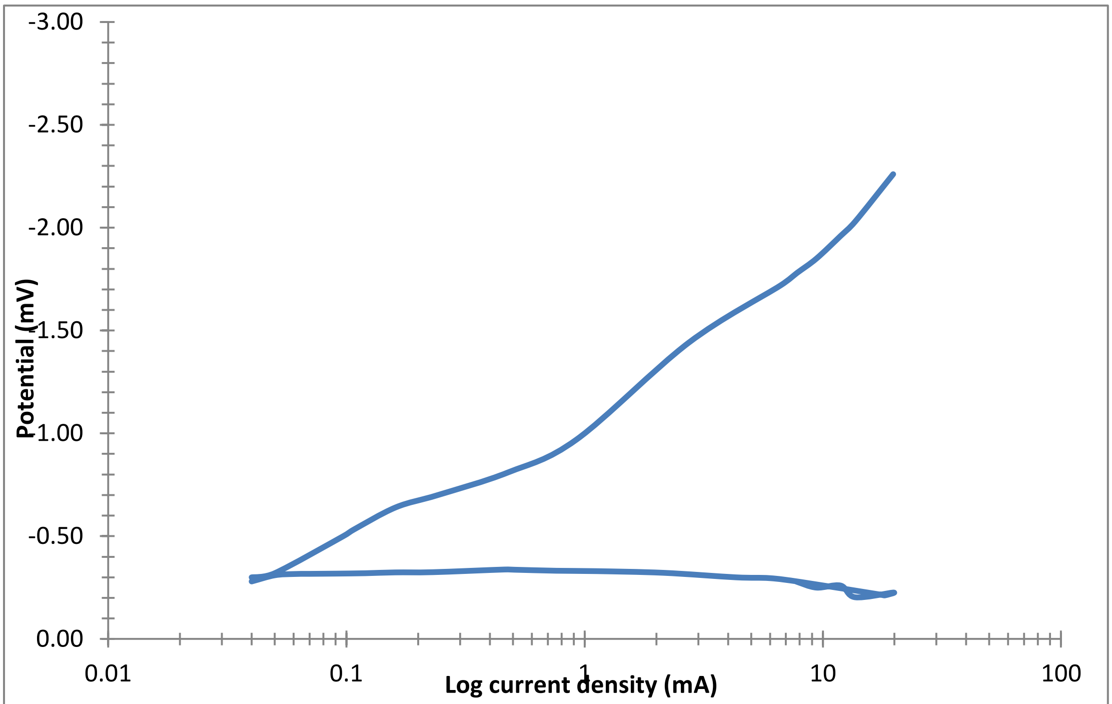
weight of baste (wt%)	I_{corr}(mA\m^2) without slat	I_{corr}(mA\m^2) with slat (10g)
1	0.1	0.38
3	5	6.2
5	7.19	8.5

Table (3): weight baste in one liter of tap water at T=50 ^{0}C without and with NaCl (10g).

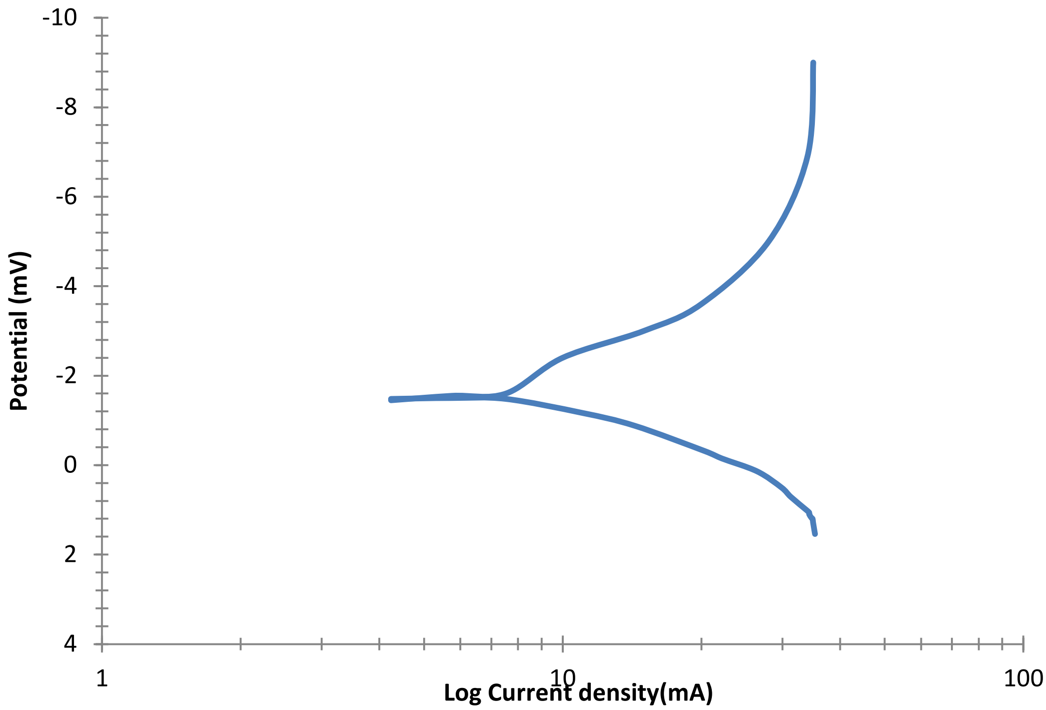
weight of baste (wt%)	I_{corr}(mA\m^2) without slat	I_{corr}(mA\m^2) with slat (10g)
1	1.1	2.13
3	6.3	7.4
5	8.4	10.3

Table (4): weight baste in one liter of tap water at T=70 ^{0}C without and with NaCl (10g).

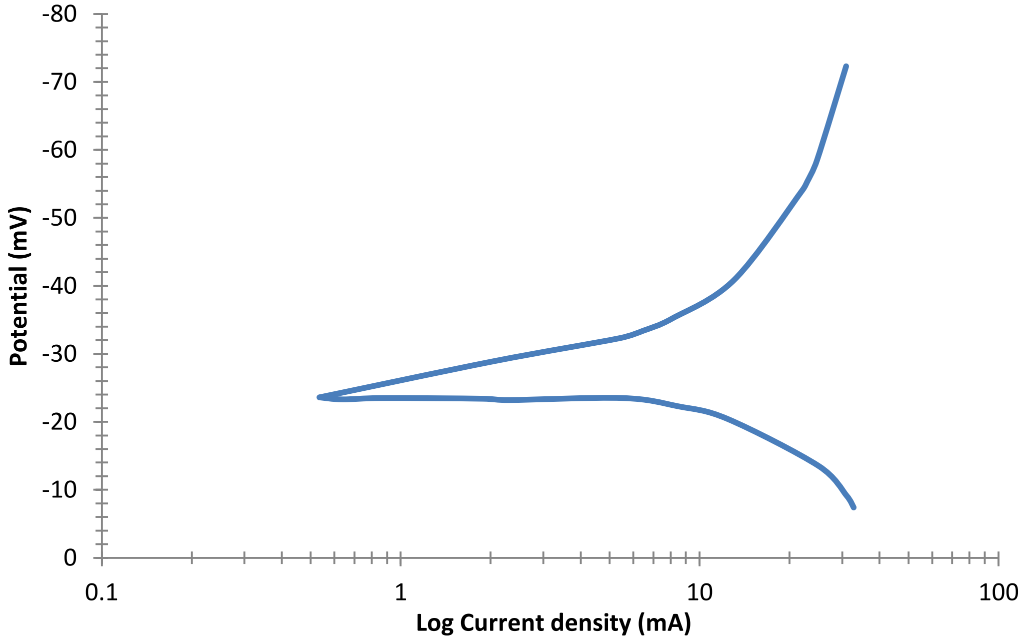
weight of baste (wt%)	I_{corr}(mA\m^2) without slat	I_{corr}(mA\m^2) with slat (10g)
1	1.5	2.67
3	7.35	8.2
5	9	17.2



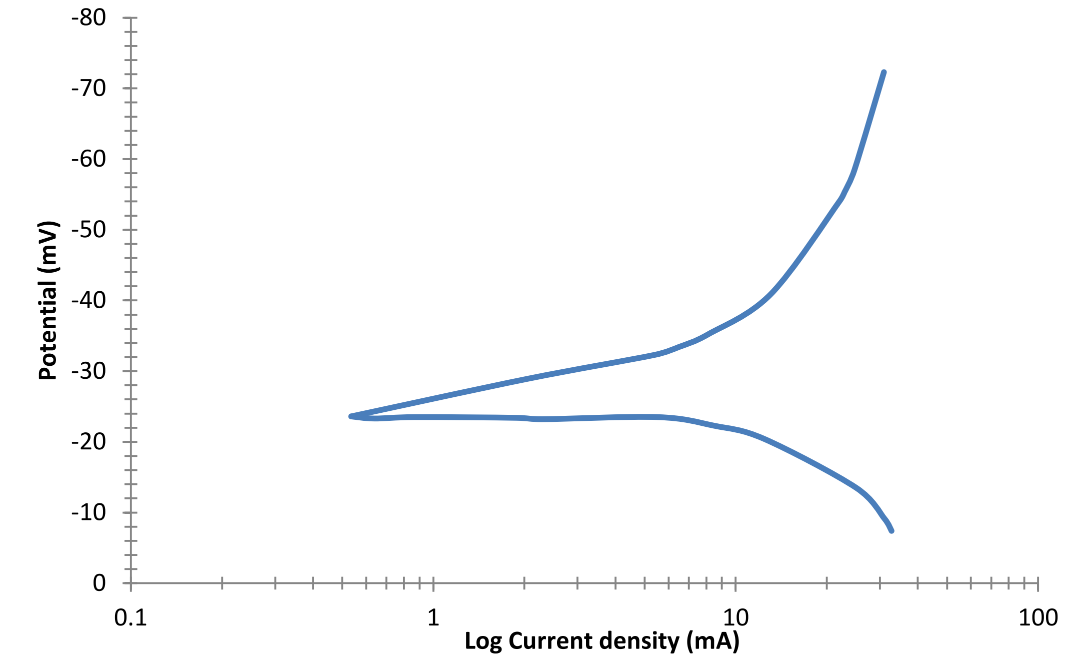
Figure(1):Potentinial Vs. Current density at baste weight =1wt% at T=30



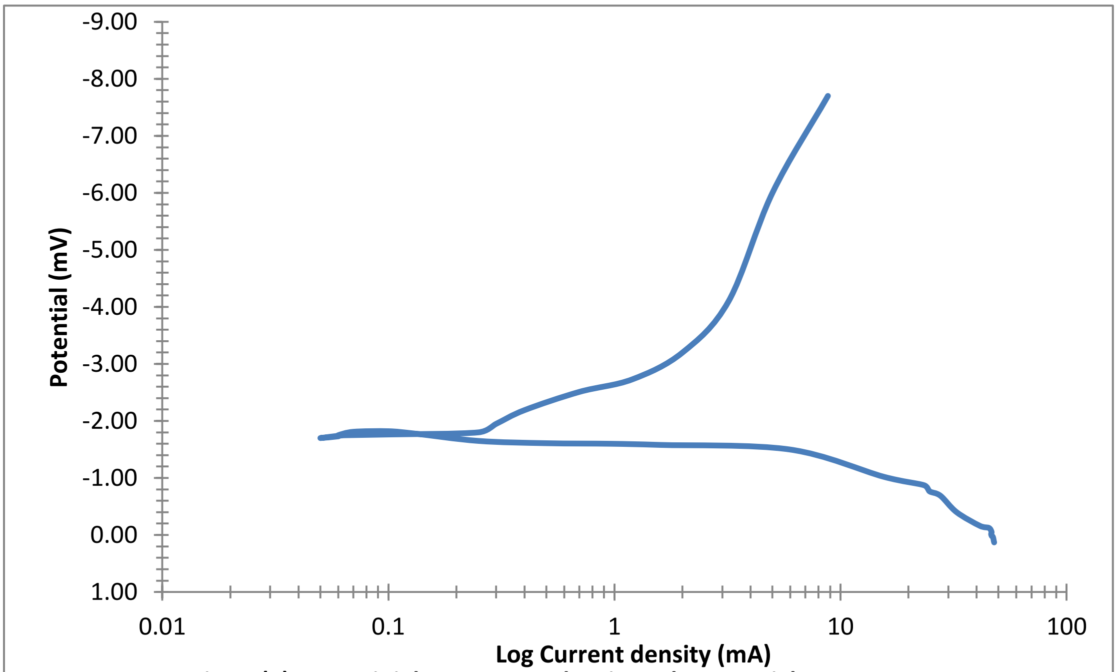
Figure(2):Potentinial Vs. Current density at baste weight=3wt% at T=30°C



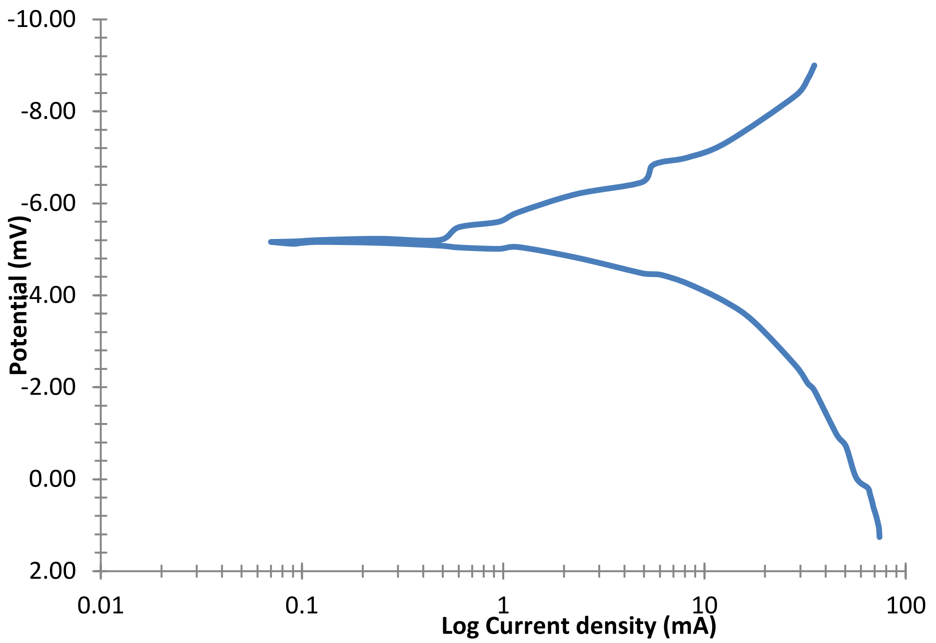
Figure(3):Potentinial Vs. Current density at baste weight=5wt% at T=30°C



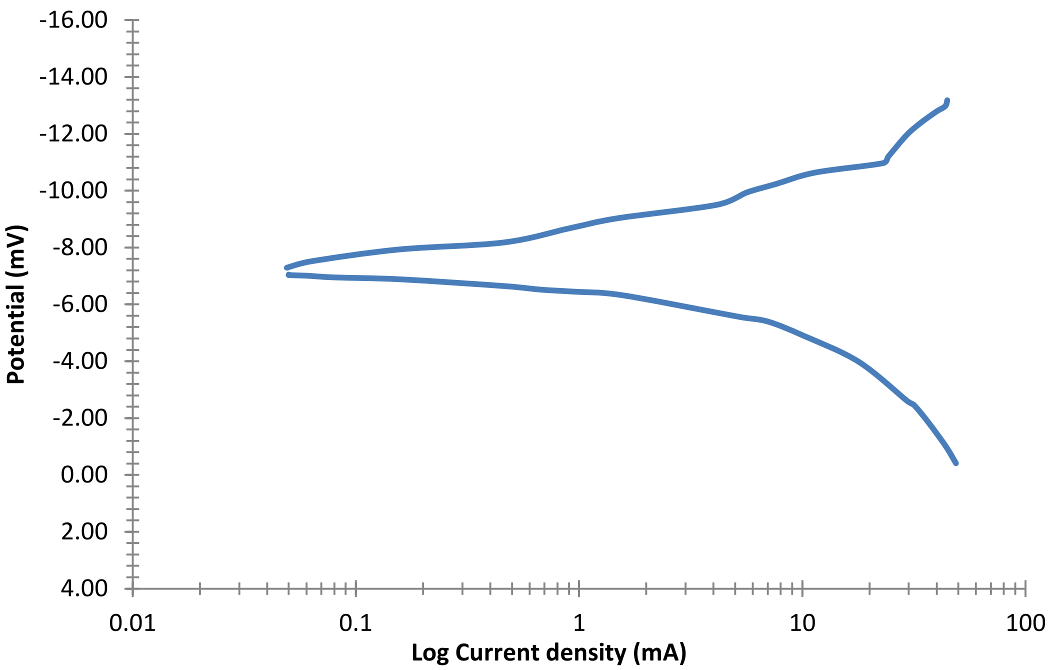
Figure(4):Potentinial Vs. Current density at baste weight=1wt% at T=50°C



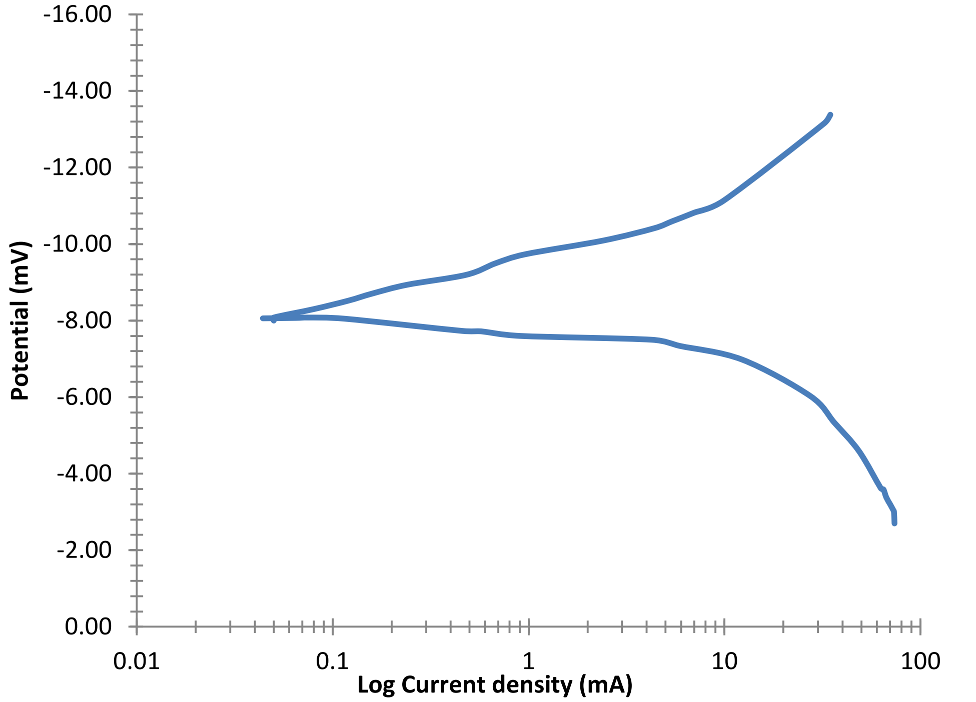
Figure(5):Potentinial Vs. Current density at baste weight=3wt% at T=50°C



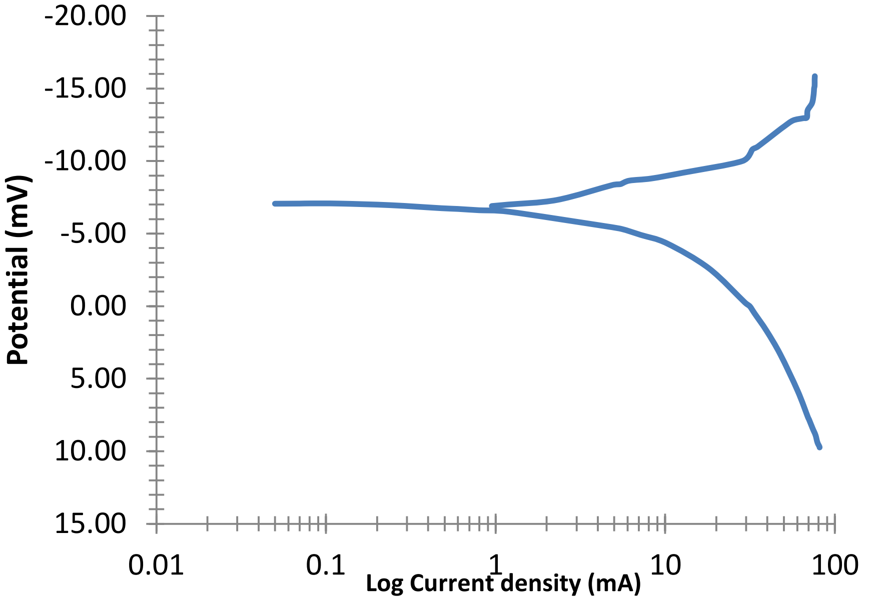
Figure(7):Potentinial Vs. Current density at baste weight=5wt% at T=50ºC



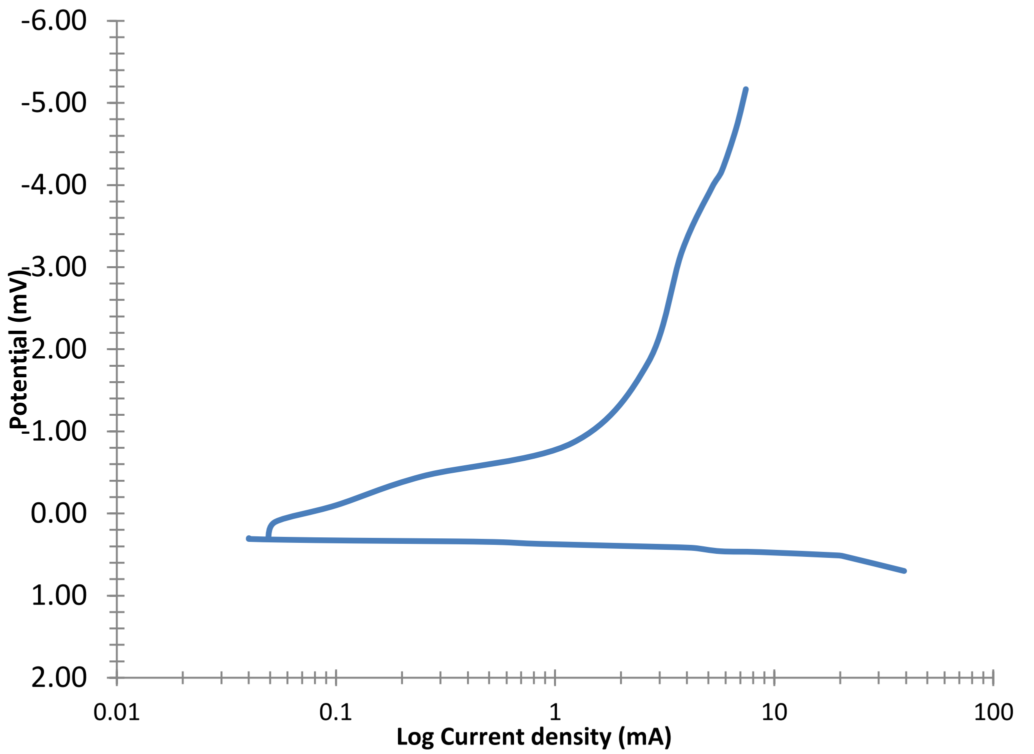
Figure(7):Potentinial Vs. Current density at baste weight = 1wt% atT=70



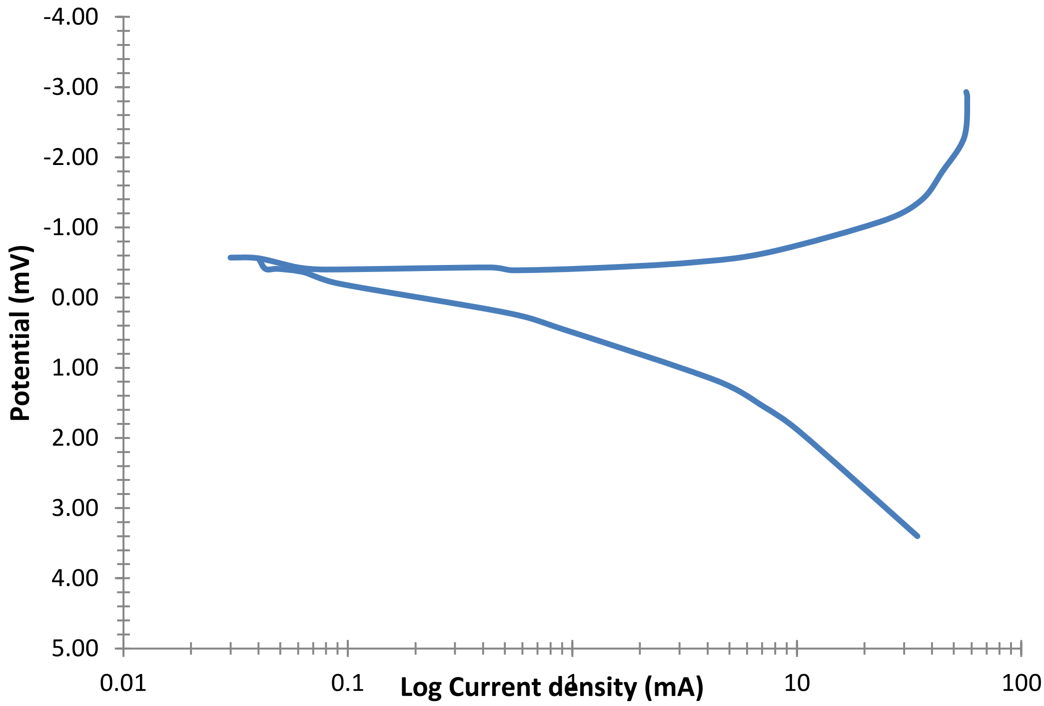
Figure(8):Potentinial Vs. Current density at baste weight=3wt% at T=70°C



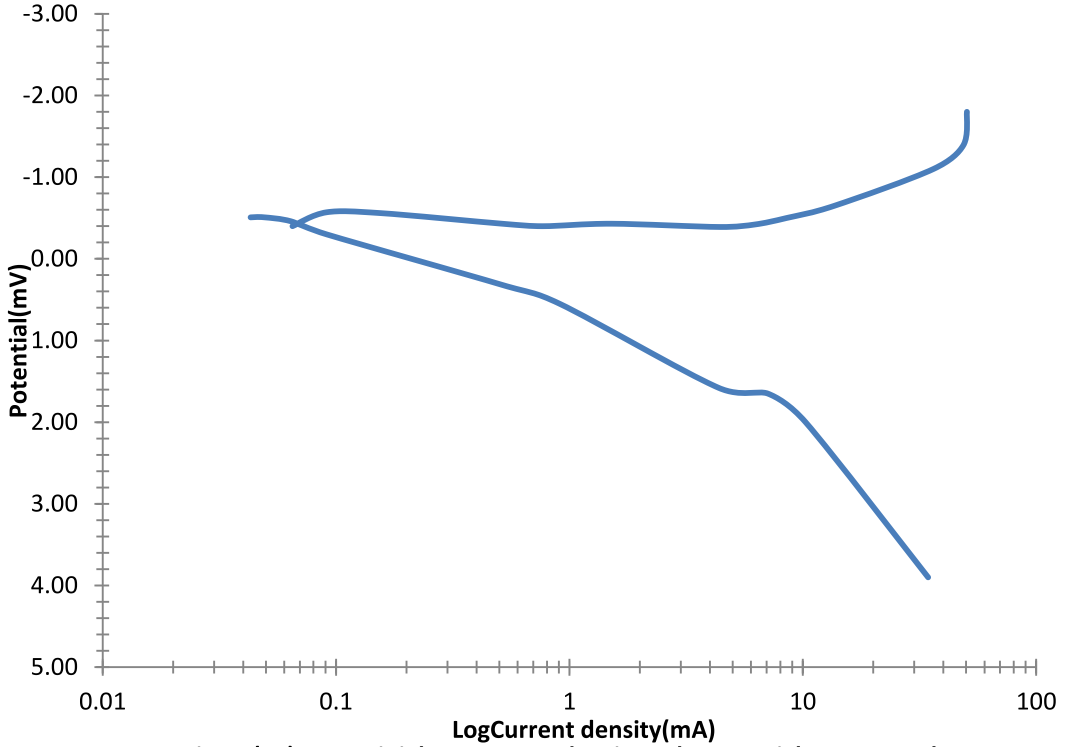
Figure(9):Potentinial Vs. Current density at baste weight=5wt% at T=70°C



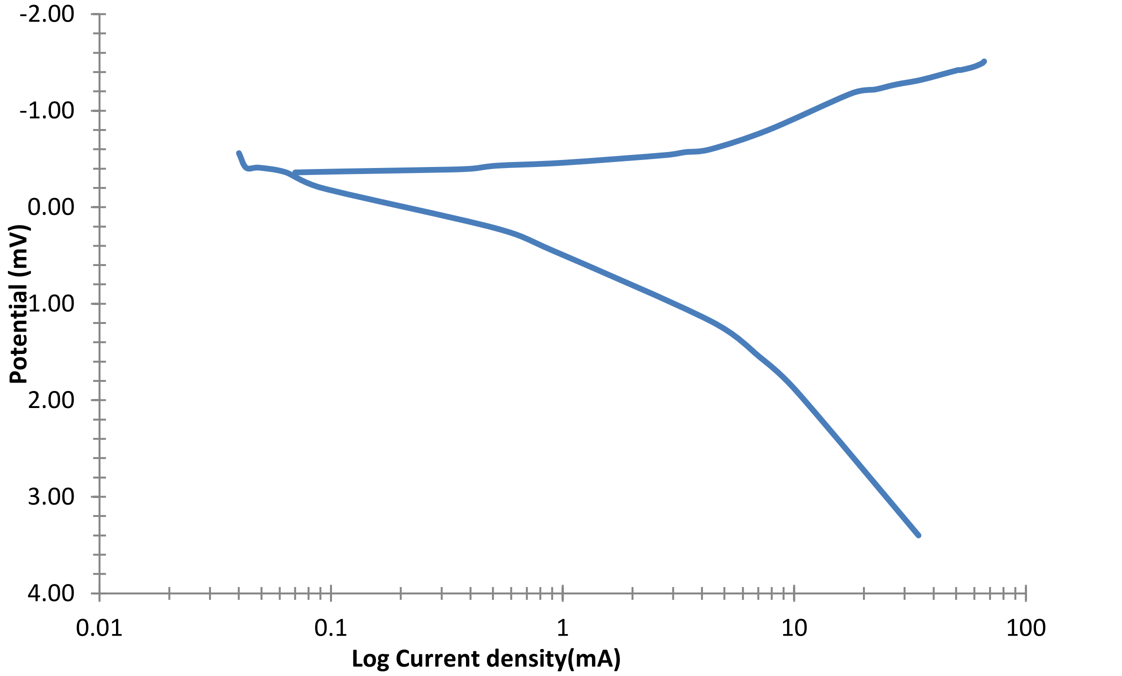
Figure(10):Potentinial Vs. Current density at baste weight=1wt% salt =1wt% at T=30°C



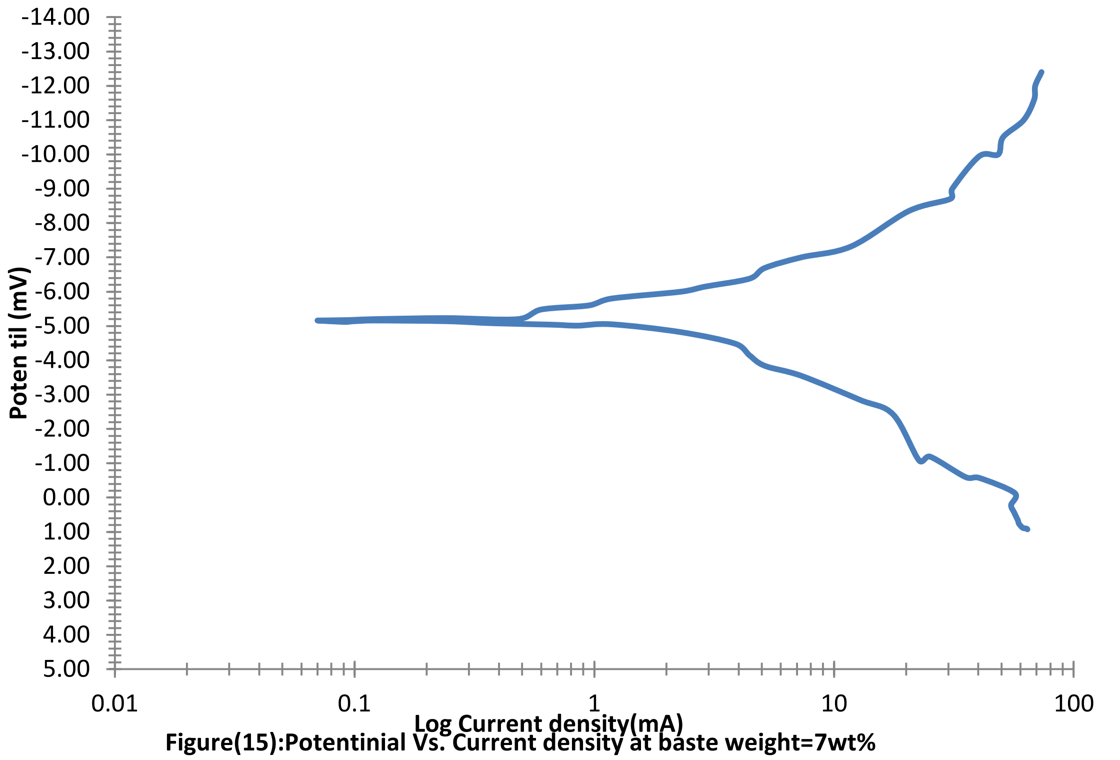
Figure(11):Potentinial Vs. Current density at baste weight=3wt% salt =1Wt% at T=30°C



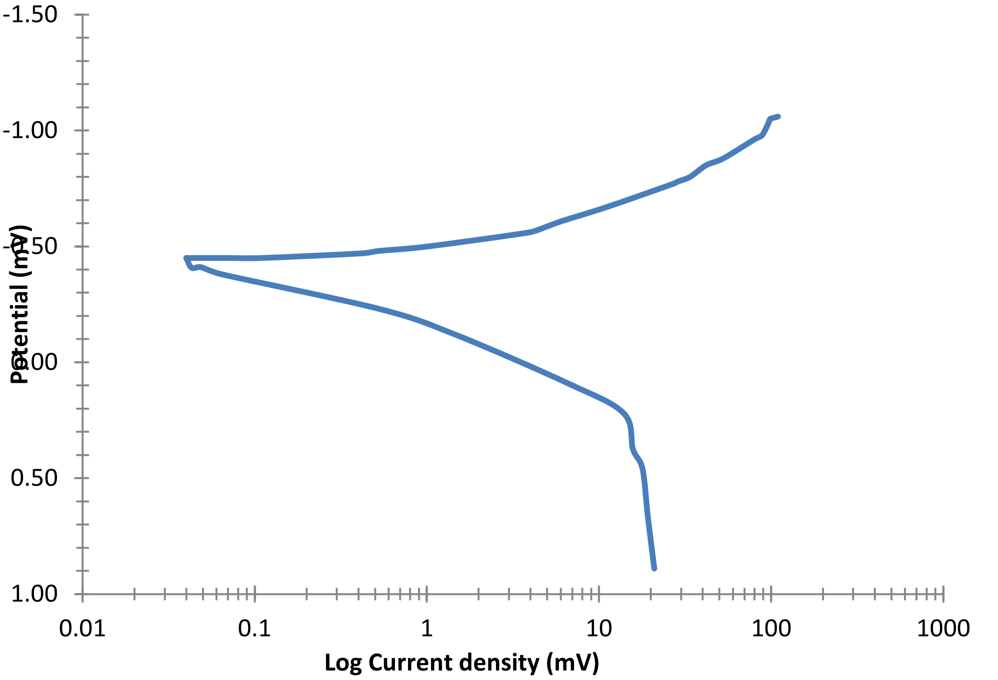
Figure(12):Potentinial Vs. Current density at baste weight=5wt% salt=1wt% T=30C



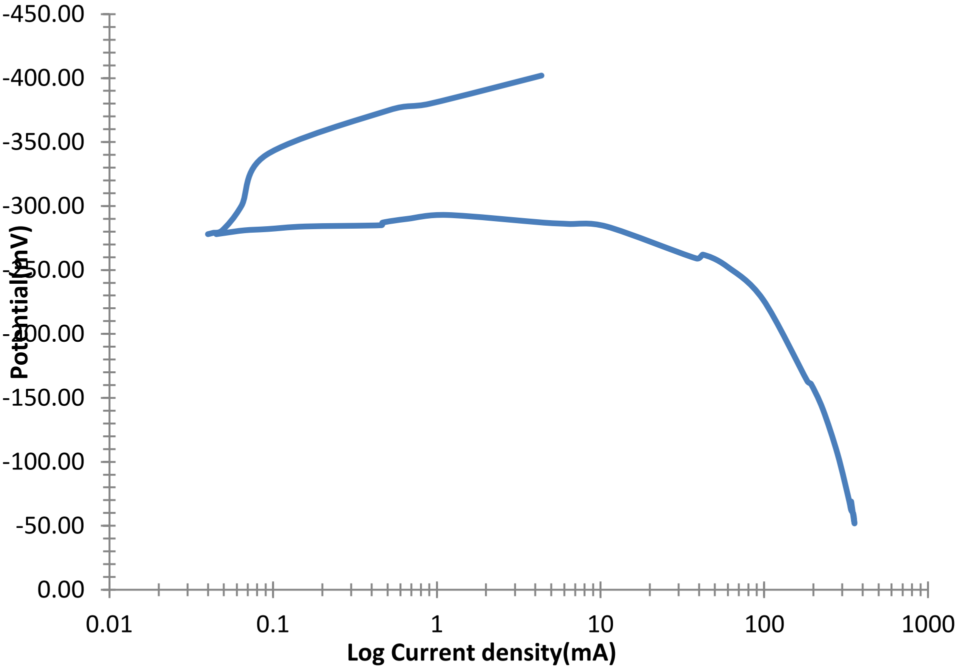
Figure(14):Potentinial Vs. Current density at baste weight=3wt% with salt =1wt% T=50c



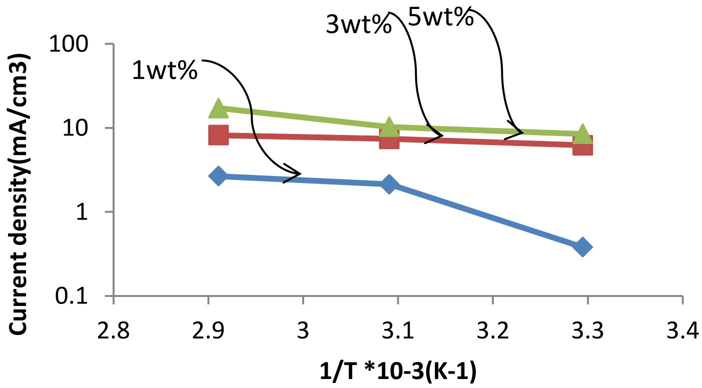
Figure(15):Potentinial Vs. Current density at baste weight=7wt% salt=1wt%T=50C



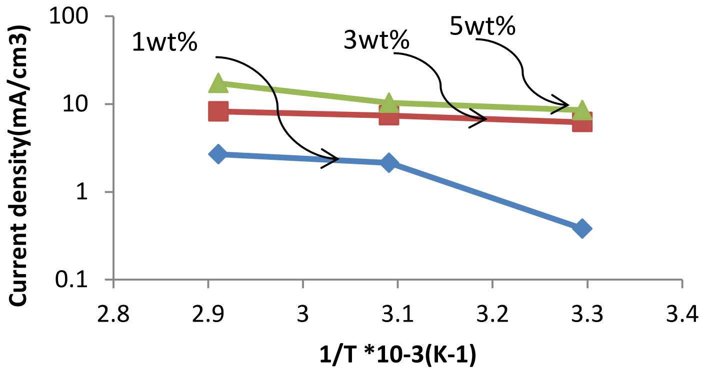
Figure(17):Potentinial Vs. Current density at baste weight=3wt% salt=1wt% T=70C



Figure(18): Potentinial Vs. Current density at baste weight=5wt% salt=1wt% T=70C



Figure(19) :Ahrenius plot of Current density Vs. Temperature for solution without salt



Figure(20):Ahrenius plot of Current density Vs. Temperature for solution with salt

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