International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 12, Issue 04, April 2023)

Investigating Corrosion Behaviour of Aluminium and Aluminium Titanium (Ti) Alloy in H_2So_4 as Anodizing Solution

Arvind Kumar Singh[1], Shailendra Kumar Singh[2], Satyendra Sharma[3].
[1]*Department of Chemistry, V.K.S.U. Ara.*
[2]*Research Scholar, Department of Chemistry, V.K.S.U. Ara.*
[3]*Department of Chemistry, R.P.M. College, Patna City, P.P.U. Patna.*

Abstract**-- The present research work investigated the corrosion behaviour of casted pure aluminium metal and aluminium titanium alloy after running weight loss tests in different concentration of H_2So_4 media at room temperature and 50^0C respectively. Corrosion pitting rate was determined within interval immersion periods of 5 hour. At room temperature, it was observed that pure aluminium samples have low corrosion rate in concentrations PH=2 and PH=3 of H_2SO_4 solutions. Moreover, corrosion rate increased slightly with increasing concentration of H2SO4 media and the attack was more significant at 50^0 C . Aluminium titanium alloy showed decreasing of weight loss and more corrosion rate in both ratios. The corrosion pitting rate of aluminium samples increased in the order Aluminium Titanium < Aluminium as a result of the formation of thin protective aluminium – Titanium oxide films. The visual observations showed that there is a streaking and grooves of both samples correlated directly with the increased exposure period in the Acidic medium but in the case of Aluminium Titanium alloy there are several horizontal fine darkened pits grew along the surface.**

Keywords **-Corrosion penetration, Aluminium, Aluminium alloys.**

I. INTRODUCTION

The increased charm for studying the performance and corrosion forms of aluminium metal and its alloys is due to their excellent characteristics such as low weight, “Its density one-third that of steel” nontoxicity high reflectivity, high conductivity, availability and widespread usage. In particular, aluminium alloys play a role in, aerodynamics, automobiles, aviation, household appliances containers and electronic devices.

Usually aluminium is used as a part of an alloy rather than as a pure metal because pure aluminium metal is not strong enough for large scale. High strength Aluminium alloys can be obtained by addition of appropriate alloying elements such as Titanium, Cu,Mg, Si and Zn. Generally, the alloying elements and other raw materials can influence the morphology and corrosion resistance of aluminium by forming different oxides that have compatible structures.

Many Aluminium alloys such as Aluminium Titanium alloys have been increasingly employed in the automotive industry, owing to their good cast, low thermal expansion coefficient and excellent mechanical properties.

The various applications of aluminium metals and alloys are often possible because of the natural tendency of aluminium to form surface– oxide film which can be deteriorated in aggressive media. The protection of aluminium and its oxide films against the corrosive action of chloride ions have been extensively discussed.

The corrosion behaviour of pure Aluminium metal and its alloys like Al-Cu and Al-Ti was investigated in aqueous solutions in the absence and the presence of common salts. Many researchers have detailed publications and have studied for several decades the pitting corrosion of aluminium alloys.

Owing to the corrosion in fundamental processes which play a vital role in industrial economics and safety. Apparently, corrosion cannot be avoided, but its aggression can be reduced to a lower magnitude. A large variety of research and test methods were employed to study in details the corrosion resistance of aluminium and its alloy using different aqueous media of acids and salt.

Different acidic media has been used for pickling, chemical and electro chemical etching of aluminium and its alloys. As well, different grades of corrosion inhibitors are used to inhibit its corrosion in the acid media.

The present research envisaged the corrosion of pure Al –metal and Al-Ti alloy in PH=2 & PH=3 of H_2SO_4 environments. The efficacy of alloying elements on corrosion behaviour of aluminium was studied under specific conditions.

II. EXPERIMENTAL PROCEDURES MATERIALS

Aluminium metals and alloys used for this research work were purchased and produced locally by casting methods in pure quality.

The percentage of alloying Titanium (10%) is added to achieve final aluminium alloys specification.

The typical chemical composition (inwt %) of pure aluminium metal is (~99.9%) and aluminium-titanium alloy is (90%:10%) respectively. AR-Grade H_2SO_4 and Nacl were used.

III. METHODS

Preparation of specimen(surface)

In this laboratory scale study, the aluminium metals and alloys were machined and cut into test specimen (2"x1") inch coupons. The samples surfaces were treated by abrading them through successive grinds of fine emery papers. They were rinsed in distilled water and then in acetone before drying. The samples were immersed in pickling solution and dried before exposing them to H_2SO_4 solution.

Preparation of Immersion media

The environments prepared for the evaluation of its corrosion behaviour was H_2SO_4. The environment ranges from a PH=2and PH=3.

H_2SO_4 which was prepared following the standard procedures.

Corrosion penetration evaluation

Aluminium samples were immersed in the prepared environments for the time intervals 1 to 5 hours and different temperatures. The samples after being removed from the corrosion environment were cleaned in distilled water and dried with cotton wool. The dried samples were weighed with digital chemical weighing balance and recorded at different immersion periods for weight loss analysis. Rate of pitting corrosion values were calculated in cm were obtained from weight loss analysis using the equation (1.1) Rate of pitting corrosion = W/A.D Com (1.1) Where W is the weight loss in gm.

D is Density of the specimen in gm/cm^3 A is the total exposed surface area of the specimen in cm^2

Corrosion Reaction Kinetic

From the rate of corrosion results obtained for all aluminium samples, the corrosion reaction kinetics also determined in media of PH=2 and PH= 3 H_2SO_4 respectively, using the parabolic rate law, as shown in equation(1.2), even with increasing the temperature to 50^0.

$$X= Kt^{y2}(1.2)$$

Where X is the measure of corrosion extent in cm.

t is the immersion time of the specimen in hour.

K is the parabolic rate constant in cm/h^{y2}

Visual morphology and topographic study

The pure aluminium and aluminium titanium alloy surfaces were tested using an imaging digital scanner (H.P Deskjet). Which displayed a real time image.

IV. RESULTS AND DISCUSSION

Weight loss measurements

As a first step of this work, the weight loss was carried out against exposure time of pure aluminium and aluminium titanium (90%-10%) alloy samples immersed in PH=2 & PH=3 H_2SO_4 media, respectively as shown in table 1. It was observed that figure 1(a) and 1(b) show that the weight losses of all pure aluminium samples increase by increasing immersion time, at room temperature and at elevated temperature in all the media. In general, pure aluminium was found to have more weight loss values in PH=2 H_2SO_4 media . Moreover, the weight loss values exhibited a characteristics decreasing in PH =3 H_2SO_4 environment under the same conditions. As for comparative study, figure 1(a) and figure 1(b) show that the weight loss values of aluminium titanium alloys slightly decreases by increasing immersion time and media concentration both but less than pure aluminium samples in all the media. At 50^0, there is a clear excess of weight loss values with the same trend as shown in figure 1(b). This corrosion resistance may be attributed to the oxidative surface of aluminium titanium alloy rather than in case of pure aluminium metal. These changes were found to be as a result of the alloying elements which can influence the corrosion resistance of aluminium metals and its alloys by forming protective aluminium oxide layers. In wet environment different aluminium titanium oxides can be obtained when an aluminium alloy is placed in corrosive medium rather than the aluminium.

Corrosion Penetration Evaluation or pitting evaluation or corrosion rate evaluation

The obtained results of static corrosion tests for aluminium and aluminium titanium samples in the solutions (PH=2 and PH=3 H_2SO_4) are shown in figure 3(a) & 3(b) as a plot of the corrosion penetration Vs. the square root of time. The corrosion penetration (cp) is calculated using equation (1.1).

As observed from table 2, the C.p is low in the first hour of immersion and it is increased with increasing the time. As well, the corrosion penetration is accelerated with increasing temperature. The corrosion reaction kinetics in PH=2 & PH=3 H_2SO_4 follows the parabolic rate law as in equation 1.2, evenwith increasing the temperature to 50^0C as in figure 4(a).

The parabolic rate constant (k) values were increased with increasing temperature. This observation might be attributed to a rapidly formed surface oxide film at lower temperature, but at high temperature this oxide film will be unstable.

As stated the dissolution rate of aluminium is increased in presence of H2SO4 , especially with increasing its concentration. Therefore, temperature could be another factor to enhance the aluminium titanium alloy dissolution. The deleterious effects of acids with increasing temperature, could be attributed to activating the cathodicreaction which has faster kinetics than oxygen reduction (equation 1.3a), and enhancing the aluminium dissolution (anodic reaction as in equation 1.4). As well, acidic medium could activate the originally passive alloy surface as in the case of iron surface.

Cathodic Reaction $6H_{+} + 6e^{-} \;\rule{2em}{0.4pt}\; 3H_2$….(1.3)

$O_2 + 2H_2O + 4e^{-} \;\rule{2em}{0.4pt}\; 4OH^{-}$ ….(1.3a)

Anodic reaction $2Al \;\rule{2em}{0.4pt}\; 2AL^{3+} + 6e^{-}$….(1.4)

Titanium at room temperature of a particular interest to notice that in the first hour of immersion the C.P is reduced by 25%(in case of Al-Ti alloy) but after 5 hours of immersion, the CP was reduced by 40% comparing to the CP in case of pure Al at such time. The reaction kinetics still follows a parabolic law (Eq^{n} 2). The CP of pure Al increases with decreasing the acidic PH. The decreasing of CP was obtained by using PH=2 H_2SO_4 and the corrosion was dramatically decreased. As proposed the Ti element has good resistance effect, especially at high ratio. In the case of decreasing the CP, Ti element may play a sole.

Oxide film passivation on metal surface, to form a protective conversion coating and a more resistant oxide film on the surface may be achieved. This film is unstable if the immersion is extended to 5 hours. This observation could be rationalized on the basis that the presence of ions (So_4 $^{2-}$) could increase the aluminium dissolution(equation 1.4).

In case of H_2So_4, the increasing of its concentration will lead to increase the sulphate ions in Solution, which help in accelerating the CP as seen when the PH 2. CP is accelerated with increasing temperature to 500c as shown in fig 5 b.This behaviour could be explained on the basis that the increasing of temperature could destabilize Al-oxide interaction and activate the corrosion reactions (equation 1.4 & 1.5). This destabilization arises because of the So_4 $^{-2}$ penetration into the oxide lattice, followed by substitution for O2- supplying heat, which is essential to complete this reaction, may enhance this substitution. It is stated that Al has a greater chemical reactivity at moderate temperatures and it combines with most non- metallic elements. The variation of the CP of Al and Al-Ti allay in presence of the tested media, especially after immersing intervals for 5 hours is important to be noticed. As presented in Table (2), the CP increases as the following order PH=2> PH=3 at Room Temperature and 50^{0}c.

V. CONCLUSIONS

This study presents the investigating the corrosion behaviour of pure aluminium and aluminium titanium alloy samples in H_2SO_4 media at room temperature and 50^{0}C. The penetration values of pure aluminium was increased with increasing H_2SO_4 concentration more than in case of aluminium titanium . This observation might be attributed to difference in aluminium titanium surface oxide layers. The corrosion reaction of aluminium and aluminium titanium in the tested solutions follows the parabolic rate law. The visual morphology of both samples affected in presence of the tested solution. The attack of the surface is increased in the presence of the concentrations, which accelerate the corrosion penetrations reduces the surface attack. The streaking and grooves of both samples correlated directly with the increased attack period in the acidic medium in which aluminium titanium alloys surface shown a clear horizontal darkened pits.

Table 1
Weight loss measurements of AI and Al-Ti samples under acid conditions of immersion time, media and temperature

Alluminium Samples	**Immersion Time Hour**	**Weight Loos (Mg/Cm^2)**			
		Room Temp.		**50^0 C**	
		PH=3	PH=2	PH=3	PH=2
Pure Al	5	0.05	0.07	0.12	0.19
	10	0.11	0.15	0.15	0.23
	15	0.12	0.20	0.17	0.27
	20	0.13	0.23	0.27	0.29
	25	0.19	0.35	0.35	0.58
Al 90% Ti 10%	5	0.05	0.07	0.10	0.10
	10	0.09	0.15	0.10	0.20
	15	0.10	0.18	0.16	0.25
	20	0.11	0.25	0.23	0.34
	25	0.15	0.30	0.31	0.42

Table 2
Effect of immessin time on the corrosion rate of Aluminium samples at different media and Temperature

Alluminium Samples	**Time Hour**	**Carrosion rate (CR)$\times10^{-5}$ CM**				**Parabolic Rate Constant (K)$\times10^{-5}$ CM/h^{½}**			
		Room Temp.		**50^0 C**		**Room Temp.**		**50^0 C**	
		PH=3	**PH=2**	**PH=3**	**PH=2**	**PH=3**	**PH=2**	**PH=3**	**PH=2**
Pure Al	5	2.2	2.9	4.7	7.4	2.2	2.9	4.7	7.4
	10	4.4	5.9	5.9	8.9	3.1	4.2	4.2	6.3
	15	4.8	7.8	6.7	10.2	2.8	4.5	3.8	5.9
	20	5.2	8.9	10.4	11.3	2.6	4.4	5.2	5.6
	25	6.7	13.3	13.2	21.9	3.0	6.0	5.9	9.8
Al 90% Ti 10%	5	1.5	1.9	3.0	3.0	1.5	1.9	3.0	3.0
	10	2.5	4.1	3.0	5.8	1.8	2.9	2.1	4.1
	15	2.8	5.0	4.7	7.2	1.6	2.9	2.7	4.1
	20	3.0	6.9	6.6	9.6	1.6	3.4	3.3	4.8
	25	4.1	8.3	8.8	11.8	1.8	3.7	3.9	5.3

Table (1) Weight loss measurements of AI and Al-Ti samples under acid conditions of immersion time, media and temperature

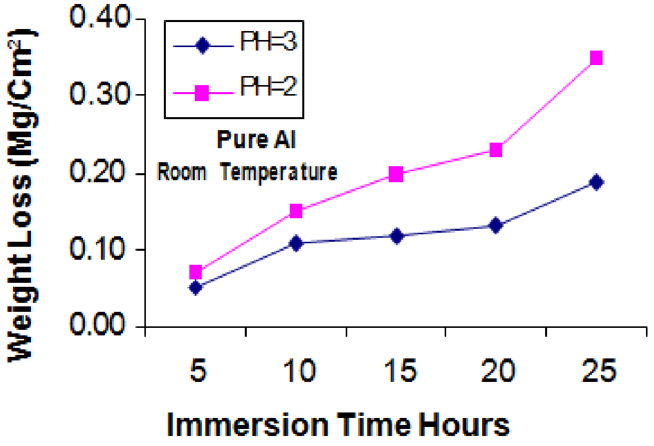

Fig - 1a

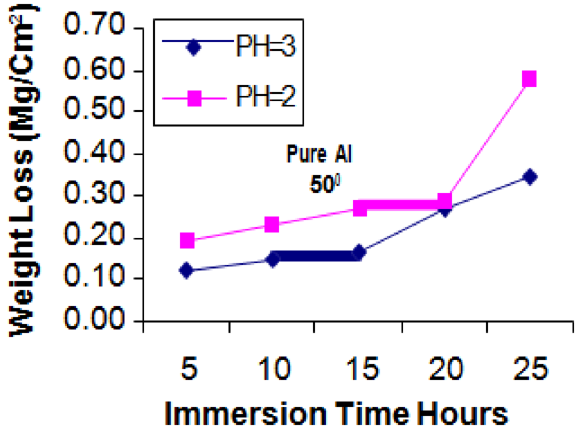

Fig - 1b

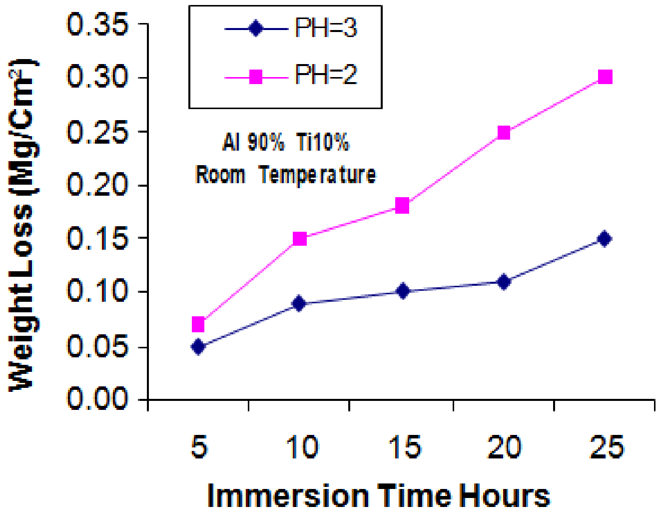

Fig - 2a

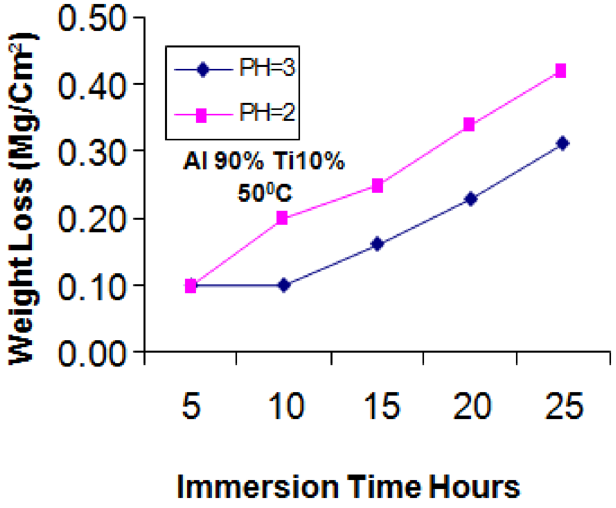

Fig - 2b

Table (2) Effect of immessin time on the corrosion rate of Aluminium samples at different media and Temperature

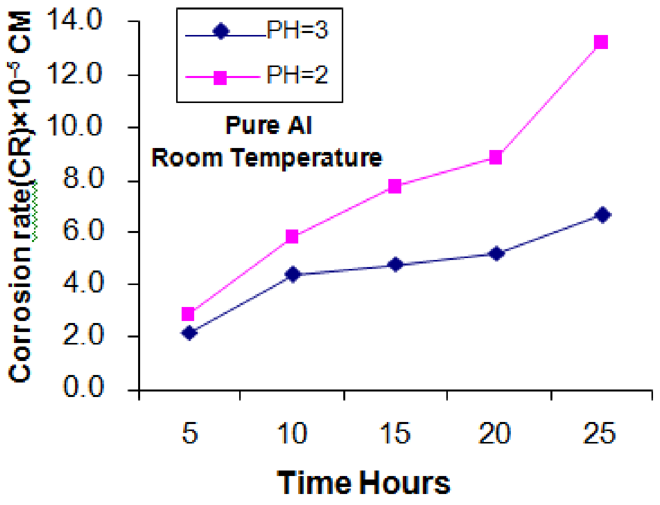

Fig - 3a

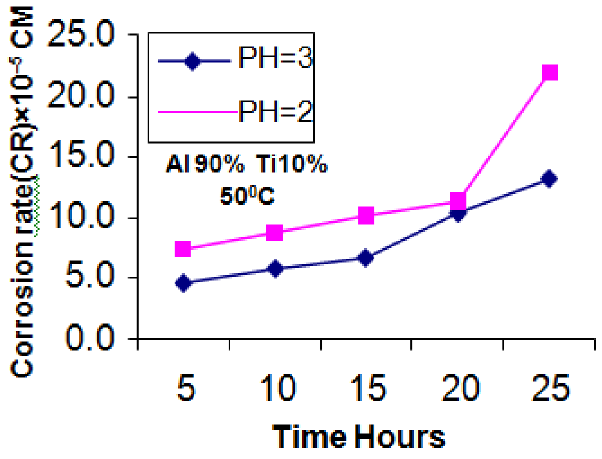

Fig - 3b

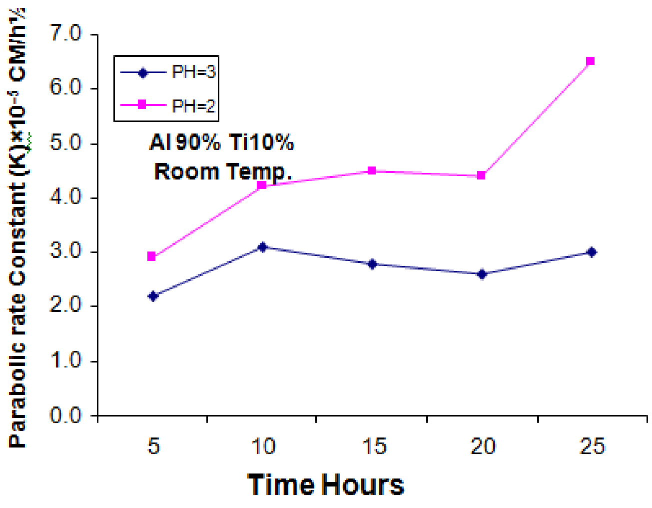

Fig - 4a

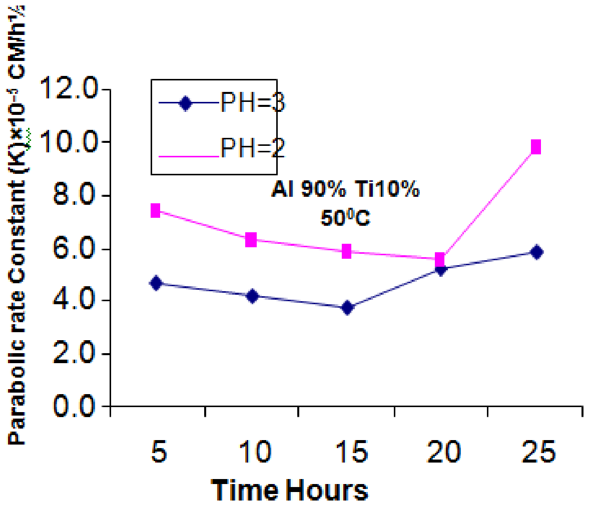

Fig - 4b

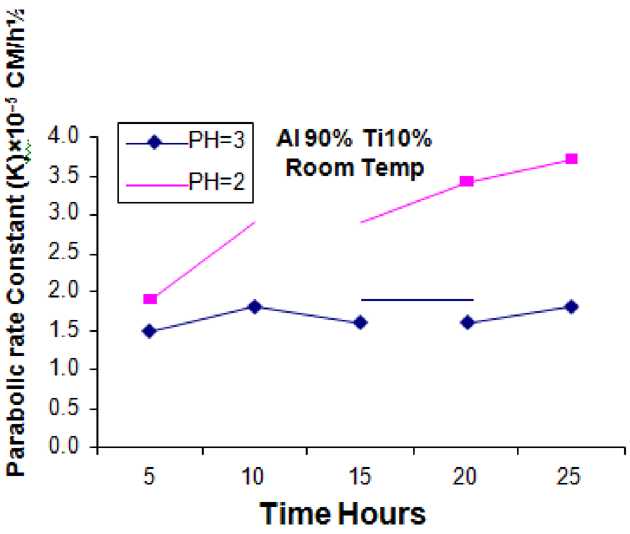

Fig - 5a

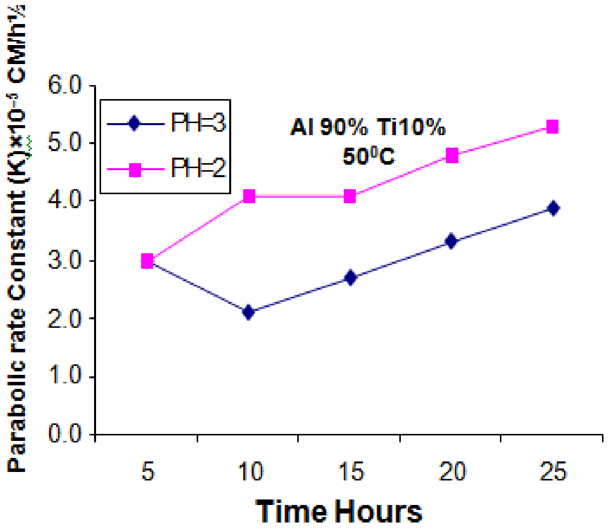

Fig - 5b

REFERENCES

[1] U.R. Evans, Trans. Electrchem. Sc. 91 : 547 (1947). Isolation of film from a passive metal by dissolving away the metal.

[2] C. Wagner, J. Electrchem Soc. 99 : 369 (1952). Alloying with noble metals to protect corroding metals.

[3] M.J. Pryor, J. Electrochem. Soc. 106 : 557 (1959). First statement of Cl– Penetration theosy of depassivation.

[4] A.K. Reddy and J. o'm Bockris, J. Bur. Standards P. 229. (1994).

[5] J. o'm Bockris, B.T. Rubin, A. Despic and B. Lovrecech, Electrochim Acta 17 : 97 (1972). Cu–Ni alloy dissolution, The dissolution rate of each alloying component is independent of its compsition in the alloys.

[6] P. Schmuki and S. Virtanen, "Modeling of passivity", Interface 6:38 (1997).

[7] O.J. Murphy, T.E. Pou, J. o'm. Bockris, L.L. Tngsen and M.D. Monkowski, J. Electrochem Soc. 130:1792 (1983). Water in the passive layer, SIMS and ISS evidence.

[8] J. o'm. Bockris, and L.minevski, J.Electroanal. Chem. 349 : 375 (1993). Protection of aluminium by means of transition metal alloys.

[9] J.O. Park, C.H. Park and R.C. Alkire, J. Electrochem. Soc. 143 : L. 174 (1996). Microelectrodes in corrosion research.

[10] J. o'm. Bockris and Y. Kong, J.Solid State Electro-chem. 1:17 (1997). Potential of Zero Charge and the protection of aluminium from Cl– attack by transition metal additives.

[11] F. Mansfeld, G. Zhong and C. Chen, Plating Surf. Finishing (Dec.) 72 (1997). Impedance measure ments on aluminium.

[12] J. Proost, J. Baklanov, M. verbeeck and k.Mrex. J. Solid State Electrochem. 2 : 15 (1998). Looking inside pits.

[13] J. o'm. Bockris, M. Genshaw and V. Brusis, Symp. Garady Soc. 6:177 (1970). Cmprehensive application of ellipsometry to Fe Passivation.

[14] J. Ginewich, J. Pezy, B.G. Baker and J. o'm. Bockris, J. Electrochem Soc. 125:17 (1978). First Figure Study of the Surface of a dissolving alloy (attempt to show that Small concentronious of Gold wud protect less noble metals).

[15] N. Casillas, S.J. Charlebois, W.H. Smyrl and H.S. White, J. Electro Chem. Soc. 140: L142 (1993). confocal laser Scanning Micrscpy used on electrdes.

[16] P.M. Natashan, E. Mc. Cafferty and G.K. Hubler, J. Electro Chem Soc. 133 : 1061 (1986). pH, pZe and the Corrosion of Al. alloys.

[17] R. W. Revie, B.G. baker and J. o'm. Bockris, Surf. Sci 52:664 (1975). First Published paper on ulav in Electro- Chemistry, the degraded passive film by Auger Spectroscopy.

[18] R. Raiceff, I. Betova, M. Bohnov and E. hazarova in modeling Corrosion, K. Trethoway and P. Roberge, eds. Kluwer Academic, Drdrecht (1994). Modeling of Corrosion seactions.

[19] H. H. Uhlig, Corros. Sci. 7 : 235 (1967). First Statement of idea that passivity is due to a monolayer of oxide.