JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 16, Preprint 1 submitted 2 January 2013

Corrosion Inhibition Study of Stainless steel in Acidic Medium – An overview

Abstract

Inhibition of corrosion with different types of Stainless steel, Medium and Inhibitors has been reviewed. Corrosion can be controlled or minimized by the use of inhibitors. Acids are frequently used to remove such scales including Hydrochloric acid (HCl), Sulfuric acid (H_2SO_4), Sulfamic acid (H_3NSO_3) and Phosphoric acid (H_3PO_4). There is a continuous search for better corrosion inhibitors to meet the need of the industrial expectations. The inhibition's efficiency of inhibitor compounds is strongly dependent on the structure and the chemical properties of the film formed on the metal surface. The adsorption of inhibitors on the metal surface through polar atoms will prevent corrosion. The protection of metals from corrosion is analyzed by many technologies such as Weight loss, Open Circuit Potential (OCP), Potentiodynamic Polarization, Electrochemical Impedance Spectra (EIS), X-ray Photoelectron Spectroscopy (XPS), X-ray Diffraction spectroscopy (XRD), Energy Dispersive X-ray Spectroscopy (EDX), Scanning Electron Microscope (SEM), FTIR, UV-Visible spectra & adsorption study.

Key words: Stainless steel, Acidic medium, Corrosion inhibition, SEM.

Introduction

Stainless steel type 304 is widely used in many applications such as desalination plants, construction materials, pharmaceutical industry, thermal power plant, chemical cleaning & pickling process, due to their stability, good corrosion resistance, high strength, workability and weldability. Corrosion is the deterioration of essential properties of a material due to reactions with its surroundings. Millions of dollars are lost each year because of corrosion. Much of this loss is due to the corrosion of iron and steel although many other metals may corrode as well. Corrosion damage can cause leakage of fluids or gases. Even more dangerous is a loss of strength of the structure induced by corrosion and subsequent failure. The application of acid corrosion inhibitors in the industry is widely used to prevent or minimize material loss during contact with acid. It has been observed that the adsorption depends mainly on certain physico-

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 16, Preprint 1 submitted 2 January 2013
chemical properties of the inhibitor molecule such as functional groups, steric factors, aromaticity, electron density at the donor atoms and Π orbital character of donating electrons and also on the electronic structure of the inhibitor. It has been reported that many inorganic, organic and heterocyclic compounds containing hetero atoms like N, O, S and P have been proved to be an effective inhibitors for the corrosion of stainless steel in acid media.

One way to protect the metal against corrosion is to add certain organic molecule that adsorb on the surface and form a protective layer. The unique advantage of the possibility of adding inhibitors is that this can be done without disruption of the industrial process. Corrosion inhibitors are useful when this addition in small amount prevents corrosion[1, 2].

Metals

Different inhibitors have been used to control the corrosion of stainless steel metals with different grade such as 410 [3], AISI 304 [10,1112,13,15,17,18,24,25,26,27,28,29,31,33,35,42,48,50,52], AISI 304L [14,23,37,45], AISI 316 [4,11,20,27,29,43], AISI 316L [14,16,19,22,40,41,44,45,51], UNSS31603 [5], 0Cr13 [8], 1Cr13 [6], 302 [30,36], ASTM 420 [32], 430 [34,38,39], Austenitic Stainless steel [47], Stainless steel [21,46,49] & iron [12].

Medium

In this overview my research paper is mainly focused on acidic medium such as Sulfuric acid and Hydrochloric acid. But few of the works carried out in the medium such as pure water, ground water, sodium chloride, sodium sulfate & sodium sulfide have been used for this purpose.

Additives

Various inhibitors have been used as corrosion inhibitor alone or combination with additive such as HEDP [8], ATMP [8], Zn^{2+} [9,24], Tween 80 [9,24], Potassium iodide [49] & Potassium thiocyanide [35]

Methods

Different methods have been used to determine the inhibition efficiency of different inhibitors by Weight loss [3,10,17,33,35,36,38,43,48,49,52], Gravimetric test [27,29], Potentiodynamic Polarization

JCSE The Journal of Corrosion Science and Engineering
ISSN 1466-8858 Volume 16, Preprint 1 submitted 2 January 2013
[3,5,6,8,13,14,15,16,17,18,19,21,22,23,27,28,29,30,31,37,39,40,41,42,44,45,46,47,48,49,50,51,52], Potentiostatic Polarization [7,10,33,36], Galvanostatic Polarization [13,25,35,38], Linear Polarization [26,32,47], Cyclic Polarization [15,32], Cyclic voltametry [11,12,14,26,44], Gasometry [7], Current Transient Analysis [21], Repassivation Potential [21], AC impedance [7,12,33], Electrochemical Impedance Spectroscopy [11,16,18,23,27,28,41,45,46,50,52], Open Circuit Potential [11,12,15,30,31,40,44,51], Temperature dependent pitting potential [4] and Synergistic effect [35,49] has been analyzed.

Surface Analysis

A protective film is confirmed by various surface examination techniques such as SEM [3,14,20,21,22,23,24,26,27,29,37,38,40,41,44,45], XRD [9,24,45], FTIR [9,24,26], EDX [14,22,27,29,38], XPS [20,21,24,27,32,34,37], X-ray mapping [29], surface reflectance – IR spectroscopy [20], X-ray photo electron [34], and Luminescence spectroscopy [9,24].

Adsorption Study

The adsorption behavior of different inhibitors on the stainless steel surface has been investigated. The following adsorption isotherms have been obeyed such as Langmuir [3,6,8,10,14,17,19,25,28,33,36,39,47,52], Frumkin [7,9], Freundlich [49], Tempkin [30,38,42,48,50] and Dubinin radushkevich adsorption isotherm [47].

A list of corrosion inhibition studies performed in different type of stainless steel is shown in table – I

Table – I List of Corrosion inhibition studies of Stainless steel.

S. No	Metal	Medium	Inhibitor	Additive	Methods	Findings	Ref	Year
1	410 Stainless steel	1 N H_2SO_4	Thiourea, Allylthiourea & n-Phenylthiourea		Weight loss, Potentiodynamic Polarisation, SEM and adsorption study.	It shows better inhibition in the following order n-Phenylthiourea > Allylthiurea > TU. A protective layer is confirmed by SEM and it	3	1990

						obeys Langmuir adsorption isotherm.		
2	AISI 304 & AISI 316 Stainless steel	0.1 M & 0.5 M NaCl	0.01 M & 0.1 M Molybdate		Temperature dependent pitting potential.	It shows better inhibition for both alloys.	4	1991
3	UNS S31603 stainless steel	0.6 M NaCl + 0.1 M Na_2SO_4	Cerium		Potentiodynamic Polarisation, Adsorption study.	It is an excellent inhibitor. Thermodynamic data suggests that the highly stable cerium oxide is responsible for blocking the active sites during cathodic and anodic reactions.	5	1993
4	1Cr13 Stainless steel	0.1 M H_2SO_4	ATMP (aminotrimethylenephosphonic acid), MADMP (methylaminodimethylenephosphonic acid), BADMP (n-butyl-aminodimethylenephosphonic acid) and HEDP (1-hydroxyethylidene 1, 1-diphosphonic acid)		Potentiodynamic Polarization and adsorption study.	It shows Mixed type of corrosion inhibitors, Their adsorption obeys the Langmuir isotherm equation	6	1994
5	AISI 304 Stainless steel	2 M H_2SO_4	2- Methyl benzoazole derivative		Weight loss, Gasometry, Potentiostatic Polarisation, AC impedance and adsorption study.	It shows excellent inhibitor. The stability of film formed was verified and it obeys the Frumkin	7	1998

						isotherm.		
6	0Cr13 Stainless steel	0.1 M H_2SO_4	SADP (N-sulfonic amino-dimethylenephosphonicacid)	HEDP (1-hydroxyethylidene-1, 1-diphosphonic acid) and ATMP (aminotrimethylenephosphonic acid)	Potentiodynamic Polarization and adsorption study.	It was found to be an efficient inhibitor for acid corrosion and it obeys Langmuir adsorption isotherm. The corrosion inhibition efficiency may be high in the following order. SADP>ATMP >HEDP		
7	AISI 304 austenitic stainless steel	Ground Water	3-phosphonopropionic acid	Zn^{2+} and Tween 80 (polyoxyethylenesorbitanmonooleate)	Luminescence, XRD, FTIR and SEM.	It shows Mixed type of inhibitor and a protective layer is confirmed by SEM and FTIR.	9	2002
8	AISI 304 Stainless steel	1.0 M HCl	Rhodanine azosulpha drugs		Weight loss, Potentiostatic Polarisation and adsorption study.	It is a mixed type excellent inhibitor and it obeys the Langmuir adsorption isotherm.	10	2002
9	AISI 316 & AISI 304 Stainless steel	0.5 M HCl& H_2SO_4	Polyaniline & Poly(o-methoxyaniline)		Open Circuit Potential (OCP), Cyclic voltametry, Impedance Spectroscopy (EIS).	Potential value move towards positive direction and it shows better inhibition, a protective layer is confirmed by impedance spectra.	11	2002
10	AISI 304 stainless steel and Iron	0.01 M NaCl	Tungstate		Open Circuit Potential, Cyclic voltametry, AC impedance spectroscopy.	Potential value move towards positive direction and it shows better inhibition.	12	2003
11	AISI 304 Stain	0.5 M H_2SO_4	4-Substituted pyrazole-5-ones		Potentiodynamic and Galvanostatic Polarisation and	It is an excellent inhibitor.	13	2003

	less steel				mechnism of inhibition.			
12	AISI 304L & AISI 316 L Stain less steel	0.5 M HCl& H_2SO_4	(MBO) 2-Mercaptoben zoxazole		Potentiodynamic Polarisation, Cyclic voltametry, EDX, SEM, and adsorption study.	It is an excellent inhibitor. It obeys the Langmuir adsorption isotherm and the formation of passive film is confirmed.	14	2004
13	AISI 304 Stain less steel	Pure Water	Oxyanions tungstate and molybdate		Open Circuit Potential (OCP), Potentiodynamic Polarisation and Cyclic Polarisation.	Potential value move towards positive direction and it shows better inhibition at higher temperatures.	15	2004
14	AISI 316L Stain less steel	Acidic & Alkaline solution of 0.3 M NaCl & pH 4,8 &10	Indole		Potentiodymanic Polarisation and Electrochemical Impedance Spectra(EIS).	It has proven to be efficient inhibitor. Indole was found to have no significant efficiency on the corrosion of the metal in alkaline solutions.	16	2004
15	AISI 304 Stain less steel	15% HCl	N-[(Z)-1-Phenylemeth yleidene]-N-{2-[(2-{[(Z)-1 phenylmethyli dine] amino}phenyl)disulfanyl] phenyl} amine		Weight loss, Potentiodynamic Polarisation, Impedance Spectroscopy (EIS) and adsorption study.	It is a mixed type excellent inhibitor and it obeys the Langmuir adsorption isotherm.	17	2005
16	AISI 304 stainl ess steel	0.5 M H_2SO_4	Thiphene derivatives		Potentiodynamic Polarisation, Impedance Spectroscopy(EIS)	It is a mixed type excellent inhibitor and a protective layer is confirmed.	18	2005
17	AISI 316L Stain elss steel	75 g/L H_2SO_4+ 25g/L HF + 30g/L H_2O_2	3-Hydroxybenz oic acid		Potentiodynamic Polarisation, and adsorption study.	It is an excellent inhibitor and obeys the Langmuir & Frumkin	19	2005

						adsorption isotherm.		
18	AISI 316 Stain less steel	0.5 M H_2SO_4	2-thiophene carboxylic hydrazide (TCH)		Surface reflectance IR spectroscopy, XPS and SEM	It is an excellent inhibitor. A protective layer is confirmed by XPS and SEM.	20	2005
19	Stain less steel	0.02 M NaCl	Copper		Current transient analysis, Polarization, repassivation potential measurements, XPS and SEM.	Copper reduces steel dissolution rates in acidic chloride medium and a protective layer is confirmed by XPS and SEM.	21	2005
20	AISI 316L Stain less steel	0.5 M NaCl	2-Mercaptoben zimidazole		Potentiodynamic Polarisation, EDX, SEM and adsorption study.	It is an efficient inhibitor, breakdown potential move towards positive direction, and the negative values of activation energy indicates spontaneous adsorption .	22	2006
21	AISI 304L Stain less steel	1 M H_2SO_4	Cysteine		Potentiodymanic Polarisation, Electrochemical Impedance Spectra and SEM.	It proves better inhibition and it forms a protective layer on the metal surface.	23	2006
22	AISI 304 Stain less steel	Ground Water	(Amino trimethylenep hosphonic acid) ATMP	Zn^{2+} along with Tween 80 (polyoxyeth ylene sorbitanmo nooleate)	Luminescence Spectra, FTIR Spectra, XRD, XPS and SEM.	To understand the mode of corrosion inhibition and also the morphological changes on the metal surface	24	2007

23	AISI 304 Stain less steel	0.1 M HCl	Pyrimidine derivatives		Galvanostatic Polarisation, adsorption study.	It is a mixed type of inhibitor and it obeys the Langmuir adsorption isotherm.	25	2007
24	AISI 304 Stain less steel	0.5 M HCl& 0.5 M NaCl	Poly(N-ethylaniline)		Linear Anodic Polarisation, Cyclic voltametry, FT-IR Spectroscopy and SEM.	It is an excellent inhibitor and a protective layer is confirmed by FT-IR, SEM.	26	2008
25	AISI 316 & AISI 304 Stain less steel	30 wt% H_2SO_4	Mo &Mn		Gravimetric test, Polarisation, Impedance Spectroscopy(EIS), SEM, EDX and XPS.	It shows excellent inhibitor, A protective layer is confirmed by SEM, EDX, and XPS.	27	2008
26	AISI 304 Stain less steel	0.1 M H_2SO_4	1,2,3-benzotriazole (BTAH)		Potentiodynamic Polarization curves, Electrochemical Impedance Spectroscopy (EIS) and adsorption study.	It was found to be an efficient inhibitor for acid corrosion and it obeys Langmuir adsorption isotherm.	28	2008
27	AISI 304 & AISI 316 Stain less steel	3.5 wt % NaCl& 6wt % $FeCl_3$	Mn& Mo		Gravimetric tests, Potentiodynamic Polarisation, SEM, X-ray mapping and EDX.	It proves better inhibition. It forms a protective layer on the metal surface and it is confirmed by SEM and EDX.	29	2008
28	302 Stain less steel	1M HCl& 1M H_2SO_4	MPT (1-methyl -3 Pyridine -2-yl-thiourea		Open Circuit potential(OCP), Potentiodynamic Polarisation, Adsorption study.	Formation of passive films, inhibitor follows Tempkin adsorption isothem.	30	2009
29	AISI 304	1.5% NaCl	Ciprofloxacin &Norfloxacin		Open Circuit potential(OCP),	It is a anodic type of	31	2009

	Stainless steel				Potentiodynamic Polarisation.	inhibitor and a potential becomes positive direction.		
30	ASTM 420 Stainless steel	3% NaCl	Polyethyleneimine		Linear, Cyclic Polarisation, and XPS.	Proves that it is a very good inhibitor in pitting corrosion and a protective layer is confirmed by XPS.	32	2009
31	AISI 304 Stainless steel	1 M HCl	Bis-N,S-bidentate Schiff base		Weight loss, Potentiostatic Polarisation, AC impedance and adsorption study.	It is a mixed type excellent inhibitor and it obeys the Langmuir adsorption isotherm.	33	2009
32	AISI 430 stainless steel	3% NaCl	polyethyleneimine.		Linear Polarisation, Cyclic Polarisation and X-ray photoelectron spectroscopy (XPS)	It proves better inhibition. It forms a protective layer on the metal surface and it is confirmed by XPS.	34	2009
33	AISI 304 Stainless steel	3.0 M HCl	4-phenylthiazole	KSCN	Weight loss, Synergistic effect, Galvanostatic Polarisation and adsorption study.	It shows that it is an excellent inhibitor also higher temperature. Synergistic role existing between the inhibitors and it obeys Temkin's adsorption isotherm and thermodynamic – kinetic model.	35	2009
34	302 Stainless steel	0.5M H_2SO_4	(BCBD) 2,2'-[bis - N(4-chlorobenzaldimine)-1.1' – dithio,		Weight loss, Potentiostatic Polarisation, Adsorption study.	It is a mixed type of inhibitors. It obeys Langmuir	36	2010

			(BAPD) bis - (2-amino phenyl) disulphide			adsorption isotherm.		
35	304L Stain less steel	0.9% NaCl	Poly (Vinyl Alcohol)		Potentiodymanic Polarisation, impedance spectroscopy, SEM, XPS.	PVA act as a good inhibitor and it confirms a stable and uniform thin film formation.	37	2010
36	430 Stain less steel	2 M HCl	Crown ethers		Weight loss, Galvanostatic Polarization, SEM, EDX and adsorption study.	It shows Mixed type of corrosion inhibitors. Protective layer is confirmed by SEM, EDX and obeys the Temkin adsorption isotherm.	38	2010
37	430 Stain less steel	0.1 M HCl	N,N'-diquaternized 4,4'-dipyridinium salts		Potentiodymanic Polarisation, adsorption study.	It is a mixed type excellent inhibitor and it obeys the Langmuir adsorption isotherm.	39	2010
38	316L Stain less steel	0.5 M H_2SO_4	Lysine (α,ε-diaminocapro ic acid)		Open circuit potential (OCP), Potentiodymanic Polarisation, and SEM.	Potential value move towards positive direction, Lysine act as a good cathodic inhibitor. A protective film is confirmed by SEM	40	2011
39	316L Stain less steel	0.5 M H_2SO_4	Triazoloisoqu inoline derivatives.		Potentiodymanic Polarisation, EIS and SEM.	A very good inhibitor. Hydrogen evolution rate is low by EIS & a protective film is confirmed by SEM.	41	2011
40	AISI 304	2 N HCl	N-Furfuryl N'-Phenyl		Potentiodymanic Polarisation, and	It shows that it is an anodic	42	2011

	Stain less steel		Thiourea		adsorption study.	inhibitor, it follows the Temkin's adsorption isotherm and the mechanism is followed by Physisorption.		
41	AISI 316 Stain less steel	0.1 M HCl	2-(4-Methyl - 3-oxo-2-phenyl-2, 3-dihydro - 1 H-pyrazolo[3, 4-b] pyridine -4-yl) acetic acid butylester		Weight loss & adsorption study.	It proves that it is an excellent inhibitor and it suggests that spontaneous adsorption takes place.	43	2011
42	AISI 316L Stain less steel	0.15 M NaCl	Molybdate& Nitrate		Open Circuit Potential(OCP), Polarisation, Cyclic voltametry and SEM.	A potential value move towards positive direction & shows that it is a good inhibitor. A protective layer is confirmed by SEM.	44	2011
43	AISI 304L & AISI 316 L Stain less steel	Oxygen free Na_2SO_4 + Na_2S at pH 3	H_2S		Potentiodynamic Polarisation, EIS, SEM and XRD.	It is a better inhibitor for both alloys & a potential value move towards positive direction. A passive layer is confirmed by XRD and SEM.	45	2011
44	Stain less steel	1 N H_2SO_4	poly-N-vinylimidazole and N-vinylimidazole		Potentiodynamic Polarization, EIS and adsorption study.	Shows that it is an excellent inhibitor. Thermodynamic data suggests that the highly stable layer is confirmed.	46	2011
45	Austenitic stainless steel	0.5 M H_2SO_4	5-benzoyl-4,6- diphenyl-1,2,3,4-tetrahydro-2-thiopyrimidin		Potentiodynamic Polarization, Linear Polarization resistance (LPR), EIS and adsorption	It shows better inhibition, and obeys the Langmuir, Dubinin–	47	2011

			(DHPM I) and 5-Benzoyl-6-phenyl-4-p-tolyl-3,4-dihydropyrimidin-2(1H)-one (DHPM II).		study.	Radushkevich adsorption isotherm.		
46	AISI 304 Stainless steel	2 N HCl	N - (2-mercaptophenyl) -N' -phenyl Thiourea		Weight loss, Potentiodynamic Polarisation and adsorption study.	It is a mixed type of inhibitors. It obeys Temkin adsorption isotherm, and the inhibition is governed by physisorption mechanism.	48	2011
47	Stainless steel	1 M HCl	Decylsulphate sodium salt (SSDS),Dodecylsulphate sodium salt (SSDDS),Hexadecylsulphate sodium salt (SSHDS), Dodecyl benzene sulfonate sodium salt (SSDDBS)	Potassium Iodide (KI)	Weight loss, Synergistic efect, Potentiodynamic Polarisation and adsorption study.	It is a mixed type excellent inhibior and it obeys the Freundlich adsorption isotherm. Synergistic role existing between the inhibitors.	49	2011
48	AISI 304 austenitic stainless steel	0.5 M H_2SO_4	hexadecylpyridinium bromide (HDPB)		Potentiodynamic polarization, EIS and adsorption study.	It is a mixed type excellent inhibitor and it obeys the Temkin adsorption isotherm.	50	2011
49	AISI 316L Stainless steel	1 M H_2SO_4	AMINIO ACIDS (Arginine. Glycine, Leucine and Valine)		Open Circuit Potential(OCP), Potentiodynamic Polarisation.	Glycine, Valine and Leucine act as corrosion inhibitors but Arginine act as corrosion accelerator.	51	2011
50	AISI 304 Stainless steel	1 M HCl	Extract of Salvia officinalis		Weight loss, Potentiodynamic Polarization, EIS and adsorption study.	It shows Mixed type of corrosion inhibitors & their	52	2012

						adsorption obeys the Langmuir isothem.		

Acknowledgement

I would like to extend my heartiest gratitude to my management, friends and my family for providing moral support.

References

1. J.O.M. Bockris, A.K.N. Reddy, 2000. Modern Electrochemistry 2B, Electrodics in chemistry, Engineering, biology and Environmental Science, second ed., Kluwer Academic/plenum publishers, New york, pp. 1703
2. H. Ashassi - Sorkhabi, E. Asghari, *Effect of hydrodynamic conditions on the inhibition performance of L-methionine as a green inhibitor*. J. Electrochim Acta., **54**, pp.162-167 (2008)
3. Reeta Agarwal and T.K.G. Namboodhiri, *The inhibition of sulphuric acid corrosion of 410 stainless steel by thioureas*. Corros. Sci,, **30**, pp.37-52 (1990)
4. M. Urgen, A.F. Cakir, *The Effect of Molybdate ions on the Temperature Dependent Pitting Potential of Austenitic Stainless steel in neutral chloride solutions*. Corros. Sci. **32**, pp.841-852 (1991)
5. Y. C. Lu and M. B. Ives, *The Improvement of the Localized Corrosion resistance of Stainless steel by cerium.* Corros. Sci., **34**, pp.1773-1785 (1993)
6. Zhou Mingpeng., Wang Kaiming., Diao Yuemin., Zhou Bensheng., *Corrosion inhibition of methylenephosphonic acids with R-N-[$CH_2PO(OH)_2$]$_2$ structure in sulfuric acid solution.* J. Chinese Society of Corrosion & Protection. **14**, pp.283-290 (1994)
7. A.M. Al-Mayout, A.A. Al-Suhybani, A.K. Al-Ameery, *Corrosion inhibition of 304SS in sulfuric acid solutions by 2-methyl benzoazole derivatives*. Desalination. **116**, pp.25-33 (1998)
8. W.Z. Yang, B.S. Zhou, *Study on corrosion inhibition by N-sulfonic amino-dimethylenephosphonic acid*. J. Chinese Society of Corrosion & Protection. **20**, pp.105-110 (2000)
9. D. Gopi, S. Rajeswari, *Surface characterization and electrochemical corrosion behaviour of 304 stainless steel in aqueous media*. J. Solid State Electrochemistry. **6**, pp.194-202 (2002).
10. M. Abdallah, *Rhodanine azosulpha drugs as corrosion inhibitors for corrosion of 304 stainless steel in hydrochloric acid solution*. Corros. Sci. **44** , pp.717-728 (2002)
11. Paul. A. Kilmartin., Lissa Trier., Graham, A., Wright, *Corrosion inhibition of polyaniline and poly (o-methoxyaniline) on stainless steels*. Synthetic metals. **131**, pp.99-109 (2002)

12. Denise S. Azambuja, Emilse M.A. Martini and Iduvirges L. Muller, *Corrosion behaviour of Iron and AISI 304 stainless steel in Tungstate Aqueous solutions containing chloride*. J.Braz.Chem.Soc. **14**, pp.570-576 (2003)
13. M. Abdallah, *Corrosion behaviour of 304 stainless steel in sulphuric acid solutions and its inhibition by some substituted pyrazolones*. Materials Chemistry and Physics. **82**, pp.786–792 (2003)
14. S.A.M. Refaey, F. Taha, A.M. Abd El-Malak, *Inhibition of stainless steel pitting corrosion in acidic medium by 2-mercaptobenzoxazole.* Applied Surface Sci. **236**, pp.175–185 (2004)
15. Celeste Rabacal Alentejano., Idalina Vieira Aoki., *Localized corrosion inhibition of 304 stainless steel in pure water by oxyanions tungstate and molybdate*. Electrochemica acta. **49**,pp. 2779-2785 (2004)
16. Meltem Dudukcu., Birgul Yazici., Mehmet Erbil., *The effect of indole on the corrosion behaviour of stainless steel*. Materials Chem & Phy **87**, pp.138–141 (2004)
17. M. Behpour, S.M. Ghoreishi, N. Mohammadi, M. Salavati-Niasari, *N-[(Z)-1-Phenylemethyleidene]-N-{2-[(2-{[(Z)-1 phenylmethylidine] amino}phenyl)disulfanyl] phenyl} amine and its derivatives on the corrosion of stainless steel 304 in acid media*. Corros. Sci. **53**, pp.3380-3387 (2005)
18. A. Galal, N. F. Atta, M.H.S. Al-Hassan, *Effect of some thiophene derivative on the electrochemical behaviour of AISI 316 austenitic stainless steel in acidic solutions containing chloride ions. I. Molecular structure and inhibition efficiency relationship*. Materials Chem & Phy. **89**, pp.38-48 (2005)
19. L. Narvaez, E. Cano, and D.M. Bastidas, *3-Hydroxybenzoic acid as AISI 316L stainless steel corrosion inhibitor in a H_2SO_4-HF-H_2O_2 pickling solution*. J. Applied Electrochemistry, **35**, pp.499-506 (2005)
20. A. Galal, N. F. Atta, M.H.S. Al-Hassan, *Effect of some thiophene derivatives on the electrochemical behavior of AISI 316 austenitic stainless steel in acidic solutions containing chloride ions II. Effect of temperature and surface studies. Materials.* Chem & Phy. **89**, pp.28–37 (2005)
21. T. Sourisseau, E. Chauveaub, B. Barouxa, *Mechanism of copper action on pitting phenomena observed on stainless steels in chloride media*. Corros. Sci. **47**, pp.1097–1117 (2005)
22. S.A.M. Refaey, F. Taha, A.M. Abd El-Malak, *Corrosion and inhibition of 316L stainless steel in neutral medium by 2-Mercaptobenzimidazole*. Int. J. Electrochem. Sci. **1**,pp. 80-91 (2006)
23. A.B. Silva, S.M.L. Agostinho, O.E. Barcia, G.G.O. Cordeiro, E. D'Elia, *The effect of cysteine on the corrosion of 304L stainless steel in sulphuric acid,* Corros. Sci, **48**, pp.3668–3674 (2006)
24. D. Gopi, S. Manimozhi, K.M. Govindaraju, P. Manisankar, S. Rajeswari, *Surface and electrochemical characterization of pitting corrosion behaviour of 304 stainless steel in ground water media.* J. Applied Electrochemistry, **37**, pp.439-449 (2007)
25. A.S. Fouda and H. El-Dafrawy, *Inhibitive effecr of some pyrimidine dericatives on the cyclic stressed specimens of stainless steel type 304 in acidic media.* Int.J. Electrochem. Sci. **2**, pp.721-733 (2007)

26. Aziz Yagan, Nuran Ozcicek Pekmez, Attila Yildiz, *Poly(N-ethylaniline) coatings on 304 stainless steel for corrosion protection in aqueous HCl and NaCl solutions.* Electrochemica Acta. **53**, pp.2474-2482 (2008)
27. A. Pardo, M.C. Merino, A.E. Coy, F. Viejo, R. Arrabal, E. Matykina, *Effect of Mo and Mn additions on the corrosion behaviour of AISI 304 and 316 stainless steels in H_2SO_4.* Corros. Sci. **50**, pp.780-794 (2008)
28. A.K. Satpati, P.V.Ravindran, *Electrochemical study of the inhibition of corrosion of stainless steel by 1,2,3-benzotriazole in acidic media.* Materials. Chem & Phy. **109**, pp.352–359 (2008)
29. A. Pardo, M.C.Merino, A.E.Coy, F. Viejo, R. Arrabal, E. Matykina, Pitting *corrosion behaviour of austenitic stainless steels – combining effects of Mn and Mo additions.* Corros. Sci. **50**, pp.1796–1806 (2008)
30. S.M.A. Hosseini, & M. Salari, *Corrosion inhibition of stainless steel 302 by 1-methyl-3-pyridine-2-yl-thiourea in acidic media. Indian J. Chemical technology.* **16**, pp.480-485 (2009)
31. R.S. Dubey & Yogesh Potdar, *Corrosion inhibition of 304 stainless steel in sodium chloride by ciprofloxacin and norfloxacin.* Indian J. Chemical technology. **16**, pp.334-338 (2009)
32. Matjaz Finsgar, Stefan Fassbender, Fabio Nicolini, Ingrid Milosev, 2009. *Polyethyleneimine as a corrosion inhibitor for ASTM 420 stainless steeel in near-neutral sline media*. Corros Sci. **51**, pp.525-533 (2009)
33. M. Behpour, S.M. Ghoreishi, N. Soltani, M. Salavati-Niasari, *The inhibitive effect of some bis- N,S-bidentate Schiff bases on corrosion behaviour of 304 stainless steel in hydrochloric acid solution.* Corros Sci. **51**, pp.1073 – 1082 (2009)
34. Matjaz Finsgar, Stefan Fassbender, Sabine Hirth, Ingrid Milosev, *Electrochemical and XPS study of polyethyleneimines of different molecular sizes as corrosion inhibitors for AISI 430 stainless steel in near-neutral chloride media*. Materials Chem & Phy. **116**, pp.198–206 (2009)
35. A.S. Fouda, A.S. Ellithy. *Inhibition effect of 4-phenylthiazole derivatives on corrosion of 304L stainless steel in HCl solution.* Corros. Sci. **51**, pp.868–875 (2009)
36. S.M.A. Hosseini, A. Azim,I. Sheikhsoaei, M. Salari, *Corroson inhibition of 302 stainless steel with schiff base compounds.* J. Iran. Chem. Soc. **7**, pp.779-806 (2010)
37. A.Samide, A. Ciuciu, C. Negrila, *Surface analysis of inhibitor film formed by Poly(Vinyl Alcohol) on stainless steel in sodium chloride solution,* Portugaliae Electrochemica acta. **28**, pp.385-396 (2010)
38. A.S. Foudaa, M. Abdallahb, S.M. Al-Ashreya, A.A. Abdel-Fattahb, *Some crown ethers as inhibitors for corrosion of stainless steel type 430 in aqueous solutions.* Desalination. **250**,pp.538–543 (2010)
39. F.M. Al-Nowaiser, *Corrosion Inhibition of Type 430 Stainless Steel in HCl Solution by Dipyridinium Salts.* J. King Abdulaziz University Sci. **22**, pp.89-100 (2010)
40. Azza El, Sayed El, Shenway, *Corrosion inhibition of lysine as basic amino acids on 316L stainless steel in 0.5M H_2SO_4 solution.* J. American Sci. **7**, pp.600-605 (2011)

41. Nada F. Atta., A.M. Fekry, Hamdi M. Hassaneem, *Corrosion inhibition, hydrogen evoluation and antibacterial properties of newly synthesized organic inhibitors on 316L stainless steel alloy in acidic medium.* International J. hydrogen energy. **36**, pp.6462-6471 (2011)
42. R. Herle, P. Shetty, S.D. Shetty, U.A. Kini, *Corrosion inhibition of 304SS in Hydrochloric acid solution by N-Furfuryl N'-Phenyl Thiourea.* Portugaliae Electrochimica Acta. **29**, pp.69-78 (2011)
43. O.O. James, K.O. Ajanaku, K.O. Ogunniran, O.O. Ajani, T.O. Siyanbola, M.O. John, *Adsorption Behaviour of pyrazolo [3, 4-b] pyridine oncorosion of stainless steel in HCl solution.* Trends in Applied Sciences Research. **6**, pp.910-917 (2011)
44. M.B.Gonzalez, S.B. Saidman, *Electrodeposition of polypyrrole on 316L stainless steel for corrosion prevention.* Corros. Sci. **53**,pp.276-282 (2011)
45. A. Davoodi, M. Pakshir, M. babaiee, G.R. Ebrahimi, *A comparative study of 304L and 316L stainless steel in acidic media.* Corros. Sci. **53**, pp.399-408 (2011)
46. Aysegul Oncul, Kerim Coban, Esma Sezer, Bahire Filiz Senkal, *Inhibition of the corrosion of stainless steel by poly-N-vinylimidazole and N-vinylimidazole.* Progress in Organic Coatings. **71**, pp.167–172 (2011)
47. Necla Caliskan, Esvet Akbas, *The inhibition effect of some pyrimidine derivatives on austenitic stainless steel in acidic media.* Materials Chem & Phy. **126**, pp.983–988 (2011)
48. Ramadev Herle, Prakash Shetty, S. Divakara Shetty, U. Achutha Kini, *Corrosion Inhibition of Stainless Steel in Hydrochloric Acid by N - (2-mercaptophenyl) -N' - phenyl Thiourea.* International J. Chemistry and Applications. **3**, pp.151-158 (2011)
49. Diwan Singh Rajan, Shiv Darshan Malik, *Surfactants as Corrosion Inhibitors for Stainless Steel in HCl Solution.* J. Pure and Applied Science & Technology. **1**, pp.23-35 (2011)
50. M.M. Hamza, S.S. Abd El Rehim, Magdy A.M. Ibrahim, *Inhibition effect of hexadecyl pyridinium bromide on the corrosion behavior of some austenitic stainlesssteels in H_2SO_4 solutions,* accepted in Arabian Journal of Chemistry. ARTICLE IN PRESS
51. N.A. Abdel Ghanyl, *The Inhibitive Effect of Some Amino Acids on the Corrosion Behaviour of 316L Stainless Steel in Sulfuric Acid Solution.* Modern Applied Science. **5**, pp.19 (2011)
52. Nasrin Soltani, Nahid Tavakkoli, Maryam Khayatkashani, Mohammad Reza Jalali, Ahmad Mosavizade, *Green approach to corrosion inhibition of 304 stainless steel in hydrochloric acid solution by the extract of Salvia officinalis leaves.* Corros. Sci. **62**, pp.122–135 (2012)