A Study on Impact of Quality of Work Life on Job Satisfaction of Self Financing College Teachers in Dindigul District	K.Rajeswari, Assistant Professor of Commerce	Commerce	Shanlax International Journal of Commerce	2019	2320-4168	UGC Approval No. 44120 http://www.shanlaxjournals.in/wp-content/uploads/sijcom_may2019_pachamuthu_women%E2%80%99s_college.pdf

OPEN ACCESS

Volume: 7

Special Issue: 1

Month: April

Year: 2019

ISSN: 2320-4168

Impact Factor: 4.118

Citation:

DOI:

A Study on Impact of Quality of Work Life on Job Satisfaction of Self Financing College Teachers in Dindigul District

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Abstract

Quality of work life significantly contributes towards increasing the job satisfaction or dissatisfaction depending upon the Teachers negative or positive perception of quality of work life dimension. Teachers indicated positive job satisfaction and would continue to stay in the same job only if they have opportunity for growth and development along with organizational prestige and financial factors. The main objectives of the study are to examine the effectiveness of teachers in achieving their quality of work life in their job, to know the impact of job satisfaction on quality of work life among the self financing college teachers and gives the suitable suggestions on the basis of the study. The study pop¬ulation comprised the self financing college teachers of Dindigul District. By using proportionate random sampling method 120 women teachers were considered as final sample for the study. In this study it is founded that there is no significant relationship between job satisfaction and quality of work life of women teacher. Also the study reveals that working environment has more impact on the quality of work life than pay and job security aspects.

Introduction

Teachers role is pivotal in providing education, creating knowledge, facilitate technological advancement and enriching the national culture. The concept of work life is based on the assumption that a job is more than just a job. This value based process is aimed towards meeting the twin goals of enhanced effectiveness of educational institution and improved quality of life at work for teachers, it is concerned with increasing teachers and managements cooperative to solve the problems of Improving institution performance and teachers satisfaction. Quality of work life and quality of life has a significant association in teaching environment. Quality of academicians, particularly in the private technical institute, is not in a better condition. Factors such as salary and wages biasness for growth is low salary and job security issues are badly affecting the relationship with administration and academicians, dissatisfaction regarding leave flexibility etc, are responsible for low quality of work life of respondents.Teaching effectiveness is important because effective teaching helps students learning and improve the quality of work life of teachers.

Statement of the Problem

The study is reference to the impact of quality of work and job satisfaction self financing college teachers in Dindigul district. The self financing college teachers have realized that quality of work life improves employee motivation, job performance and institution growth but some of the factors influence the quality of work life are individual employee's wages, working hours, work place condition, and fairness in the work place personal characteristics such as anxiety or depression.

Objectives of the Study

- To examine the effectiveness of teachers in achieving their quality of work life in their job.
- To know the impact of job satisfaction on quality of work life among the self financing college teachers.
- To give the suggestions on the basis of the findings of the study.

Review of Literature

The study analyzed on the College Teachers revealed that, there is a positive relationship between job satisfaction and QWL dimensions. They founded that QWL of college teachers, particularly in the Private Technical and Professional Institute is not in a better condition. There is a huge difference between salary and job security of the same qualified teachers of private aided and unaided institutes. [1]. The study stated that there is a positive significant relationship between job satisfaction and quality of work life of women teacher. Also the study reveals that working environment has more impact on the quality of work life than pay and job security aspects. So educational institutions need to concentrate more on better working conditions to increase the quality of work life of working women teachers [2]. The study regards to the results of hypotheses and theoretical and experimental studies, they analyzed the hypotheses and discussed their comparisons with the literatures.[3].

Sampling Technique

By using proportionate random sampling method 120 women teachers were considered as final sample for the study. The data was collected from the sample respondents through survey method by administering questionnaire developed for the purpose.

Analysis and Interpretation

Basis		No. of respondents	Percentage
Age Group	20-25	11	9.2
	26-35 years	107	89.0
	36-45 years	2	1.8
	Total	120	100
Gender	Male	27	22.5
	Female	93	77.5
	Total	120	100

Marital Status	Married	84	70
	Unmarried	36	30
	Total	120	100
Qualification	PG	14	11.7
	M.PHIL	100	83.3
	PhD	6	5.0
	Total	120	100
Income	Upto Rs.8000	113	94.2
	Rs.11,000-20,000	6	5
	Above 20,000	1	0.8
	Total	120	100

The above table reveals that more than half of the respondents (89%) come under the age group of 26-35years and 9.2% of the respondents belong to the age group of 20- 25years and Only 1.8% of the respondents were in the age group of 36-45years and below. It is understood from the table given above that vast majority of (89%) of self financing college teachers were in the middle age. To analyze the hypothesis whether "there is no significant relationship between age of the respondents and quality of work life on job satisfaction of college teachers". The analysis of variance was applied and the result shown in the following table.

	Sum of square	d.f	Mean square	F	Sig
Between group (combined) Within group	0.134 12.191	2 117	0.642 0.104	0.642	0.528
	12.325	119			

The table reiterate (77%) of respondents are female whereas (22.5%) of respondents are male. A best part of the respondents (77%) are female respondent. To analyze further whether "there is no significant relationship between gender of the respondents and impact of quality of work life on job satisfaction. The analysis of variance was applied and the result shown in the following table.

	Sum of square	d.f	Mean square	F	Sig
Between group (combined) Within group	0.965 19.960	2 117	0.483 0.171	2.829	0.063
	20.925	119			

The table interprets (70%) respondents are married and at the level of quality of work life on job satisfaction whereas (30%) of respondents are unmarried to analyze furthermore hypothesis is framed that "there is a no significant relationship between marital status of respondents and quality of work life on job satisfaction of respondents" the analysis are made through analysis of variance and the results are shown below.

	Sum of square	d.f	Mean square	F	Sig
Between group (combined) Within group	0.179 25.021	2 117	0.090 0.214	0.419	0.659
	25.200	119			

It is also evident from the table that (83.3%) of respondents where completed M.Phil and they have a medium level of quality of work life on job satisfaction and (11.7%) respondents who are post graduates and (5%) of respondents are Ph.D. Most of the respondents are M.phil graduates.

Their level of quality of work life towards job satisfaction " there is no significant relationship between educational qualification of the respondents and the level of quality of work life towards job satisfaction of respondents the results are shown below

	Sum of square	d.f	Mean square	F	Sig
Between group (combined) Within group	0.633 18.83	2 117	0.317 0.161	1.968	0.144
	19.467	119			

The above table also indicates that (94.2%) of respondents are earning below Rs,6000 and (5%) of respondents are earning Rs.6000-Rs.10000 and (0.8%) of respondent earning above 20000 hypothesis is framed for further analysis that "there is a no significant relationship between income of the respondents and quality of work life toward job satisfaction of respondents".

Findings of the Study

- The major findings of the study stated that the Respondents belonging to the age group of above 26-35years have a high level of quality of work life on job satisfaction than other two groups .
- Respondents of female have a high level of quality of work life on job satisfaction when comparing to male respondents.
- Respondents with M.Phil qualification have a high level of quality of work life on job satisfaction than with the qualification of P.G and Ph.D.
- Respondents earnings Rs. 8000 having high level of significant.
- The analysis of variance shows the result that there is no significant relationship between age, gender, marital status, educational qualification, income and quality of work life on job satisfaction of respondents.

Suggestion

- The study suggested that Faculty members play a significant role for economic growth by contributing their knowledge, skills and efforts. So in Self financing colleges the management should emphasize on the policy implications based on the concerned issues of Quality of Work Life improvement.
- To encourage the faculty members, they should use motivational factors such as, providing compensation and salary, adequate conditions for work, perfect appreciation of their work; develop a sense of belonging and collaboration to do duty, sympathetic understanding etc. These should be considered as satisfying motivators of their job.
- The government should also take a measure to improve the quality of work life and job satisfaction by reducing the turnover rate of self financing college teachers.

Conclusion

Based on the above discussion it is concluded that, the study reveals that working environment has more impact on the quality of work life on job satisfaction. If college teachers are happy with the factors such as attention paid to their opinion, responsibility, recognition, and attention paid to their suggestions, they experience better quality of work life. So educational institutions need to concen¬trate more on better working conditions to increase the quality of work life of teachers. The present study was limited to the population of the self financing college teachers in Dindigul District only. Hence, the generality of the results may not represent the entire college teachers across the all over state or country.

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A Study on Dimensions of Quality of Work Life and its Impact on Job Satisfaction of Self Financing College Teachers in Dindigul District	K.Rajeswari Assistant Professor of Commerce	Commerce	The International journal of analytical and experimental modal analysis	2019	ISSN NO: 0886-9367	**UGC-CARE Group 'II' Journals list -Serial No. 36272** **https://app.box.com/s/oalm7koipxe8e792z0etk3zf3kpqo61l**

A Study on Dimensions of Quality of Work Life and its Impact on Job Satisfaction of Self Financing College Teachers in Dindigul District

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ABSTRACT

Quality of work life plays an important role in work-life balance and it also shows its impact on job satisfaction of teachers in self financing colleges. Quality of work life is a multi dimensional concept which includes all the aspect of teachers in their work environment. The teachers satisfaction level arises from the different level of dimensions in quality of work life. The motivation and satisfaction of self financing college teachers make them to work better and it also increase the positive attitude of teachers in performing their work. The various dimensions of quality of work life which affect the satisfaction of teachers and it result in lack of commitment in work, decrease the level of performance, job turnover, absenteeism, job stress and lack of physical and psychological well being at work of self financing college teachers. The objective of the study is focused on determining the dimensions of quality of work life and their impact on job satisfaction of self financing college teachers. The study also determined the various dimensions of quality of work life which affects the satisfaction of self financing college teachers such as skill & knowledge development, opportunities for growth, recognition & rewards, decision making, organizational communication, safe and healthy working conditions, work and total life space, job security, job promotion, motivation for work these dimensions were analyzed through statistical tools simple percentage analysis, ANOVA, t-test and weighted average method. The study selected 160 samples from self financing college teachers around Dindigul District by using random sampling method for data collection through structured questionnaire. The result revealed that there is a significant relationship with the impact of dimensions of quality of work life on job satisfaction of self financing college teachers in Dindigul District.

Keywords: dimensions, job satisfaction, quality of work life, self financing college teachers, work performance.

I.INTRODUCTION

Quality of work is being concerned with human dimensions of work and relates to job satisfaction of self financing college teachers which leads to institution growth and development. Quality in work is attained from the relationship between teachers and their working environment. The growth and development of the institution depends upon the teachers' attitude and satisfaction towards their work. The dimensions of quality of work life play an important role in work performance of teachers in self financing college. It also allows the institution to measure the teacher efficiency through designing their job and work environment. The Quality of work life dimensions depends upon the teachers satisfaction which is directly connected with institution work allotment depends upon the skills & knowledge and tackling power of teachers in facing problem arises from work and life. The positive work-life balance of teachers result in stress free attitude both in work and life and it enable them to work better in their job and maintain peacefulness relationship with family members so the balanced life style of teachers will make them more strong and powerful both Physical as well as mentally. Therefore the study is carried out to examine the various dimensions of Quality of work life which impact the job satisfaction of teachers such as skill & knowledge development, opportunities for growth, recognition & rewards, decision making, organizational communication, safe and healthy working conditions, work and total life space, job security, job promotion, motivation all these leads to dissatisfaction of teachers and it further results in lack of commitment in work, decrease the level of performance, job turnover, absenteeism, job stress and lack of physical and psychological well being at work thus it is necessary to determine how dimensions of quality of work life impact the satisfaction of teachers in self financing colleges.

II. STATEMENT OF THE PROBLEM

The teacher satisfaction in the job depends upon the various dimension of quality of work life in self financing colleges. If the teacher needs are satisfied then the work environment will become effective and efficient and it also helpful in improving the quality of work life in self financing colleges. The term quality of work life and job satisfaction has to be examined careful by self financing colleges and they should have a clear insight between these two terms because it is interdependent which helpful in achieving the objectives of the institution. In self financing colleges the satisfaction level of teacher can be determined through their work performance and job involvement. There are also several dimensions of quality of work life which is associated with the dissatisfaction of teachers in the work place they are absenteeism, lack of involvement in work, turnover and job stress. This study is an attempt to identify the various dimensions of quality of work life and its impact on job satisfaction of self financing college teachers in Dindigul District.

III.OBJECTIVIES OF THE STUDY

i. The main objective of the study is to find out the various dimensions of quality of work life and its impact on job satisfaction of self financing college teachers in Dindigul District.

ii. To examine the relationship between quality of work life and job satisfaction.

iii. To determine the various dimension of quality of work life with influence the job satisfaction of self financing college teachers In Dindigul District.

IV. REVIEW OF LITERATURE

Zohreh Anbari et .al (2014) identified that there is significant relation between job satisfaction and staffs quality of work life. The result of the study shows that there is a significant difference in WHI, WCS, CAW and quality of work life between different jobs in the factory. The survey confirmed that there is better condition evaluated in finishing and casting units which lead to better work conditions and these unit staffs also have highest average while analyzing their quality of work life. In mean while the staff in aluminum and CNC wards were suffering from poor quality of work life and work condition. Therefore their study concluded that safe and healthy work environment, proper work conditions and work-home relations have considerable reducing negative effects on personal life of staff the study also recommended the factory managers to measure the different units through WHI, WCS and CAW by conducting comprehensive studies in quality of work life.

Mohammad Hossein Nekouei et al (2014) studied Quality of work life and job satisfaction among employee in government organization in Iran. The aim of the study is focused on determining the effects of quality of work life and the factors contribute toward job satisfaction of employees government organization in Iran. The study used structured questionnaire model for determining the relationship between variables in the model of quality of work life and job satisfaction. The result of the study revealed that quality of work life significantly influences on job satisfaction and managerial dimension of quality of work life is a superior predicator for job satisfaction of employees in government organization. **S.Khodadi et al (2014)** examined Quality of work life dimensions effect on the Shuhstar's Schohola Hospital employees' job satisfaction. The study analyzed the variables into two categories such as independent variables which included permanent security providing, salary and benefits payment policies, development and promotion opportunity and depended variables as job independence and job satisfaction. The study selected random sampling method and data collected through two questionnaires which includes both "Quality of work life" and "Job satisfaction". Therefore the study founded the salary and benefits policies have a significant and positive effect on the Shuhstar's Schohola Hospital employees' job satisfaction.

V. RESEARCH METHODOLOGY

This study was conducted through descriptive research method to examine the various dimension of quality of work life influence the job satisfaction of self financing college teachers in Dindigul District. The research study focused on determining and analyzing the various dimensions of quality of work life and its impact on job satisfaction of self financing college teachers. The researcher utilized random sampling method to collect 160 teachers as a sample from self financing colleges in Dindigul District. The structured questionnaire provided to respondents for data collection which is based on determining the dimensions of quality of work life and its impact on job satisfaction of teachers. The data collected from sample were properly tabulated and utilized for appropriate interpretation. The study taken various dimensions of quality of work life such as skill & knowledge development, opportunities for growth, recognition & rewards, decision making, organizational communication, safe and healthy working conditions, work and total life space, job security, job promotion, motivation for work these dimensions were analyzed through statistical tools simple percentage analysis, ANOVA, t-test and weighted average method and shown its impact on job satisfaction of self financing college teachers in Dindigul District.

VI. FINDINGS OF THE STUDY

Table 1. Showing the Mean value of constructs based on Dimensions compared with Quality of work life and Job satisfaction

DIMENSIONS	QUALITY OF WORK LIFE	JOB SATISFACTION
Skill & knowledge	34.7493	108.9027
Opportunities for growth	39.6567	111.7652
Recognition & rewards	52.6316	105.6713
Participating in management decision making	39.3736	107.4321
Organizational communication	41.3267	130.4300
Safe and healthy working conditions	43.0040	130.4500
Work and total life space	39.2331	107.1732
Job security	41.4642	117.5683
Job promotion	42.9439	120.6247
Motivation for work	38.7642	115.1979

Table 1.1 ANONVA

		Sum of Squares	DF	Mean Square	F	Sig
Quality of work life	Between groups (combined)	2.038	2	1.019		
	Within groups	64.754	157	0.553	1.841	0.163
		66.792	159			
Job satisfaction	Between groups (combined)	0.028	2	0.014		
	Within groups	84.564	157	0.723	0.019	0.981
		66.792	159			

The table shows the significant value of both the constructs is less than 0.05, so the null hypothesis is rejected and it is concluded that the respondents having different views which differ significantly in their opinion on dimensions of quality of work life and its impact on job satisfaction of self financing college teachers. The study analyzed various dimensions by using ANOVA table for examining the views of self financing college teachers through comparison of two variables Quality of work life and job satisfaction. The study founded that the dimensions such as skill & knowledge development, opportunities for growth, recognition & rewards, decision making, organizational communication, safe and healthy working conditions, work and total life space, job security, job promotion, motivation for work shows significant relationship with the quality of work life and job satisfaction of self financing college teachers.

Table 2: "t"- TEST – Dimensions of quality of work life and its impact on job satisfaction

S.No.	Dimensions	N	Mean	Std. Deviation	F	Sig
1.	Skill & Knowledge	160	3.4219	0.65541	0.320	0.042
2.	Opportunities for growth	160	3.7430	0.56072	7.323	0.025
3.	Recognition& rewards	160	3.2561	0.68853	5.134	0.031
4.	Participation in management decision making	160	3.8274	0.75321	2.077	0.351
5.	Organizational communication	160	3.3715	0.87654	9.355	0.032
6.	Safe and healthy working conditions	160	3.7418	0.68837	0.820	0.004
7.	Work and total life space	160	3.9721	0.56640	4.153	0.050
8.	Job security	160	3.2305	0.68743	5.560	0.054
9.	Job promotion	160	4.0027	0.85376	4.138	0.058
10.	Motivation for work	160	3.3074	0.74720	2.055	0.036

It is inferred from the above table that the various dimensions of Quality of work life shows a significant relationship in impacting the job satisfaction of teachers through t- test analysis it is identified that the dimensions of quality of work life listed out here has a direct influence with the job satisfaction of self financing college teachers they are skill & knowledge development, opportunities for growth, recognition & rewards, participation in management decision making, organizational communication, safe and healthy working conditions, work and total life space, job security, job promotion, motivation for work .These dimensions are compared with mean and t-test value and the standard deviation is not consistent in all dimension of quality of work taken as variables it implies that there is a significant relationship between variables.

Table 3.3 Dimension of quality of work life influence the job satisfaction

S.No	Dimensions	1	2	3	4	5	6	7	8	9	10	Total score
1.	Skill and Knowledge	19	20	12	5	25	10	24	20	15	10	174
		20	30	30	20	15	30	20	10	10	15	
2.	Opportunities for Growth	20	21	14	10	20	15	10	15	20	15	160
		20	30	20	40	40	80	70	60	40	30	
3.	Recognition& rewards	20	17	15	24	22	13	14	20	5	10	250
		25	20	15	30	20	15	30	45	55	60	
4.	Participation in Management Decision Making	10	17	25	20	14	15	20	25	10	4	272
		20	40	50	50	60	70	12	14	23	15	
5.	Organizational Communication	20	11	30	17	22	15	20	10	5	10	220
		60	70	80	30	20	50	20	40	15	25	
6.	Safe and Healthy Working Conditions	20	13	30	20	10	15	5	20	15	12	138
		5	15	35	12	16	40	45	55	7	18	
7.	Work and Total Life Space	15	35	25	10	20	15	25	10	5		330
		40	30	40	50	40	20	35	45	50	20	
8.	Job Security	10	25	30	20	18	12	15	10	15	5	312
		20	30	30	40	40	80	70	60	40	30	
9.	Job Promotion	5	20	25	19	10	14	37	15	5	10	300
		20	45	45	35	45	5	10	75	30	35	
10.	Motivation for Work	10	25	15	24	13	17	15	16	5	20	315
		25	30	40	55	50	60	40	20	35	45	

The above table shows the dimensions of quality of work life and their influence on job satisfaction of teachers in self financing college through weighted average method. The work and total life space have highest weighted score 330, followed by motivation to work is the second weighted score 315, the least weighted score 138 is safety and healthy working conditions of self financing college teachers. Through the above table it is clear that the work and life space has been scored high which shows one of the important dimensions in influencing the quality of work life on job satisfaction of teachers in self financing college.

VII.SUGGESTION

The suggestion is based on the finding of the study the self financing colleges have to consider the various dimensions of Quality of work life which impacting teachers satisfaction. The Management of self financing colleges has to take part in enhancing the quality of teachers both in work and life. The teachers are playing an important role in the student growth &

welfare, development of colleges, and in economic growth through contributing their skills and knowledge. So the management of self financing colleges has to take a measure for protecting teachers from the various dimensions which impact the teachers in work place. The administrator of self financing colleges have to ensure the job security, job promotion, and safety and healthy working conditions additional they have to support teachers through faculty development program and they have to implement motivational factors such as participation in management decision making, reward, recognition and salary. If the self financing colleges improve the quality of work of teachers then it lead to higher level of job satisfaction of teachers. The Government has to take a measure for the development and improvement of teacher in self financing colleges.

VIII. CONCLUSION

The study reveals that there is a positive significant relationship with the dimensions of quality of work on job satisfaction of teachers in self financing college the study further analyzed the various dimension of quality of work life have a direct impact with job satisfaction of teachers in self financing college of Dindigul District. The self financing institution has to improve the working condition of teachers which helps them to improve their standard in work place and it also helps them to balance their work and life. Therefore the study concluded that the dimension of quality of work life is directly impact on job satisfaction of self financing college teachers in Dindigul District.

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Preparation and Characterization of Al doped SnO2 Nanocrystalline Thin Films by Spray Pyrolysis Technique	S. Porchelvi Assistant Professor of Physics	Physics	International Journal for Research in Applied Science & Engineering Technology	Feb 2020	**ISSN: 2321-9653**	https://www.ijraset.com/fileserve.php?FID=26554

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

Preparation and Characterization of Al doped SnO_2 Nanocrystalline Thin Films by Spray Pyrolysis Technique

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Abstract: Al-doped Tin Oxide (SnO_2) nanostructured (ATO) thin films are prepared by Spray Pyrolysis technique on glass substrates Prepared at 400°C and annealed at 500°C, 600°C. Using a solution consisting of $SnCl_4.5H_2O$ starting material and doping source was $AlCl_3$ with various Al doping ratio. $Sn_{1-x}Al_xO_2$ (x = 0.04, 0.06 and 0.08) were dissolved in ethanol and stirred four hours at 50°C. The effect of changes in doping content and annealing effect of Al:SnO_2 nanostructured thin films was investigated. The result of X-ray diffraction has shown that peak located at around 2Θ = 37.9° is corresponding to (200) plane which confirmed the presence of SnO_2 in tetragonal crystal system. All the observed characteristic peaks are well matched with the standard data base values. The UV-Visible transmittance figures are clearly depicting that all the prepared thin films are having transparency of 80%, the optical band gap was estimated to be around 2.56ev to 3.6ev. The scanning electron microscopic (FESEM) analyses show the crack-free and dense nature of the thin film formation. The size of the particle was measured from FESEM images and it was found to be in the range of 40-54nm. In AFM the average crystallite size was estimated 45nm and the root mean square roughness value was found to be 20 nm. EDAX to confirm the presence of dopant elements in the nanostructured thin films.
Keywords: Spray Pyrolysis, XRD, morphological and optical properties.

I. INTRODUCTION

The transparent conducting tin oxide (SnO_2) thin films have been widely used in many field owing to their, unique properties such as high electrical conductivity and high transmittance in the UV-Visible region[1,2]. Its properties are strongly depend on the deviation of stoichiometry, oxygen deficiency and the nature of the presence of impurity [3,4]. This material has proved itself to be one of the most attractive materials for gas sensor applications due to its special properties such as chemical and thermal stability and non-stoichiometry. Many researchers have been working to tailor the physical properties of SnO_2 thin films by employing different cationic and anionic dopant like Fluorine, Antimony, Zinc, Nickel, Aluminium etc., Depending upon the dopant, the SnO_2 thin films exhibit n-type or p-type conductivity. Aluminium is one of the acceptor impurity which acts as a lower valence cation in SnO_2 and can cause the p – type conductivity. Al doped tin oxide (ATO) nanocrystalline thin films can be prepared by a number of method such as spray pyrolysis [5], sputtering [6], CVD [7], Plasma and sol-gel methods [8-11].Spray Pyrolysis is suitable for a variety of oxide materials and relatively inexpensive. ATO thin films have been prepared using a spray pyrolysis technique and different amount of Al doped SnO_2 thin films were prepared at T_S=400°C and annealed at 500°C, 600°C. The effect of Al doping on the structural, optical, morphological and electrical properties of SnO_2 thin films have been studied. The prepared Al doped SnO_2 thin film has been used to many applications for gas sensing device.

Tin Oxide (SnO_2) is one of the transparent conducting Oxide (TCO) material having wider band gap of 3.6 eV [12] and ionic radius is Sn^{4+} r = 0.71Å [13]. To our knowledge undoped SnO_2 is an n-type semiconductor due to the presence of intrinsic defects like oxygen vacancies. Recent investigations have been focused on increasing n type conductivity of this material [14, 15], while both high quality n-and p type SnO_2 are essential for fabrication of SnO_2 based semiconductor devices. SnO_2 behaves as an n–type semiconductor, However when there is a suitable dopant doped with it, the carrier conversion takes place and change to P type semiconductor [16]. A lower valency cation as acceptor impurity such as Al^{3+} (ionic radius r = 0.51Å) [13] in tin oxide decreases n type conductivity and increases the hole concentration and hence the p – conductivity. However, it is to be noted that in a successful acceptor doping process, besides doping level, effect of annealing and the atomic or cationic size of the acceptor dopant is very important. The current investigation was done on the fully transparent conductive sprayed Al: SnO_2 nanostructure thin films. The n type SnO_2 inverted to P type conductivity prepared by SPD was evidenced [13].

In this paper, we report the effect of Al doping percentage and annealing effect of films, variation on structural, electrical and optical properties of SnO_2:Al thin films prepared by homemade Spray pyrolysis technique.

II. EXPERIMENTAL

Aluminum doped SnO_2 films were deposited onto the glass by Spray pyrolysis technique. The starting material for Sn was ($SnCl_4.5H_2O$) and doping source was aluminum chloride ($AlCl_3$). Both precursor and doping compound were dissolved in ethanol. The starting doping ratio (Al/Sn) was 4% in the solution. The resulting solution were stirred four hour at temperature 50ºC, spray rate and substrate to nozzle distance were maintained respectively at 10ml/min and 25cm. The glass substrate was mounted on hot plate then heated to 400ºC which was controlled by dimmastrate and digital thermometer connected to the hot plate. Then prepared samples were annealed at 500ºC and 600ºC by muffle furnace. After synthesizing the films, their structural, optical and electrical characterizations were performed. The structural properties of our samples were carried out by a Rigaku X–ray Diffractometer model DMAX 2200 with a copper anticathode (CUKα, λ = 1.5Å) with an angle range (2θ) of 20-70º. The optical parameters of the as – synthesized and annealed Al - SnO_2 films were measured using a shima DZU UV – 3101PC double beam spectrometer. The samples surface morphology was analyzed by the Field emission scanning electron microscope (FESEM:JEOL JSM 6701F), Atomic Force Microscopy (AFM). The elemental composition of the samples was determined by oxford instrument– INCAPENTAFET-X3 Elemental dispersive X-ray analyzer (EDAX).

III. RESULT AND DISCUSSION

A. *Structural Properties*

The effect of Al doping on SnO_2 has been investigated by various researchers in the past [17, 18]. With increasing Al dopant and annealing temperature in the tin oxide film, the crystalline of SnO_2 decreased. Hence the doping element Al is a grain growth inhibitor. The X-ray diffractogram of Al doped SnO_2 thin films prepared at the substrate temperature T_S= 400˚C and annealed at 500˚C, 600˚C are shown in Figures (1a),(1b) and (1c). A peak located at around 2Θ=37.9° is corresponding to (200) plane which confirmed the presence of SnO_2 in tetragonal crystal system. All the observed characteristic peaks are well matched with the standard data base values (JCPDS File No.88-0287). It can be clearly seen that the intensity of observed peaks are decreasing upon the increase of doping concentration. At the same time by comparing the XRD pattern of pure SnO_2 thin film a very small peak shift is observed in the case of Al doped SnO_2 thin films. This peak shift and the decrease in the intensity are due to the hinder of grain growth. The crystallite size was calculated using Scherrer's formula [19] and the average crystallite size found to be 32, 37,40 nm for 400˚C, 500˚C and 600˚C respectively.

Furthermore increasing the temperature leads to higher degree of crystallization and as a result new characteristic peak corresponding to (211) is observed. There is no any peak corresponding to Aluminium oxide, which implies the substitution of Al inside the SnO_2 lattice. It was observed that the peaks base was broadened. It should confirm the nanostructures occurrence of the Al - SnO_2 sample. This was in well agreement with the FESEM and EDAX. Fig (1b) shows that Al doping content and annealing effect to reduce the grain size. and annealing effect to reduce the grain size.

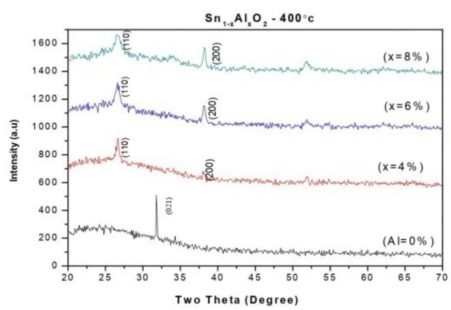

Fig. 1a XRD pattern of Al doped SnO_2 films deposited on glass substrates at 400ºC

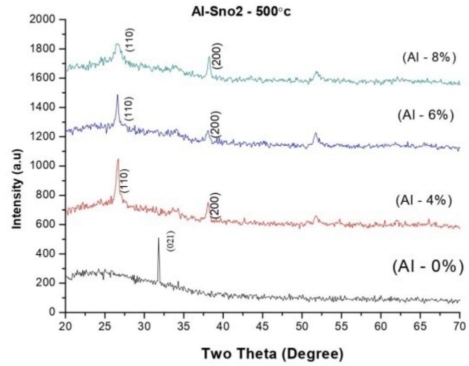

Fig. 1b XRD pattern of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

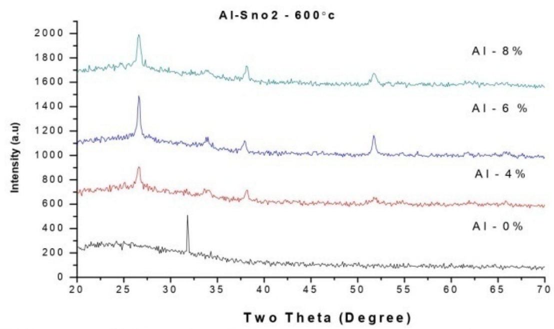

Fig. 1c XRD pattern of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

B. *Optical Properties*

Figures (2a-c) shows the UV-Visible spectra of Al doped SnO_2 thin films prepared at the temperature of T_S = 400°C and annealed temperature at 500°C and 600°C respectively. These figures are clearly depicting that all the prepared thin films are having transparency of 80%. Thin films annealed at 500°C shows the highest transparency (Figure 2a) of 90%. Further increasing the annealing temperature leads to the decrease of transparency. This is may be due to the increase of the density of the films upon the increasing of temperature. . From the fig it is observed that the transmission of the film decreases with increase in Al concentration and annealing effect. The average percentage of transmission of all the thin film samples is lies between (25% - 85%) in visible region. The optical band gap of the deposited Al - SnO_2 thin films are calculated by using the following formula [19]

$$(\alpha h\nu) = (h\nu - Eg)^{1/2} \quad (1)$$

Where α (m^{-1}) is the absorpation coefficient h (J.S) is Planck's constant ν (HZ) is the photon frequency Eg (eV) is the band gap energy. Figure (3a), (3b) and (3c) show the Tauc's plot drawn between $(\alpha h\upsilon)^2$ and hυ (eV). As seen from these figures, the band gap energy was found to be 4% to 8% aluminum content at deposition temperature 400ºC (prepared), annealing at 500ºC and annealing at 600ºC. The calculated direct band gap values of Al - SnO_2 films lay in the range 3.62 eV to 2.63ev for Al doped and un doped SnO_2 respectively. Which are also comparable with the values already reported 3.604 to 4.105 eV [20], 3.87 to 4.21eV [18]. The band gap narrows down due to the decrease in the number of charge carriers with increasing in Al doping and annealing temperature.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
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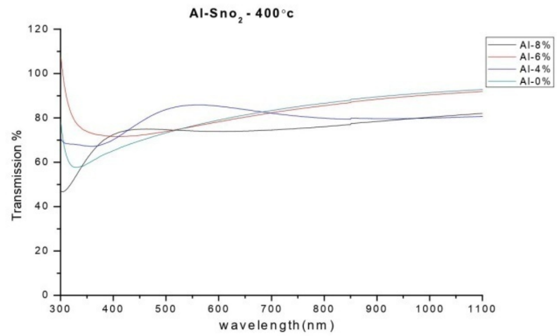

Fig. 2a Transmission spectrums of Al doped SnO_2 films deposited on glass substrates at 400ºC

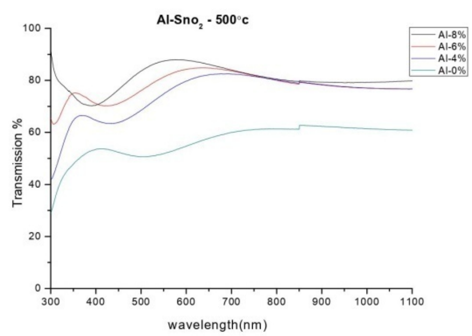

Fig. 2b Transmission spectrums of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

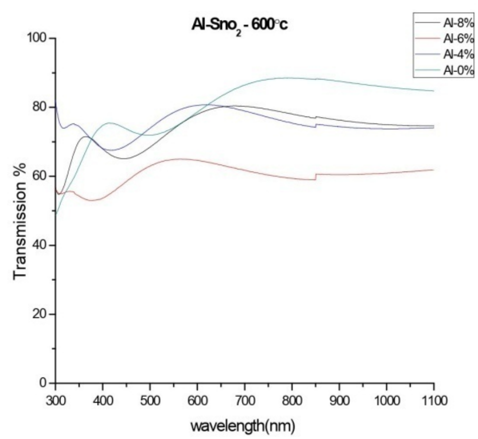

Fig. 2c Transmission spectrums of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

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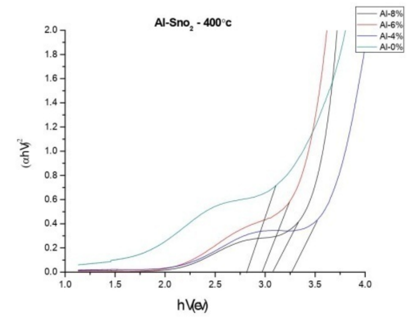

Fig. 3a Optical band gap of Al doped SnO_2 films deposited on glass substrates at 400ºC

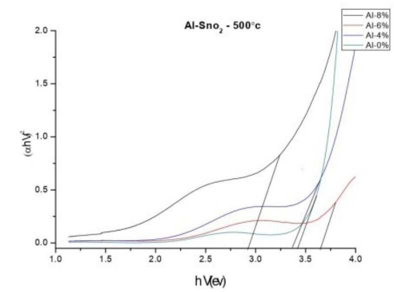

Fig. 3b Optical band gap of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

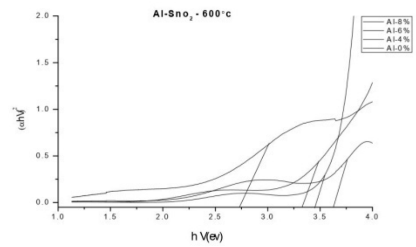

Fig. 3c Optical band gap of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

C. Morphological and Elemental Studies

In order to ascertain the film nature and the morphology, the prepared thin films have been examined by FESEM analysis. Figure (4a) showing the FESEM image of Undoped SnO_2 thin films prepared at the substrate temperature of T_S=400°C, Figures (4b), (4c) and (4d) are showing the FESEM images of 4%, 6%, and 8% of Al doped SnO_2 thin films prepared at the substrate temperature of T_S=400°C and annealed temperature at 500°C and 600°C respectively. Those figures show the crack-free and dense nature of the thin film formation. But there are agglomerated particles present on the film surface. Increasing the doping concentration leads to decrease of agglomeration. In all the cases FESEM images depicted the clear and dense nature of the film surface with homogeneous distributions of spherical shaped nanoparticles. The size of the particle was measured from FESEM images and it was found to be in the range of 40-54nm. Also the increase of particle size with increased of annealing temperature caused by the grain growth.

The presence of aluminum in the SnO_2 thin films (prepared at T_S=400°C and annealed temperature at 500°C and 600°C) was confirmed by EDAX spectra Figures (5a), (5b) and (5c). All the EDAX spectra showed the Al peaks and some other peaks are also found which is due to the substrate. The peaks show the element that has been detected from the sample confirming the presence of Al, Sn and Oxygen in Al - SnO_2 thin films.

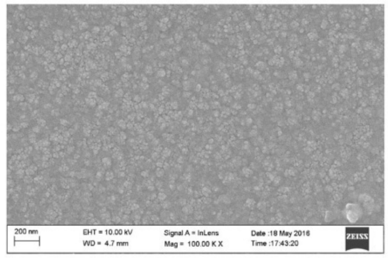

Fig. 4a FESEM of undoped SnO_2 films deposited on glass substrates at 400ºC

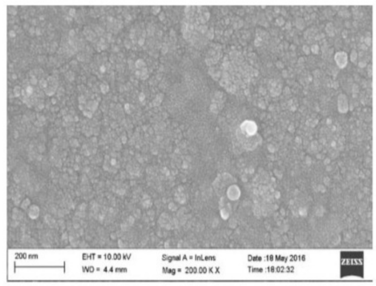

Fig. 4b FESEM of Al doped SnO_2 films deposited on glass substrates at 400ºC

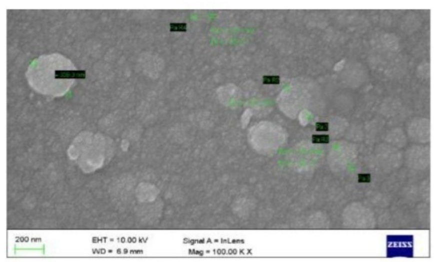

Fig. 4c FESEM of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

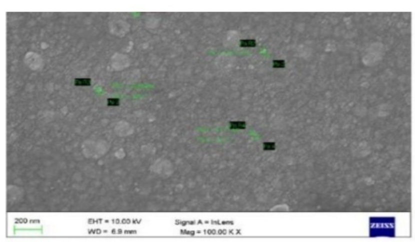

Fig. 4d FESEM of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

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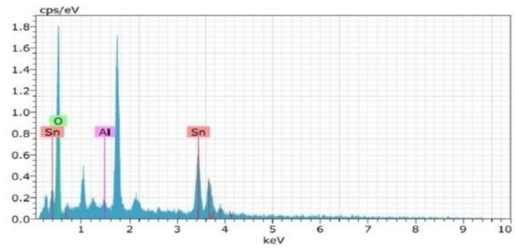

Fig. 5a EDAX of Al doped SnO_2 films deposited on glass substrates at 400ºC

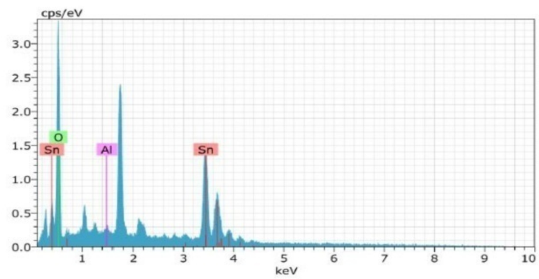

Fig. 5b EDAX of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

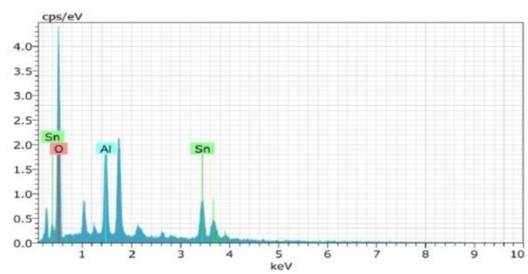

Fig. 5c EDAX of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

D. AFM Analysis

The prepared thin films have been subjected to analyze the topography and nanostructure of the prepared Al doped SnO_2 thin films and the corresponding 3D AFM, Figure (6) showing the AFM image of Undoped SnO_2 thin film. The Figure 6a shows the homogeneously distributed crystallites. As seen from the figure 6b and 6c, the crystallites have grown from the inner towards the surface. This indicates that the growth of crystallites at 500°C has been faceted towards the top of the surface and looking like nano tips. There is no any presence of voids in the films. The average root mean square roughness (R_{ms}) values of the film (20nm) determined using the relation [13]. The estimated crystallite size is in consistent with the crystallite size measured from XRD data. A similar kind of topography was found in the literature [14]. Furthermore, increasing the annealing temperature caused the agglomeration.

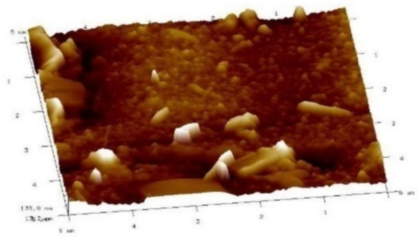

Fig. 6a AFM image of undoped SnO_2 films deposited on glass substrates at 400ºC

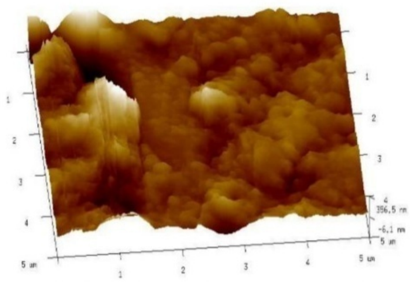

Fig. 6b AFM image of Al doped SnO_2 films deposited on glass substrates at 400ºC

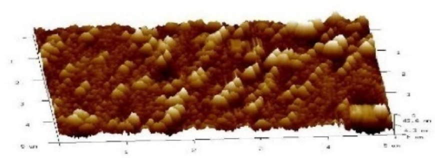

Fig. 6c AFM image of Al doped SnO_2 films deposited on glass substrates annealing at 500ºC

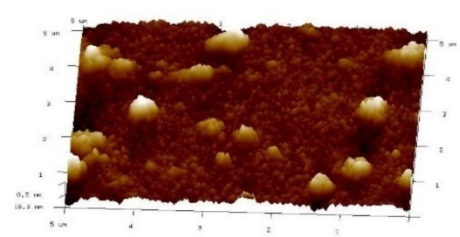

Fig. 6d AFM image of Al doped SnO_2 films deposited on glass substrates annealing at 600ºC

IV. CONCLUSION

Aluminium doped SnO_2 nanocrystalline thin films have been successfully deposited onto glass substrate using simplified low coast homemade Spray pyrolysis technique with various of aluminum concentration (4%, 6%, 8%) and annealing at 500ºC and 600ºC. The effect of Al concentration and annealing to influence the changes of physical properties in Al: SnO_2 thin films, the presence of SnO_2 with tetragonal crystal structure were confirmed by XRD analysis and the average crystallite was estimated to be 45nm. The X-ray diffraction patterns confirmed the proper phase formation of material and EDAX studies of the films showed that the exact amount of Al in the films are less that taken in the solution. FESEM images demonstrated the presence of nano sized particles and substantiated the presence of Al, Sn and O elements. The prepared thin films are having good transparency (65%-85%) in the visible range, in the visible region and the transparency decreases with the increase of Al doping and annealing effect in the films. The direct allowed band gap of the films has been found to lie with the range of 2.6 to 3.6eV. More interesting the particle size, band gap decreasing with increasing Al concentration and annealing temperature. AFM image showed the dense and nanotips like topography for the thin films annealed at 500°C. High electrical conductivity and high carrier concentration that we obtained are quite promising for gas sensing devices and solar cell application.

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Influence of zinc sulphate on the corrosion resistance of L80 alloy immersed in sea water in the absence and presence of sodium potassium tartrate and trisodium citrate	Dr.V. Johnsirani Assistant Professor of Chemistry	Chemistry	*Int. J. Corros. Scale Inhib*	2020	**ISSN : 2305 - 6894**	http://ijcsi.pro/papers/influence-of-zinc-sulphate-on-the-corrosion-resistance-of-l80-alloy-immersed-in-sea-water-in-the-absence-and-presence-of-sodium-potassium-tartrate-and-trisodium-citrate/

Influence of zinc sulphate on the corrosion resistance of L80 alloy immersed in sea water in the absence and presence of sodium potassium tartrate and trisodium citrate

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Abstract

Seawater can be used in cooling water systems. L80 can be used as pipeline carrying sea water. However, this alloy will undergo corrosion. Corrosion can be prevented by addition of inhibitors such as sodium potassium tartrate (SPT), trisodium citrate (TSC), and zinc sulphate. Corrosion resistance of L80 alloy in sea water in the absence and presence of the above inhibitors has been evaluated by polarisation study and AC impedance spectra. It is observed that SPT and TSC show better inhibition efficiency in the presence of Zn^{2+}. Further it is found that SPT–Zn system is better than the TSC-Zn system. When the SPT or TSC inhibitor is added to sea water, a protective film is formed on the metal surface. This prevents the transfer or release of electrons from the metal surface to the bulk of the solution. Thus corrosion is controlled. This is revealed by the fact that, during polarisation study, the linear polarisation resistance value increases and corrosion current value decreases. During electrochemical impedance study, charge transfer value increases and double layer capacitance value decreases. In the presence of Zn^{2+}, corrosion resistance of the metal further increases, which is supported by the fact that the linear polarisation resistance value further increases and corrosion current value further decreases. Similarly during electrochemical impedance study, the charge transfer resistance increases tremendously and the double layer capacitance value decreases to a great extent. It is inferred that in the presence of Zn^{2+}, more inhibitor is transported towards the metal surface as a Zn^{2+}–inhibitor complex. On the metal surface, an iron inhibitor complex is formed on the anodic sites of the metal surface and Zn^{2+} is released. The released Zn^{2+} combines with OH^- to form $Zn(OH)_2$ on the cathodic sites of the metal surface. Thus in the presence of Zn^{2+}, both anodic reaction and cathodic reaction are controlled effectively. This accounts for the increase in corrosion resistance of metal in sea water in the presence of inhibitor and Zn^{2+}.

Keywords: *corrosion inhibition, seawater, sodium potassium tartrate, trisodium citrate, polarisation study, AC impedance spectra, L80 alloy.*

Received: June 25, 2020. Published: August 10, 2020 doi: 10.17675/2305-6894-2020-9-3-12

Introduction

Seawater makes up the oceans and seas, covering more than 70 percent of Earth's surface. Seawater is a complex mixture of 96.5 percent water, 2.5 percent salts, and smaller amounts of other substances, including dissolved inorganic and organic materials, particulates, and a few atmospheric gases [1]. Almost anything can be found in seawater. This includes dissolved materials from Earth's crust as well as materials released from organisms. The most important components of seawater that influence life forms are salinity, temperature, dissolved gases (mostly oxygen and carbon dioxide) and nutrients [2].

Seawater can be used in cooling water systems, especially in ships and in marine environments. In these systems L80 alloy can be used to carry out the seawater. Hence knowledge of corrosion resistance of L80 alloy in seawater in presence of inhibitors will be useful. Corrosion resistance of aluminium and its alloys [3, 4], zinc and its alloys [5, 6], copper and its alloys [7, 8], mild steel [9, 10], stainless steel [11, 12], nickel and its alloys [13, 14] in seawater has been evaluated. Corrosion inhibitors such as, inorganic compounds [15, 16] and natural products [17, 18] have been used to prevent the corrosion of metals and alloys. In the present study corrosion resistance of L80 alloy in seawater in presence of sodium potassium tartrate (SPT) and trisodium citrate (TSC) has been evaluated by electrochemical studies such as polarization study and AC impedance spectra. Influence of Zn^{2+} on the corrosion resistance of the above systems has also been evaluated.

Experimental

Electrochemical studies

In the present work corrosion resistance of L80 alloy immersed in various test solutions were measured by polarization study and AC impedance spectra.

Polarization study

In the present study polarization studies were carried out in a CHI Electrochemical work station/analyzer, model 660A. It was provided with automatic IR compensation facility. A three electrode cell assembly was used (Figure 1).

The working electrode was L80 alloy. A SCE was the reference electrode. Platinum was the counter electrode. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit potential. The working electrode and the platinum electrode were immersed in sea water in the absence and presence of inhibitor. Saturated calomel electrode was connected with the test solution through a salt bridge. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic =

b_a and cathodic = b_c and *LPR* (linear polarisation resistance) value were determined. The scan rate was 0.01 V/s. The hold time at (E_{fcs}) was zero and the quiet time was 2 seconds.

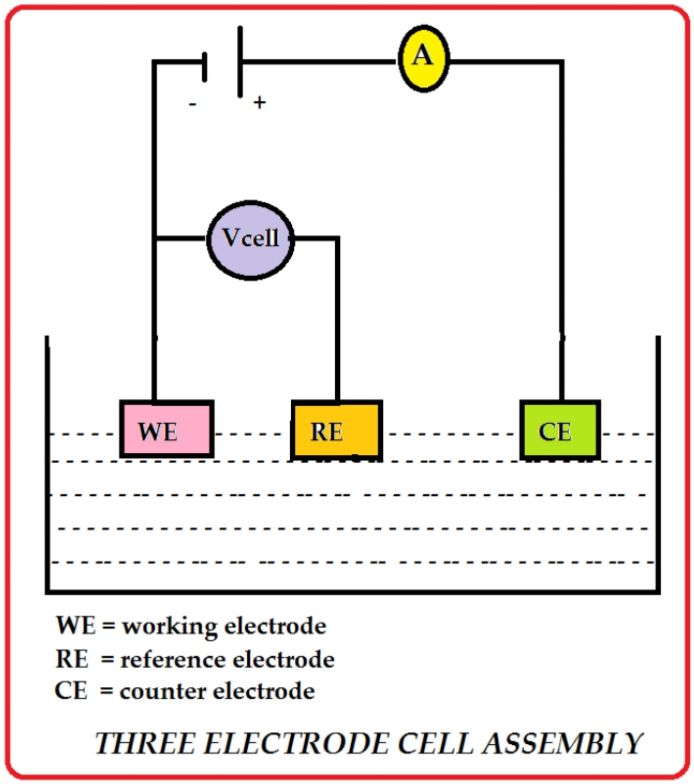

Figure 1. Three electrode cell assembly.

AC Impedance spectra

In the present investigation the same instrument and set-up used for polarization study was used to record AC impedance spectra also. A time interval of 5 to 10 min was given for the system to attain a steady state open circuit potential. The real part (Z′) and imaginary part (*Z*″) of the cell impedance were measured in ohms at various frequencies. AC impedance spectra were recorded with initial *E*(V) = 0, high frequency (Hz = $1\cdot10^5$), low frequency (Hz = 1), amplitude (V) = 0.005 and quiet time (s) = 2. From Nyquist plot the values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated.

$$R_t = (R_s + R_t) - R_s$$

Where R_s = solution resistance.

C_{dl} values were calculated using the relationship

$$C_{dl} = 1/2 \cdot 3.14 \cdot R_t \cdot f_{max}$$

Where f_{max} = frequency at maximum imaginary impedance.

Sea water

The composition of sea water used in this study is given in Table 1. Sea water was collected in Bay of Bengal, located at Kanampadi, East Coast Road, Chennai, India.

Table 1. Composition of sea water.

Physical Examination	Acceptable Limit	Permissible limit	Sample Value
1. Colour	–	–	Colourless & Clear
2. Odour	Unobjectionable		Unobjectionable
3. Turbidity NT Units	1	5	0.2
4. Total dissolved solids mg/L	500	2000	29400
5. Electrical conductivity $\mu Ohm^{-1}/cm$	–	–	42000
Chemical Examination	**Acceptable Limit**	**Permissible limit**	**Sample Value**
6. pH	6.5–8.5	6.5–8.5	7.46
7. pH Alkalinity as $CaCO_3$	–	0	0
8. Total alkalinity as $CaCO_3$	200	600	140
9. Total hardness as $CaCO_3$	200	600	4000
10. Calcium as Ca	75	200	1200
11. Magnesium as Mg	30	100	240
12. Iron as Fe	0.1	1	0
13. Manganese as Mn	0.1	0.3	NT
14. Free ammonia as NH_3	0.5	0.5	0.48
15. Nitrite as NO_2	0.5	0.5	0.104
16. Nitrate as NO_3	45	45	25
17. Chloride as Cl	250	1000	15000
18. Fluoride as F	1	1.5	1.8
19. Sulphate as SO_4	200	400	1170
20. Phosphate as PO_4	0.5	0.5	1.47
21. Tids test 4 hrs as O_2	–	–	NT

L80 Alloy

Manufactured to API specification 5CT. This is a controlled yield strength material with a hardness testing requirement. L80 is usually used in wells with sour (hydrogen sulfide) environments. Chemical composition of L80 alloy is given in Table 2.

Table 2. Chemical composition of L80 alloy.

	C	Mn	Mo	Cr	Ni	Cu	Ti	P	S	Si	V	Al
Min	–	–	–	–	–	–	–	–	–	–	–	–
Max	0.430	1.900	–	–	0.250	0.350	–	0.030	0.030	0.450	–	–

The remaining *Wt*% was iron.

Inhibitors used

Pure samples of sodium potassium tartrate (SPT), trisodium citrate (TSC) and zinc sulphate were used as corrosion inhibitors.

Results and Discussion

Electrochemical studies

In the present work corrosion resistance of L80 alloy immersed in various test solutions were measured by polarization study and AC impedance spectra.

L80 alloy–sodium potassium tartrate (SPT) system

Polarization study

The polarization parameters are given in Table 3. The polarization curves are shown in Figures 2–4. It is seen from Table 3 that when SPT is added to sea water, the corrosion resistance of L80 alloy increases. This is revealed by the fact that when SPT is added to sea water, the *LPR* values increases and I_{corr} value decreases (Figures 2–5).

Table 3. Corrosion parameters of L80 alloy immersed in sea water in the absence and presence of SPT and zinc sulphate ($ZnSO_4 \cdot 7H_2O$) obtained by polarization study.

System	E_{corr} mV SCE	b_c mV/decade	b_a mV/decade	*LPR* Ohm·cm^2	I_{corr} A/cm^2
Sea water	–830	161	221	355	$1.138 \cdot 10^{-4}$
Sea water + SPT (300 ppm)	–822	119	212	677	$4.908 \cdot 10^{-5}$
Sea water + SPT (300 ppm) + $ZnSO_4$ (100 ppm)	–537	209	252	$2.388 \cdot 10^{7}$	$2.079 \cdot 10^{-9}$

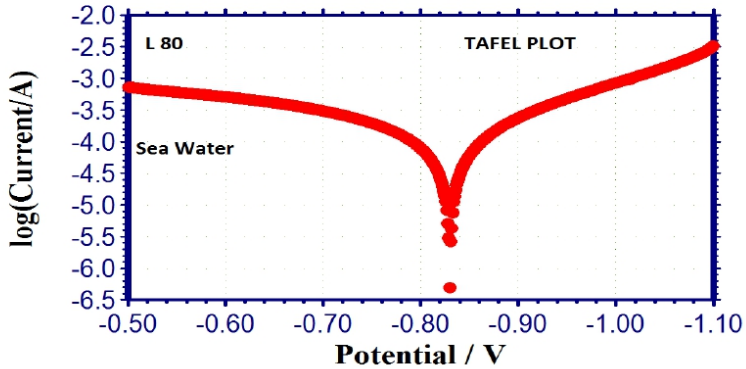

Figure 2. Polarisation curve of L80 alloy immersed in sea water.

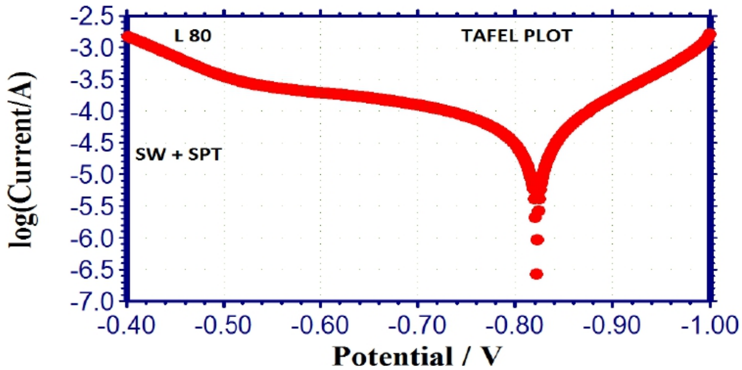

Figure 3. Polarisation curve of L80 alloy immersed in sea water + SPT.

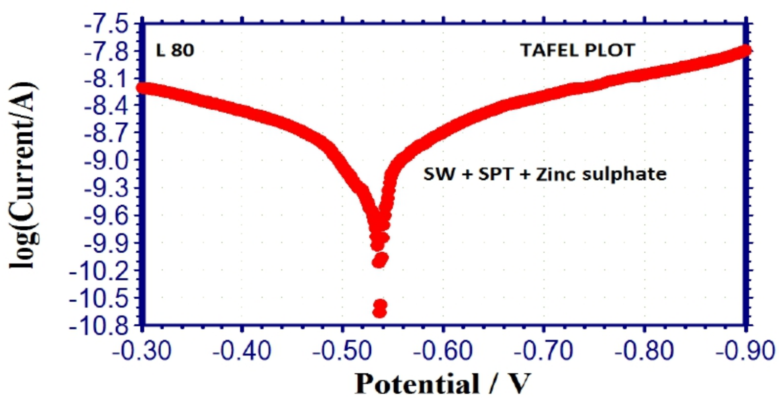

Figure 4. Polarisation curve of L80 alloy immersed in sea water + SPT + zinc sulphate.

Influence of zinc sulphate ($ZnSO_4·7H_2O$)

When $ZnSO_4·7H_2O$ is added to the above system, the *LPR* value increases tremendously to a very great extent Figure 5 and the I_{corr} decreases very much. This indicates that in presence of SPT–$ZnSO_4·7H_2O$ system the corrosion resistance of L80 alloy in sea water increases to a great extent. A protective film is formed on the metal surface. This protective film is compact and very stable. This prevents transfer of electrons from anodic site to cathodic site. Hence *LPR* value increases which results in decrease in corrosion current value. In addition a synergistic effect exists between SPT and Zn^{2+} ions.

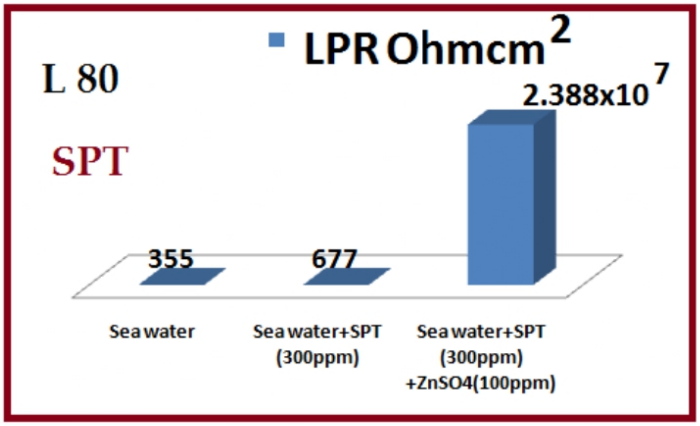

Figure 5. Comparison of *LPR* values.

AC impedance spectra

The AC impedance spectra (Nyquist plots, Bode plots) of L80 alloy immersed in various test solutions are shown in Figures 6–11. The corrosion parameters are given in Table 4. It is observed from Table 4, that when SPT is added to sea water, the corrosion resistance of L80 alloy increases. This is revealed by the fact that there is increase in R_t value, impedance value and decrease in C_{dl} value.

Table 4. Corrosion parameters of L80 alloy immersed in sea water in the absence and presence of SPT and Zinc sulphate ($ZnSO_4·7H_2O$) obtained by AC impedance spectra.

System	R_t Ohm·cm²	C_{dl} F/cm²	Impedance Log(z/Ohm)	Phase angle (degree)
Sea water	5.026	$0.010x10^{-4}$	0.9149	22.03
Sea water + SPT (300 ppm)	5.653	$9.021x10^{-7}$	0.9604	24.01
Sea water + SPT (300 ppm) + $ZnSO_4$ (100 ppm)	$1.281·10^{7}$	$3.982·10^{-13}$	7.123	96.33

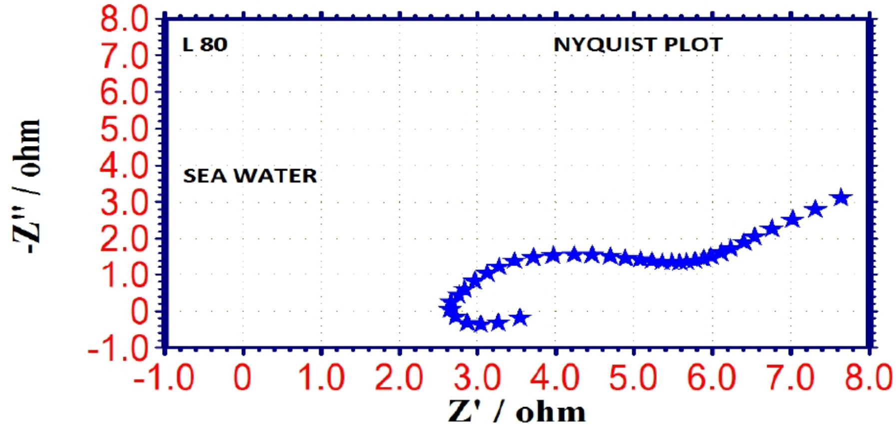

Figure 6. AC impedance spectra (Nyquist plot) of L80 alloy immersed in sea water.

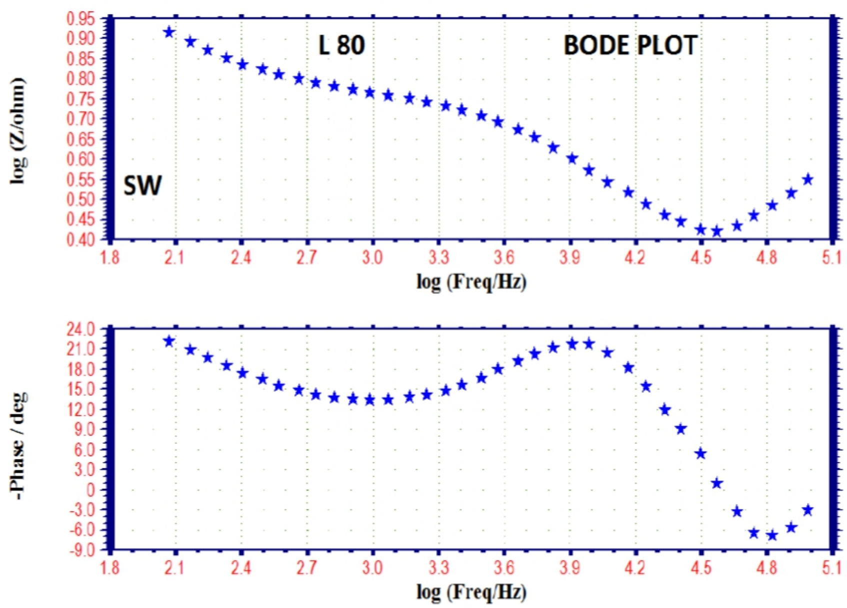

Figure 7. AC impedance spectra (Bode plot) of L80 alloy immersed in sea water.

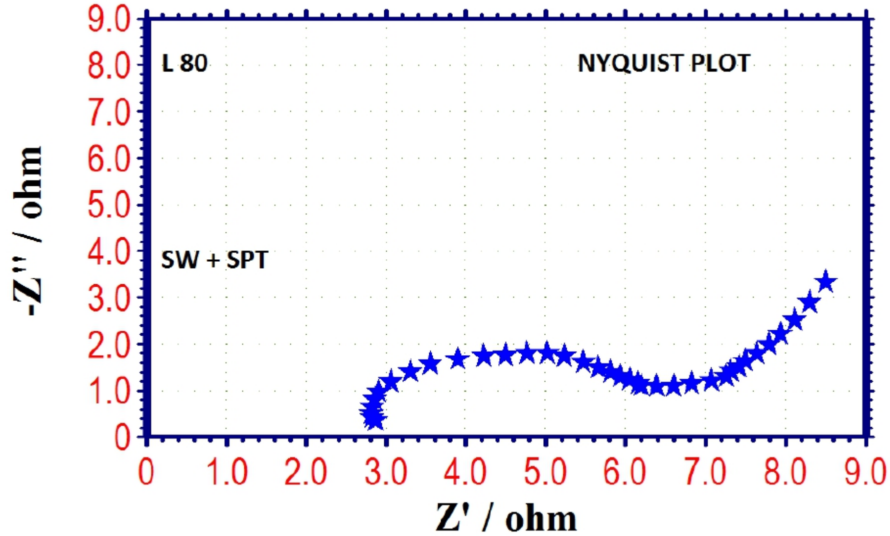

Figure 8. AC impedance spectra (Nyquist plot) of L80 alloy immersed in sea water + SPT.

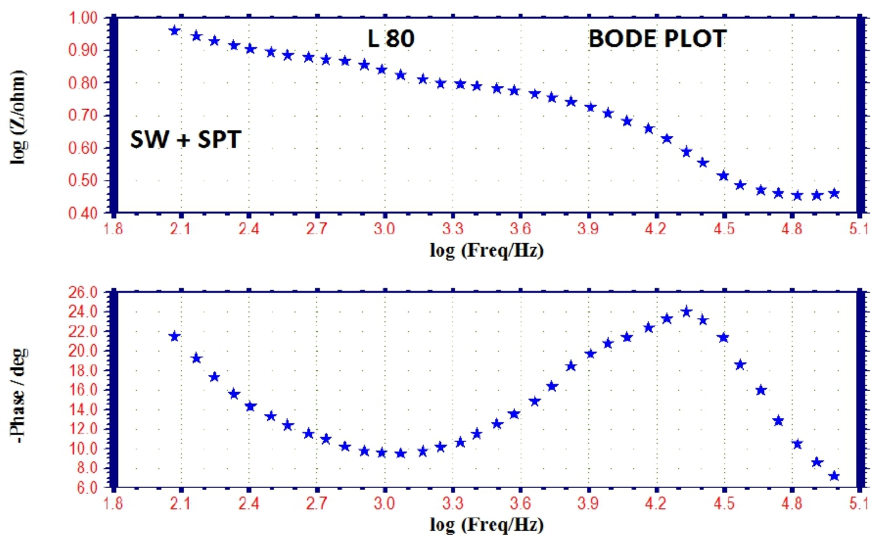

Figure 9. AC impedance spectra (Bode plot) of L80 alloy immersed in sea water + SPT.

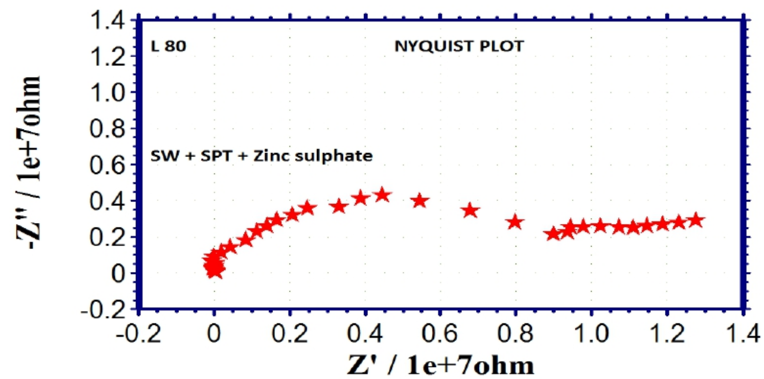

Figure 10. AC impedance spectra (Nyquist plot) of L80 alloy immersed in sea water + SPT + zinc sulphate.

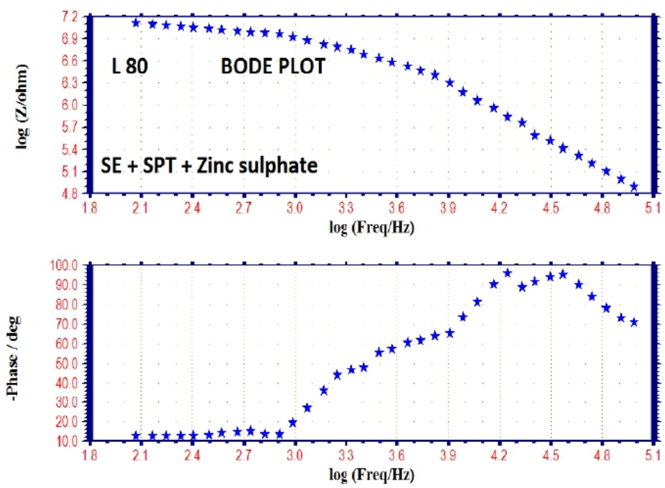

Figure 11. AC impedance spectra (Bode plot) of mild steel immersed in sea water + SPT + $ZnSO_4$.

Influence of zinc sulphate ($ZnSO_4 \cdot 7H_2O$)

When $ZnSO_4 \cdot 7H_2O$ is added to the above SPT system, the corrosion resistance further increases (Figure 12). This is revealed by the fact that there is increase in R_t value and impedance value. There is decrease in C_{dl} value. The tremendous increase in R_t value is due to the synergistic effect existing between TSC and Zn^{2+}. Thus electrochemical studies reveal that the corrosion resistance of L80 alloy in sea water decreases in the following order:

Sea water + SPT + $ZnSO_4$ > Sea water + SPT > Sea water

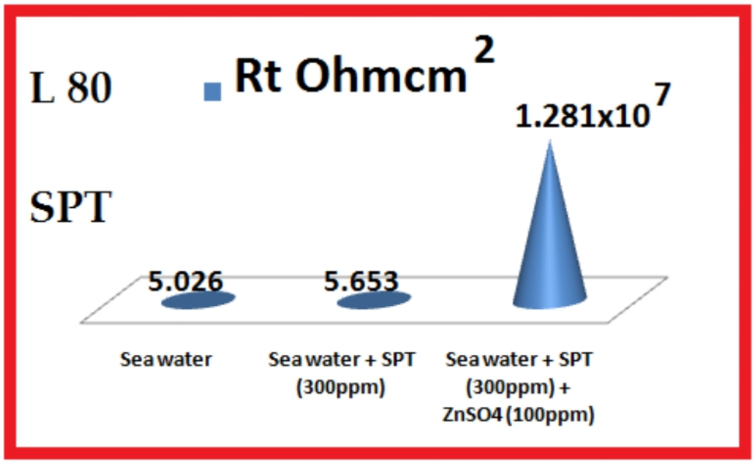

Figure 12. Comparison of R_t values.

L80 Alloy – TSC system

Polarization study

The polarization parameters of L80 alloy immersed in sea water in presence of TSC system are given in Table 5. The polarization curves are shown in Figures 13 and 14. It is seen from Table 5 that when TSC is added to sea water, the corrosion resistance of L80 alloy increases. This is revealed by the fact that when TSC is added to sea water, the *LPR* value increases and I_{corr} value decreases (Figures 13, 14). There is formation of a protective film on the metal surface. So transfer of electron from anodic site to cathodic site is restricted. Hence *LPR* value increases and correspondingly corrosion current value decreases.

Table 5. Corrosion parameters of L80 alloy immersed in sea water in the absence and presence of TSC and zinc sulphate ($ZnSO_4 \cdot 7H_2O$) obtained by polarization study.

System	E_{corr} mV SCE	b_c mV/decade	b_a mV/decade	*LPR* Ohm·cm²	I_{corr} A/cm²
Sea water	–830	161	221	355	$1.138 \cdot 10^{-4}$
Sea water +TSC (300 ppm)	–761	165	232	391	$1.076 \cdot 10^{-4}$
Sea water +TSC (300 ppm) + $ZnSO_4$ (100 ppm)	–704	146	209	465	$8.044 \cdot 10^{-5}$

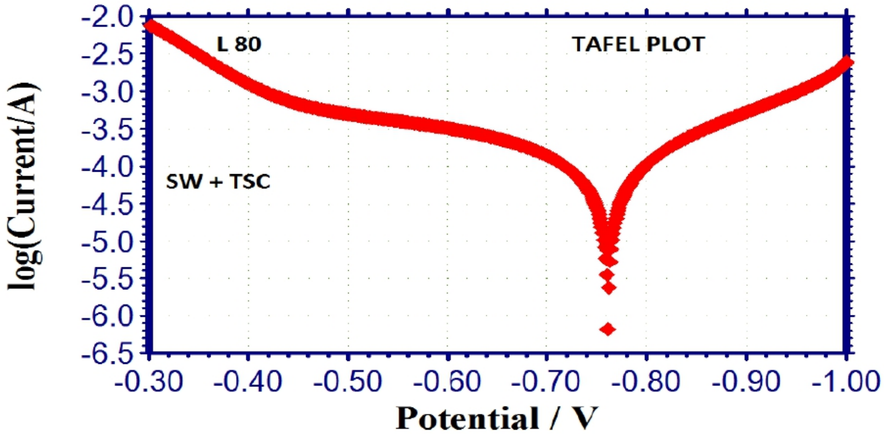

Figure 13. Polarisation curve of L80 alloy immersed in sea water + TSC.

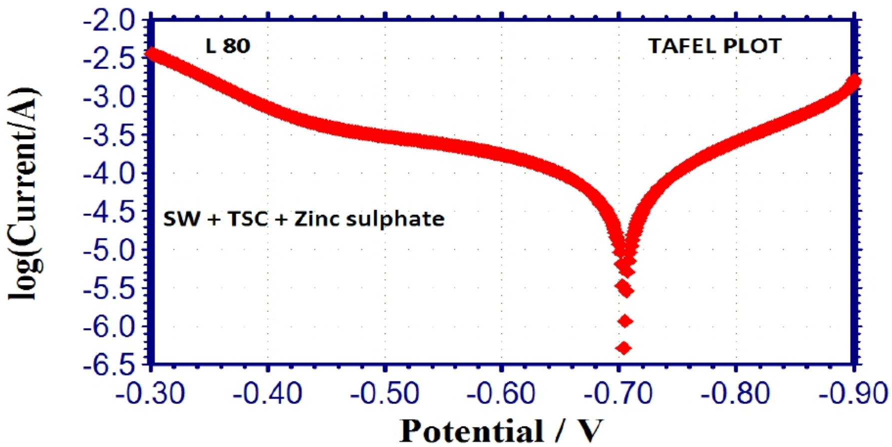

Figure 14. Polarisation curve of L80 alloy immersed in sea water + TSC + zinc sulphate.

Influence of zinc sulphate ($ZnSO_4 \cdot 7H_2O$)

When $ZnSO_4 \cdot 7H_2O$ is added to the above system, the *LPR* value increases tremendously to a very great extent (Figure 15) and the I_{corr} decreases very much. This indicates that in presence of SPT–$ZnSO_4 \cdot 7H_2O$ system the corrosion resistance of L80 alloy in sea water increases to a great extent. This is due to the synergistic effect existing between SPT and Zn^{2+}.

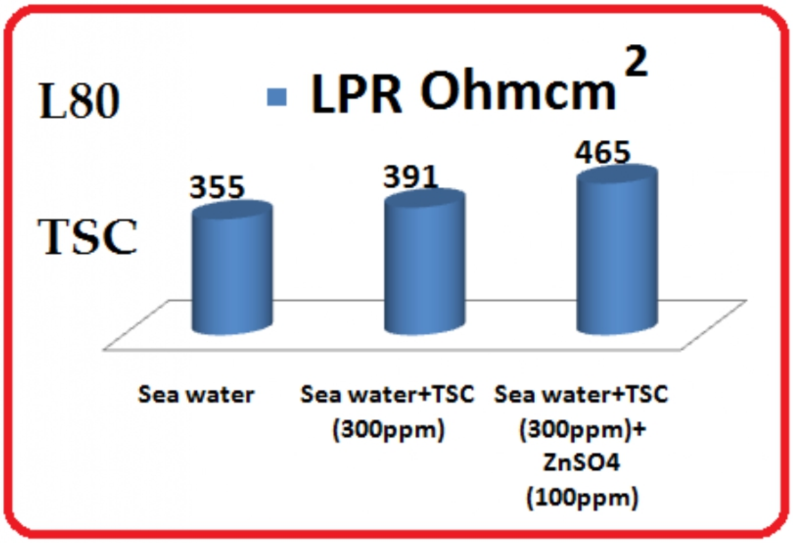

Figure 15. Comparison *LPR* values.

AC impedance spectra

The AC impedance spectra (Nyquist plots, Bode plots) of L80 alloy immersed in various test solutions are shown in Figures 16–19. The corrosion parameters are given in Table 6. It is observed from Table 6 that when TSC is added to sea water, the corrosion resistance of L80 alloy increases. This is revealed by the fact that there is increase in R_t value, impedance value and decrease in C_{dl} value.

Table 6. Corrosion parameters of L80 alloy immersed in sea water in the absence and presence of TSC and Zinc sulphate ($ZnSO_4 \cdot 7H_2O$) obtained by AC impedance spectra.

System	R_t Ohm·cm²	C_{dl} F/cm²	Impedance Log(z/Ohm)	Phase angle degree
Sea water	5.026	$0.010 \cdot 10^{-4}$	0.9149	22.03
Sea water + TSC (300 ppm)	6.282	$0.022 \cdot 10^{-4}$	0.9671	26.22
Sea water + TSC (300 ppm) + $ZnSO_4$ (100 ppm)	7.077	$7.206 \cdot 10^{-7}$	1.021	28.84

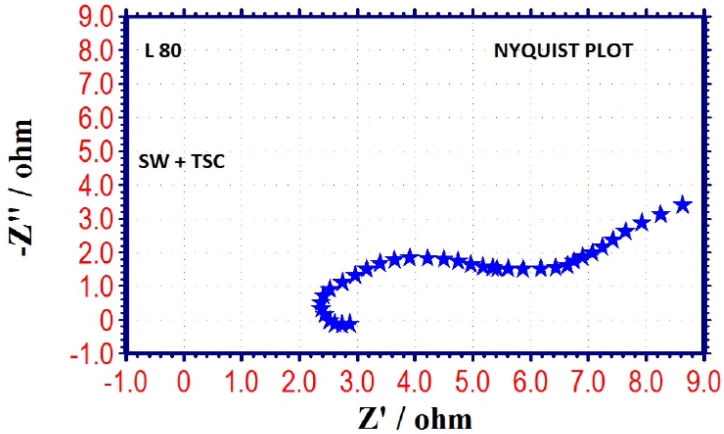

Figure 16. AC Impedance spectra (Nyquist plot) of L80 alloy immersed in sea water + TSC.

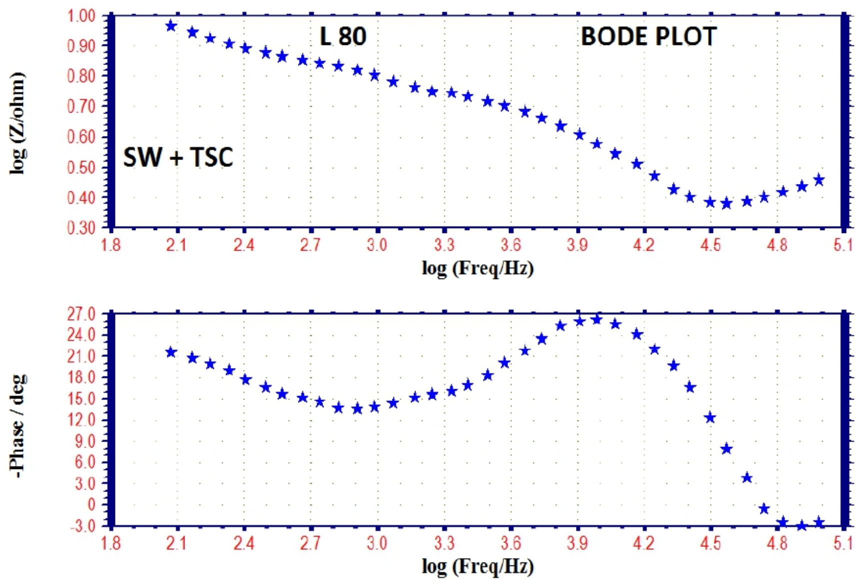

Figure 17. AC impedance spectra (Bode plot) of L80 alloy immersed in sea water + TSC.

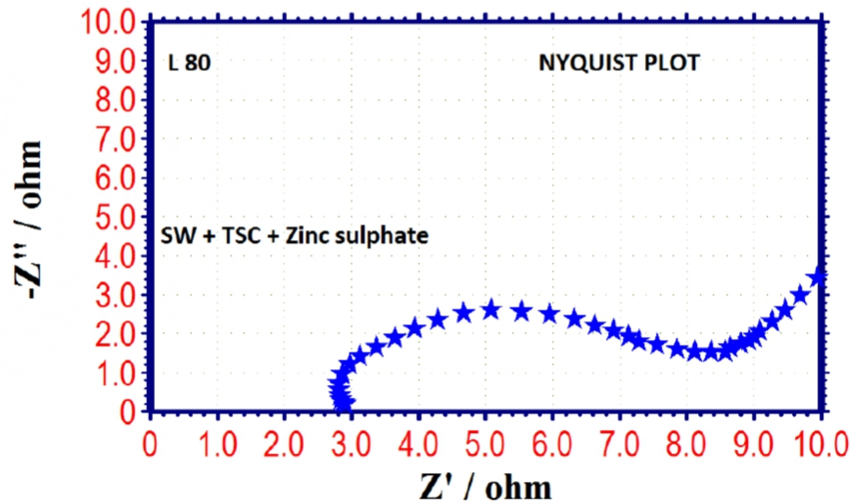

Figure 18. AC impedance spectra (Nyquist plot) of L80 alloy immersed in sea water + TSC + $ZnSO_4$.

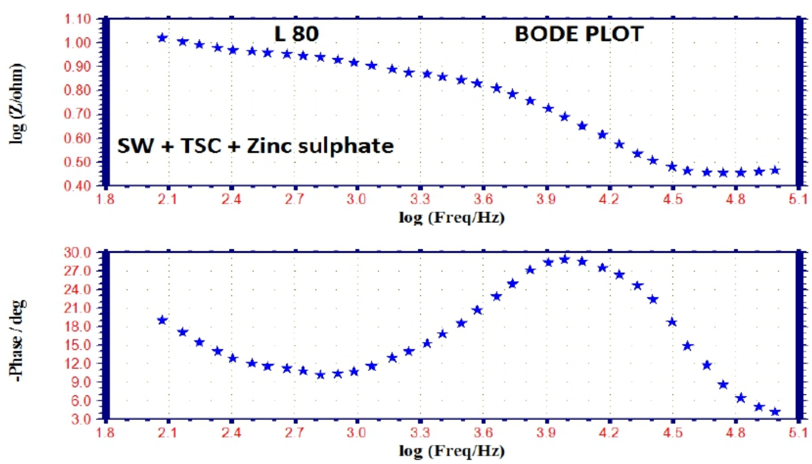

Figure 19. AC impedance spectra (Bode plot) of L80 alloy immersed in sea water + TSC + $ZnSO_4$.

Influence of zinc sulphate ($ZnSO_4 \cdot 7H_2O$)

When $ZnSO_4 \cdot 7H_2O$ is added to the above TSC system, the corrosion resistance further increases. This revealed by the fact that there is increase in R_t values (Figure 20) and impedance value. There is decrease in C_{dl}. Thus electrochemical studies such as polarisation study and AC impedance spectra [19–36] reveal that the corrosion resistance of L80 alloy in sea water decreases in the following order:

Sea water + TSC + $ZnSO_4$ > Sea water + TSC > Sea water

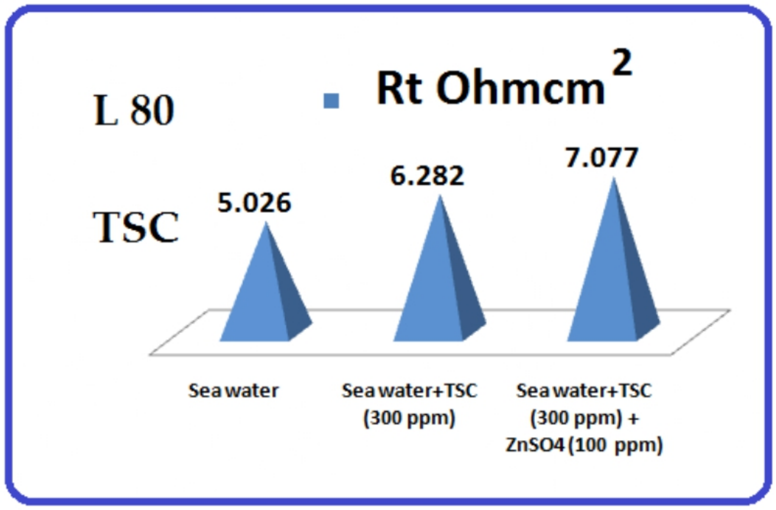

Figure 20. Comparison of R_t values.

Equivalent circuit diagram for the Nyquist plots

The Nyquist plots (Figures 6, 8, 10, 16 and 18) in the present study reveal that diffusion controlled reactions are involved in the corrosion controlling processes. The equivalent circuit diagram is shown is Figure 21.

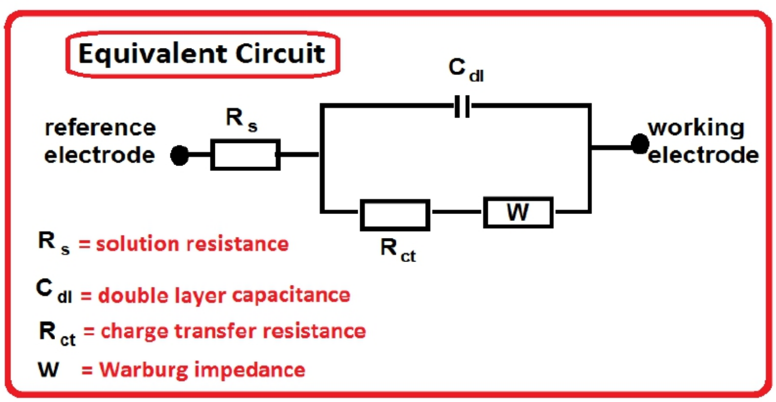

Figure 21. Equivalent circuit diagram for diffusion controlled process.

Mechanism of corrosion inhibition

In presence of Zn^{2+}, corrosion resistance of the metal further increases (better than the SPT/TSC system alone), which is supported by the fact that the linear polarisation resistance value further increases and corrosion current value further decreases. Similarly during electrochemical impedance study, charge transfer value increases tremendously and double layer capacitance value decreases to a great extent. It is inferred that in presence of Zn^{2+}, more inhibitor (SPT/TSC) is transported towards the metal surface, as Zn^{2+}–inhibitor complex. On the metal surface iron inhibitor complex is formed on the anodic sites of the metal surface and Zn^{2+} is released. The released Zn^{2+} combines with OH^- to form $Zn(OH)_2$ complex on the cathodic sites of the metal surface. Thus in presence of Zn^{2+}, both anodic reaction and cathodic reaction are controlled effectively. This accounts for the increase in corrosion resistance of metal in sea water in presence of inhibitor and Zn^{2+}. In presence of Zn^{2+} and inhibitor a loose complex is formed between Zn^{2+} and inhibitor. The bond between them is strong enough to carry the inhibitor to the metal surface and weak enough to release the inhibitor in presence of Fe^{2+} to form Fe^{2+}–inhibitor complex on the anodic sites of the metal surface (Figures 22 and 23).

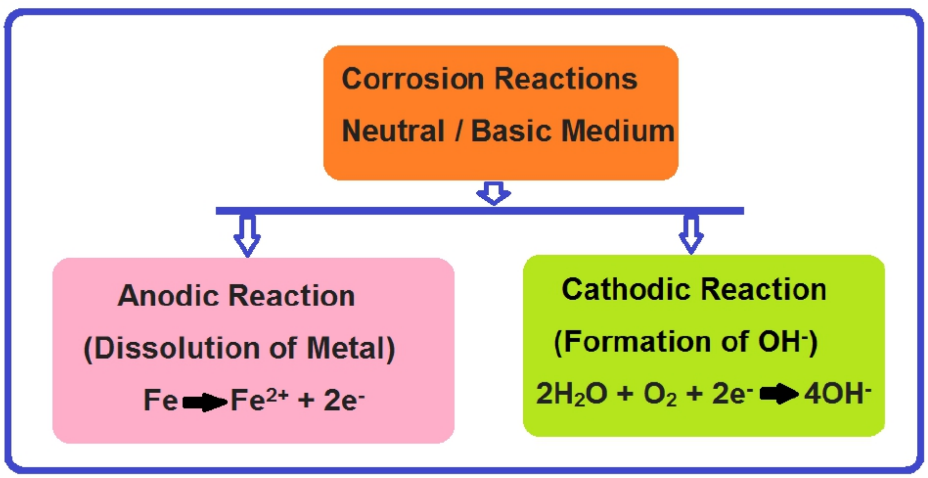

Figure 22. Anodic and cathodic reactions in corrosion process.

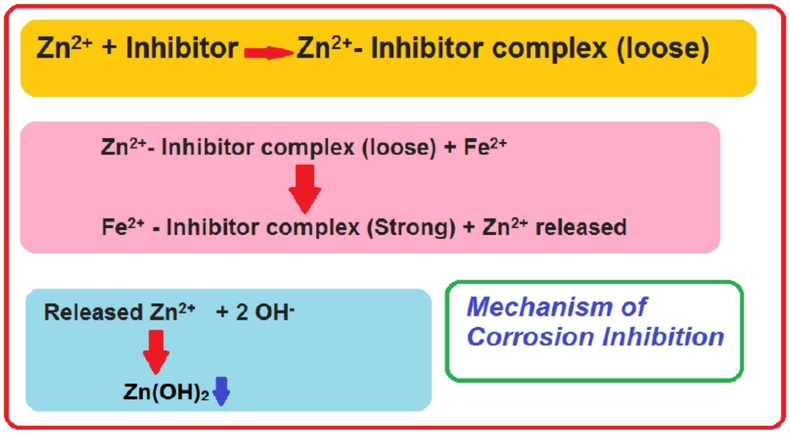

Figure 23. Corrosion inhibition mechanism.

Conclusion

The corrosion resistance of L80 alloy in sea water in the absence and presence of sodium potassium tartrate (SPT), trisodium citrate (TSC) and zinc sulphate ($ZnSO_4{\cdot}7H_2O$) has been evaluated by electrochemical studies such as polarization study and AC impedance spectra. The study leads to the following conclusions:

L80 alloy – SPT system

Electrochemical studies reveal that the corrosion resistance of L80 alloy in sea water decreases in the following order:

$$\text{Sea water} + \text{SPT} + ZnSO_4 > \text{Sea water} + \text{SPT} > \text{Sea water}$$

L80 alloy – TSC system

Electrochemical studies reveal that the corrosion resistance of L80 alloy in sea water decreases in the following order:

$$\text{Sea water} + \text{TSC} + ZnSO_4 > \text{Sea water} + \text{TSC} > \text{Sea water}$$

Addition of zinc sulphate improves the corrosion resistance of the TSC and SPT systems.

Acknowledgment

The authors are thankful to their respective managements for their help and encouragement. Special thanks to Rev. Dr. Antony Pushpa Ranjitham (Superior General), Rev. Sr. Thanaseeli Sengole (Asst. General), Rev. Sr. M. Margaret Inbaseeli (College Secretary), Rev.

Dr. Pramila (Principal), Rev. Sr. Gnana Soundari (Provincial) and Mrs J. Antony Justina Mary (Vice Principal) for their Prayer and Blessings.

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