"Study of Corrosion phenomenon in aluminium foils using NaOH electrolyte and sea water"

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by

Nehal Chandu Naik
22P0430023

Under the supervision of
Dr. Rajesh Kumar Shankar Hyam

School Of Physical and Applied Science
Physics discipline

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Examined by:

Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Study of Corrosion phenomenon in aluminium foils using NaOH electrolyte and sea water" is based on the results of investigations carried out by me in the Physics Discipline at the School of Physical and Applied Sciences, Goa University under the Supervision of Dr.Rajesh Kumar Shankar Hyam and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations / experimental or other findings given the dissertation.I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed.

Nnaik

Name: Mr.Nehal Chandu Naik

Roll no: 22P0430023

Discipline: Physics

School of Physical and Applied Sciences

Date: 8/5/24
Place: Goa University

COMPLETION CERTIFICATE

This is to certify that the dissertation "Study of Corrosion phenomenon in aluminium foils using NaOH electrolyte and sea water" is a bonafide work carried out by Mr. Nehal Chandu Naik under my supervision in partial fulfilment of the requirements for the award of the degree of M.Sc in Physics at the School of Physical and Applied Sciences, Goa University.

Supervisor: Dr. Rajesh Kumar Shankar Hyam

Physics

Date: 8/5/24

Dean: Prof. Ramesh. V. Pai

Physics

School of Physical and Applied Sciences

Date:

Place: Goa University

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Contents

1 Introduction

Corrosion is a natural process that converts a refined metal into a more chemically stable oxide It is the gradual deterioration of materials (usually a metal) by chemical or electrochemical reaction with their environment.Most commonly this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen, hydrogen, or hydroxide. Corrosion can also occur in materials other than metals, such as ceramics or polymers. A refined metal naturally undergoes corrosion to become a more chemically stable oxide. It is the process by which materials (often metals) gradually deteriorate due to chemical or electrochemical reactions with their surroundings.This most frequently refers to the electrochemical oxidation of metal in response to an oxidant such hydroxide, hydrogen, or oxygen. Materials other than metals, such as ceramics and polymers, can also experience corrosion.

2 The importance of corrosion Studies

- Studies on corrosion are important for two reasons. The first is financial, encompassing the mitigation of material losses due to the deterioration or unexpected breakdown of metal parts of machinery, tanks, ships, hulls, maritime structures, etc.
- The second is conservation, which is mainly used in relation to metal resources, of which there is a finite supply worldwide and whose waste includes the equivalent losses of energy and water resources that come with the manufacture and construction of metal structures.[1]

2.1 Factors affecting corrosion

- The metals' exposure to air that contains gases, such as CO_2, SO_2, SO_3, etc
- Metals exposed to moisture, particularly seawater, which accelerates corrosion.
- The existence of contaminants such as salt (NaCl, for instance).
- Temperature: Corrosion is accelerated by rising temperatures.

- Nature of the initial oxide layer formed: Certain oxides, such as Al_2O_3, can stop further corrosion by forming an insoluble protective coating. Some, like rust, degrade quickly and expose the remaining metal.
- Acidity of the atmosphere: Acids can quickly fasten the rusting process.[2]

2.2 Classification of Corrosion

All metallic materials are made up of atoms with shareable or donateable valency electrons. The elements of a metallic material undergo ionization in a corrosive environment, and the flow of the electrons creates a galvanic or electrochemical cell that causes elemental oxidation, reduction, dissolution, or simple diffusion.There are many types for corrosion, including direct oxidation, electrochemical corrosion, low temperature and high temperature corrosion, etc. Dry or chemical corrosion and wet or electrochemical corrosion are the two categories that are preferred.[3]

- Chemical corrosion: The metal turns into its oxide when it comes into contact with a reactive gas or non-conducting liquid.
- Electrochemical corrosion: When a metal is immersed in a conducting liquid that contains dissolved reactive material, a hydrous oxide coating forms. Because of the heterogeneity on the metal surface, which produces local anodic and cathodic sites on the metal, the reaction is considered to take place at the metal-solution interface.

3 Types of Corrosion

3.0.1 Uniform corrosion

Uniform corrosion is a type of corrosive attack in which the corroded areas occur in a manner evenly distributed across the material being attacked.Uniform corrosion can occur on many different materials. Steel, aluminum, copper and many other materials quite commonly become victims of uniform corrosion. A rusty bolt is an example item that has been affected by uniform corrosion.Although uniform corrosion can be incredibly devastating, it is typically easily detectable and readily preventable.[4]Uniform corrosion is readily preventable through various means to decrease a material's susceptibility to uniform corrosion such as:

(i) Galvanizing steel components.

(ii)Fixing a substance with a substitute anode.

(iii) Coating or painting a surface.

(iv)Uniform rusting can cause failure if ignored.When the material thins and weakens to the point where it can no longer fulfill its original purpose, it may continue to corrode throughout the exposed region.

3.0.2 Galvanic corrosion

When two dissimilar metals come into electrical contact in an electrolyte, the more active metal tends to corrode while the more noble metal is shielded from corrosion damage. This process is known as galvanic corrosion. In order for galvanic corrosion to happen, three requirements need to be fulfilled:

- Metals that are electrochemically different must exist.
- Metals must be in electrical contact.
- Metals must be exposed to an electrolyte.

The following are some of the main factors influencing galvanic corrosion rates:

- Potential difference between materials.
- Cathode efficiency.
- Surface areas of connected materials (area ratio).
- Electrical resistance of the connection between the materials and of the electrolyte.

Some of the most common techniques for avoiding galvanic corrosion include:

- Electrical Insulation
- Isolating the Electrolyte
- Appropriate Metal selection

- Apply Corrosion Inhibiting Compounds
- Minimize the Cathode to Anode Area Ratio:-

3.0.3 Localized corrosion

The term "localized corrosion" describes how quickly passive metals corrode in corrosive surroundings. It is defined by a severe attack on limited sections of the surface components, with much slower surface corrosion in the remaining area.

3.0.4 Crevice corrosion

The term "crevice corrosion" refers to the way a stagnant solution in small cracks, such as those surrounding rivet heads and nuts, attacks metal surfaces. An environment where water collects and corrodes the part is created when dust, sand, and other corrosive materials are deposited on surfaces. It can occur between a metal and a nonmetal or between two metals. This results in the metallic part being damaged, which is caused by the chemical concentration gradient. Crevice corrosion can be prevented by :-

- Use welded butt joints in place of riveted joints.
- Continuous welding and soldering will eliminate lap joint cracks.
- Empty the surfaces of any solutions that are still on them to prevent stagnation.
- Employ stronger alloys

3.0.5 Pitting

Pitting is a type of corrosion that occurs in materials that have protective films. It is an attack with localized holes on the metal's surface. The attack can penetrate the metal very rapidly, while some parts of the metal surface remain free from corrosion. Pitting is vigorous when the solution on the metal surface contains chloride, hypochlorite or bromide ions. Other harmful solutions are those that contain fluorides and iodides, while sulfides and water are known to enhance the pitting process.

Pitting corrosion can be controlled by:

- Use of a more resistant material
- Ensuring that the fluids that are in contact with the material are either washed away or are injected at a high velocity.
- Use of cathodic protection
- Avoiding stagnant zones

3.0.6 Inter granular corrosion

Similar to other elements, metals and alloys have microstructures that are referred to as grains. There are grain boundaries that divide all of the grains that can be found in metals. An attack around the grain border or along the boundaries of many grains in the metal, with the majority of the grain remaining unharmed, is known as intergranular corrosion.

3.0.7 Dealloying

Dealloying is an electrochemical reaction that results in the selective removal of one of an alloy's constituent elements, degrading the alloy's fundamental characteristics. The study of dealloying is significant because:

- It causes widespread damage and failures in specific alloys.
- Damage can be monitored and failures can be prevented.
- Heat treatment methods are being developed to avoid and minimize this type of corrosion.

3.0.8 Erosion corrosion

Erosion corrosion is the result of erosion and corrosion working together, and it is brought on by a turbulent fluid flowing quickly across a metal surface. Turbulence is mostly caused by pitting, which is frequently observed on the inner surfaces of pipes. In turbulent conditions, the rate of erosion accelerates and can cause leaks in pipelines and tubes. Inadequate construction might also lead to erosion and corrosion. Inner burrs in the tubes impede the fluid's smooth passage and create localized turbulence when they are not removed during installation. The following techniques can be used to minimize or prevent erosion corrosion:

- Reduce the turbulence of the fluid in the tube by streamlining the piping.
- Control the velocity of the fluid to reduce high-flow velocities.
- Ensure that the entire piping system has been de-burred.
- Reduce the amount of oxygen dissolved in the fluid.
- Adjust the pH value of the fluid.

3.0.9 Stress corrosion cracking (SCC)

Tensile stress and a corrosive environment work together to cause stress corrosion cracking (SCC), a gradual breaking that happens in metals. SCC can be controlled in numerous ways, including:

- Selecting a material that is not susceptibleto SCC
- Controlling stresses through careful design and minimizing stress
- Keeping concentrations below the critical value
- Reducing stresses through heat treatments
- Using corrosion inhibitors during cleaning operations
- Coating the material and effectively isolating the material from the environment..

3.0.10 Filiform corrosion

A type of corrosion known as filiform corrosion looks like tiny worms or filaments spreading beneath a metal's covering. This is where it only happens.It can only harm metals that have a coating because water entering through the coating and onto the metal surface initiates the corrosion process if the coating has any defects or irregularities.

4 Prevention of Corrosion

To prevent significant losses, corrosion prevention is crucial. Bridges, cars, machinery, and even home furnishings like doorknobs and window grills are all included in this. Metallic items can slow or avoid corrosion damage by using a variety of treatments. This is particularly applied to materials that are regularly subjected to adverse weather conditions, seawater, acids, or other environments. Electroplating, galvanization, anodization, passivation, biofilm coatings, anti-corrosion protective coatings, painting and lubricating, using corrosion inhibitors or drying agents, and periodic cleaning of metal surfaces are a few common ways to stop corrosion.

5 Characterization technique

5.1 Raman Spectroscopy

A non-destructive method of chemical investigation, Raman Spectroscopy yields precise data on molecular interactions, phase and polymorphy, crystallinity, and chemical structure. It is predicated on how light interacts with a material's chemical connections. A molecule scatters incident light from a high intensity laser light source using the Raman technique of light scattering. Rayleigh scattering is the term for the majority of scattered light that is at the same wavelength (or color) as the laser source and does not offer any meaningful information. Nonetheless, a tiny quantity of light is scattered at various colors or wavelengths according on the analyte's chemical composition. This phenomenon is known as Raman Scatter. Raman analysis of several types of samples Raman analysis is applicable to a wide range of samples. In general, it can be used for analysis of: Gases, liquids, gels, slurries, solids, and powders
Materials that are inorganic, organic, and biological
pure substances, mixtures, and combinations.
In general, it is inappropriate for analysis of: Metals and their alloys Typical applications for Raman nowadays include:

- Characterization of pigments, ceramics, and gemstones in art and archaeology
- Carbon materials: defect/disorder characterisation, nanotube structure and purity
- Structure, purity, and reaction monitoring in chemistry
- Geology: fluid inclusions, phase transitions, and mineral distribution and identification
- Life sciences: medication interactions, disease diagnosis, single cells and tissues

- Pharmaceutics: component distribution and consistency of substance
- Semiconductors: intrinsic stress/strain microscopy, alloy composition, and purity.

5.1.1 History of Raman Spectroscopy

The term Raman spectroscopy honors Sir Chandrasekhara Venkata Raman, an Indian physicist who was born in the old Madras Province of India and won the 1930 Nobel Prize in Physics for his groundbreaking work in the field of light scattering. Raman lived from November 7, 1888, to November 21, 1970. In 1921, while traveling around Europe, Raman observed that the Mediterranean Sea and glaciers were blue in color. He was driven to find out why blue was the color it was. Raman conducted tests that clarified the phenomenon by examining how light is scattered by transparent ice blocks and water. Raman used monochromatic light from a mercury arc lamp to record the spectrum of transparent material by allowing the light to pass through it and land on a spectrograph.He saw lines in the spectrum that were subsequently identified as Raman lines. On March 16, 1928, he presented his idea at a scientific conference in Bangalore. In 1930, he was awarded the Nobel Prize in Physics. There was first skepticism in Munich since several physicists were unable to replicate Raman's findings. But Peter Pringsheim was the first German to effectively duplicate Raman's findings, and he handed Arnold Sommerfeld his spectra. Pringsheim is credited with being the first to describe the "Raman effect" and "Raman lines".[1]

5.1.2 Working principle of Raman Spectroscopy

The Raman scattering phenomenon, which happens when a photon interacts with a molecule and causes a shift in its energy and wavelength, is the basic concept behind Raman spectroscopy. Most of the scattered photons from an interaction between a molecule and a monochromatic light source, such a laser, have the same energy and frequency as the incident photon. A tiny percentage of the scattered photons, however, will interact with the molecule's vibrational modes and have distinct frequencies as a result. The Raman shift, known as such because of its shift in frequency, is indicative of the chemical structure and surroundings of the molecule. The incident photon's interaction with the molecule's vibrational modes results in the Raman shift.The incident photon's interaction with the molecule's vibrational modes results in the Raman shift. The molecule vibrates at a specific frequency as a result of the interaction between the photon and the molecule, which creates a dipole moment in the molecule. Because of the interaction with the vibrating molecule, the scattered photon will therefore have a slightly different frequency than the incident photon. The chemical structure and vibrational modes of the molecule are revealed by this shift in frequency. There are two modes of Raman spectroscopy: anti-Stokes and Stokes scattering.[2]

5.1.3 Stokes and Anti-Stokes Scattering

When the scattered photon's energy and frequency are lower than the incident photon's, Stokes Raman scattering takes place. This happens as a result of the photon being dispersed and losing energy to the molecule in the process. At a frequency that is lower than the excitation laser frequency, Stokes lines can be seen in the Raman spectrum. The vibrational transitions from higher energy levels to lower energy levels are represented by the Stokes lines.[3]

When the scattered photon has a higher energy and frequency than the initially emitted photon, it is known as anti-Stokes Raman scattering. This happens when the photon that is dispersed gets energy from the molecule while it is being scattered. The Raman spectrum exhibits anti-Stokes lines with a frequency greater than that of the excitation laser. Vibrational transitions from lower to higher energy levels are represented by the anti-Stokes lines.The temperature of the sample has an impact on the strength of the Stokes and anti-Stokes lines. Because the Boltzmann distribution, which favors the lower energy levels at room temperature, determines the population of vibrational modes, the strength of the Stokes line is substantially stronger than that of the anti-Stokes line.Because of this, at room temperature, the Stokes line is substantially stronger than the anti-Stokes line.However, when the temperature rises, the number of higher energy states increases, increasing the anti-Stokes line's strength.

6 Synthesis and Corrosion studies of Aluminium

The chemical element aluminum has the atomic number thirteen and the symbol Al. It is a ductile, non-magnetic, silvery-white metal belonging to the boron group. After oxygen and silicon, it is the third most prevalent element in the Earth's crust. Because of its low density, high strength, resistance to corrosion, and good thermal and electrical conductivity, it is widely employed in a variety of industries.Aluminum is widely utilized in many different industries and is subjected to a variety of conditions, including water, air, and other chemicals. Studies on aluminum corrosion are crucial for enhancing the functionality, robustness, and safety of aluminum products across a range of industries and for reducing the negative effects of corrosion on the environment. [1] Through this project, we have learned about the phenomenon of aluminum corrosion at various concentrations. We have learned about the corrosion phenomenon of aluminum in various sodium hydroxide (NaOH) concentrations through this project. There are various reasons why researching aluminum corrosion in sodium hydroxide media is crucial. Sodium hydroxide is a chemical that is frequently used in many industrial processes, including the manufacturing of soap, textiles, and pulp and paper. In addition, it is utilized in the synthesis of other chemicals and as a cleaning agent.

7 Electrochemical cell

A device or system that can both use electrical energy to create chemical reactions and generate electrical energy from chemical reactions is known as an electrochemical cell.[2] The behavior of corrosion in metals and alloys is extensively studied through the use of electrochemical methods. Electrochemical cells, potentiostats or galvanostats, as well as a variety of electrodes and solutions, are commonly used in the setup for electrochemical corrosion investigations. The anode, cathode, and electrolyte solution make up the electrochemical cell, which is the central component of the apparatus. An external circuit connects the anode and cathode, and the electrolyte's reference electrode is inserted to measure the potential of the anode relative to a known standard. The circuit is completed and the current flow is balanced by a counter electrode.It is made up of two electrodes submerged in an electrolyte solution, an anode and a cathode. These are the fundamental parts of an electrochemical cell used to research corrosion.

- Anode: The electrode that corrodes is called the anode. The metal (in this case, aluminum) under analysis is usually used as the anode in metal corrosion studies.
- Cathode: The electrode where reduction reactions take place is called the cathode. Al-

though it can be formed of many different materials, inert materials like platinum are usually used in corrosion studies. The fluid that surrounds the electrodes and allows ions to move between them is known as the electrolyte.In my case, Sodium hydroxide is the electrolyte solution.

7.0.1 Working electrode

The working electrode is the electrode being studied (anode). In my case,it is the aluminium specimen. The Function of a Working Electrode: Between the working electrode and the reference electrode, a fixed potential difference is applied. The electrochemical reaction at the surface of the working electrode is driven by this potential. At the counter electrode, a current flowing in the opposite direction counters the current generated by the electrochemical reaction at the working electrode. The redox pair uses the reference electrode as a point of reference. The electrochemical reaction produces current, which is amplified and shows up as a peak on the recording device when plotted against time.

7.0.2 Auxiliary electrode

A three-electrode electrochemical cell's auxiliary electrode is a particular electrode used for voltammetric analysis.A counter electrode is another name for an auxiliary electrode.In other reactions where a current is anticipated to flow, it can also be employed. In order to apply current to the working electrode, the auxiliary electrode is used to connect to the electrolyte. An auxiliary electrode must be made of a noble metal, such as platinum, carbon, or gold, or an inert material, such as graphite. It must be prevented from dissolving in the electrolyte by doing this.

7.0.3 Reference Electrode

A reference electrode has a known electrode potential and is stable. Its high stability is achieved by employing the redox system, which must contain saturated concentrations in each of the participating solutions of the reaction.Reference electrodes can be classified as aqueous, calomel, non-aqueous and own-constructing. The most common aqueous reference electrodes used include

Standard hydrogen electrode,normal hydrogen electrode,saturated calomel electrode,silver chloride electrode,copper-copper sulfate electrode,dynamic hydrogen electrode etc.

7.1 Electrochemical reaction

Electrons move from a solid electrode to a material, like an electrolyte, during an electrochemical reaction. Heat is released or absorbed by the reaction when this flow begins an electric current that passes across the electrodes. Different kinds of reactions can produce various types of electric current flows. For instance, when two electrodes come into contact with one another, a reduction and oxidation (redox) process takes place, changing the oxidation numbers of every atom involved in the reaction.

7.2 A potentiostat

A potentiostat is an electronic instrument that measures and controls the voltage difference between a working electrode and a reference electrode. It measures the current flow between the working and counter electrodes. This allows for precise control of the electrochemical conditions and the ability to study the corrosion behaviour under a wide range of conditions. A potentiostat needs a low-impedance reference electrode. Potentiostats are less forgiving of high-impedance reference electrodes than pH meters. A potentiostat is comprised of three primary components:

- Control amplifier – Supplies power to maintain the controlled potential between the working and reference electrodes.
- Electrometer – Measures the potential difference between the reference and working electrodes.
- Current-to-voltage converter – Measures the current between the working and counter electrodes.

Assemble the parts listed above in an suitable beaker and connect them to the potentiostat/galvanostat to set up the electrochemical cell for corrosion study. Make sure the working electrode is not in contact with the cathode or any other conducting substance, and that the electrodes are completely submerged in the electrolyte solution. Without contacting it, the reference electrode should be placed close to the working electrode. Using the potentiostat/galvanostat, apply the required potential or current to the working electrode and observe the current or potential that develops. Using an electrochemical setup, the corrosion of bare aluminum in various concentrations of sodium hydroxide (NaOH)in distilled water and sea water in the presence and absence of PVA (Polyvinyl Alcohol) was studied in relation to temperature.

8 Electrochemical Cell

Another common method for studying corrosion using electrochemical cells is to perform polarization experiments, which involve measuring the current and potential of the corroding metal surface as a function of an applied voltage or current.Polarization experiments can be used to identify the different types of corrosion that occur, such as uniform corrosion, pitting corrosion, or crevice corrosion, and to determine the effects of various factors on corrosion, such as the concentration of corrosive species or the presence of corrosion inhibitors.

8.1 Preparation of Aluminium specimens

Using a cutting machine, bare aluminum was cut into an electrode measuring 5 cm x 1 cm. It is important to notice that the edges must be finely sharpened. To remove the oxide layer from the aluminum specimen, it was first cleaned for two minutes with a soap solution and then again with distilled water. After being dried, the specimen was examined for corrosion.

8.1.1 Preparation of stock solution for corrosion studies

Analytical grade sodium hydroxide pellets were dissolved in distilled water to create a stock solution of sodium hydroxide. Using the dilution formula, a solution with the required concentrations of 50 mM, 250 mM, and 500 mM was obtained. Weight of NaOH=(Molar mass* concentration* volume) / 1000 . To prepare 500mM Sodium hydroxide solution in 50 ml distilled water, the amount of NaOH needed can be calculated as: (40*0.5*50)/1000 =1g. 1g of sodium hydroxide pellets was weighed on weighing machine and was added to 50ml distilled water. sodium pellets were dissolved using glass rod. Similarly, the stock solution of strength 50mM and 250mM was prepared.

8.1.2 Procedure for corrosion studies

- Mount the aluminium specimen on the working electrode holder and connect it to the potentiostat/galvanostat.
- Insert the reference electrode (eg:-Ag/AgCl electrode) and the counter electrode (eg:-platinum electrode) .
- Add the electrolyte solution to the electrochemical cell.
- Stir the solution with a magnetic stirrer to ensure uniform mixing.
- Keep the setup for 5-10 minutes, so the corrosion phenomenon starts.
- Apply a potential or current to the aluminium specimen using the potentiostat/galvanostat.
- Measure the corrosion potential and corrosion current of the aluminium specimen using the potentiostat/galvanostat.
- Monitor the temperature of the solution during the experiment.
- Record the experimental data and analyse the corrosion behaviour of aluminium in sodium hydroxide.

8.2 Reaction of Aluminium in stock solution of Sodium Hydroxide

The process of aluminum corrosion in sodium hydroxide solution is initiated by the occurrence of a very alkaline environment on the metal's surface. This causes the aluminum oxide layer to dissolve and expose the underlying metal to the corrosive medium. Soluble aluminate ions ($Al(OH)_4^-$) are created when aluminum is exposed to NaOH solution and hydroxide ions (OH-) in the solution react with the aluminum oxide layer on the metal's surface. $\mathrm{Al_2O_3 + 2NaOH + 3H_2O = 2Na[Al(OH)_4]}$

The aluminum hydroxide layer dissolves as a result of this reaction, exposing the underlying

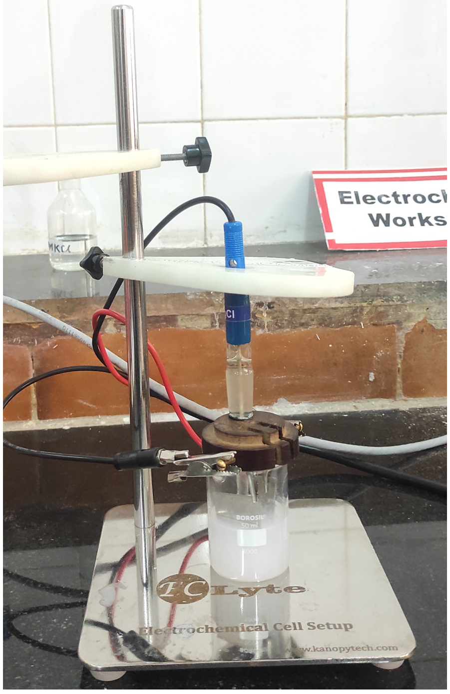


Figure 1: Electrochemical Workstation

metal to the alkaline solution. By reducing water molecules, the extremely alkaline environment at the metal's surface can also result in the production of hydrogen gas.

$2H_2O + 2e^- = H_2 + 2OH^-$

Hydrogen gas formation has the potential to accelerate aluminum corrosion and cause metal embrittlement. The concentration and temperature of the solution, the amount of dissolved oxygen, the metal's surface features, and other factors all affect how quickly and how much aluminum corrodes in NaOH solution. Aluminum can corrode more quickly at higher temperatures and NaOH concentrations. We're going to study how elevated concentrations and temperatures accelerate aluminum corrosion.

9 Tafel Polarization Method

A corrosion study of aluminium in sodium hydroxide solution at different temperature variation was studied to understand the effect of NaOH concentration on the corrosion behaviour of Aluminium.

The effect of Sodium hydroxide medium on the corrosion rate of bare aluminum sample was studied using Tafel polarization technique. Corrosion parameters such as open circuit potential (OCP), corrosion potential (Ecorr), corrosion current density (Icorr), anodic slope (ba) and cathodic slope (bc) are obtained from the Tafel polarization curves.

9.1 Open circuit potential

Open circuit potential (OCP) is defined as the potential that exists in an open circuit. That is, it is the voltage present when the terminal ends of a circuit are detached, and there is no external load.When an electrode is immersed in an electrolyte, it will adopt an open circuit potential. This potential ultimately defines its ability to either be oxidized or reduced.

In a typical electrochemical cell, two metals are immersed in an electrolyte, causing both of them to adopt an open circuit potential. If a voltmeter is connected to the two electrodes, their potential difference (the difference in potential between the two electrodes) can be measured.

If the two metals are electrically connected (e.g., with a cable), the difference in potential that exists between the two electrodes will result in a flow of electricity as electrons move from the metal with the lower potential to the metal with the higher potential. The material with the lower potential becomes the anode, while the material with the higher potential becomes the cathode.

9.2 Corrosion potential (Ecorr)

It is the electrodes potential of the metal in a specific environment where corrosion may occur.The corrosion potential is the intersection of the anodic and cathodic Tafel lines, which represents the equilibrium potential of the electrochemical reaction that governs metal corrosion.

9.3 Corrosion current density (Icorr)

The corrosion current density is the current density at the corrosion potential, which represents the rate at which metal ions are dissolved from the metal surface due to electrochemical reactions

9.4 The Tafel plot

It is a graphical representation of the relationship between the logarithm of the current and the applied potential in an electrochemical cell. The slope of the Tafel plot provides information about the rate-determining step of the electrochemical reaction.

$Tafelslope = (del(lnI)/del(E))^-1$

Where, I is the current density and E is the applied potential. To calculate the Tafel slope, it is necessary to determine the values of ba and bc. These are constants that are related to the reaction mechanism and can be calculated using the following equations:

$ba = (2.3RT)/(\alpha a * n' * P)$

$bc = (-2.3RT)/(\alpha c * n' * F)$

where, R is the gas constant

T is the temperature in Kelvin

n' is the number of electrons transferred in the rate-determining step of the reaction

P is the partial pressure of the reactant gas

F is Faraday's constant

αa and αc are the transfer coefficients for the forward and backward reactions.

For anodic half reaction for potential Ecorr, current density is given by

$I_{corr} = I_{0a} exp[(2.3(E_{corr} - Ea)/ba)]$

Where, Ea equilibrium potential for anodic half reaction

Ioa anodic exchange current For cathodic half reaction

$I_{corr} = I_{0c} exp[(-2.3(E_{corr} - Ec)/bc)]$

Where, Ec equilibrium potential for anodic half reaction

$I_o c$ cathodic exchange current

For applied potential difference, change in the current is given by

$del(I) = 2.3I_{corr}(del(E)/ba + del(E)/bc)$

$Wheredel(E) = (E - E_{corr})$

On rearranging, $I_{corr} = [(ba * bc * del(I)/(2.3ba + del(E) * bc)$

The corrosion rate was calculated by using following equation

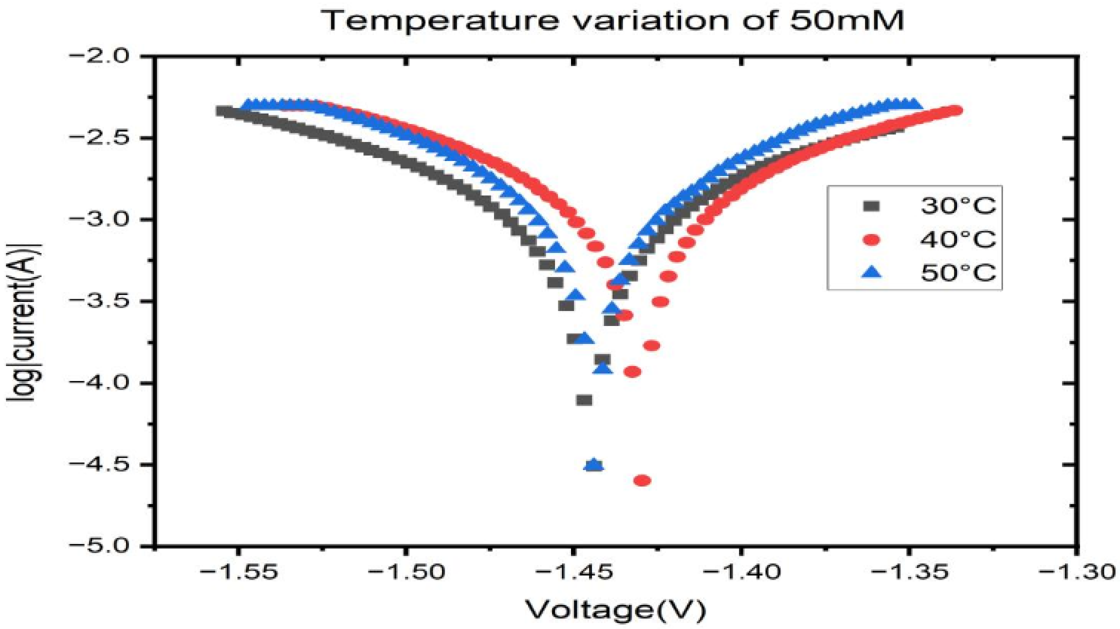
Corrosion Rate = $3270 \times I_{corr} \times M/A \times n \times 10$

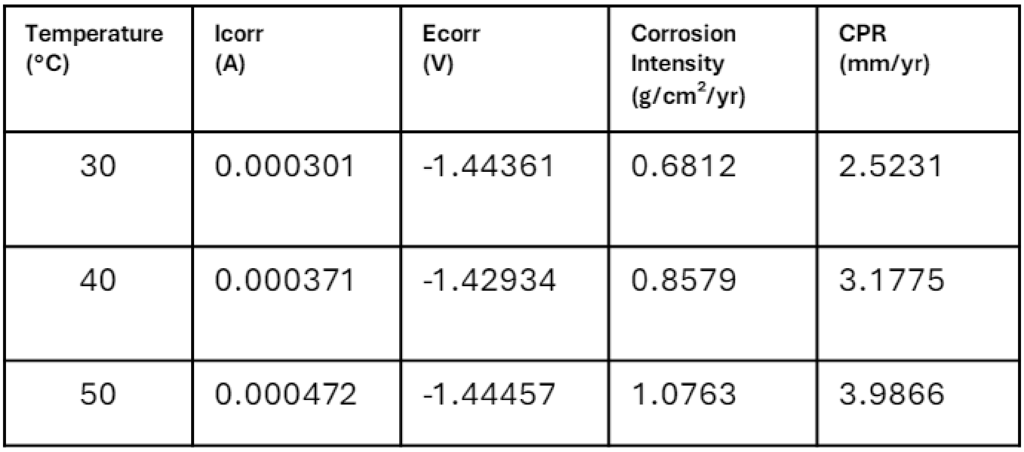
Where, Icorr = Corrosion current

A = Area of working electrode dipped inside the solution.

n = Valency of the Aluminium

M = Molecular weight of Aluminium

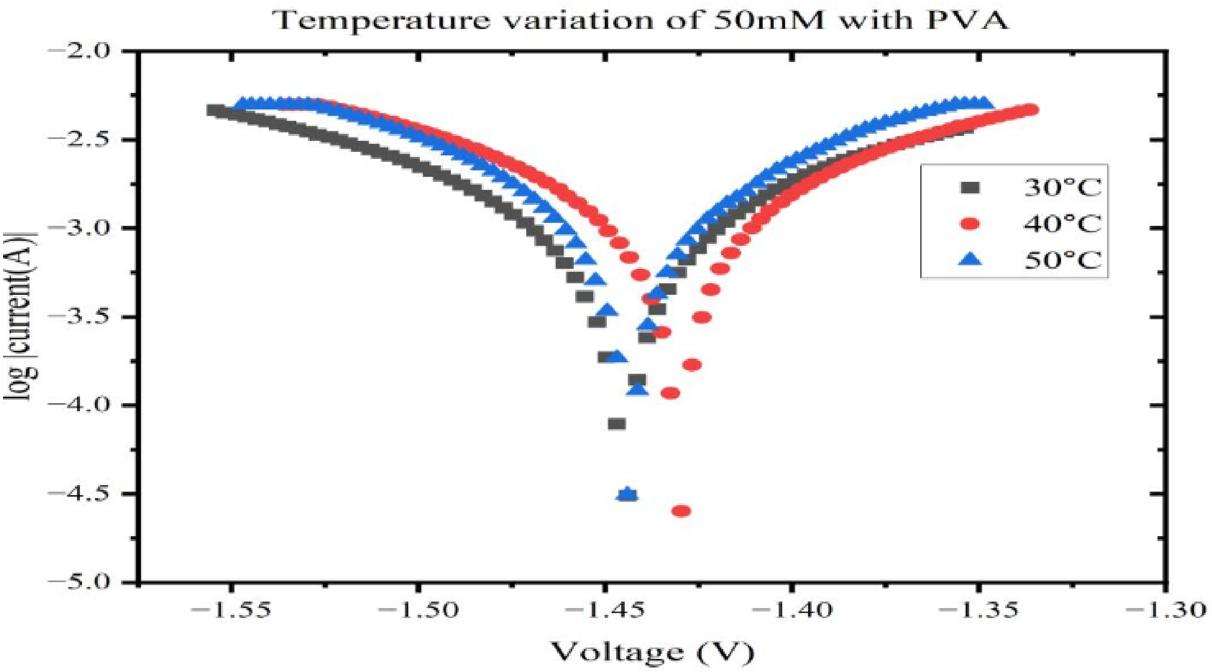


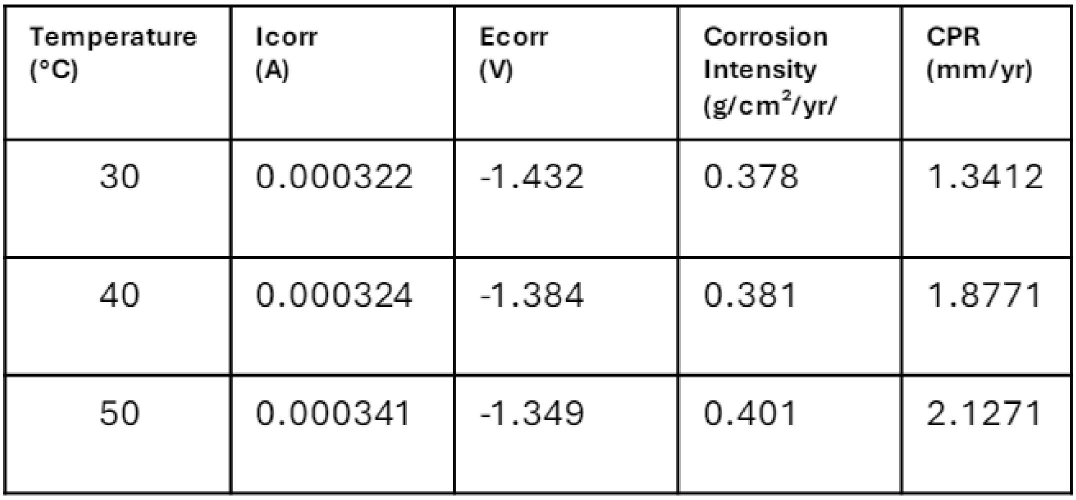


Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion Intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.000301	-1.44361	0.6812	2.5231
40	0.000371	-1.42934	0.8579	3.1775
50	0.000472	-1.44457	1.0763	3.9866

Figure 2: Temperature variation of 50mM

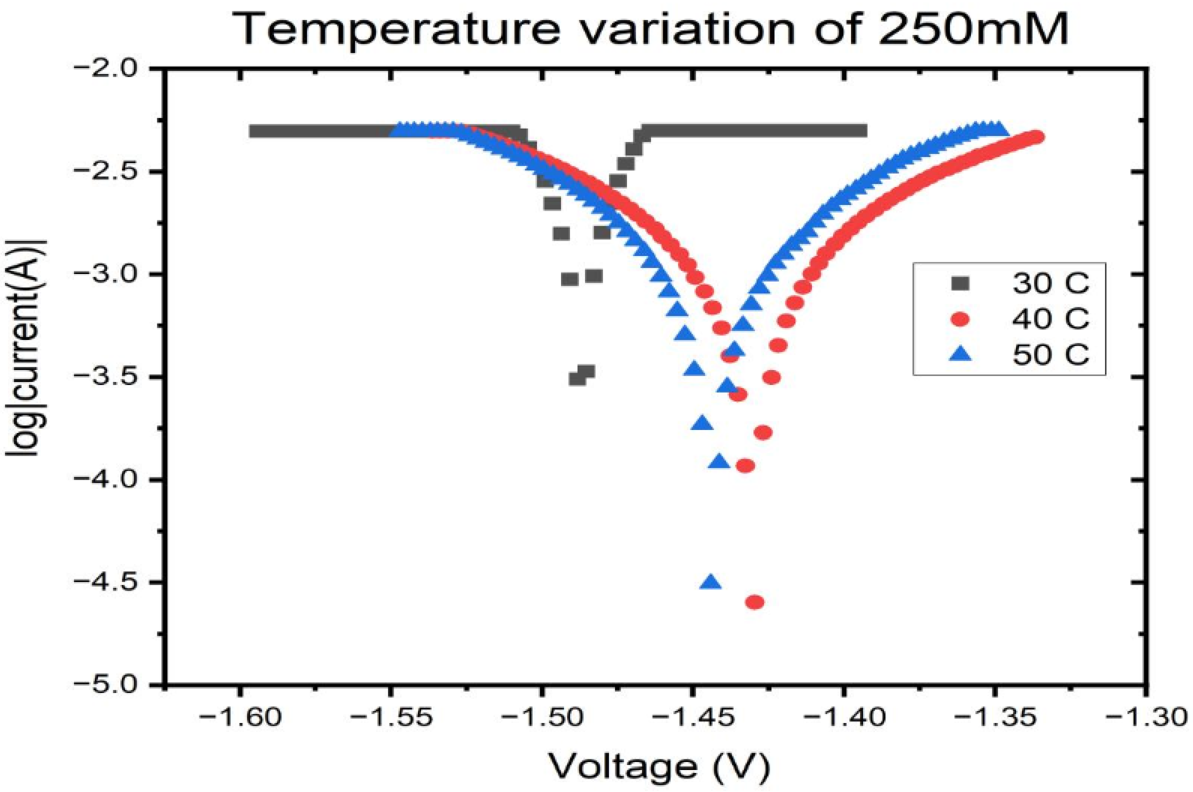
As from above graph[fig.12],the peak at 2903 $cm^{-}1$ indicate C-H stretching vibrations.
Peak at 2903$cm^{-}1$ in the Raman spectrum of PVA on aluminum corresponds to the asymmetric stretching vibrations of methyl groups within the PVA molecule.
The intensity of this peak, which is quite high (ranging up to 7234.90 a.u.) that suggests a strong presence of PVA on the aluminium surface.





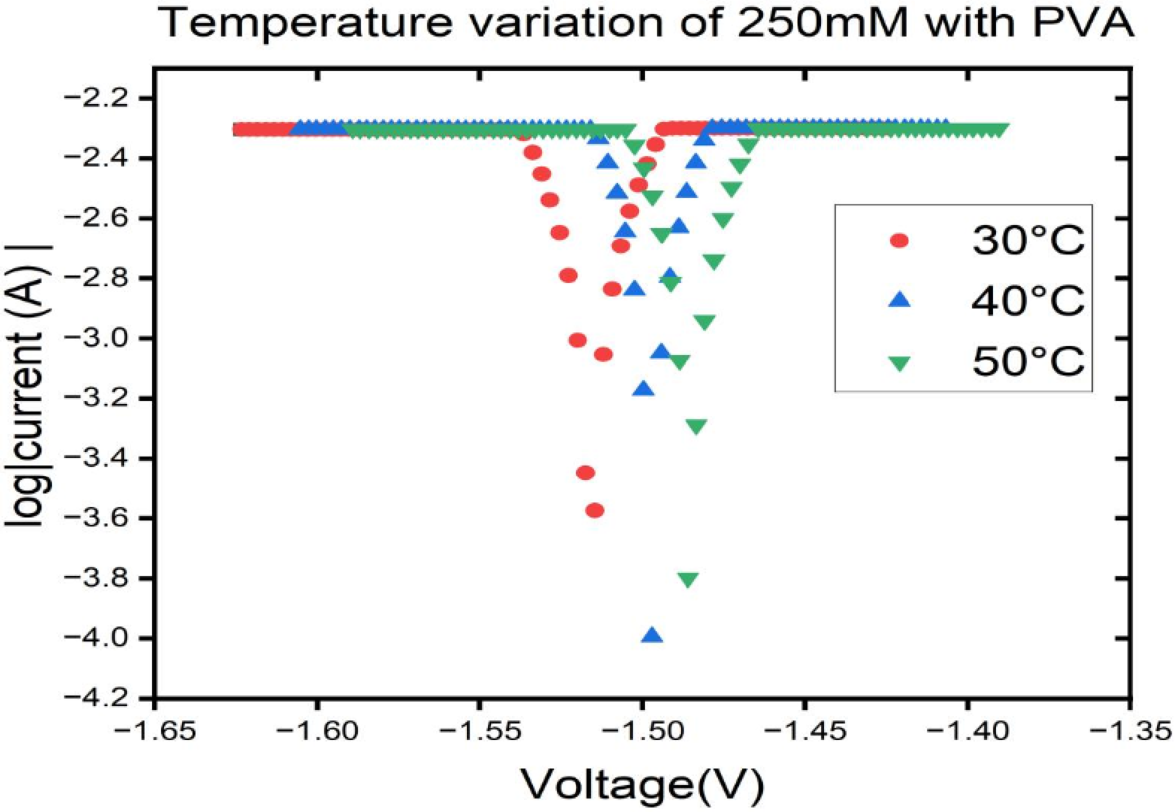
Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion Intensity (g/cm^2/yr/	CPR (mm/yr)
30	0.000322	-1.432	0.378	1.3412
40	0.000324	-1.384	0.381	1.8771
50	0.000341	-1.349	0.401	2.1271

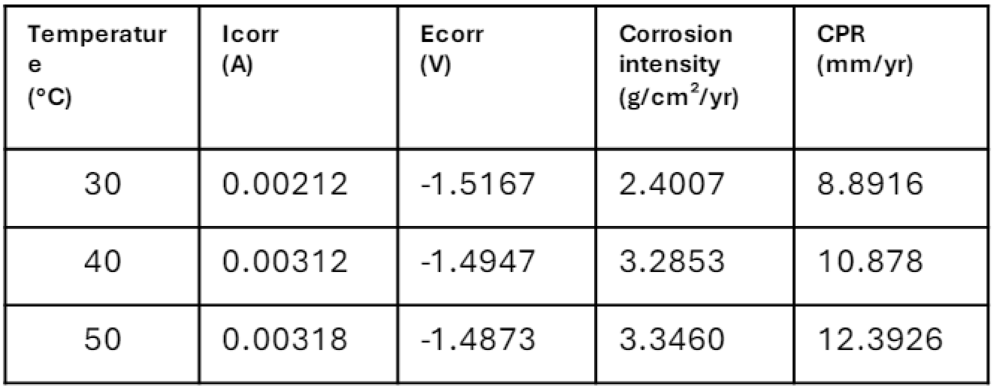
Figure 3: Temperature variation of 50mM with PVA



Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.00242	-1.4829	2.9765	11.024
40	0.00252	-1.4883	3.0902	11.445
50	0.00280	-1.4875	3.4344	12.720

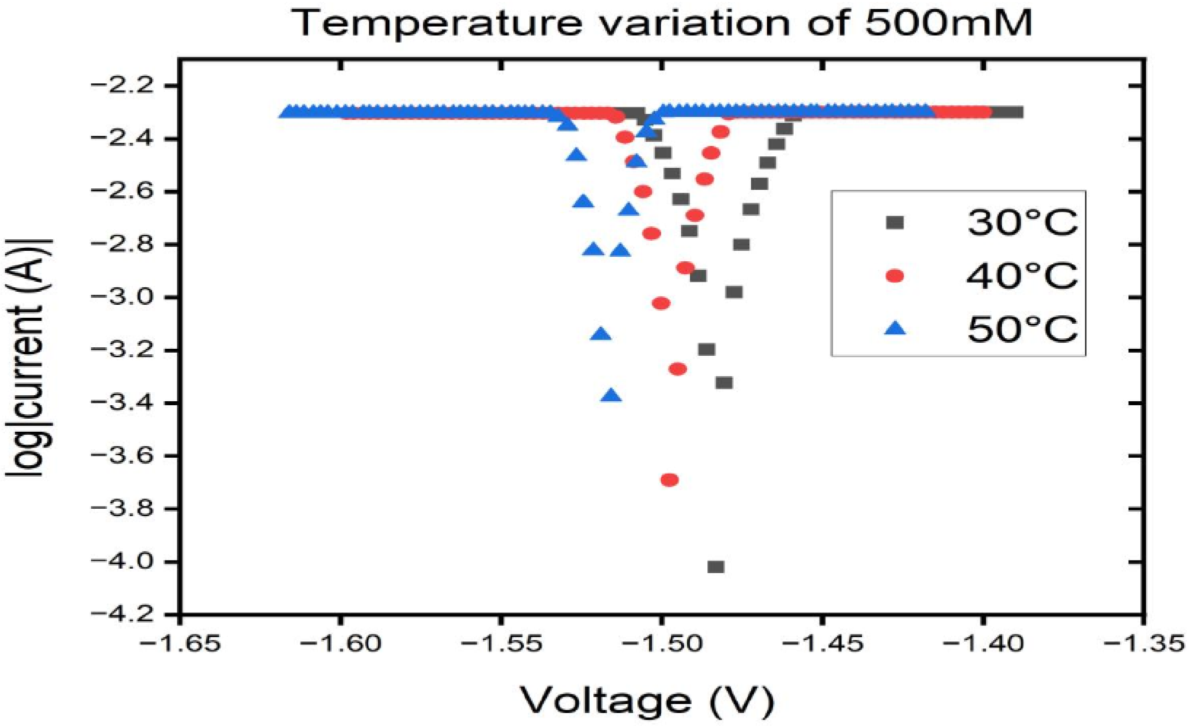
Figure 4: Temperature variation of 250mM

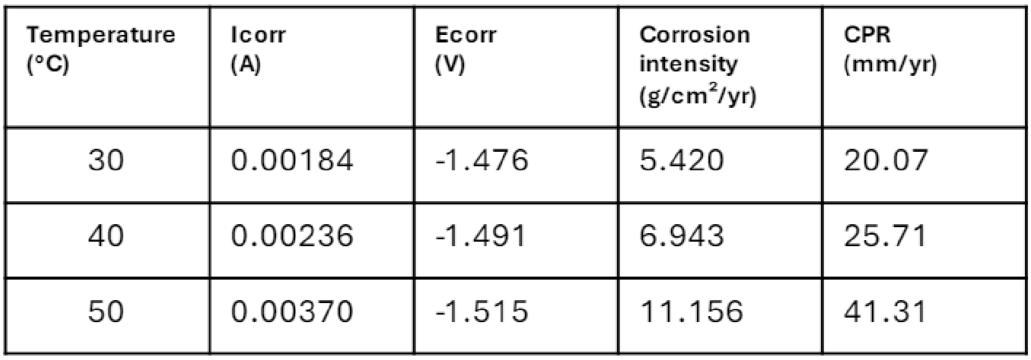




Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity ($g/cm^2/yr$)	CPR (mm/yr)
30	0.00212	-1.5167	2.4007	8.8916
40	0.00312	-1.4947	3.2853	10.878
50	0.00318	-1.4873	3.3460	12.3926

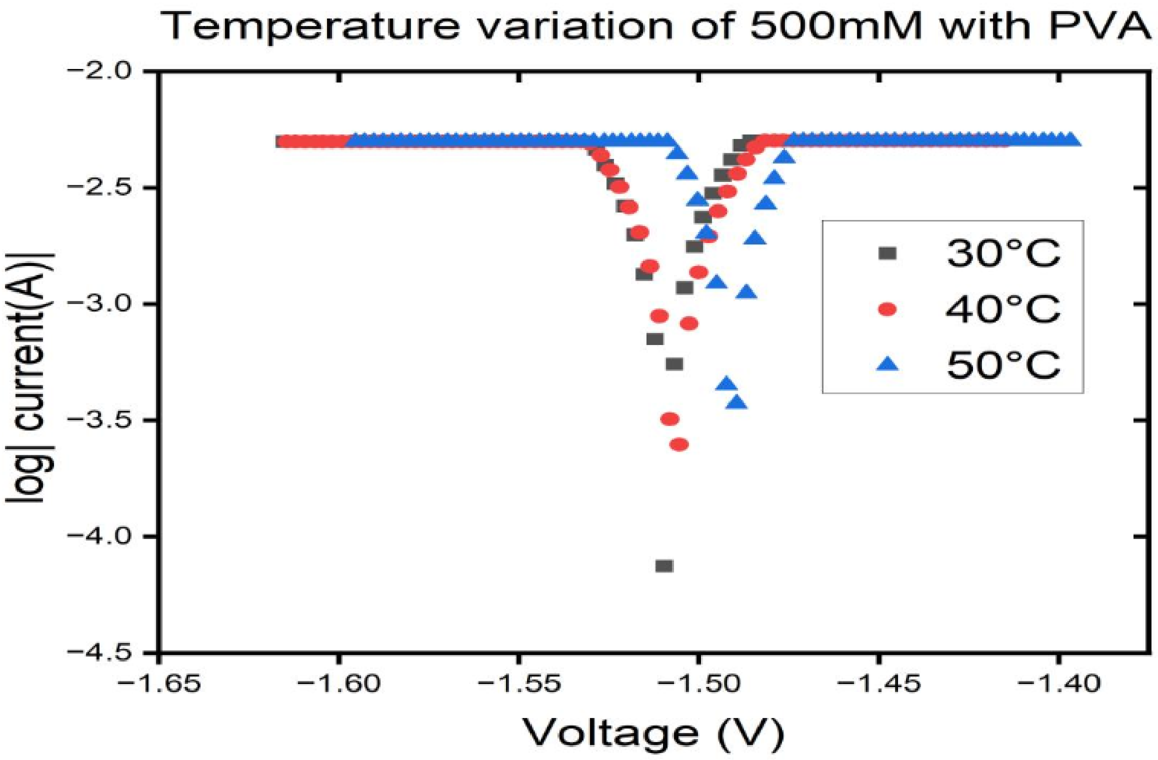
Figure 5: Temperature variation of 250mM with PVA

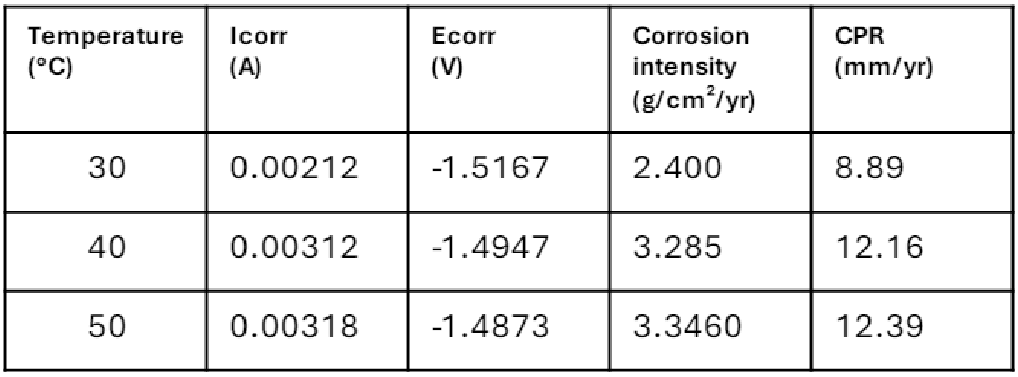




Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity ($g/cm^2/yr$)	CPR (mm/yr)
30	0.00184	-1.476	5.420	20.07
40	0.00236	-1.491	6.943	25.71
50	0.00370	-1.515	11.156	41.31

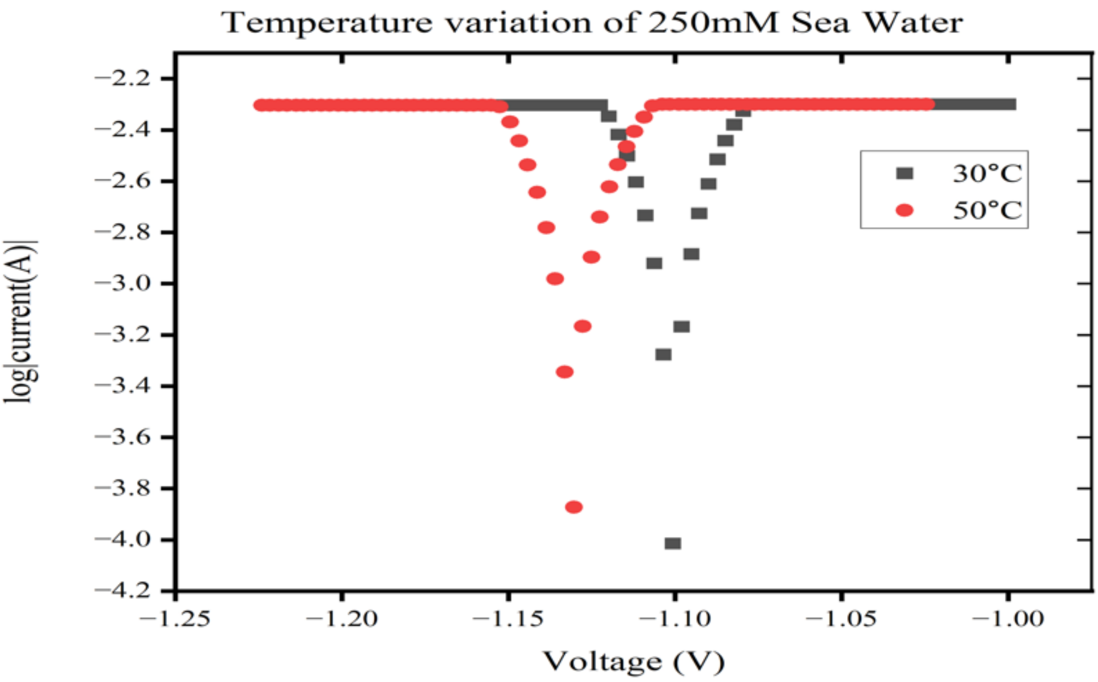
Figure 6: Temperature variation of 500mM

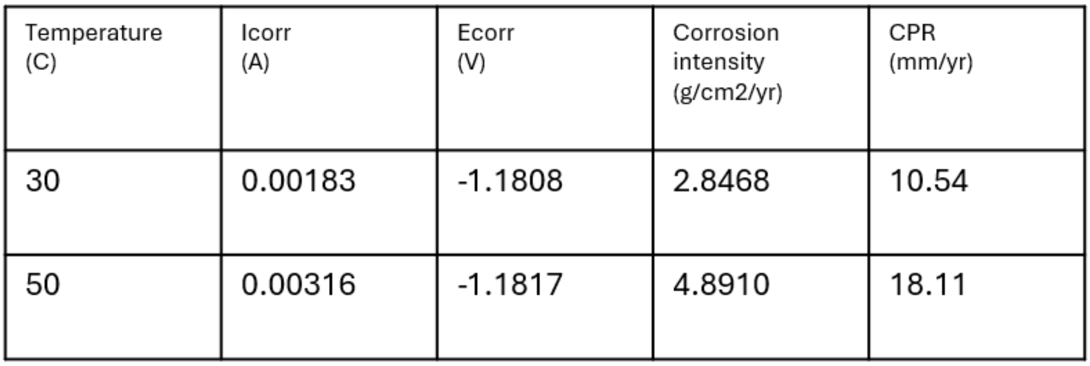




Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.00212	-1.5167	2.400	8.89
40	0.00312	-1.4947	3.285	12.16
50	0.00318	-1.4873	3.3460	12.39

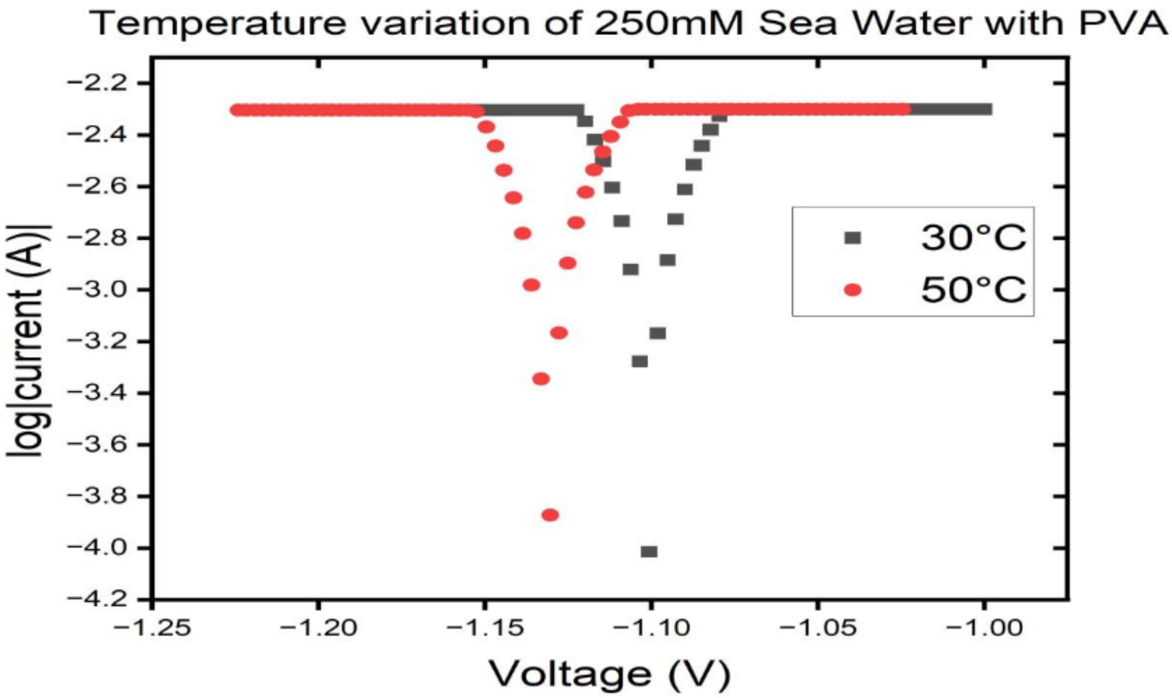
Figure 7: Temperature variation of 500mM with PVA

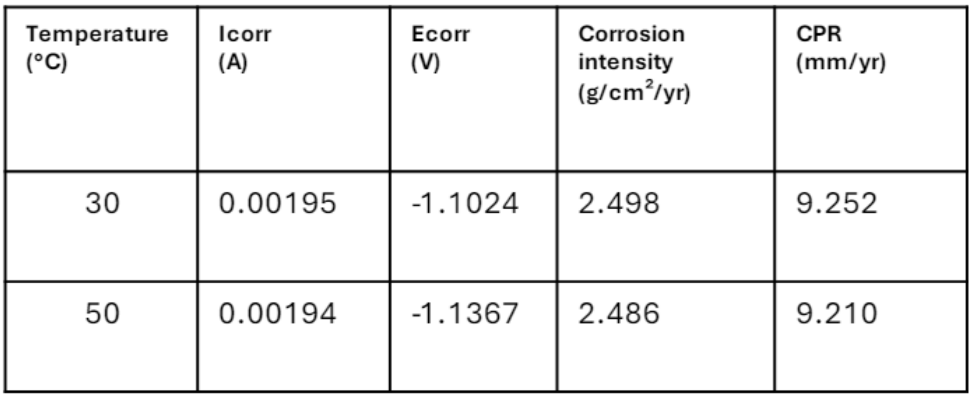




Temperature (C)	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm2/yr)	CPR (mm/yr)
30	0.00183	-1.1808	2.8468	10.54
50	0.00316	-1.1817	4.8910	18.11

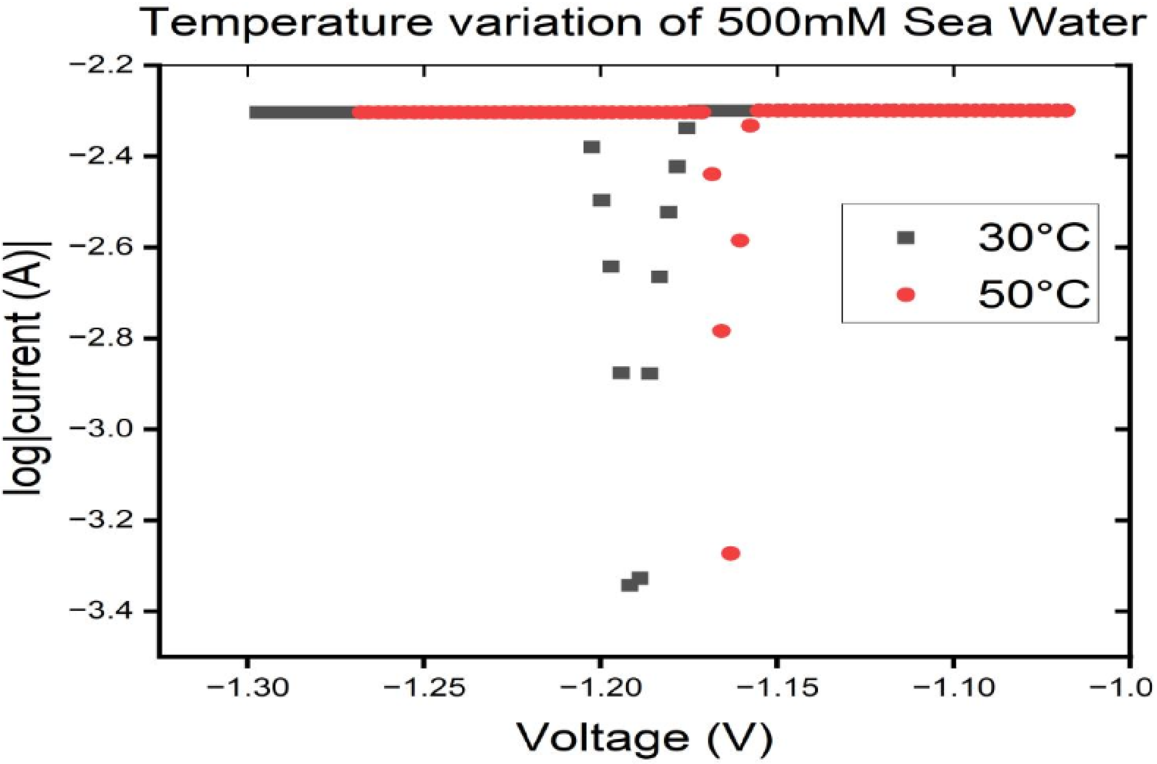
Figure 8: Temperature variation of 250mM sea water





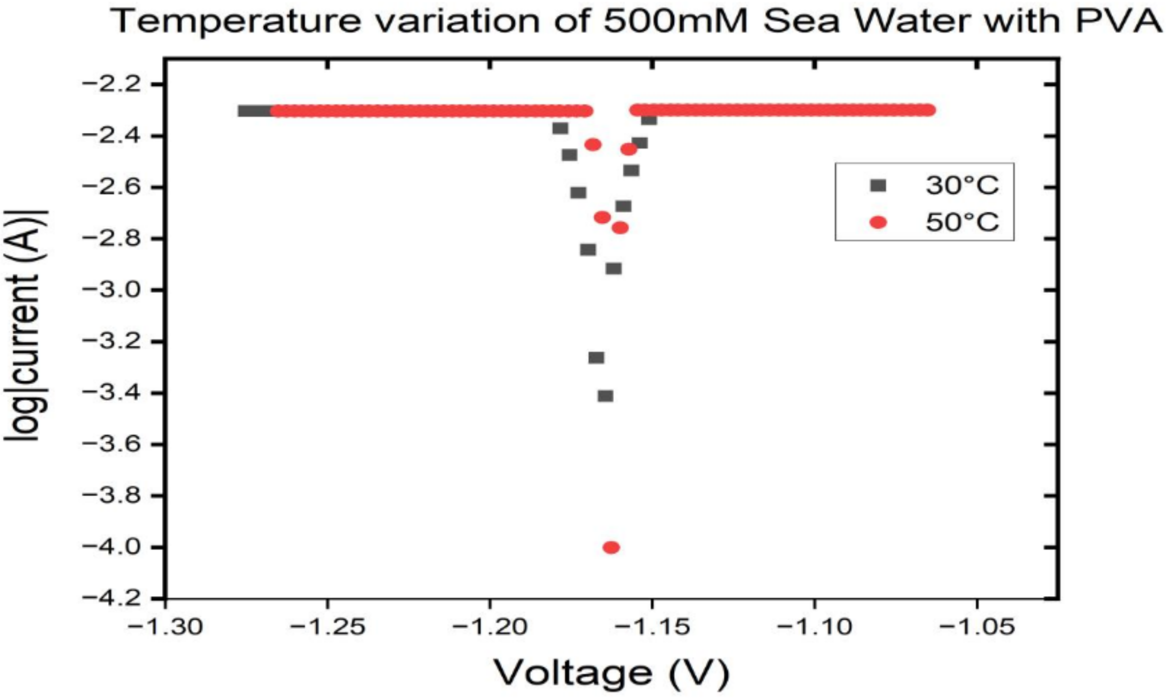
Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.00195	-1.1024	2.498	9.252
50	0.00194	-1.1367	2.486	9.210

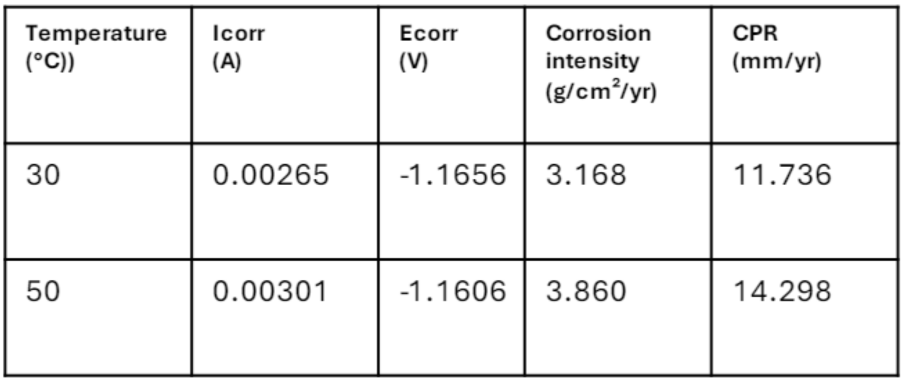
Figure 9: Temperature variation of 250mM sea water with PVA



Temperature (°C)	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.00299	-1.1843	4.6322	17.156
50	0.00363	-1.1673	5.0973	18.879

Figure 10: Temperature variation of 500mM sea water





Temperature (°C))	Icorr (A)	Ecorr (V)	Corrosion intensity (g/cm^2/yr)	CPR (mm/yr)
30	0.00265	-1.1656	3.168	11.736
50	0.00301	-1.1606	3.860	14.298

Figure 11: Temperature variation of 500mM sea water with PVA

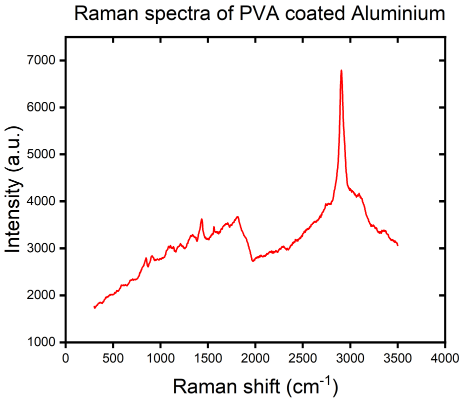


Figure 12: Raman spectra of PVA coated Aluminium

10 Result

The above mentioned result shows that the corrosion rate of aluminum in NaOH increases as temperature rises because of both kinetic and thermodynamic factors that influence the corrosion process. The corrosion process is a chemical reaction that releases hydrogen gas when aluminum metal dissolves in aqueous solution. This reaction is known as an exothermic reaction. The solution's temperature rise causes the reaction rate to increase, which in turn causes the corrosion rate to increase. Additionally, because of the reaction's activation energy, the tafel plot measurement of the rates of anodic and cathodic reactions can vary with temperature.The anodic and cathodic processes' activation energies may drop at higher temperatures, which would lower the Tafel slope and increase the rate of corrosion.

As from above graph[fig.12],the peak at 2903 cm^-1 indicate C-H stretching vibrations. Peak at 2903cm^-1 in the Raman spectrum of PVA on aluminum corresponds to the asymmetric stretching vibrations of methyl groups within the PVA molecule. The intensity of this peak, which is quite high (ranging up to 7234.90 a.u.) that suggests a strong presence of PVA on the aluminium surface.

Figure 13: Corroded samples of 50mM ,250mM and 500mM with and without PVA

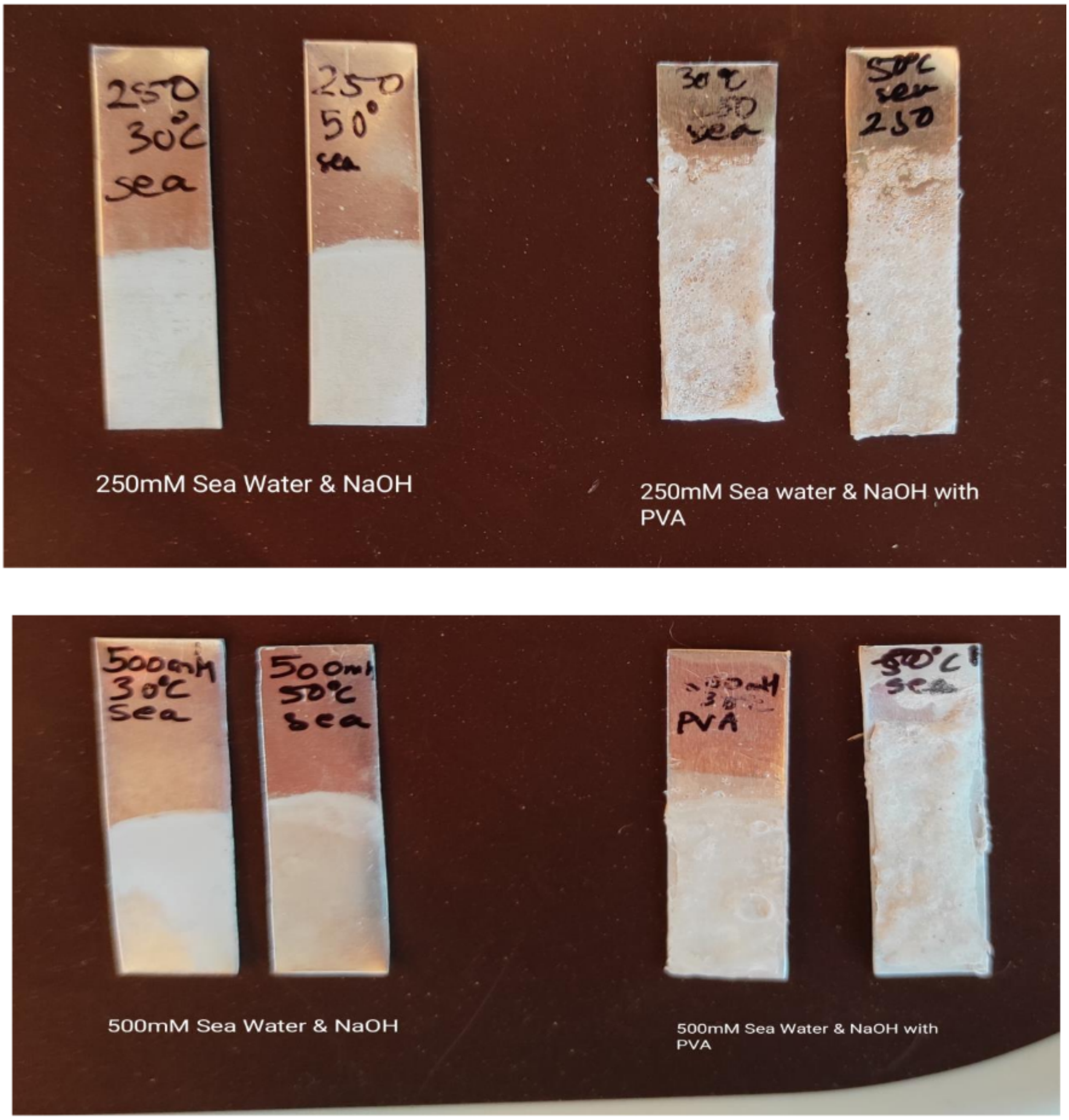


Figure 14: Corroded samples of 250mM and 500mM Sea water with and without PVA

11 Conclusion

- Corrosion of Aluminium in sodium hydroxide solution was studied using electrochemical technique (Tafel plot , polarization curve) and found that the corrosion rate of aluminium in sodium hydroxide increases with increase in concentration and also with the increase in temperature.

- By keeping concentration of electrolyte constant and varying the temperature from 30°C -50°C , we observe that the corrosion rate increases as temperature increases.

- Corrosion of aluminium was studied in sea water and found out that corrosion rate increases as temperature increases .

- The polymer coating (PVA)inhibits corrosion further decreasing the corrosion rates.

12 References

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