

TAJHIZ SAN'AT IRSA CO.

Pipeline Supply Chain management

Coatings and Surface Preparation, Corrosion Resistance and Cathode Delamination for Underground Pipelines

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History of Main line coating

Coating Developments 1940 - Present

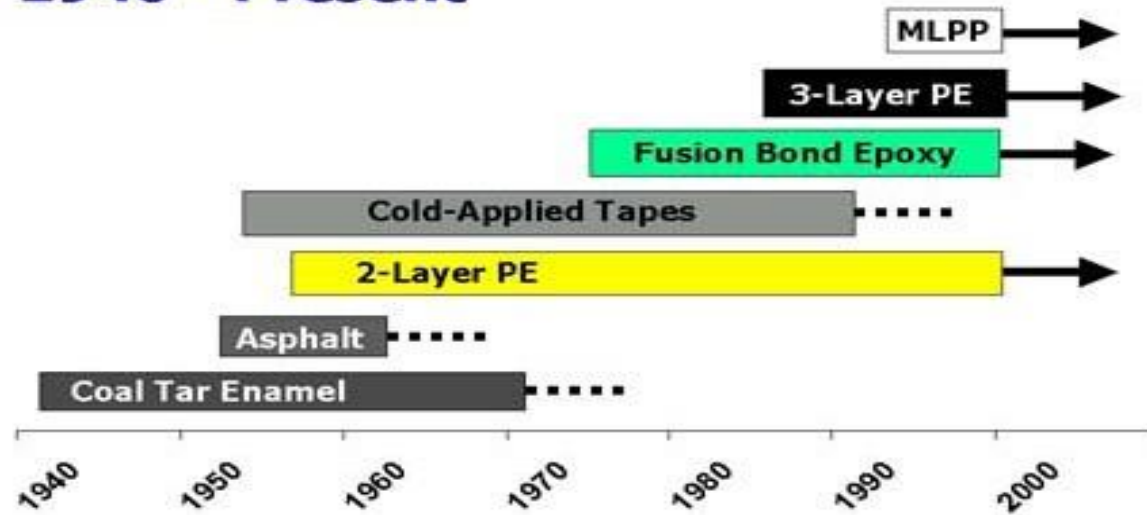


Figure 1

Multi-layer polyp

»S.

History of Girth weld coating

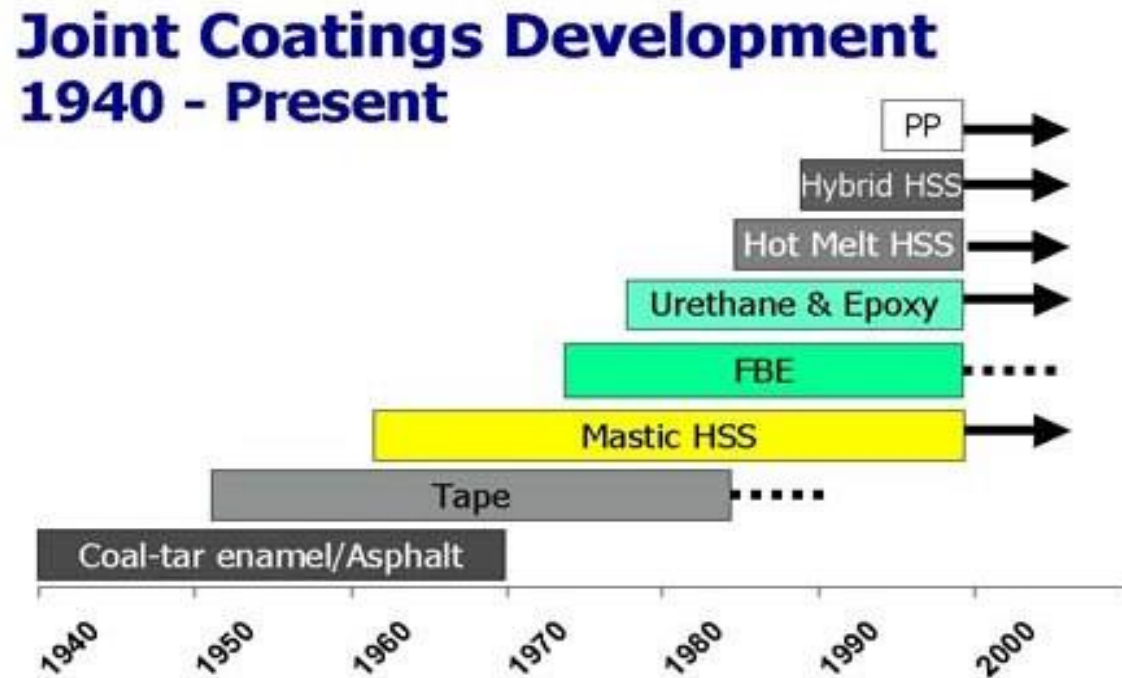


Figure 2




Contents

- ❑ **Surface preparation and adhesion of coatings on the underground pipelines**
 - Various surface preparation methods
 - Chemical treatment of steel surface and its effects on the coating adhesion properties

- ❑ **Coatings and cathodic delamination of underground pipelines**
 - The cathodic delamination mechanism
 - Effective parameters influencing coating disbondment
 - Ways to reduce cathodic delamination

- ❑ **Coatings and corrosion resistance of underground pipelines**



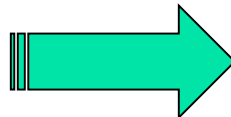
**Various surface
preparation methods**



*Mechanical and Chemical
treatment*



Alkaline and Acid washing



Conversion coatings



Surface preparation methods

1- Pre-cleaning of the pipes prior to blast cleaning for :

- *removal of surface contaminations (salts, soil, grease, oils, organic matter and contaminants)*
- *loosening mill scale*
- *removal of moisture*

Methods :

- High Pressure Fresh Water for removal of salts and soil
- Hydrocarbon solvent (xylene or mineral spirits) for removal of organic contaminations
- Preheating of pipe surface by flame burners to 75 degree C for loosening mill scale, removing moisture, burning of organic matter and conditioning pipe surface for blast cleaning.

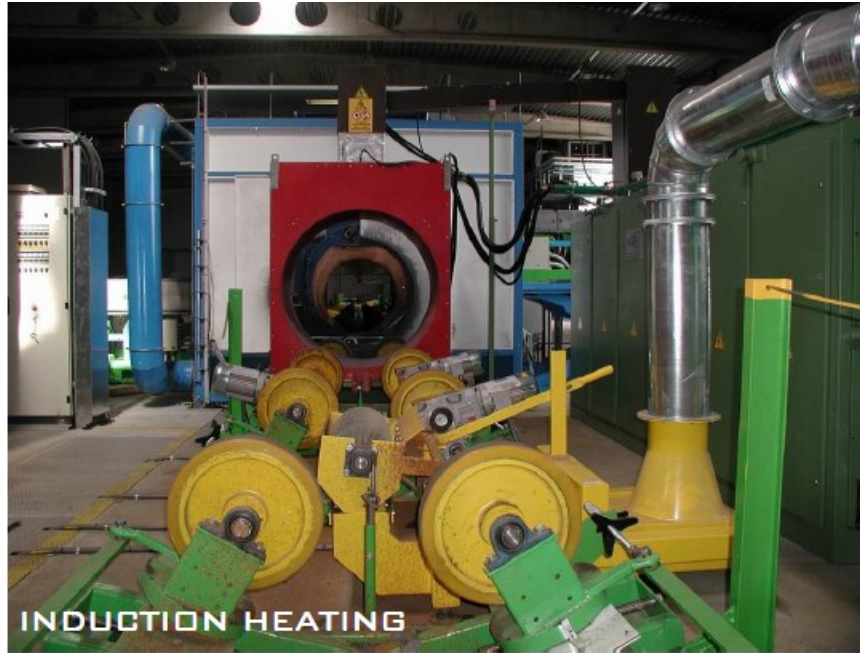
Surface preparation methods



2- Shot/Grit Abrasive Blast Cleaning:

The purpose of cleaning is to obtain clean steel surface with the cleanliness degree of Sa 2 ½ and an anchor pattern with the average profile depth of 25 – 80 microns.

Blast cleaning may also remove pipe defects (slivers, burrs, laminations, scabs, gouges). If not, grinding can be also used for removal of such defects on pipe surface.



3- Heating of the Pipes:

The pipe surface shall reach the temperature of 200-220 degree C prior to powder epoxy application. The pipe surface temperature shall not exceed 270 degree C.

Metallurgical or surface defects can occur at over 270 degree C. Bluing or darkening of the pipe surface is an indication for over heating of pipes.

4- Surface Treatment

Chromate pretreatment (1% - 5% of concentrated solution)



Coatings and Cathodic Protection for Underground Pipelines

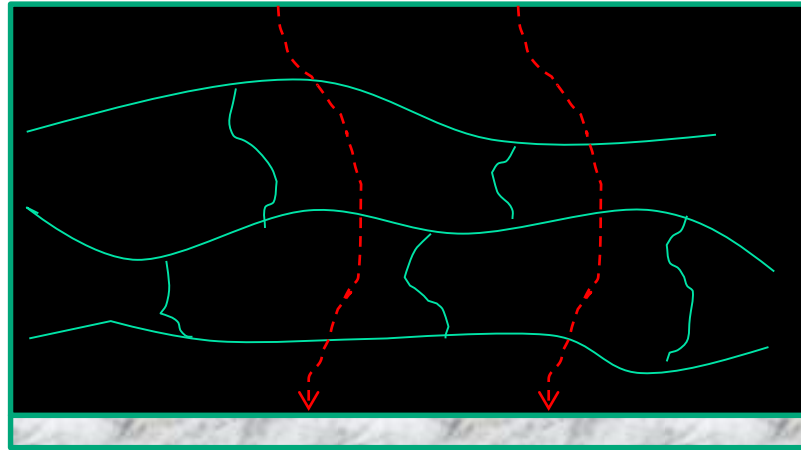
Coatings and Cathodic Protection for Underground Pipelines

Barrier effect



Barrier protection is obtained by impeding the transport of aggressive species into the surface of the substrate by application of a coating system with low permeability for liquids, gases, and ions.

Corrosive ions (Cl^-), Oxygen, Water



The degree of protection offered by an organic coating system is highly dependent on:

- The coating thickness
- The coating the generic type and
- The nature of the binder system
- Pigmentation

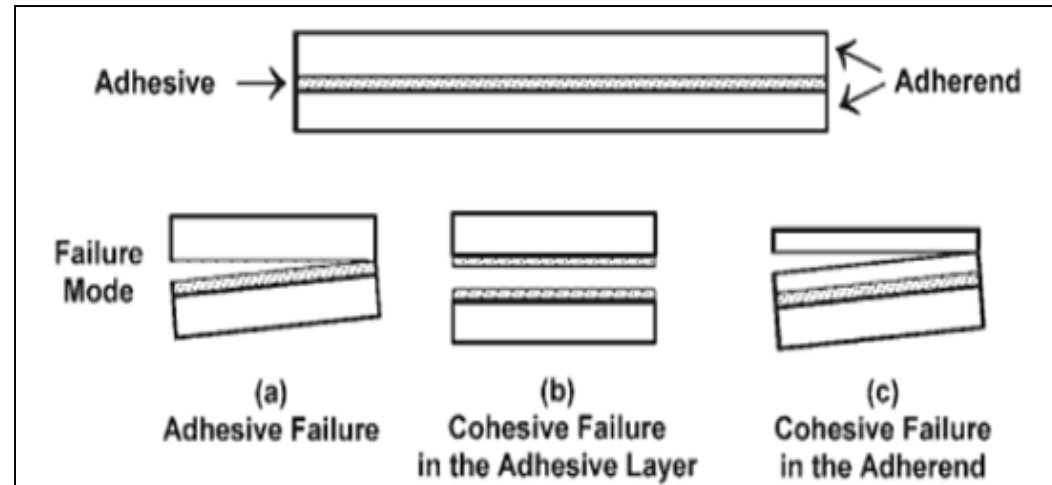


Coatings control corrosion by providing a barrier against oxygen and water.

- ❑ All organic coatings are semi-permeable to O₂ and water.**
- ❑ The water permeability coefficient of fusion bonded epoxies, one of the best coating systems, is approximately 10⁻⁶ gms/mil/24 hours**
- ❑ The minimum concentration of oxygen and water that can start the corrosion process is 10⁻²⁸ M.**

- ❑ **The critical properties of the coating that will work with or against the CP system.**

Adhesive strength and cohesive strength of the coating are two important properties that are to be understood properly in this context.

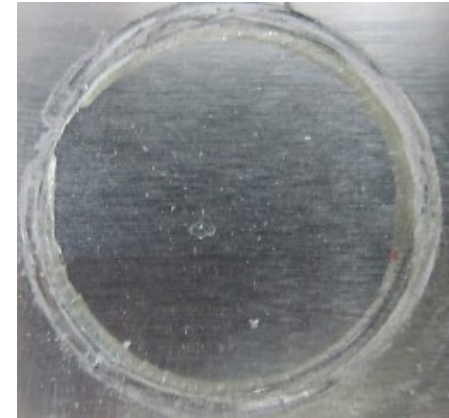


- ❑ Adhesive strength is the strength needed to pull the coating from the substrate without tearing it.
- ❑ Cohesive strength is the force needed to tear the coating, meaning it is a measure of the film's strength.

Coatings and Cathodic Protection for Underground Pipelines

The adhesion property is an integral to the coating's corrosion prevention properties

Cohesive strength dictates the coating's ability to resist mechanical damages.



Both cohesive strength and adhesive strength are extremely important and the higher these values, the better the system is.

□ Adhesion, Cohesion and CP

Adhesive strength is the sum of several components. The major portion comes from mechanical adhesion, polar-polar adhesion and chemical adhesion.

□ Mechanical adhesion is the gripping force of the coating onto the substrate.

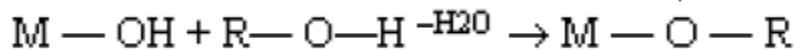
□ The polar-polar adhesion is the force of attraction between the positive and negative poles of the substrate and the coating.



M represents the metal substrate and R-O-H the coating.

❑ Adhesion, Cohesion and CP

Chemical adhesion is due to the chemical bonds that are established between the substrate and the coating through chemical reaction. This can be represented as follows:



- ❑ Mechanical, polar-polar and chemical adhesion all play a significant role in the total adhesive strength
- ❑ It is claimed that a chemical bond is 20 to 1000 times stronger than a polar-polar bond.

❑ Influence of surface preparation and coating application on adhesive strength

- ❑ Most of the high performance powder coating systems require an extremely clean surface. For FBE, the minimum required cleanliness is Sa 2.5 per ISO 8501-1/SIF or NACE level-2.
- ❑ The two important components of adhesion, polar-polar and chemical, are directly linked to the number of hydroxyls of the substrate surface.



The absence of these hydroxyl groups can adversely affect the overall adhesive strength of the coating. An improperly cleaned surface can limit the number of hydroxyls available for bonding.

❑ **Influence of surface preparation and coating application on adhesive strength**

- ❑ *Another important step is the removal of water-soluble salts and organic contaminants. If left on the surface, salts, especially chlorides and sulfates, can initiate water absorption by osmosis that lead to coating blisters.*
- ❑ *It has been reported that chloride contamination will seriously affect adhesion and cathodic disbondment properties.*

International standards of NACE and CSA address this issue in their FBE application specifications

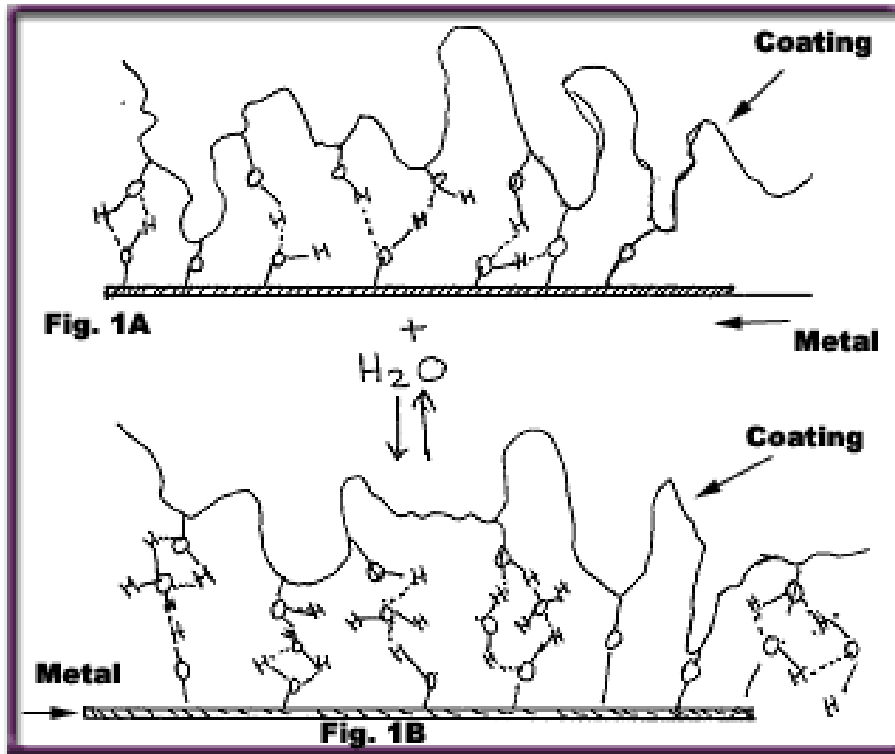
The standard procedure to remove soluble salts, (such as chloride), involves washing the pipe with phosphoric acid followed by deionized water. The maximum allowable chloride concentration is 2.0 mg/m², according to NACE standards.

Adhesion of Coating In Wet Condition

The initial adhesive strength can diminish during the service life due to several reasons mentioned below:

- Degradation of the organic components in the coating*
- Permeation of water molecules which can destroy adhesion is another reason.*
- Water, once reaches the interface can destroy polar-polar bonds between the coating and the substrate by establishing hydrogen bonds with them separately.*

Adhesion of Coating In Wet Condition



Destruction of the polar-polar bonds by the presence of water molecules will reduce the overall adhesive strength of the coating.

However, this is not a serious concern since a reduction in adhesion does not necessarily mean a loss of adhesion.

**Fig. 1 Polar-Polar adhesion)
(A. Dry and B. Wet)**

Influence of Adhesive Strength and Cohesive Strength on CP Performance for Underground Pipelines

A coating with better cohesive strength is desirable to ensure minimal damage during transportation and pipeline construction.



But in some cases, this highly desirable property can be an obstacle in the performance of the CP-Coating combination

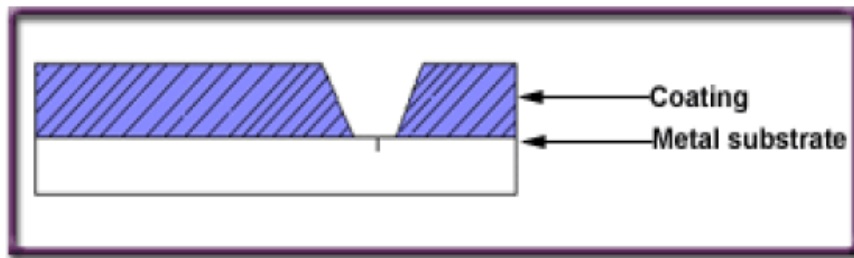
Comparing the CP performance on impact-damaged areas of two coating systems; *one with higher adhesive strength than cohesive strength and the other vice versa.*

In the CP-Coating combination system, the CP is designed as a supplementary system to provide protection if coating fails.

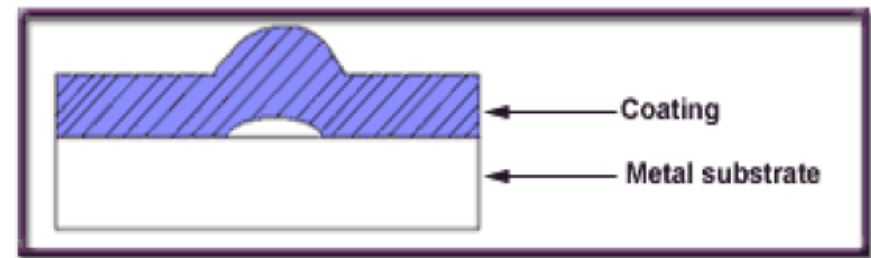
If coating fails it becomes the primary protection system and its performance becomes extremely critical.

Coatings and Cathodic Protection for Underground Pipelines

Impact damages can be minor bruises, damaging only the outer layer of the coating. But if the impact is high enough, the coating can break or delaminate, depending on the cohesive and adhesive strengths of the coating.



Ruptured Coating



Delaminated Coating

- The coating with higher adhesive strength than cohesive strength, will break before it disbonds from the pipe surface.
- The coating whose adhesive strength is lower than its cohesive strength, will delaminate without any break.



Coatings and Cathodic Protection for Underground Pipelines

- In the first case where coating has ruptured due to impact, the electrical resistance is non-existent and the electrons from the CP system can reach the pipe surface.
- But in the second case where the coating has only delaminated without any brak, electrons cannot reach the surface due to the high resistance of the coating. In this case, the CP system cannot protect the area.

Resistance to disbondment

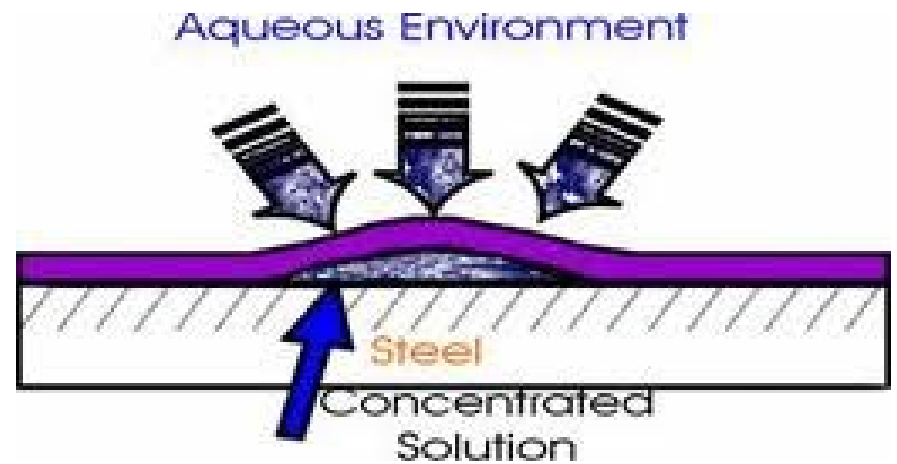
- Because most pipelines are cathodically protected, the coating must be compatible with CP.
- The amount of CP required is directly proportional to the quality and integrity of the coating.
- The negative aspects of CP are that it may drive water through the coating and that the interface bond surrounding a holiday may have a tendency to disbond.

Following concepts regarding coatings have emerged

- (i) Selection of the best coating and proper application are very important.*
- (ii) CP must supplement the coating for 100% protection.*
- (iii) In-the-ground tests are more reliable than laboratory tests.*
- (iv) Results of adhesion tests do not correlate with those of cathodic disbondment tests.*
- (v) Cathodic disbondment tests are the best tests to measure coating performance.*
- (vi) The current required for CP is the best measure of coating performance.*
- (vii) Optimum coating thickness is important.*
- (viii) Soil stress is one of the main problems.*
- (ix) Resistance to cathodic disbondment and soil stress are very important requirements of a pipe coating.*

Blistering: loss of adhesion

Blistering is a sign of failure of the coating-substrate system. Blistering occurs when moisture penetrates through the film and accumulates at the coating-substrate interface in sufficient quantity so as to force the coating up from the substrate.



The process of blister formation is as follows:

- (i) A coating imbibes water from the solution which may or may not contain dissolved salts*

- (ii) Sufficient amount of water containing chloride ions passes through to the underlying metal and activates primary corrosion sites at the interface.*

- (iii) While corrosion proceeds at anodic areas at the coating-substrate interface, hydroxyl ions build up at cathodic sites.*

The process of blister formation is as follows:

(iv) The alkaline environment at the cathodic sites seriously affects the adhesion of coating with the substrate whilst producing osmotically active substances at the coating-substrate interface.

(v) These substances at the interface promote either osmotic or endosmotic passage of water through the coating from its environment.

Two types of blistering in organic coatings

(i) Alkaline blistering

- ❑ Alkaline blistering occurs when cations, such as sodium (Na^+), migrate along coating-substrate interface to cathodic areas through the pores and/or defects like scratches in the coating.
- ❑ At the cathodic areas, the cations combine with the hydroxyl anions produced by corrosion to form sodium hydroxide (NaOH). This result is a strongly alkaline aqueous solution at the cathodic area.
- ❑ As osmotic forces drive water through the coating to the alkaline solution, the coating is deformed upwards resulting into formation of a blister.

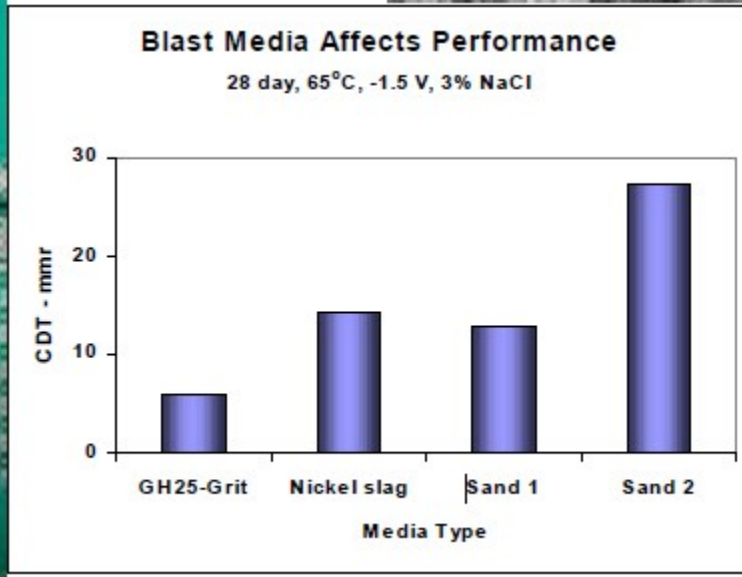
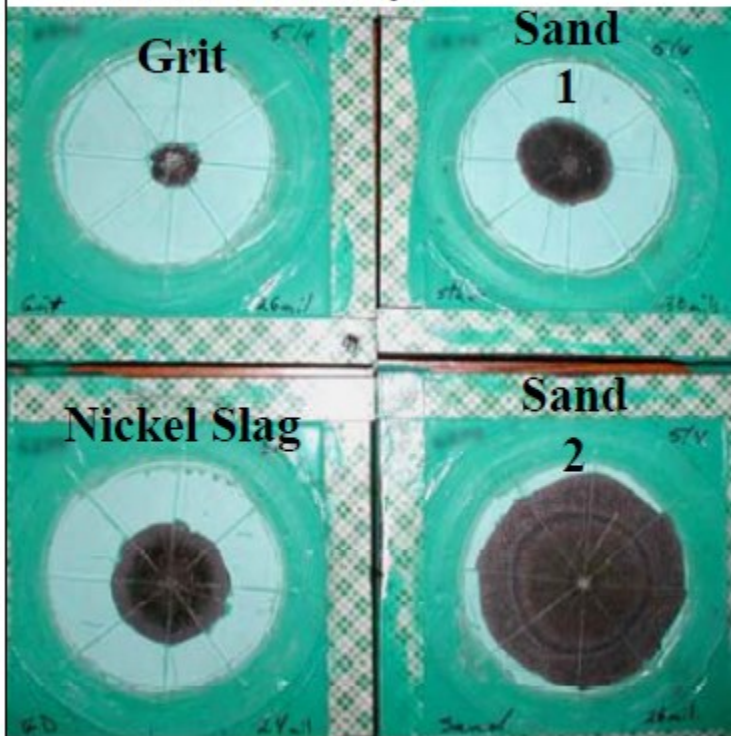
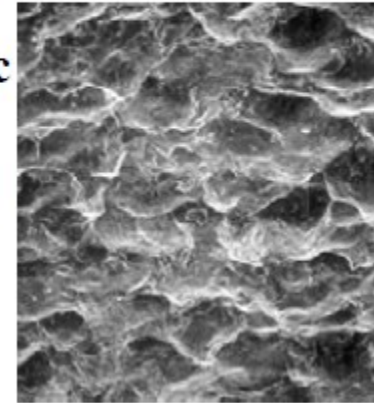
Neutral blistering

Neutral blisters contain solution that is weakly acid to neutral with no involvement of any alkali cations. The first step is undoubtedly reduction of adhesion due to water clustering at the coating-substrate interface and differential aeration is responsible for neutral blistering.

Blast Media: Choice Affects Coating Performance

CDT: 28 days, 65°C, -1.5 V,
3% NaCl electrolyte

Microscopic
view of
grit-blasted
profile





Coatings and Cathodic Protection for Underground Pipelines

- Buried steel pipes are protected from corrosion by covering the exterior with an electrically insulating organic coating.
- Often times an imposed current (cathodic protection, CP) applied to prevent corrosion, initiates the reduction of water and oxygen around a holiday or defect in the coating.
- Hydroxyl ions are created, elevating the pH at the interface. Such increases in pH affect the adhesion between the coating and the metal leading to de-bonding.
- Cathodic disbondment is the loss of adhesion between the organic coating and a metal substrate that results from the cathodic reaction under the coating.



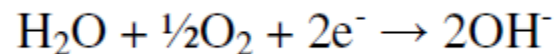
Cathodic disbondment mechanism

The first stage is dissolution of the metal oxide following a logarithmic rate.

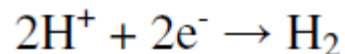
The second stage is due to the failure at the metal oxide/polymer interface at a linear rate.

A third stage reported by Higgins suggests a change in the failure kinetics from metal oxide/polymer degradation

The major driving force for cathodic delamination are electrochemical processes in the presence of air (oxygen reduction):



At a potential of -0.8V the dominant reaction is oxygen reduction



At potentials more negative than -1.0V the dominant reaction is hydrogen evolution



Factors affecting cathodic disbondment

□ Electrolyte

The nature of the environment surrounding a buried pipeline has an important effect on the rate of cathodic disbondment.

The effect of the cation which dissociates from the electrolyte had a strong influence on the rate of cathodic disbondment.

The rate of CD was also found to increase with increasing oxygen concentration



Factors affecting cathodic disbondment

□ pH

Disbondment of organic coatings of cathodically protected steel is typically the result of high pH at the coating/metal interface generated from oxygen reduction reactions.

- (1) Cohesive failure within the polymer at the interface as the result of hydrolysis of bonding groups*
- (2) Displacement of the coating by film of a high pH water at the interface*
- (3) Disbondment by dissolution of the oxide film beneath the coating*



Factors affecting cathodic disbondment

Electron mobility

The concentration and supply of electrons at the delaminating front is an important variable.

Covering the metal surface with a non-conductive layer, such as a phosphate, reduces the availability of electrons for the cathodic reaction and can minimize the disbondment of organic coatings



Factors affecting cathodic disbondment

- ❑ Chemical structure of coating

Alkaline degradation by hydrolysis may also take place within the polymer coating bulk which decreases the cohesive strength of the coating. This failure typically requires gross permeation of the coating by hydroxyl ions and their metal counter ions.



Factors affecting cathodic disbondment

Mechanical (internal and external) stresses experienced by an organic coating will also play a role in its cathodic disbondment performance.



Relationship between ion transport and the failure behavior of organic coating

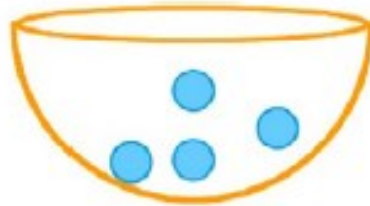
Different stages of ions penetration into the coating:

- Water was first absorbed by the coating, causing an increase in C_c and decrease in coating resistance. At this point, the coating was plasticized and degraded to some extent.
- Cl ions were believed to migrate into the coating because the membrane potential of the pure epoxy resin was positive and showed anionic selectivity.
- The epoxy resin membrane was neutralized by the penetration of Cl ions such that the ionic selectivity of the membrane disappeared
- K^+ ions then diffused into the coating in the form of hydrated ions, causing further decrease in the coating resistance.

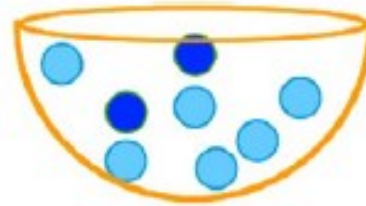
- ❑ Conduction paths of random depths were formed on the coating surface.
- ❑ Paths of complete penetration developed with time, thereby allowing the electrolyte to come into contact with the metal oxide interface and corrosion cells were formed.
- ❑ The mechanism of ion transport into the coating thus changed from active diffusion to direct transmission of the electrolyte



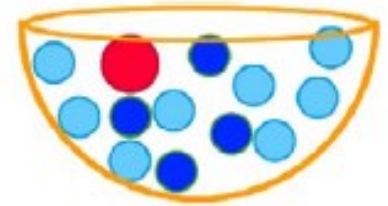
0 days



13 days

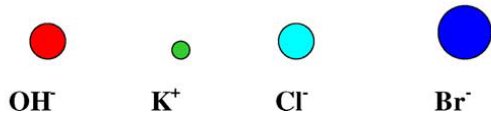
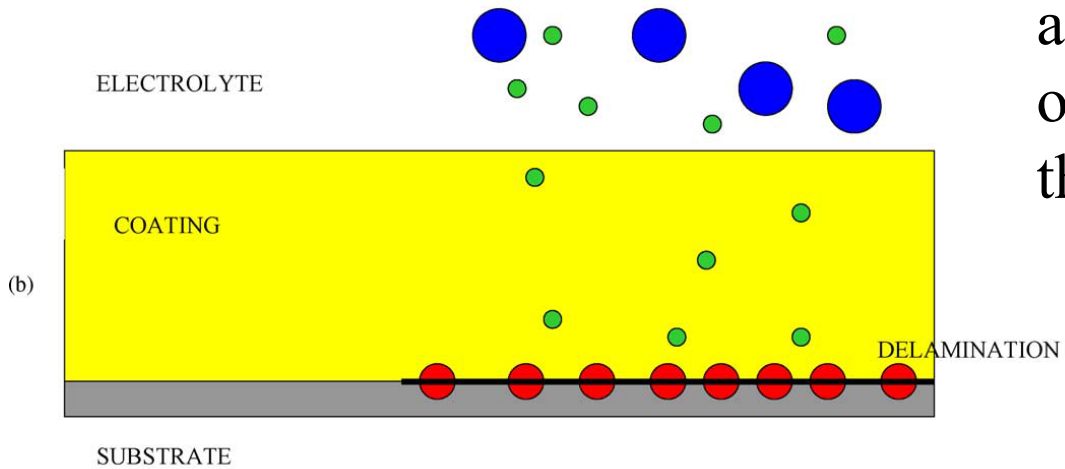
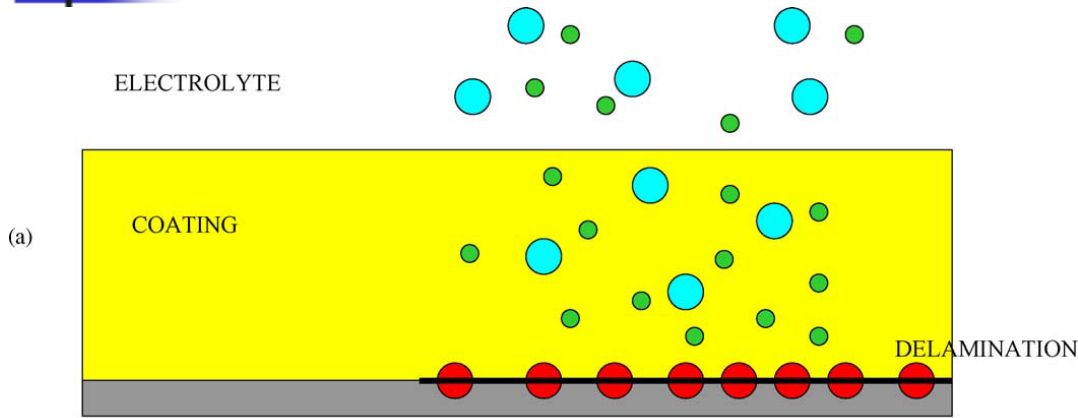


45 days



70 days

● Cl ● K ● Fe



The anions diffusion plays an important role in the case of positive ions diffusing through the coating



An EIS study of ion diffusion through organic coatings

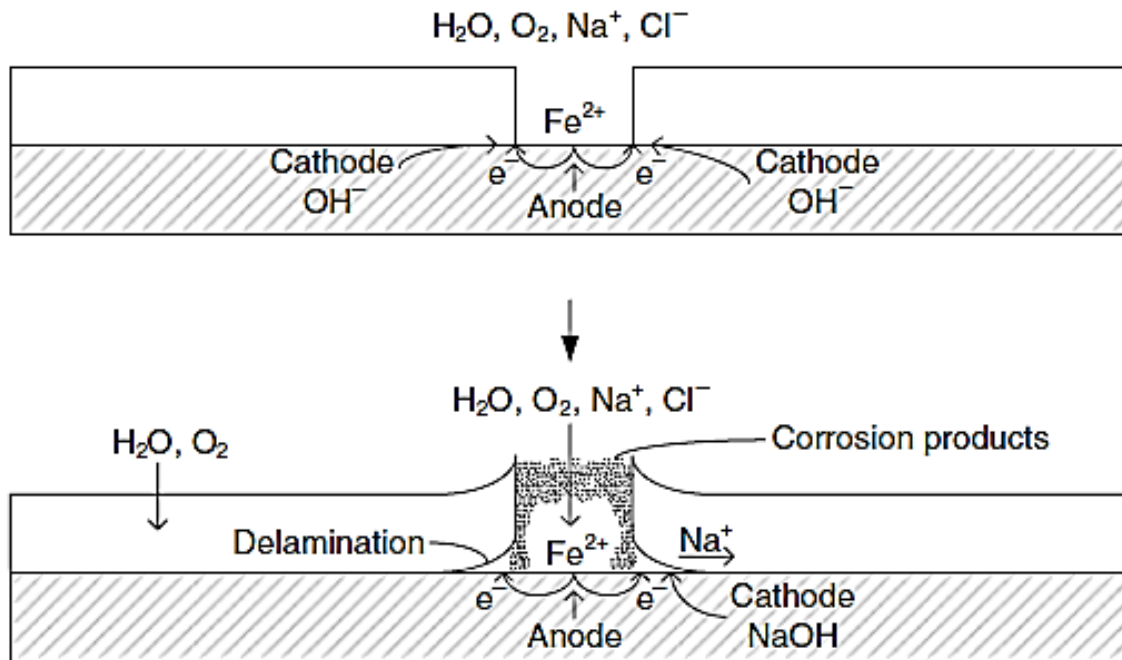
The diffusion process of ions, water and oxygen, can occur essentially through two ways:

- (1) through the defect in the coating promoting the corrosion process and the delamination as well as through the delaminated interface;*
- (2) through the intact coating.*

An EIS study of ion diffusion through organic coatings

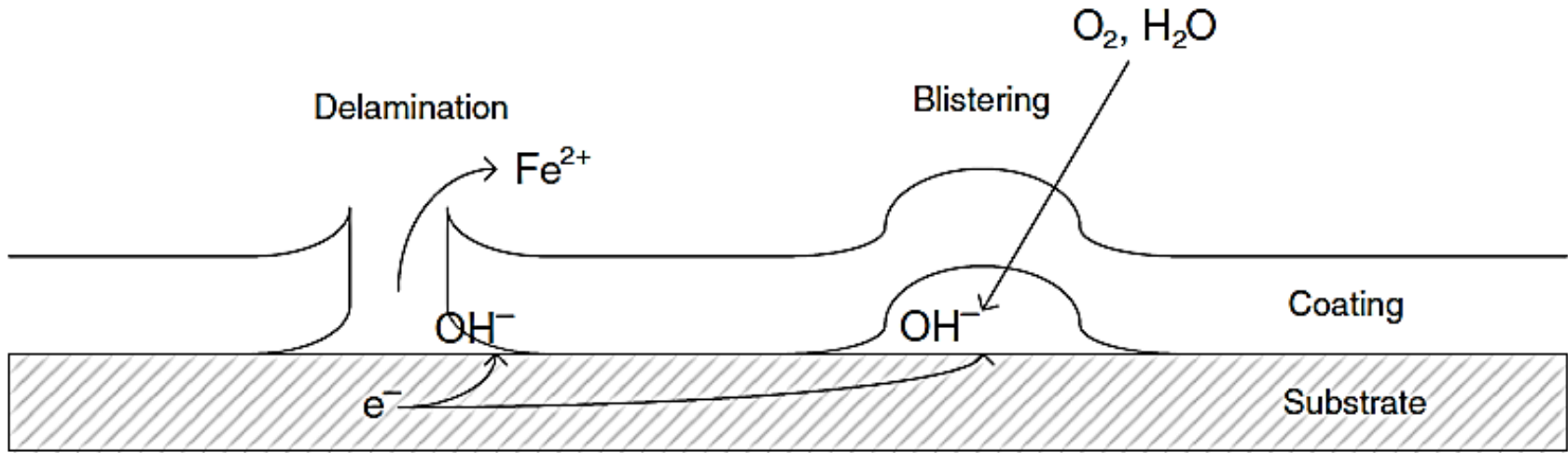
The cathodic delamination is one of the more important processes promoting the degradation of a protective organic coating. It can occur by:

1- In the case of coating on cathodically protected structures



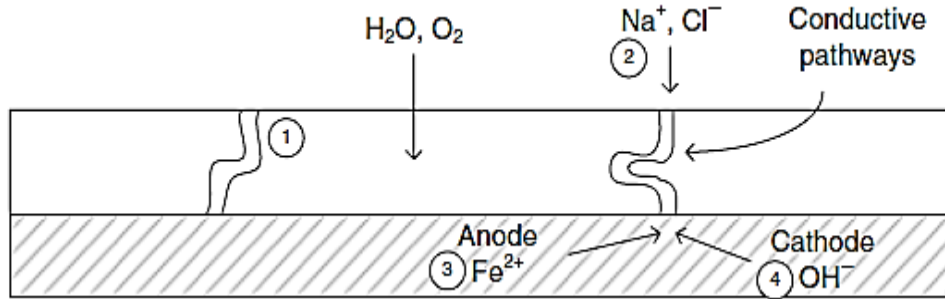
An EIS study of ion diffusion through organic coatings

2- In the case of organic coated steel at the free corrosion potential.

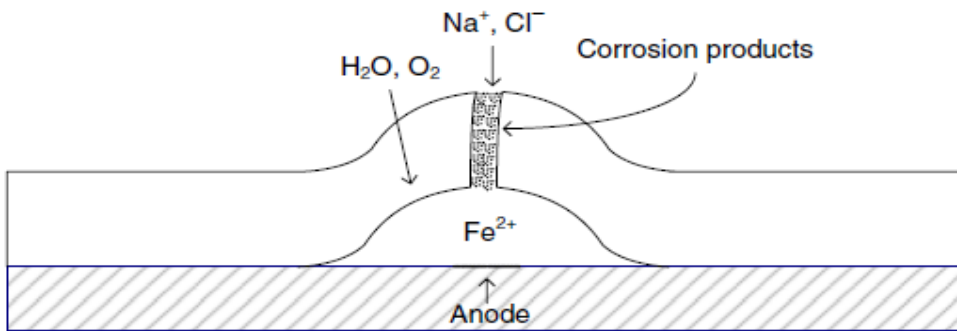
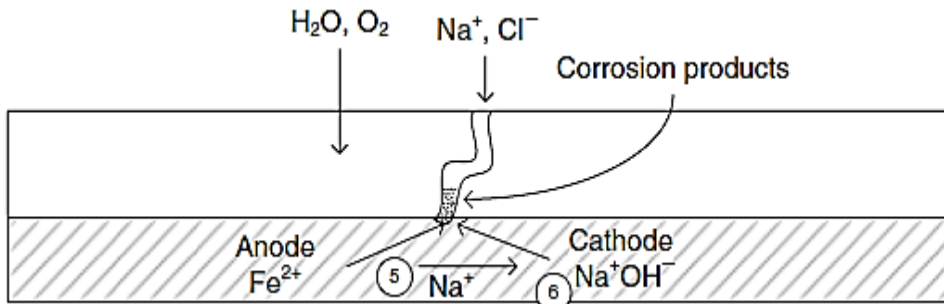


Cathodic disbonding of the coating from the substrate caused by the local alkaline environment due to the reaction of oxygen reduction producing OH^- anions.

EIS evaluation of the samples coated by organic coatings



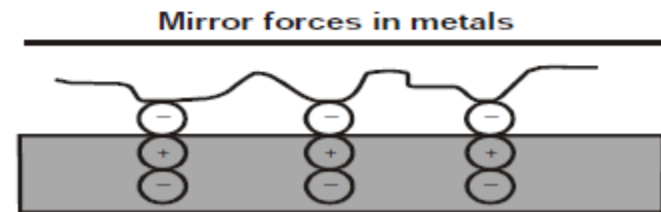
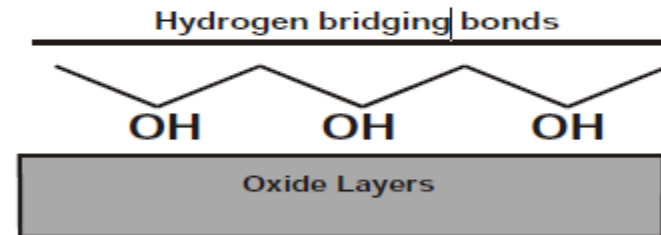
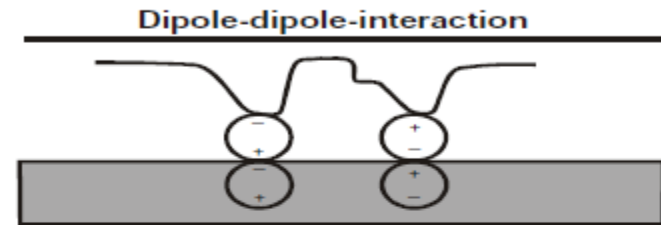
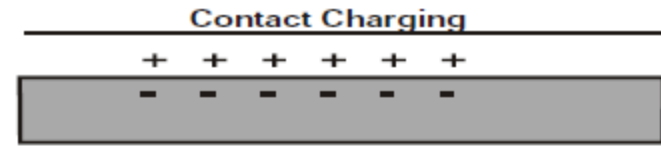
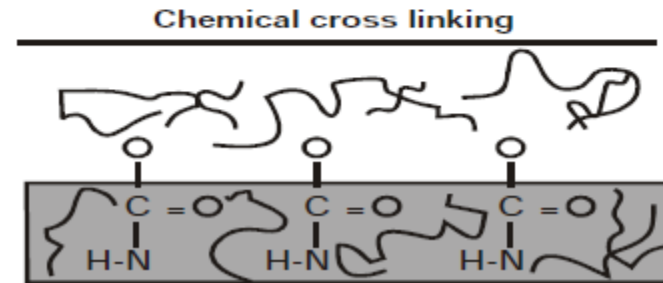
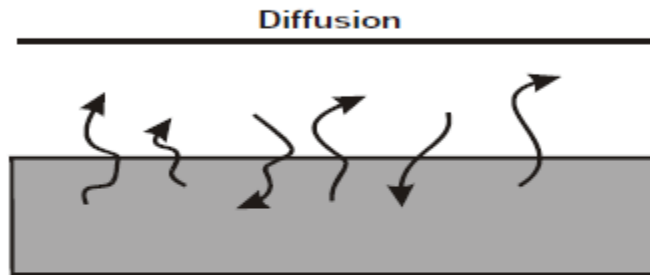
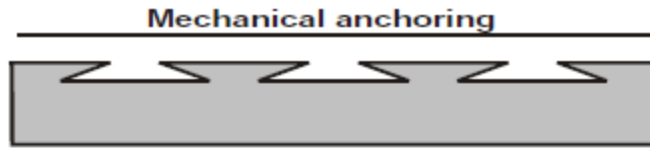
Coating with defect





Coatings, adhesion mechanisms and chemical treatments

Coatings and Cathodic Protection for Underground Pipelines



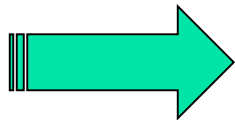
Physical/Chemical causes for adhesion of coatings to the substrate

Adhesion theories:

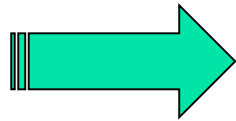
- 1- Mechanical inter-locking theory
- 2- Adsorption theory
- 3- Electrostatic theory
- 4- Diffusion theory
- 5- Weak boundary layers



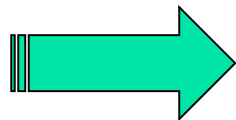
The role of conversion coating



Removal of oxide layer and producing more stable layer



Enhancement of the steel surface wetting and adhesion properties



Enhancement of the adhesion properties of the organic coating



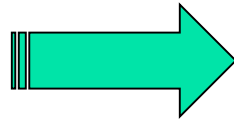
Conversion coatings



Chromate based



Phosphate based



*Cerium and Zirconium
based*



Application methods:

Immersion

Spray

Application methods:

Polarizing current → **Electrolytic**

Absence of polarizing current →
Chemical treatment

Conversion coating:

Phosphating

Chromating

Passivation

Anodizing

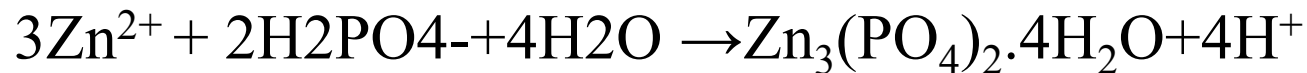


Phosphate conversion coating

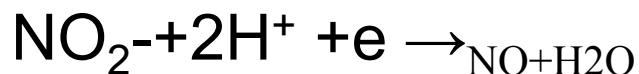
A. Acidic attack of the metal



B. Coating deposition



C. Nitrate acceleration



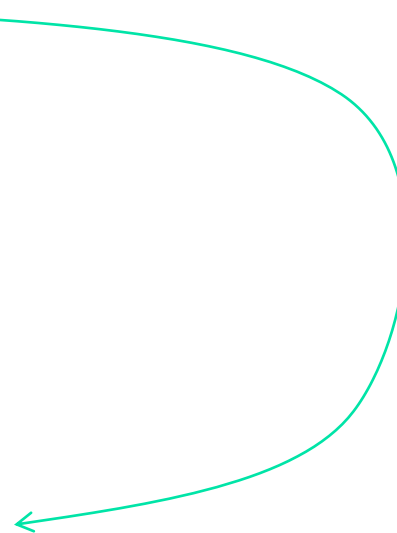
Phosphate conversion coating

Phosphate conversion coating: Phosphating process can be defined as the treatment of a metal surface so as to give a reasonably hard, electrically non-conducting surface coating of insoluble phosphate which is contiguous and highly adherent to the underlying metal

Step I: Hydrogen evolution occurs at the microcathodic sites:



The formation of soluble primary ferrous phosphate leads to a concurrent local depletion of free acid concentration in the solution resulting in a rise in pH at the metal/solution interface.





Phosphate conversion coating

$\text{Zn}(\text{H}_2\text{PO}_4)_2 \rightarrow \text{ZnHPO}_4 + \text{H}_3\text{PO}_4$ Secondary phosphate
(Insoluble and unstable salt)

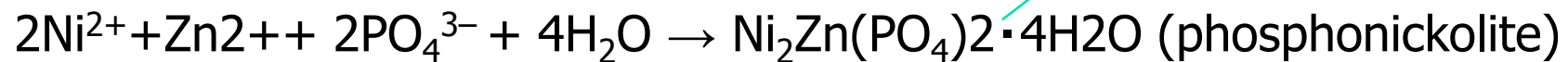
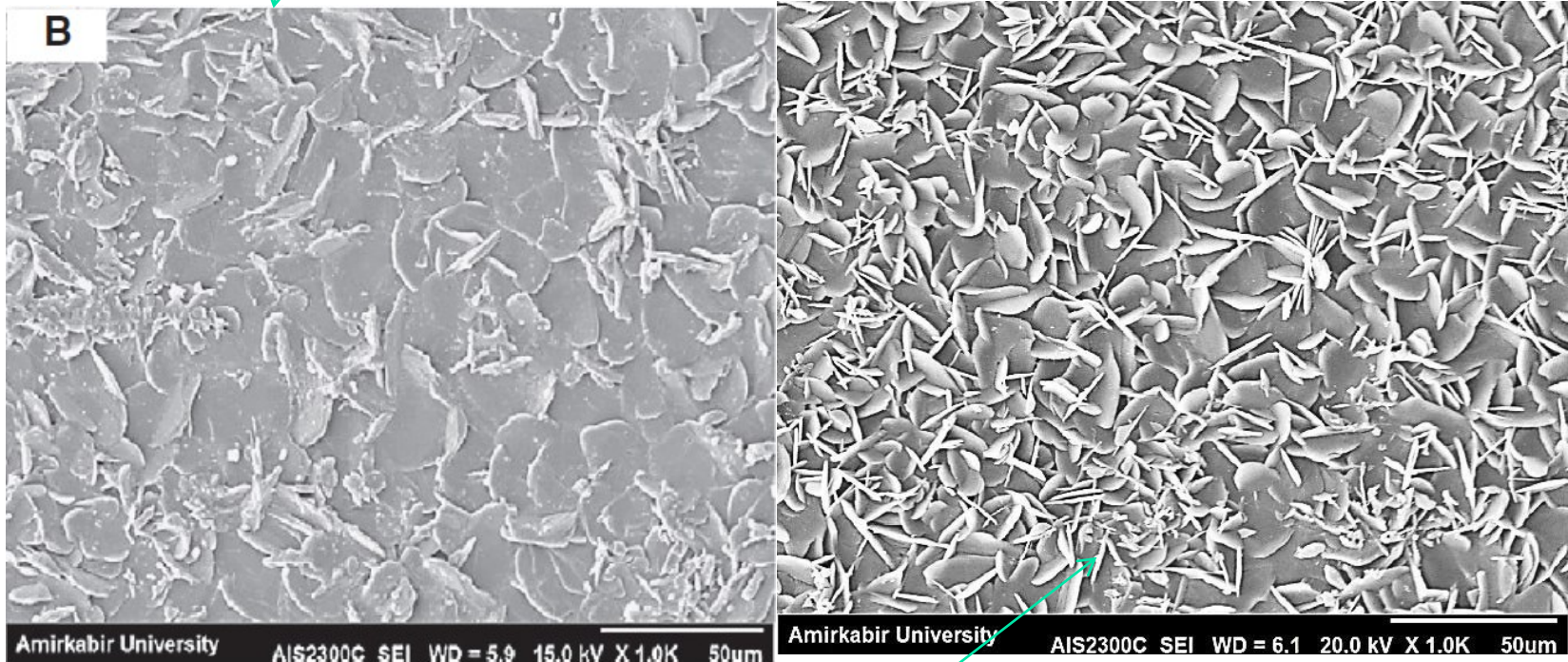
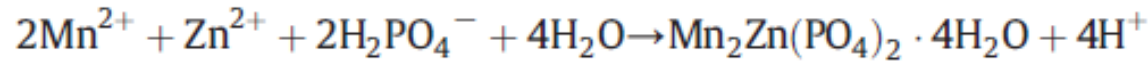
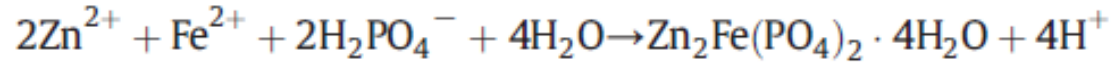
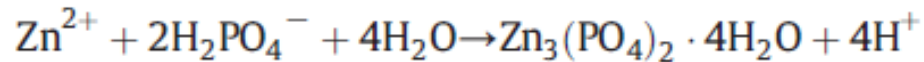
$3\text{ZnHPO}_4 \rightarrow \text{Zn}_3(\text{PO}_4)_2 + \text{H}_3\text{PO}_4$ tertiary phosphates
(Insoluble and stable salt)

Hopeite phase: $\text{Zn}_3(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$

Phosphophyllite phase: $\text{Zn}_2\text{Fe}(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$ and $\text{Zn}_4\text{Fe}_5(\text{PO}_4)_6 \cdot 4\text{H}_2\text{O}$.



Phosphate conversion coating





Phosphate conversion coating

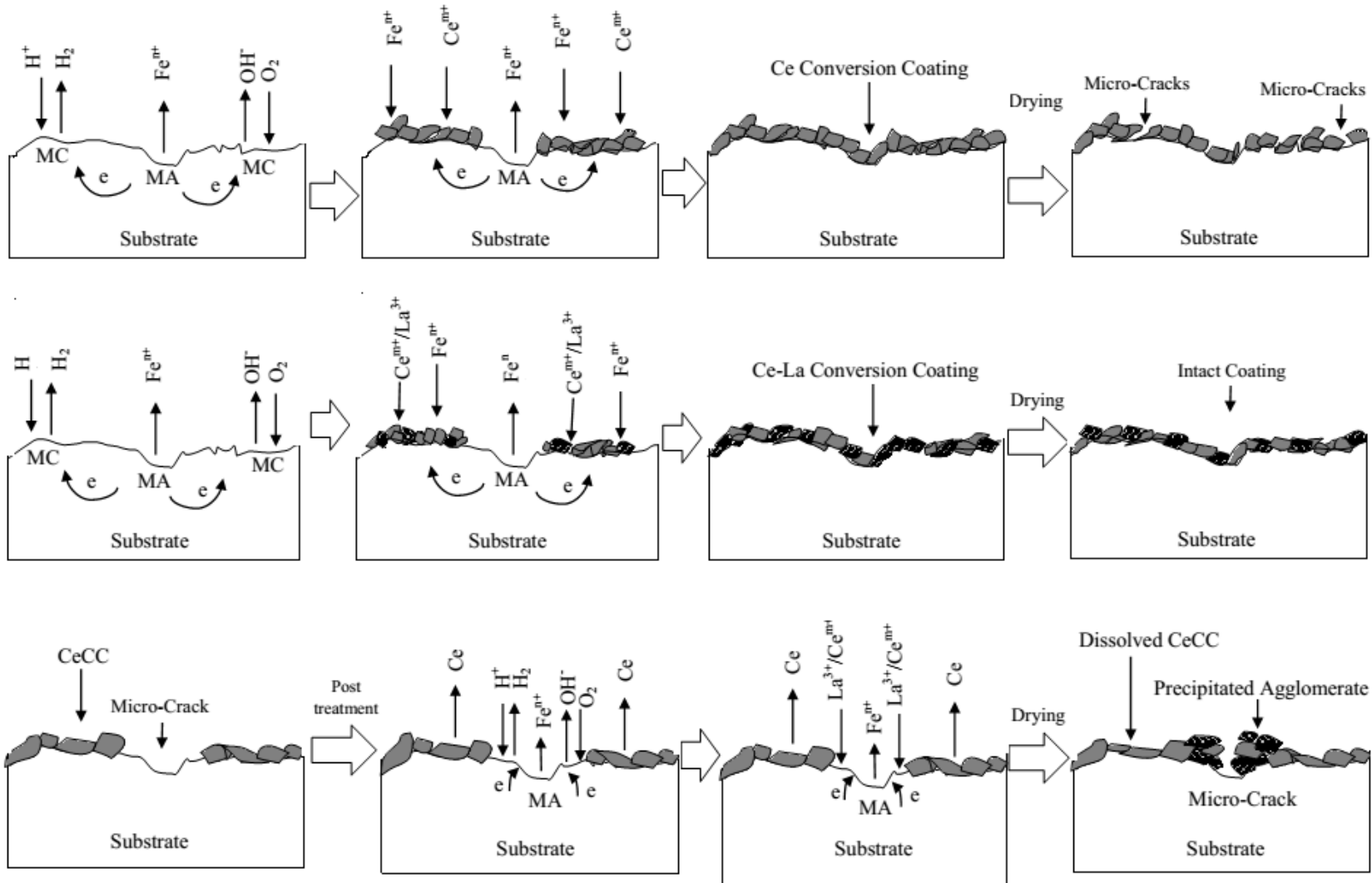
Advantages of surface treatment by phosphate conversion coatings:

- Good adhesion to the metal surface
- Good adhesion to the subsequent organic paint
- Increasing the surface free energy
- Increasing the surface roughness and number of adhesion sites
- Zinc phosphate insulates the anodic and cathodic sites on the steel surface

Disadvantages of surface treatment by phosphate conversion coatings:

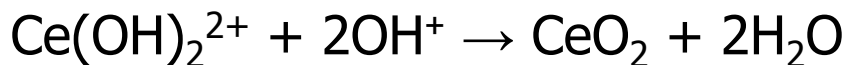
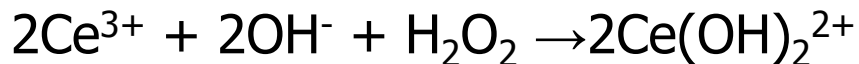
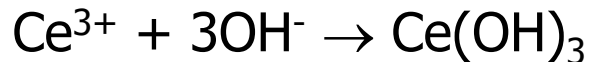
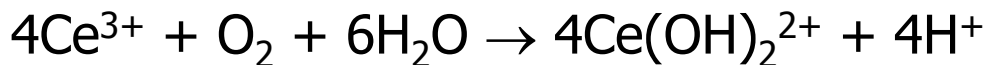
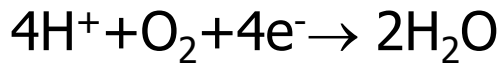
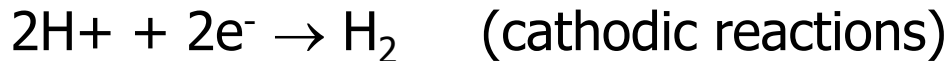
- Zinc phosphate film is porous and permeable against electrolyte diffusion, so the zinc phosphate film needs an additional step of surface preparation by chromate solution which is toxic
-
- Zinc phosphate film do not show good stability at alkaline conditions and loss of adhesion of coating occurs in wet conditions
-
- Zinc phosphate process needs high temperature
-

Cerium conversion coating

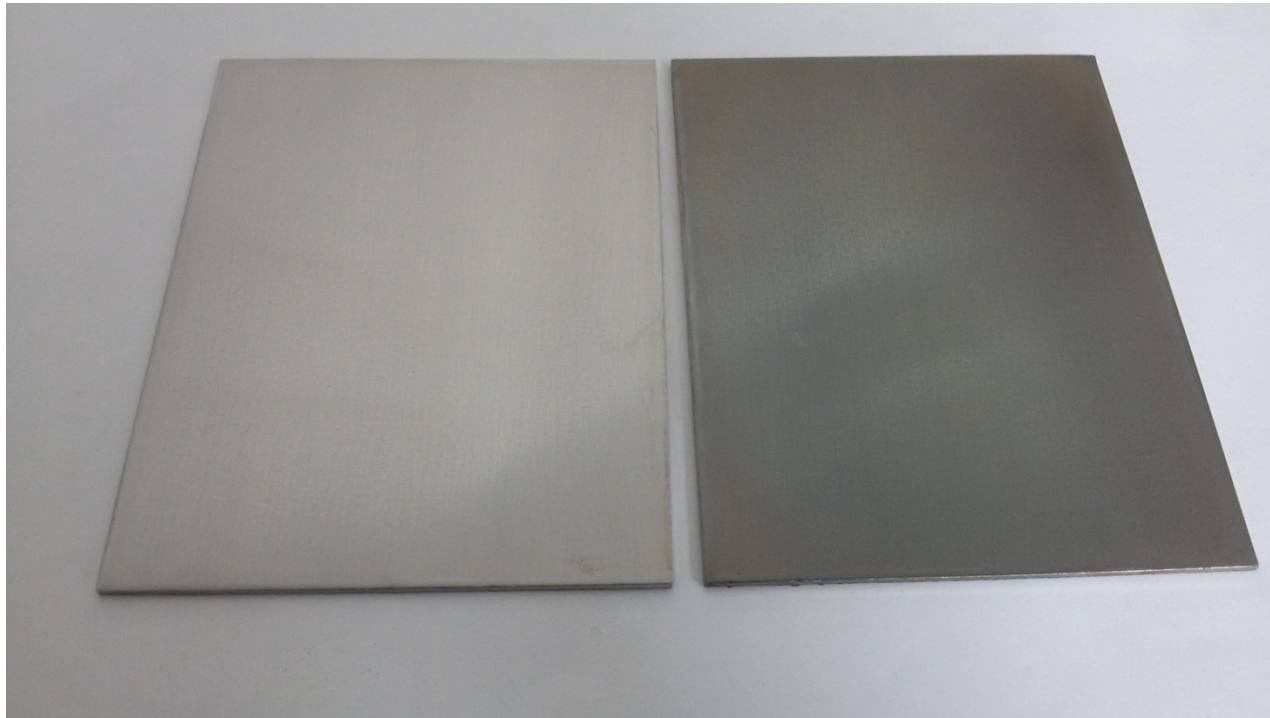




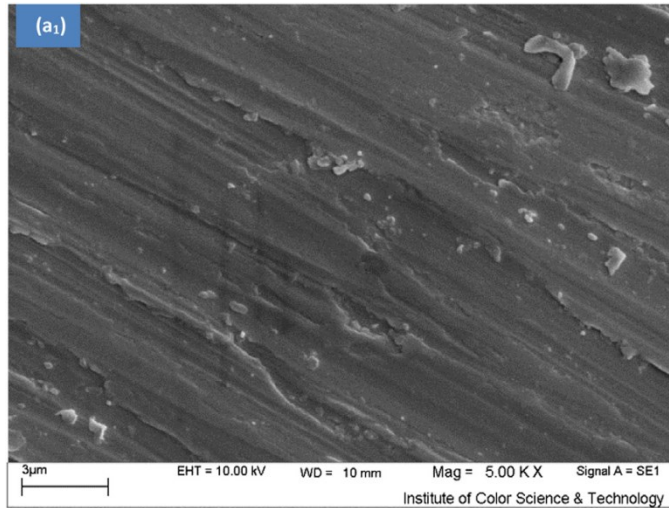
Cerium conversion coating



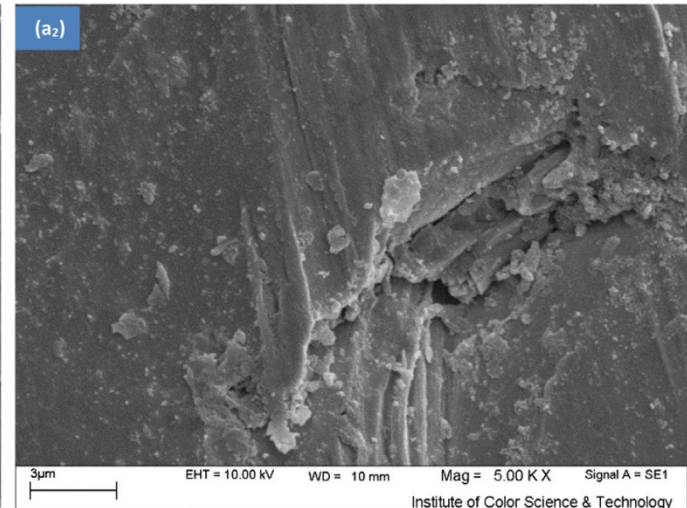
The effects of conversion coatings on the adhesion of organic coating



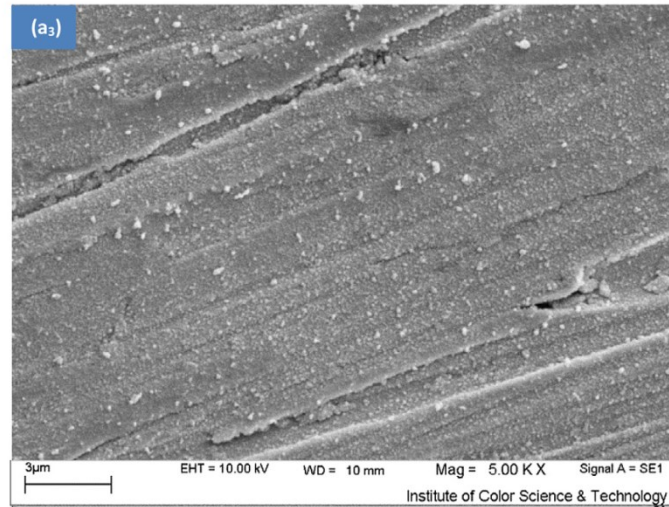
The effects of conversion coatings on the adhesion of organic coating



Bare steel

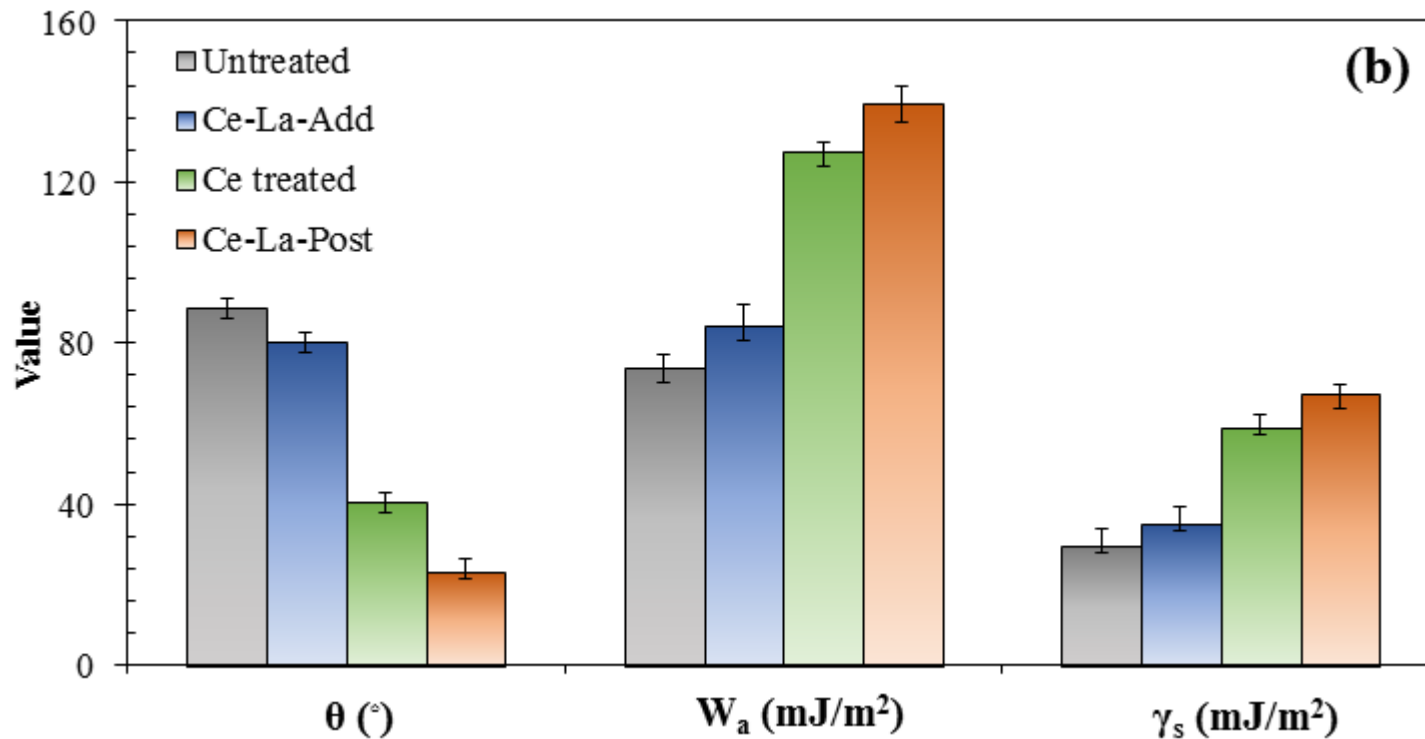
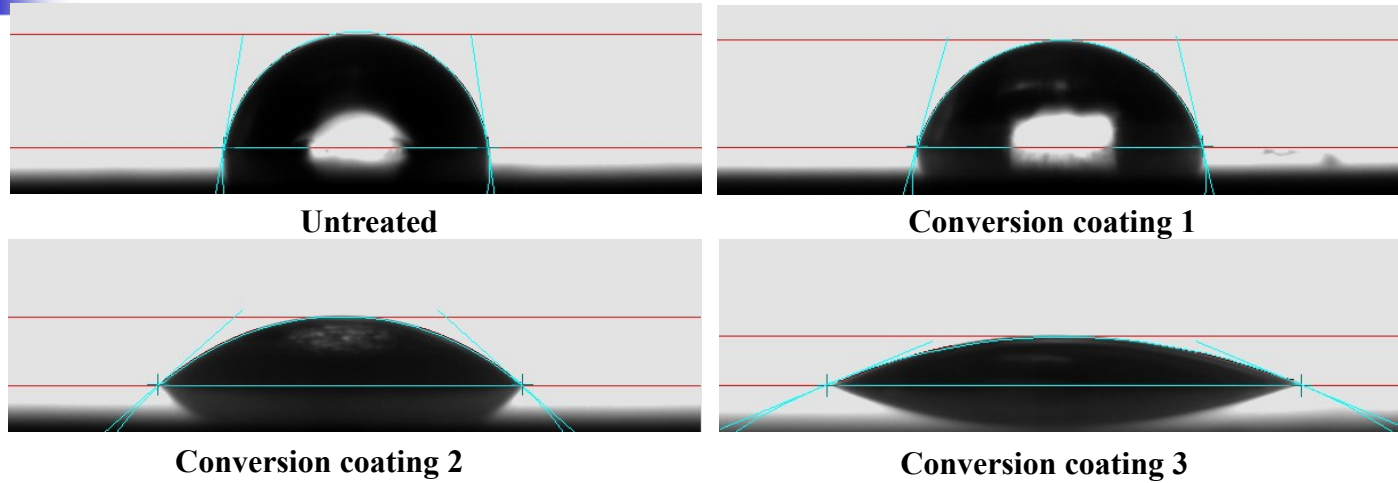


Acid washed



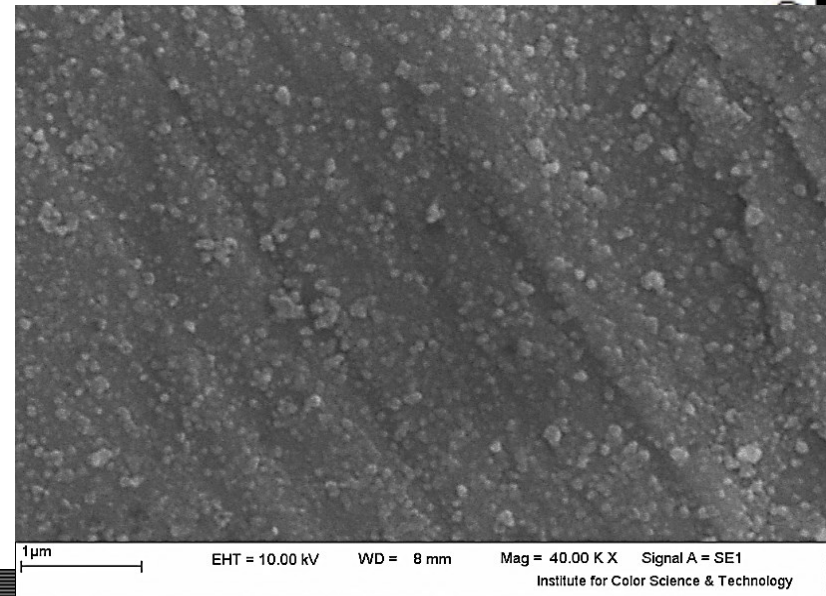
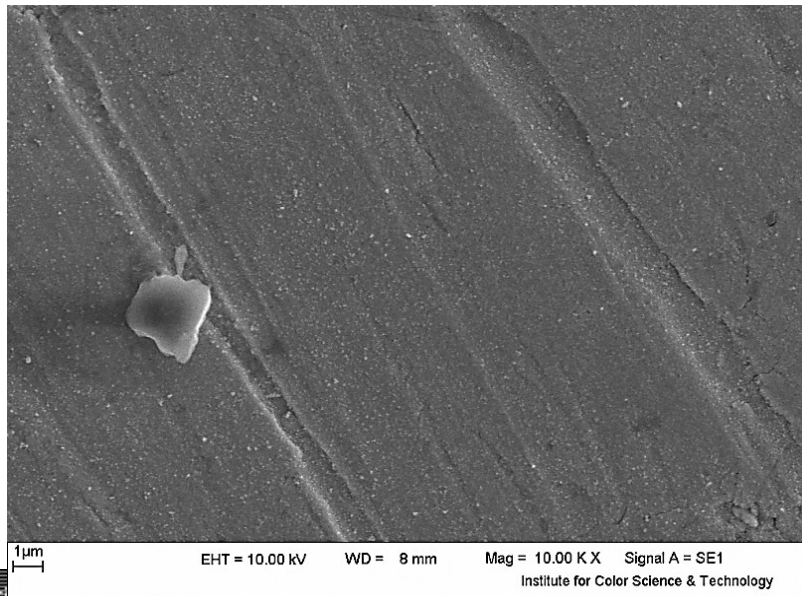
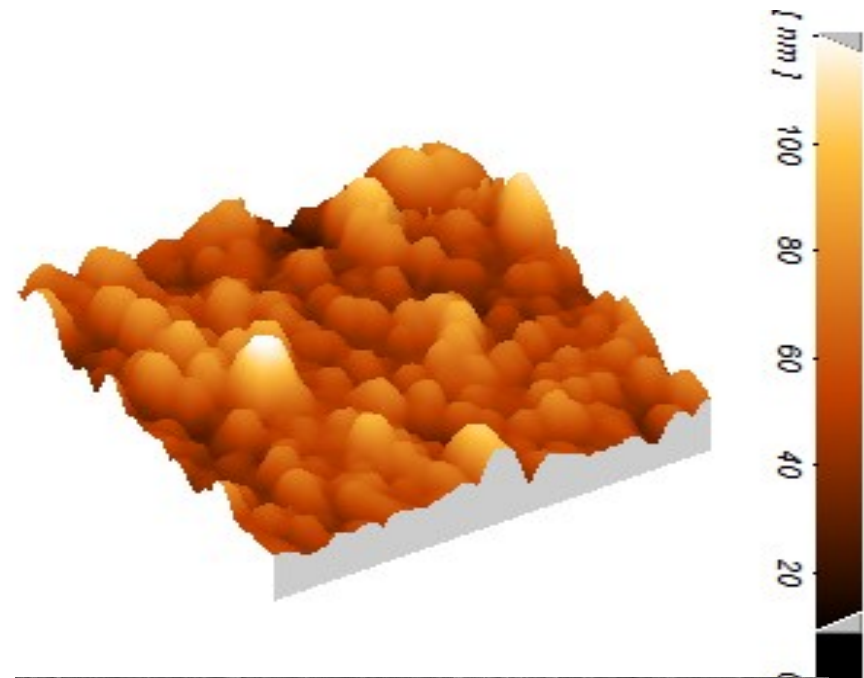
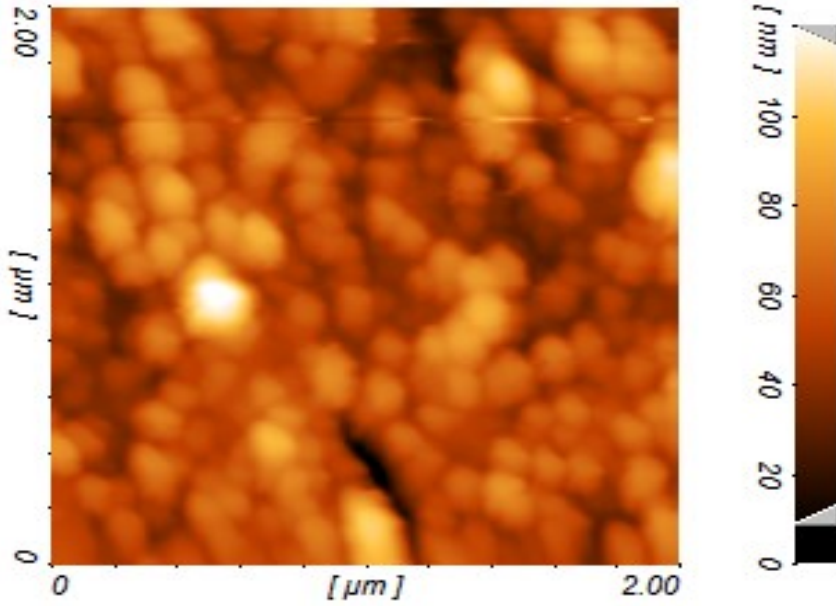
Chemically treated

The effects of conversion coatings on the adhesion of organic coating

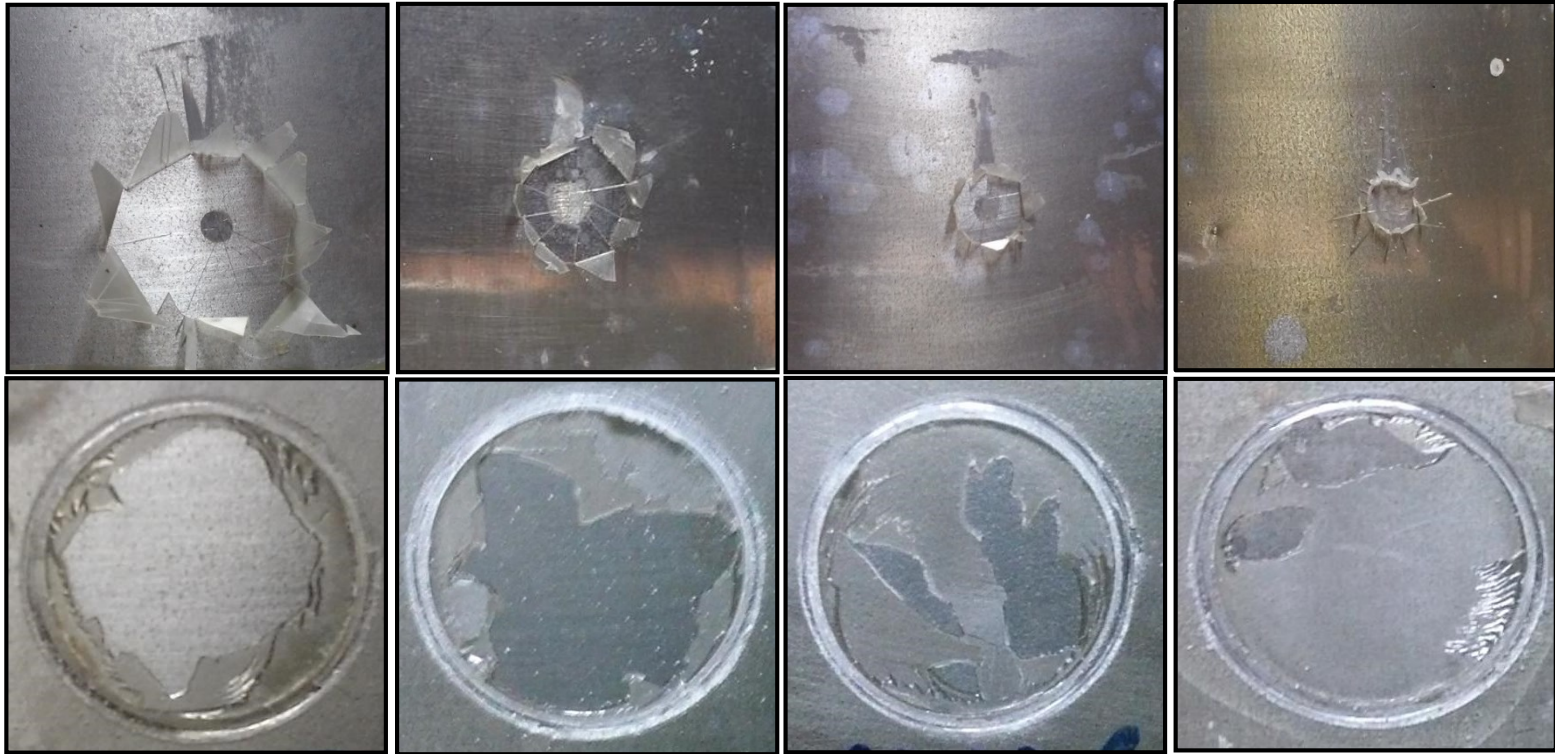


The effects of conversion coatings on the adhesion of organic coating

[113 nm] 125 nm



The effects of conversion coatings on the adhesion of organic coating



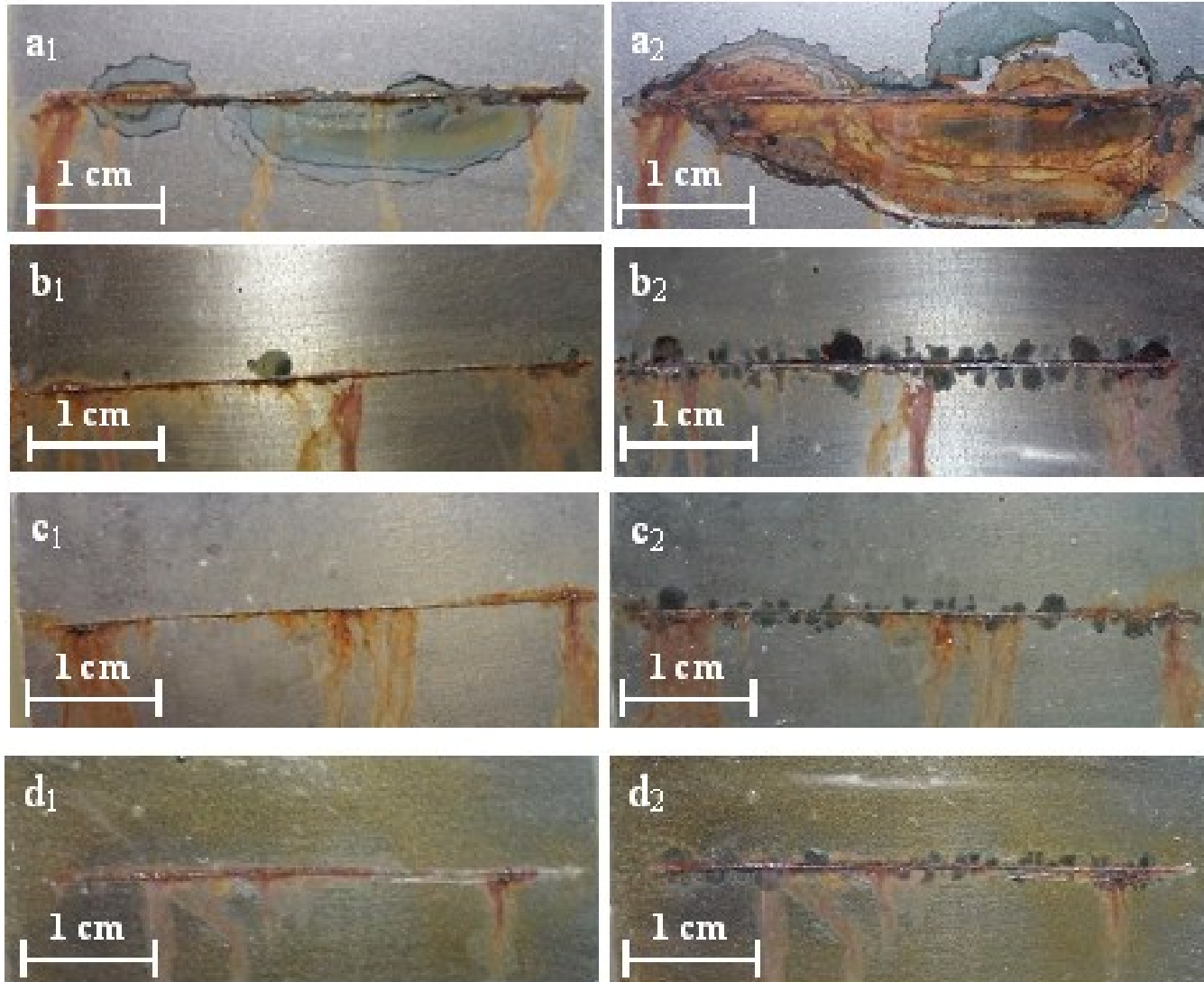
Untreated

Conversion coating 1

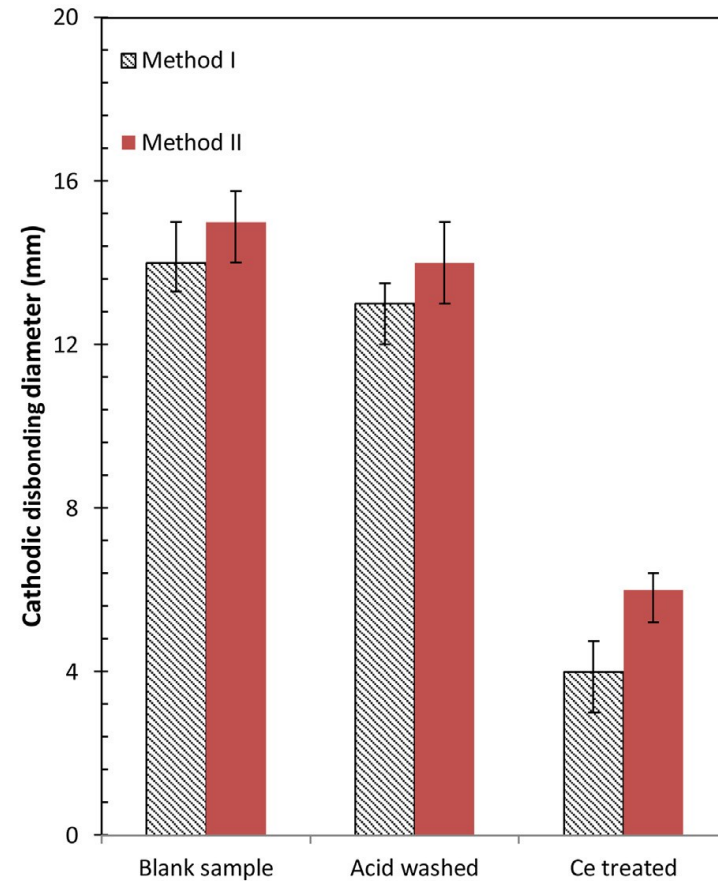
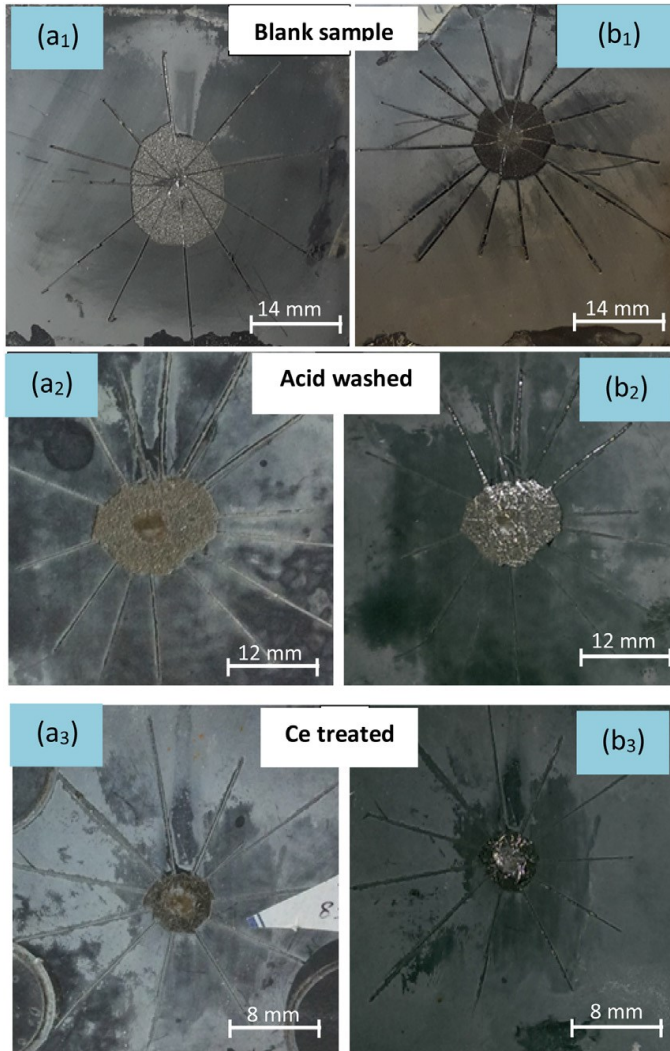
Conversion coating 2

Conversion coating 3

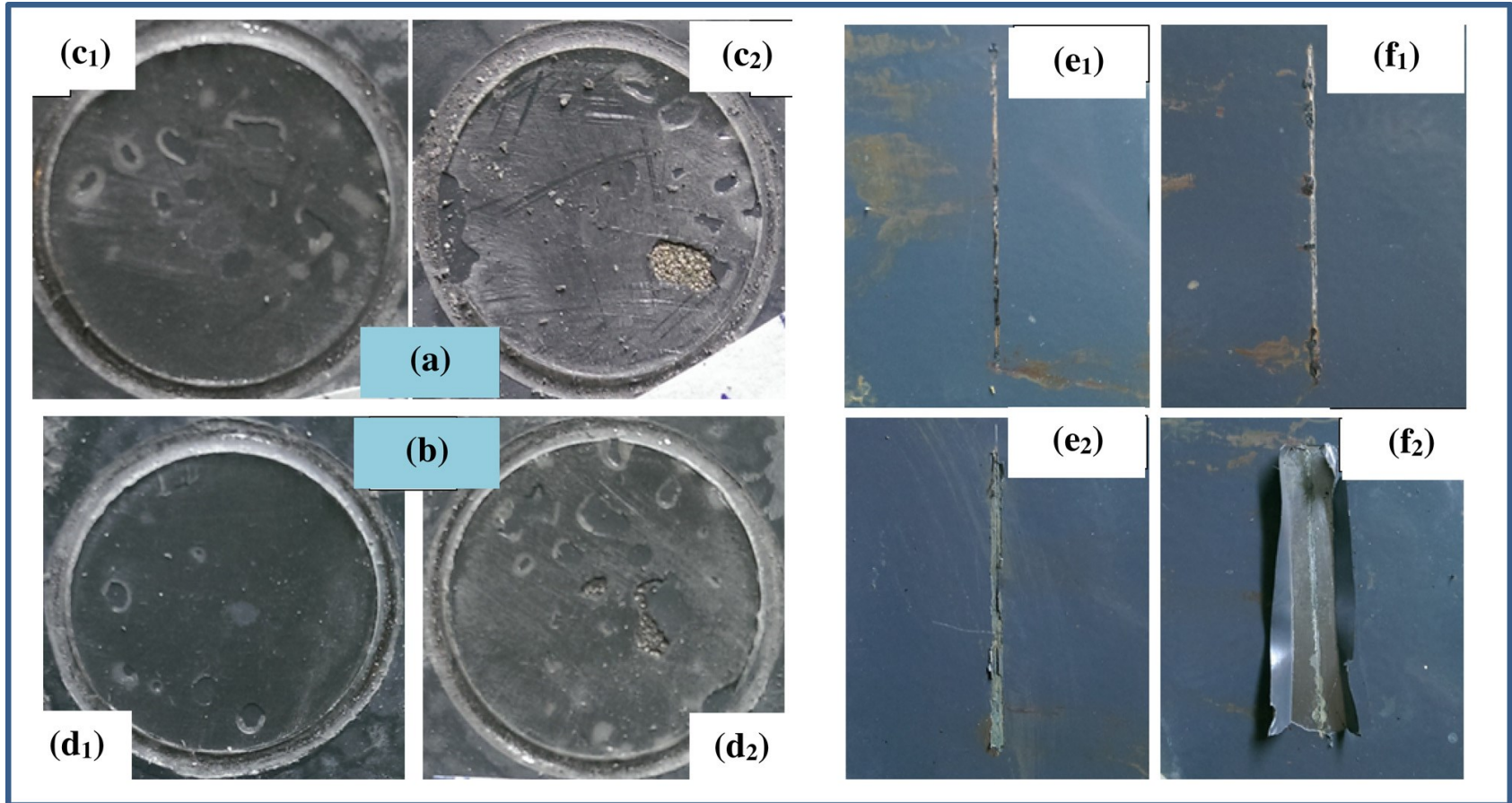
The effects of conversion coatings on the adhesion of organic coating



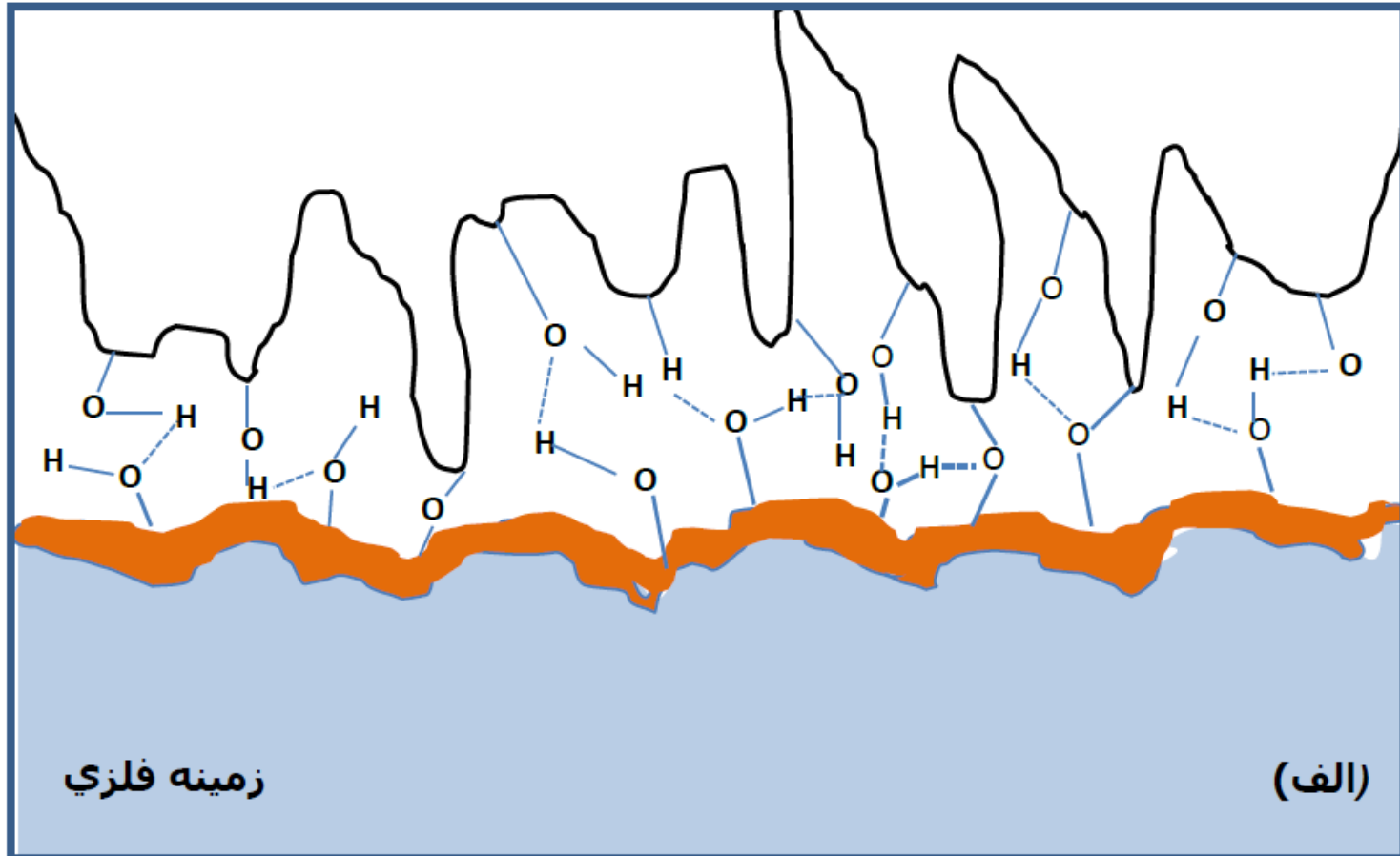
The effects of conversion coatings on the adhesion of organic coating



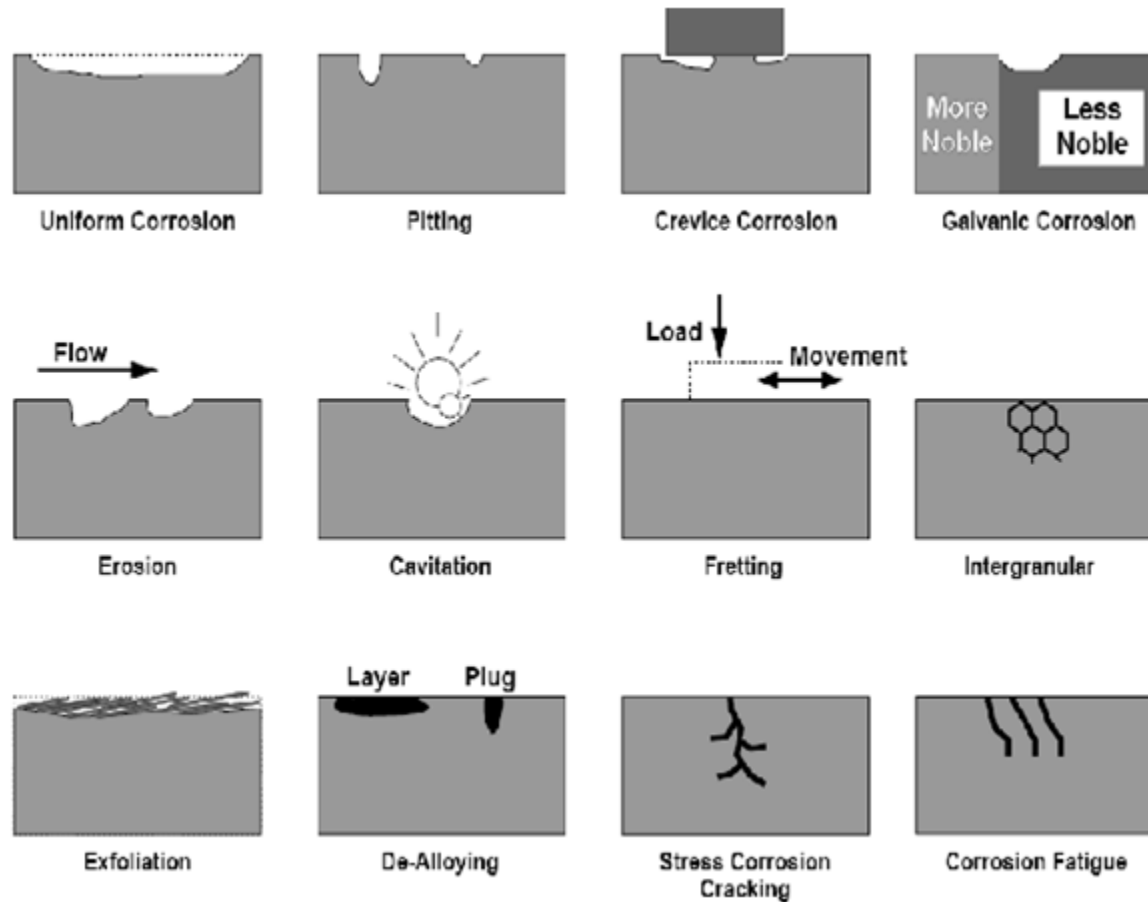
The effects of conversion coatings on the adhesion of organic coating



The effects of conversion coatings on the adhesion of organic coating



Forms of Corrosion



Forms of Corrosion

General corrosion: General corrosion or rusting is the most familiar form of steel corrosion. It can be considered a uniform corrosion process in which numerous micro corrosion cells are activated at the corroded area.

Pitting corrosion: A non uniform, highly localized form of corrosion that occurs at distinct spots where deep pits form. (A pit is a small electrochemical-corrosion cell, with the bottom of the pit acting as the anode.) Chloride-induced corrosion is of this type and can be seen frequently in structures exposed in coastal areas.

Forms of Corrosion

Galvanic corrosion: When two metals of different electrochemical potential are joined or coupled electrically in the presence of moisture or an aqueous solution, one will act as the anode and corrode;

Stress-corrosion: Under stress, corrosion processes proceed much faster and can lead to brittle failure as corrosion tends to be localized.

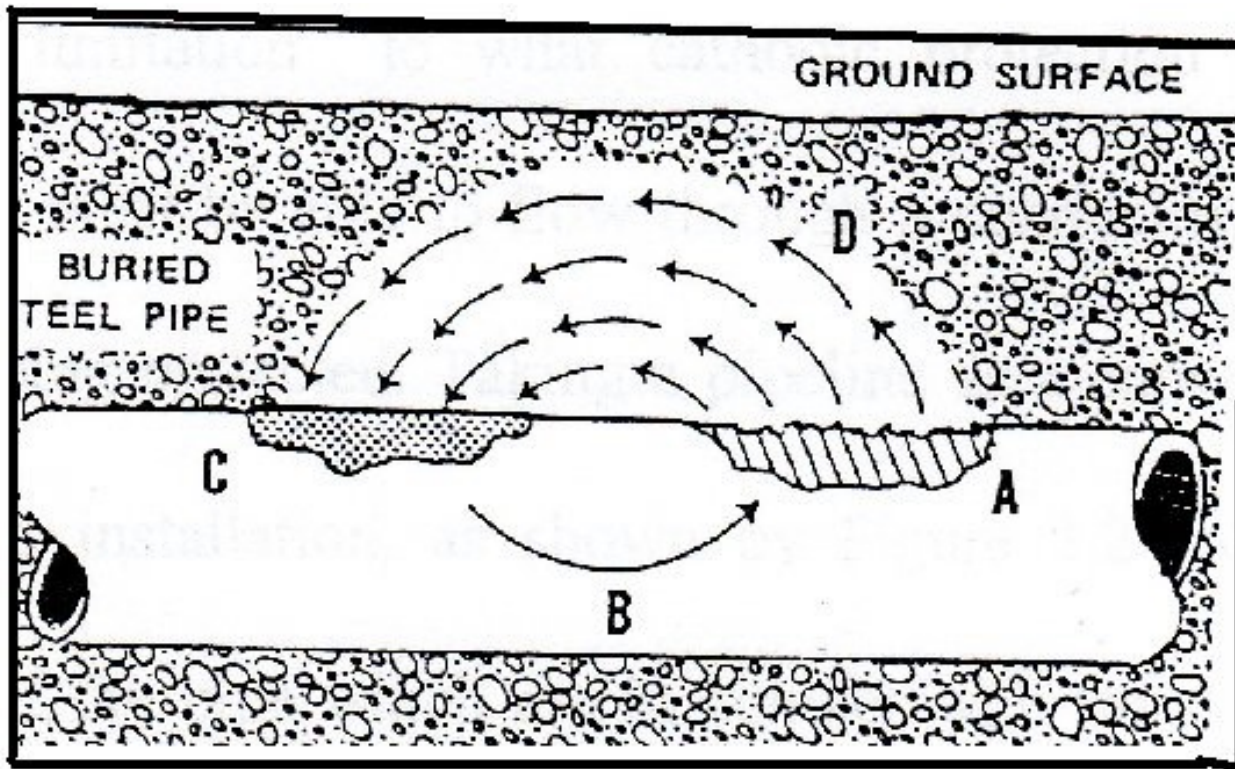
Crevice corrosion: This form occurs when moisture and contaminants retained in crevices accelerate corrosion.

Underground corrosion

- Most of the corrosion of underground metal is as a result of an electrochemical reaction.
- Corrosion occurs through the loss of the metal ions at anodic area to the electrolyte.
- Cathodic areas are protected from corrosion because of the deposition of hydrogen or other ions that carry current

Coatings and corrosion resistance for Underground Pipelines

The areas of anodes and cathodes are important. That includes the size of anode or cathodes, the higher the contact resistance between it and the electrolyte. For example, coating of good quality can interpose a very high resistance into circuit.



The flow of direct current between anodic and cathodic areas on a section of buried pipe.

Factor affecting underground corrosion

❑ Soil Resistivity

- ❑ Soil resistivity depends on *the natural ingredient* the amount of salt dissolved in the soil and *moisture content*.
- ❑ For the cathodic protection applications , galvanic anodes are used generally in those cases where relatively small increments of current are required in areas where soil resistivity is low that enough to permit obtaining the desired current with a reasonable number of anodes.

Factor affecting underground corrosion

□ Soil pH Value

The main factor that affects underground corrosion process is the soil pH value. The more acidic the soil is, the higher the corrosion rate. This pH ranges generally from 5 to 10 in soil pH for indicates value, where lower value considered acidic and higher value is alkaline

Coating ability to resist development of holidays with time

- ❑ After the coating is buried, two areas that may destroy or degrade coatings are **soil stress** and **soil contaminants**.
- ❑ **Soil stress**, brought about in certain soils that are alternately wet and dry, creates forces that may split or cause thin areas.
- ❑ To minimize this problem, one must evaluate the **coating's abrasion resistance, tensile strength, adhesion, and cohesion**.
- ❑ The coating's resistance to chemicals, hydrocarbons, and acidic or alkaline conditions should be known for evaluating their performance in contaminated soils.

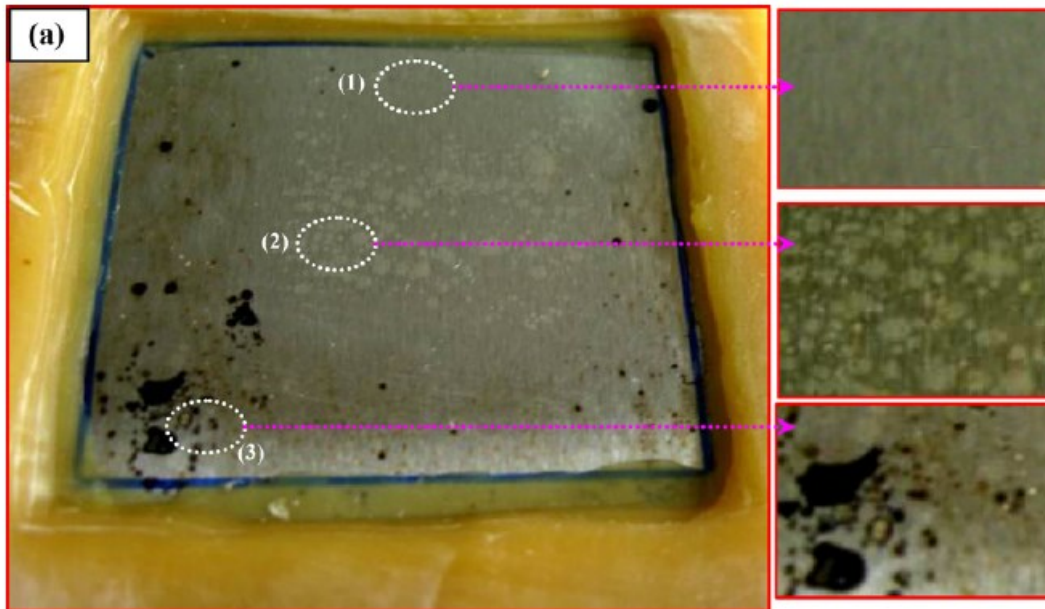


Ability to maintain substantially constant electrical resistivity with time

The effective electrical resistance of a coating per average square foot depends on the following:

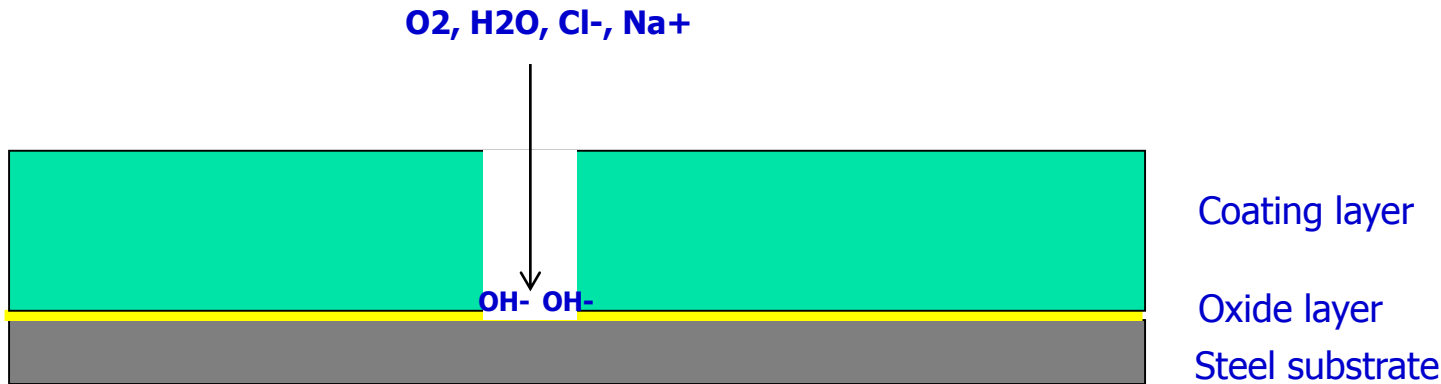
- (i) Resistivity of the coating material*
- (ii) Coating thickness*
- (iii) Resistance to moisture absorption*
- (iv) Resistance to water vapor transfer*
- (v) Frequency and size of holidays*
- (vi) Resistivity of the electrolyte*
- (vii) Bond or adhesion of coating*

EIS evaluation of the samples coated by organic coatings



The mechanisms of loss of adhesion caused by the alkaline pH

(1) oxide reduction

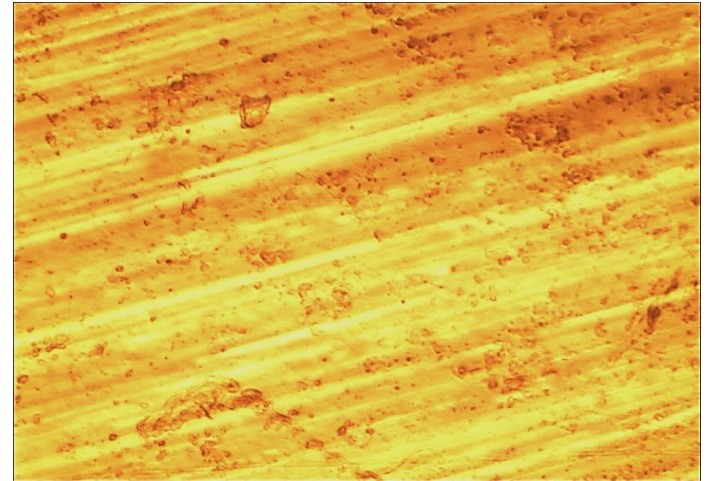


- ❑ Every steel surface is covered by a thin surface oxide. The reduction of the iron from Fe³⁺ to Fe²⁺ leads to the production of oxides partially soluble in the local alkaline environment causing the detachment of the coating.
- ❑ Such mechanism has been reported in the case of epoxy coatings on cathodically protected structures

The mechanisms of loss of adhesion caused by the alkaline pH

(2) alkaline hydrolysis of the polymer

In the case of alkaline hydrolysis of the polymer there is a chemical degradation of the polymer matrix of the coating because of very elevated pH (saponification reaction).



(3) weakening of the interface (interfacial fracture).

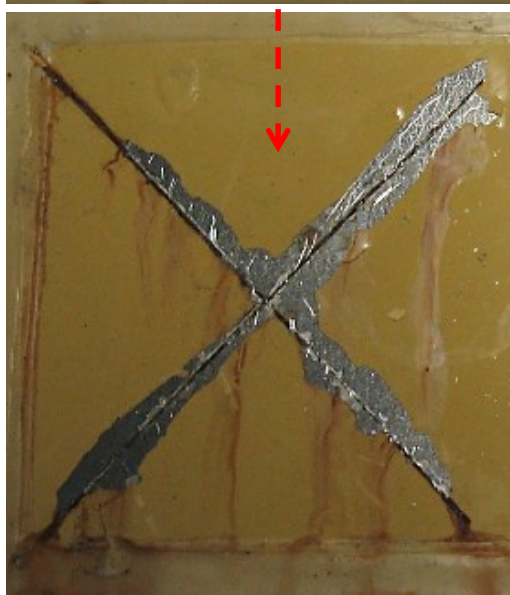
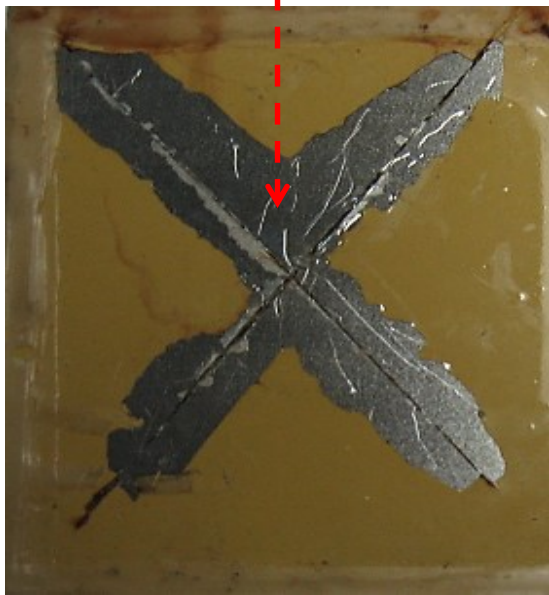
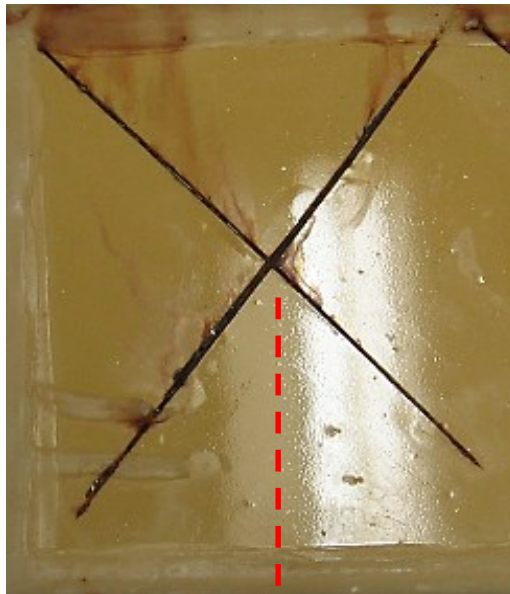
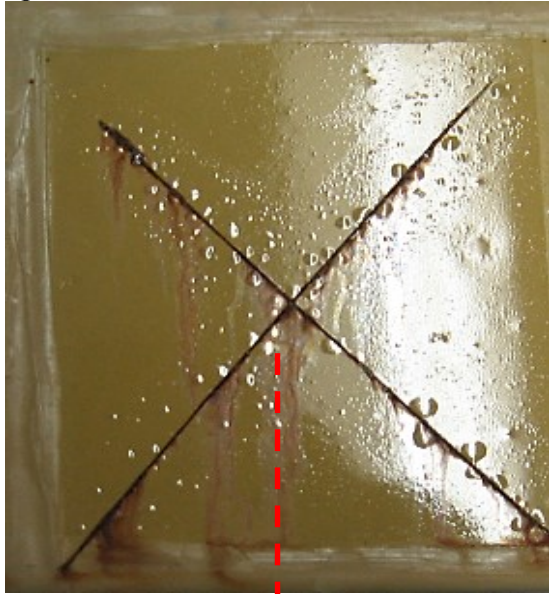
Salt spray test on coated substrates



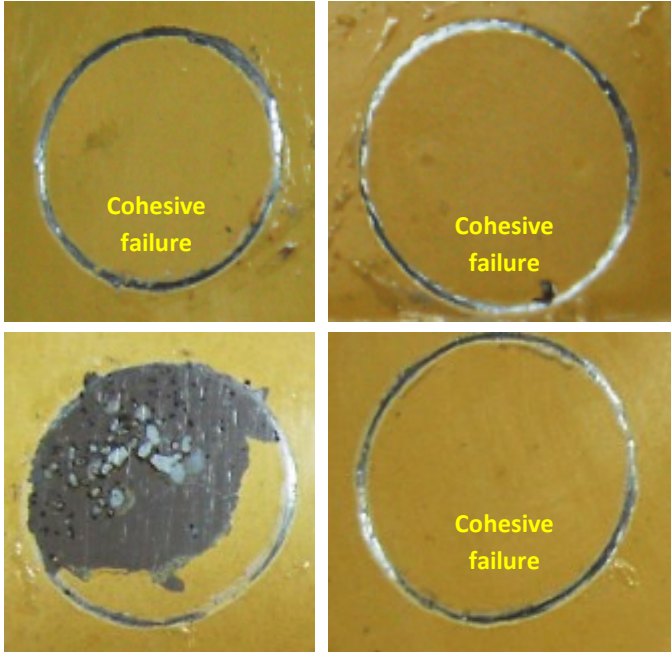
- Blister formation around scribes
- Blister formation at inscribed parts
- Corrosion product formation beneath the coating
- Corrosion products formation around scribes
- Coating delamination from scribes.



Salt spray test on coated substrates



Adhesion test on coated substrates

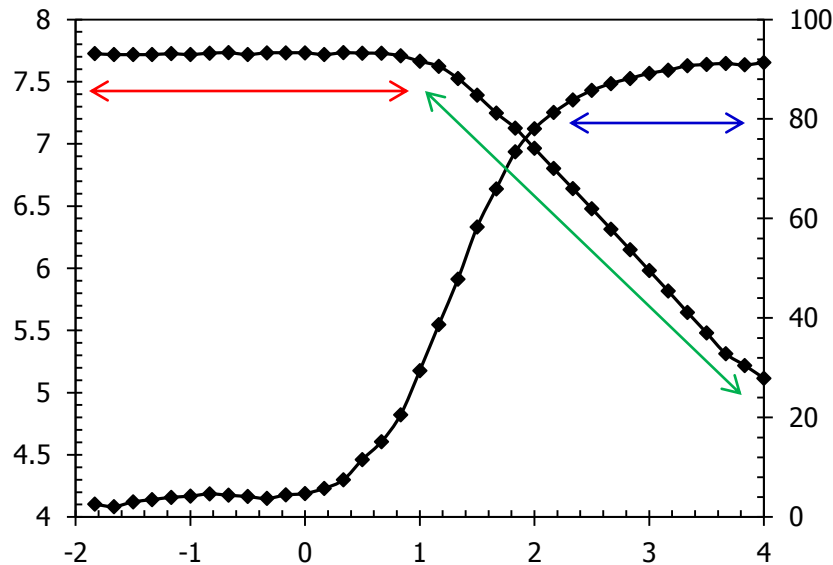
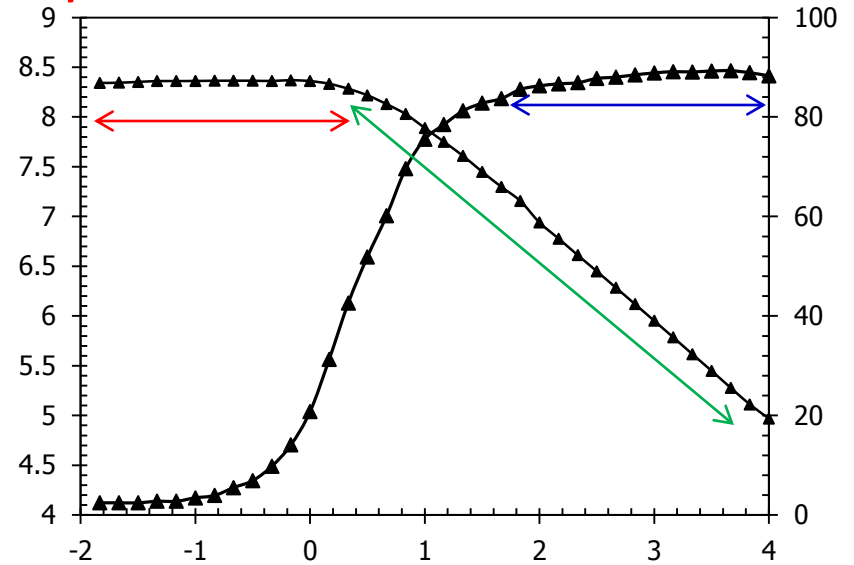
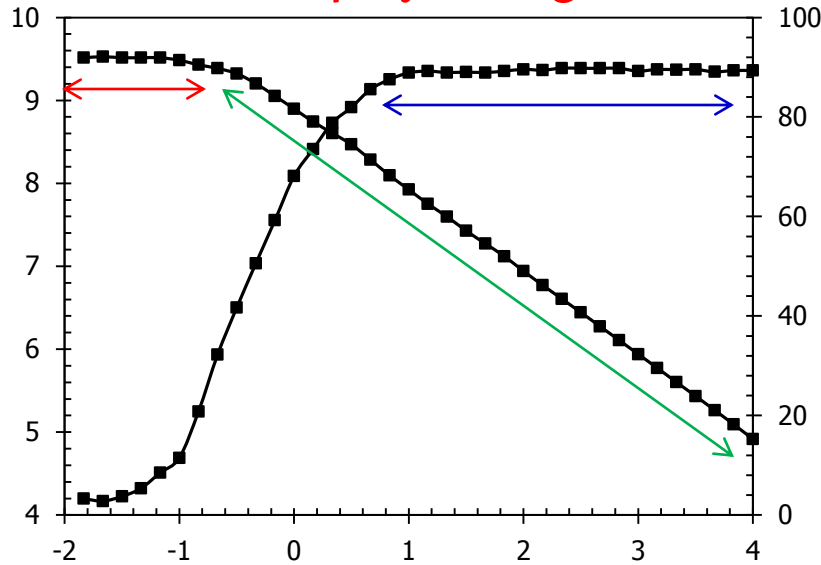


Dry pull-off adhesion test

Wet pull-off adhesion test

The EIS evaluation of the organic coating performance

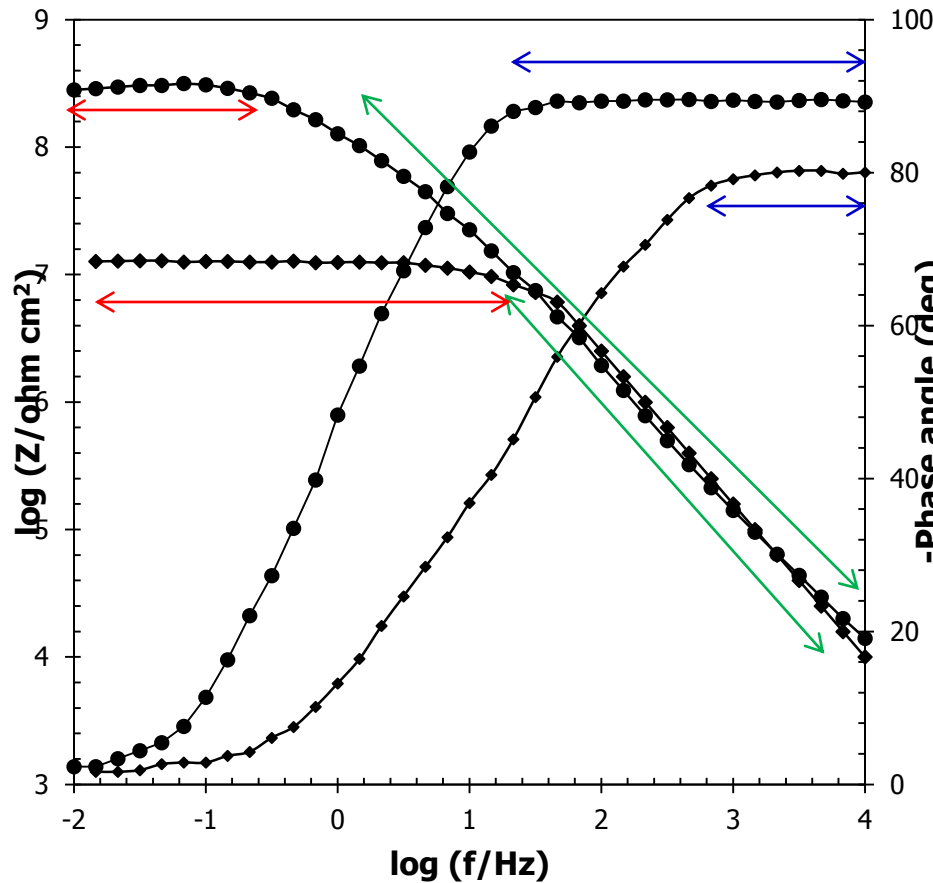
Epoxy coating on steel substrate exposed to 3.5 wt% NaCl solution



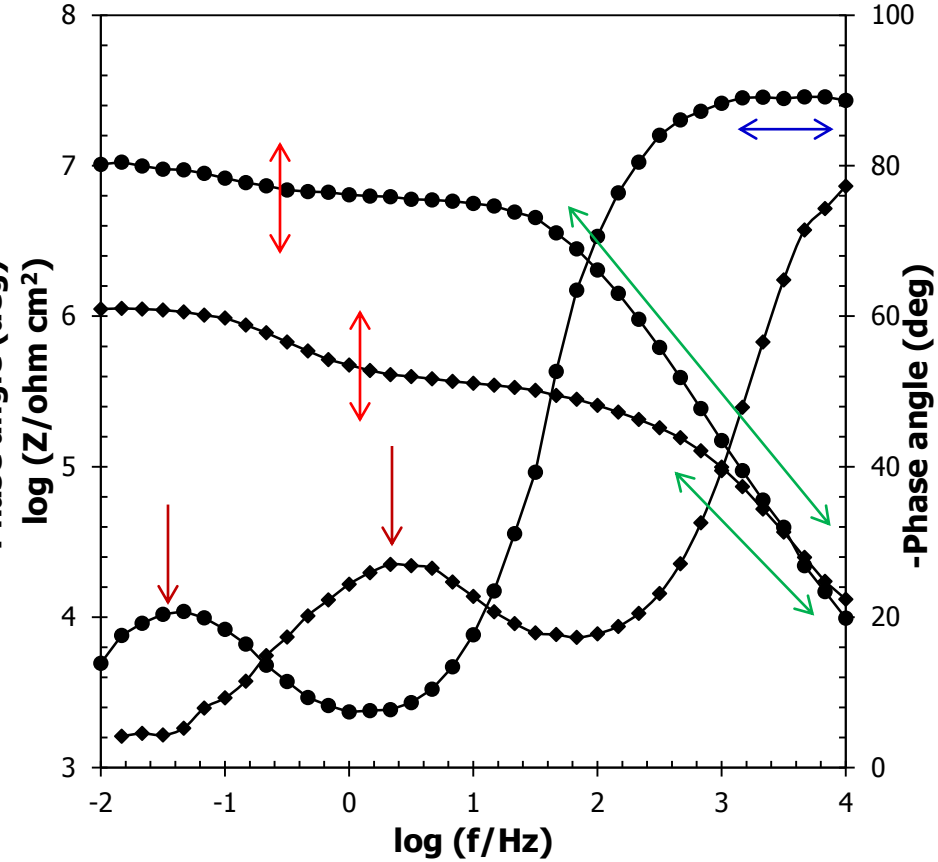
50 DAYS

The EIS evaluation of the organic coating performance

Epoxy coating on steel substrate exposed to 3.5 wt% NaCl solution

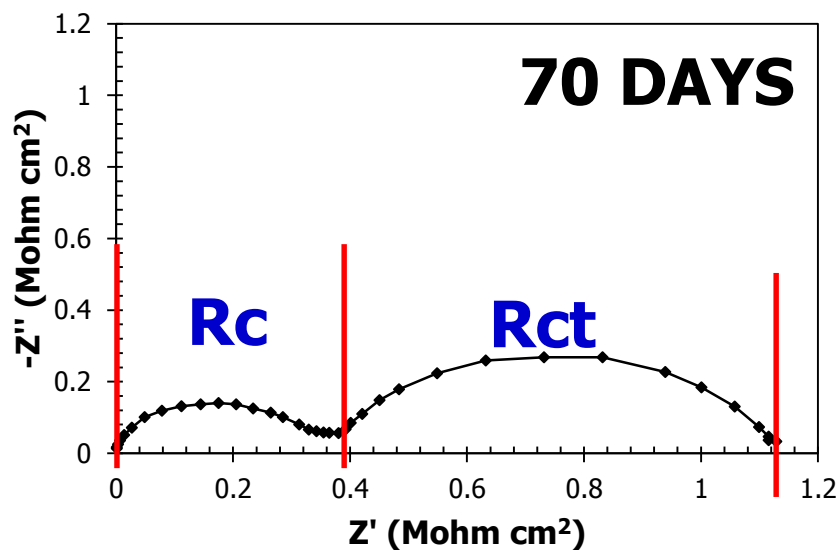
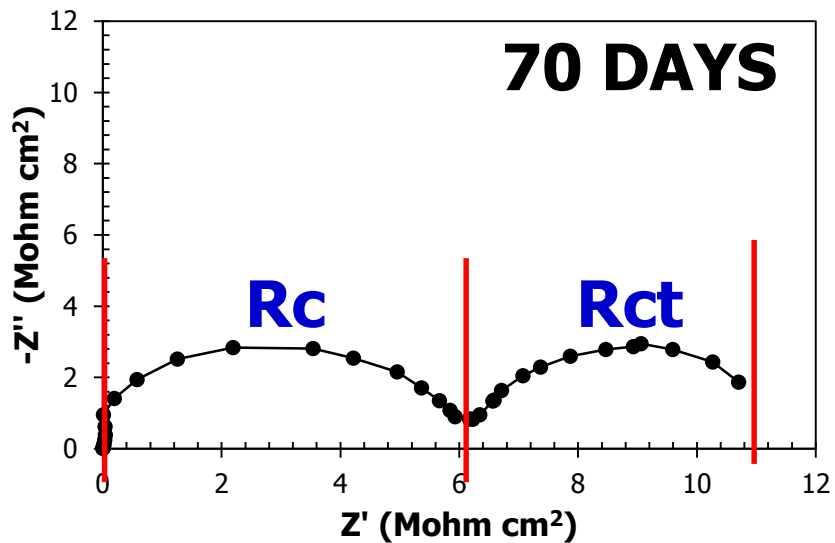
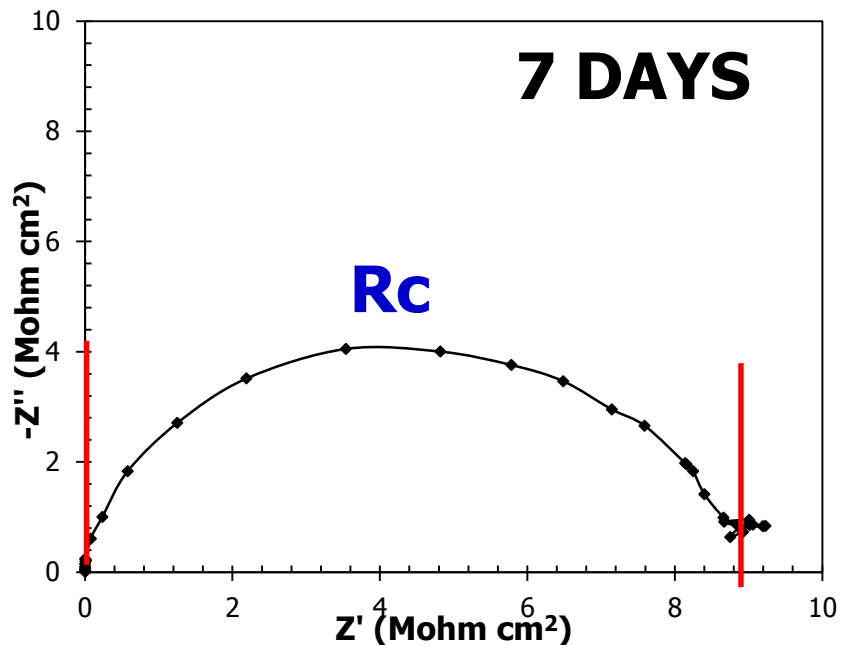
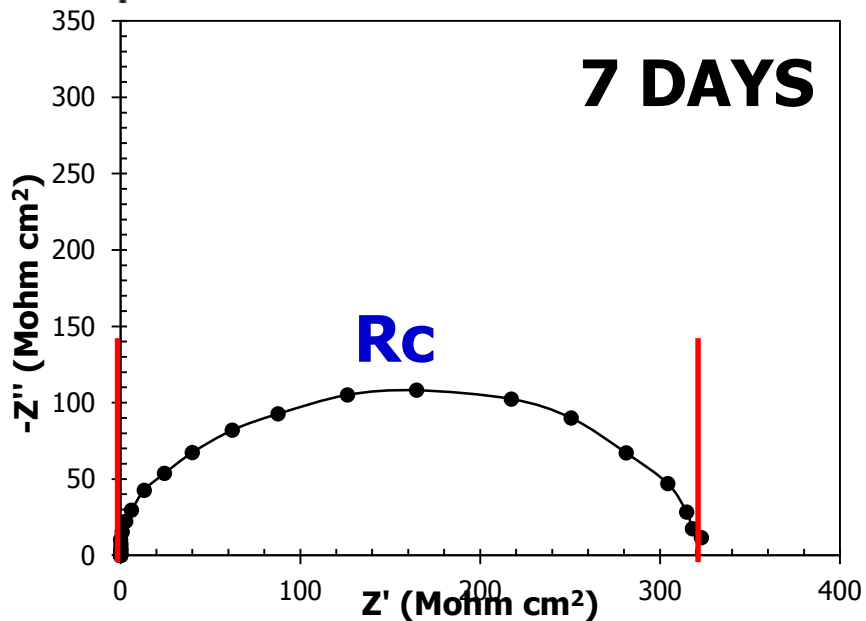


7 DAYS

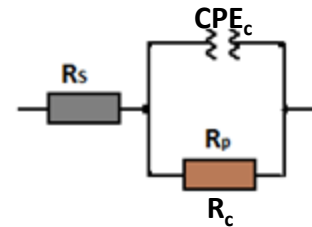
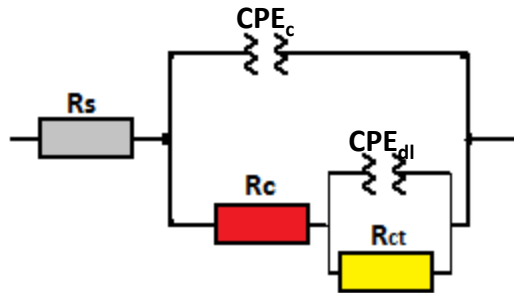
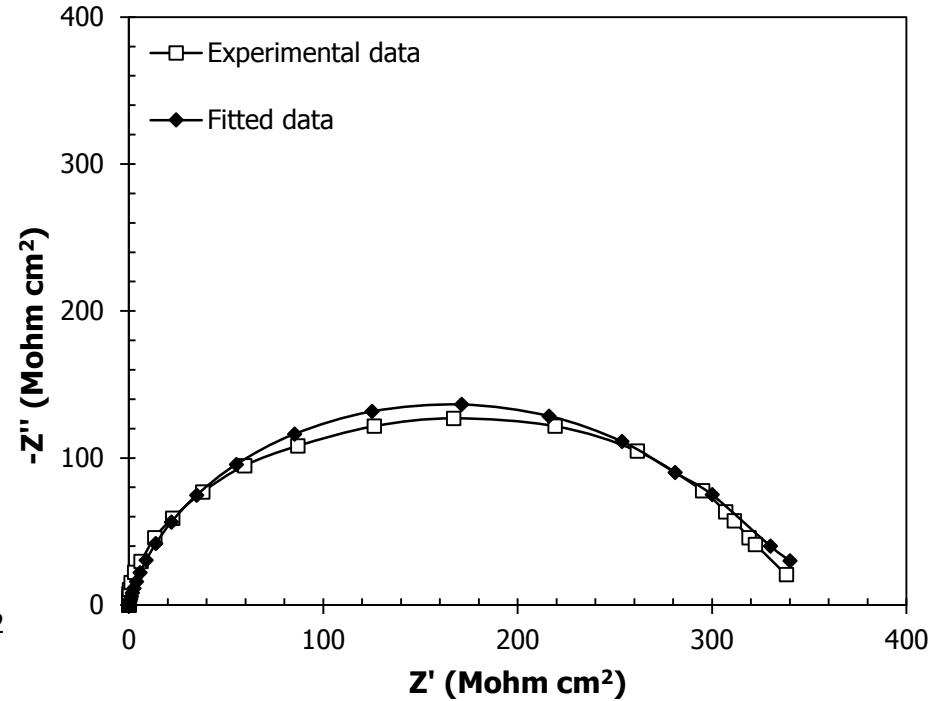
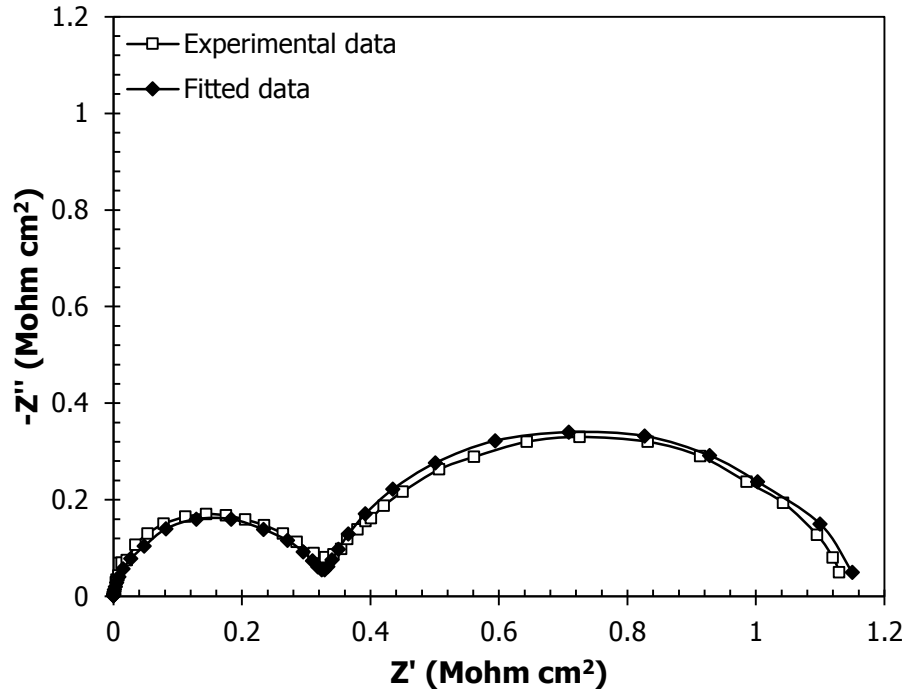


70 DAYS

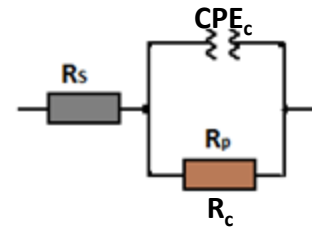
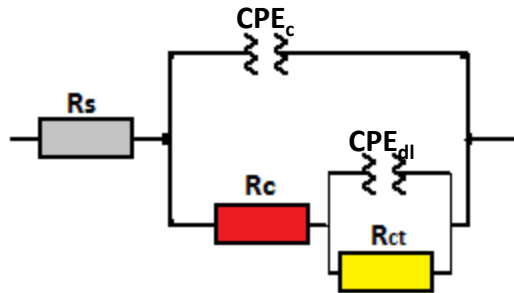
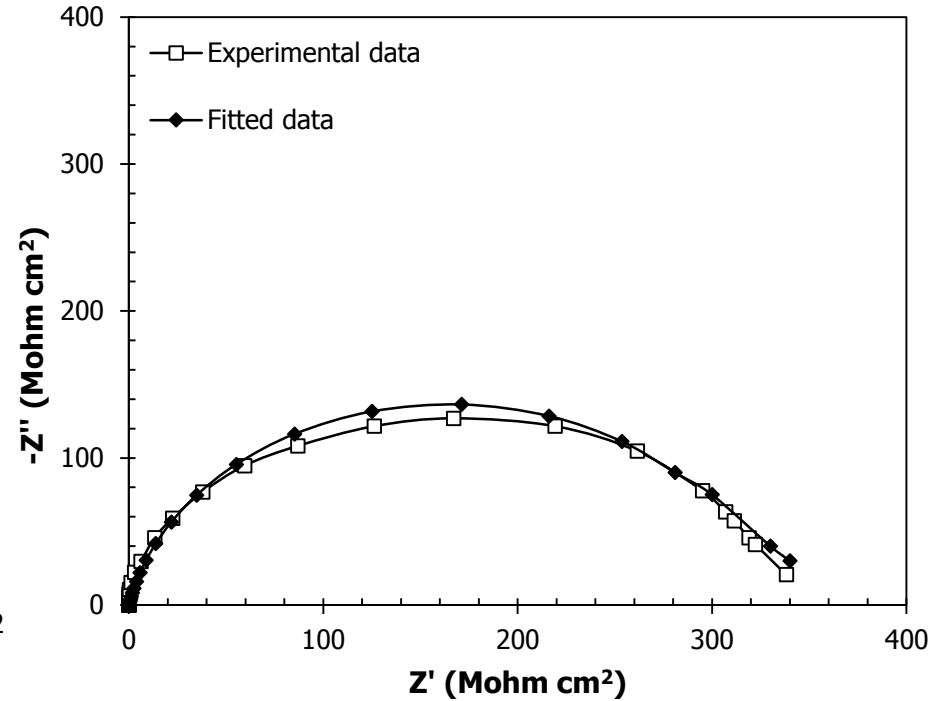
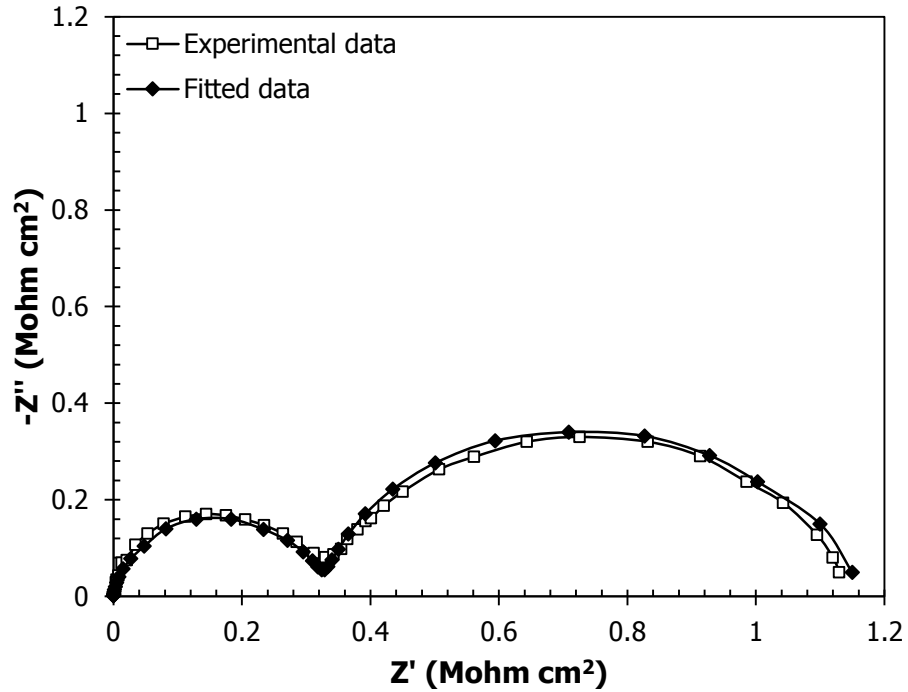
The EIS evaluation of the organic coating performance



The EIS evaluation of the organic coating performance



The EIS evaluation of the organic coating performance



IRSA Group.

Thanks for your attention.

Date:
12/13/2017

