

Advancing Sustainable Surface Treatments

Key Results and Progress Towards Hexavalent Chromium-Free Solutions



16 September 2026



10:00 - 11:00 am CET



Zoom



Alexandre Bastos
Researcher Department
of Materials and Ceramic
Engineering
CICECO – Aveiro Institute
of Materials.
Universidade de Aveiro



Frederico Maia
General Manager
SMALLMATEK



Rosalina Pérez
Senior Researcher
and Project Manager
CIDETEC SURFACE
ENGINEERING



Raúl Páez
Researcher
and Project Manager
TITANIA

About the webinar

During this webinar, project partners will share the latest technical developments, validation activities and pilot results achieved to date, providing participants with a comprehensive overview of the project's progress and future outlook.

REGISTER FOR THE WEBINAR VIA ZOOM

Cooperating is in your hands



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UNIVERSITÉ
DE PAU ET DES
PAYS DE L'ADOUR

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Création de services
de proximité

UTA
União Tecnológica do Alentejo

Project (GA number: S1/1.1/E0025) co-financed by the Interreg Sudoe Programme through the European Regional Development Fund (ERDF).

Ongoing project: 2024 – 2026

Webinar Pilot 2 - September 16th, 2026.

Advancing Sustainable Surface Treatments

Corrosion inhibitors and Layered Double Hydroxides (LDH)



universidade de aveiro
theoria poiesis praxis



Dr. Alexandre Bastos
Researcher at DEMaC / CICECO

Organized:

Interreg
Sudoe



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the European Union

RESINSURF

Co-financed:

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Sudoe



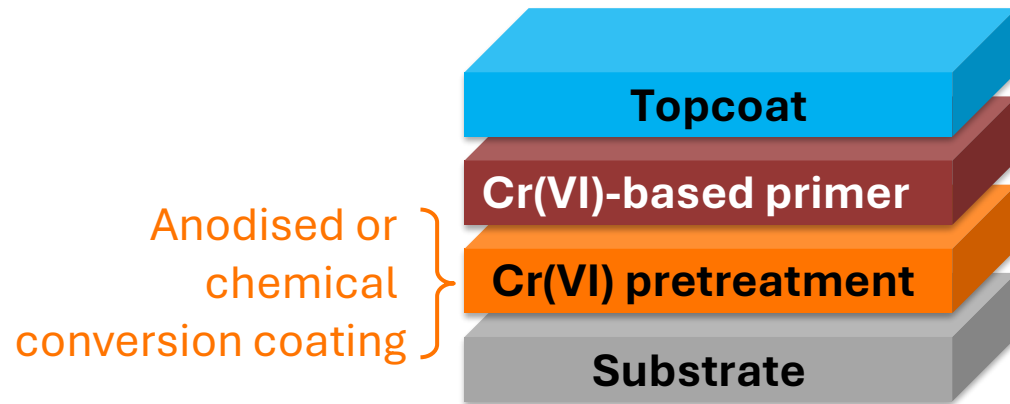
Co-funded by
the European Union

Corrosion protection in the aerospace industry

Until recently...

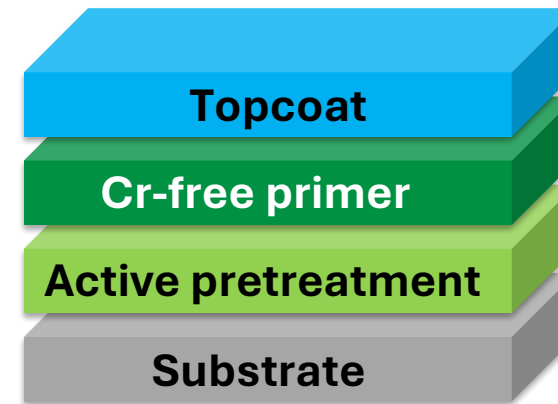


Cr(VI)



Nowadays...

Cr(III) or Cr-free



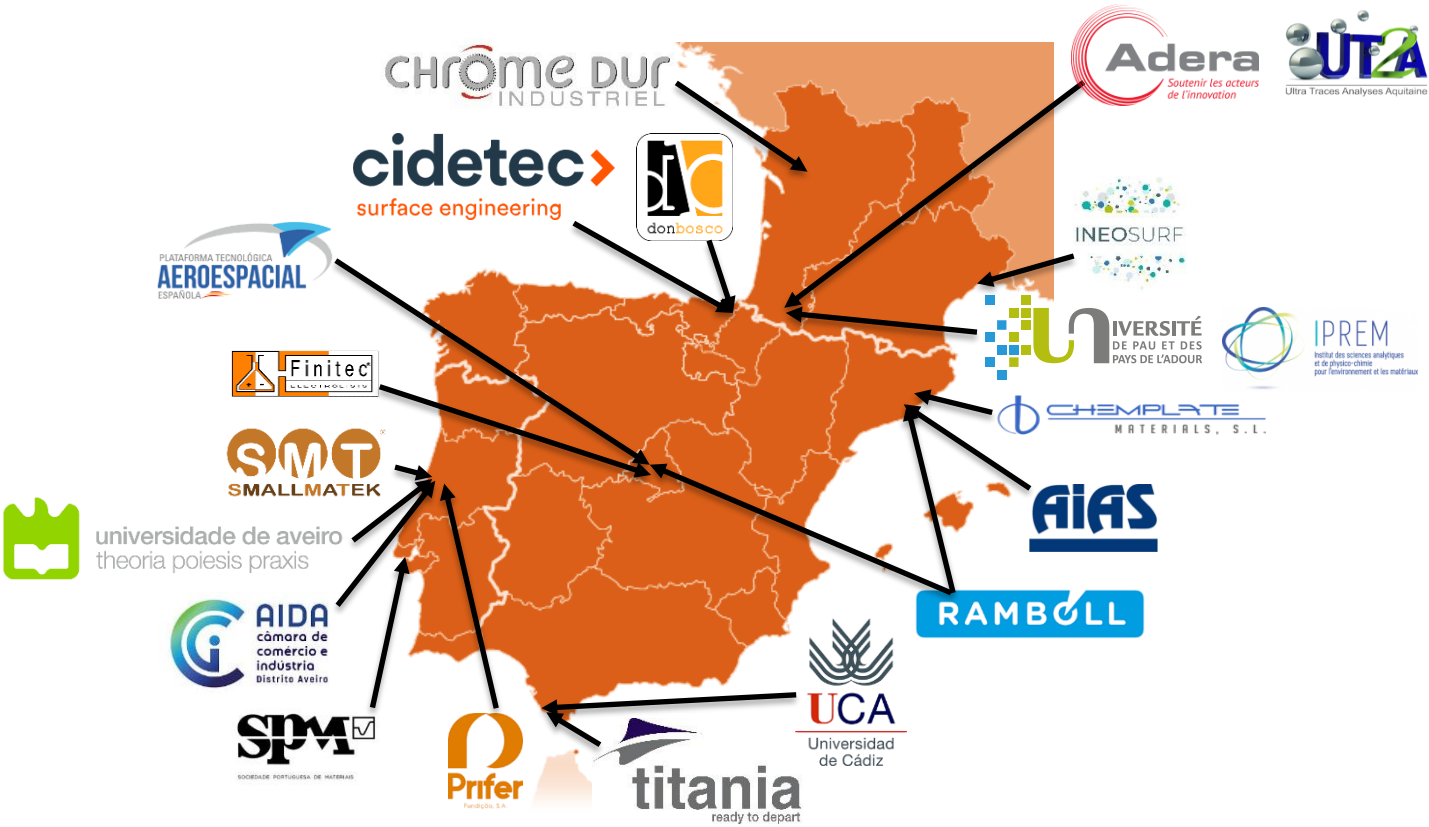
RESINSURF project

Towards more resilient, sustainable, competitive and intelligent electrochemical surface treatments

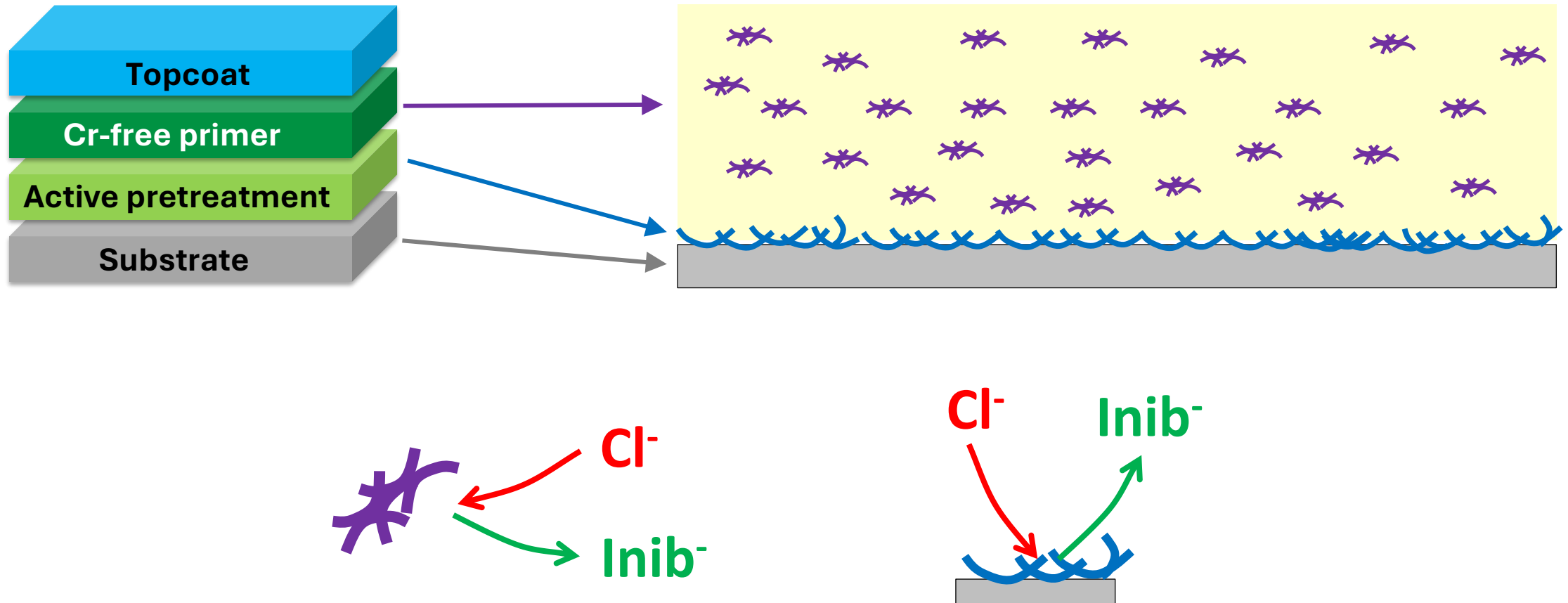
Interreg
Sudoe



Co-funded by
the European Union

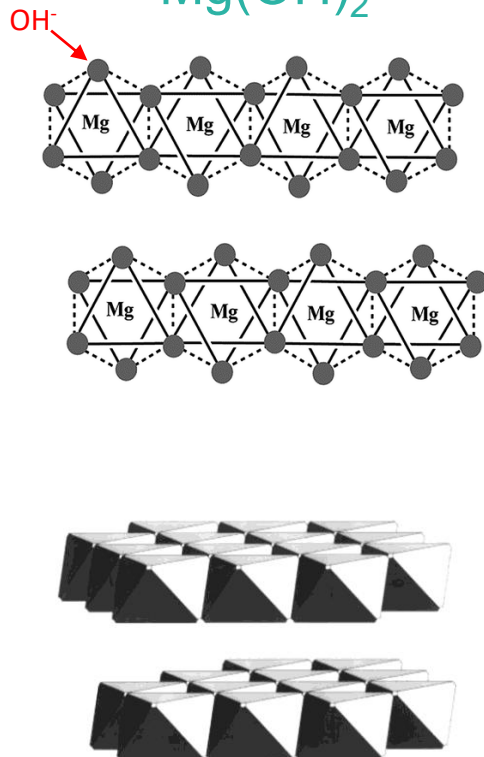


New approach based on layered double hydroxides

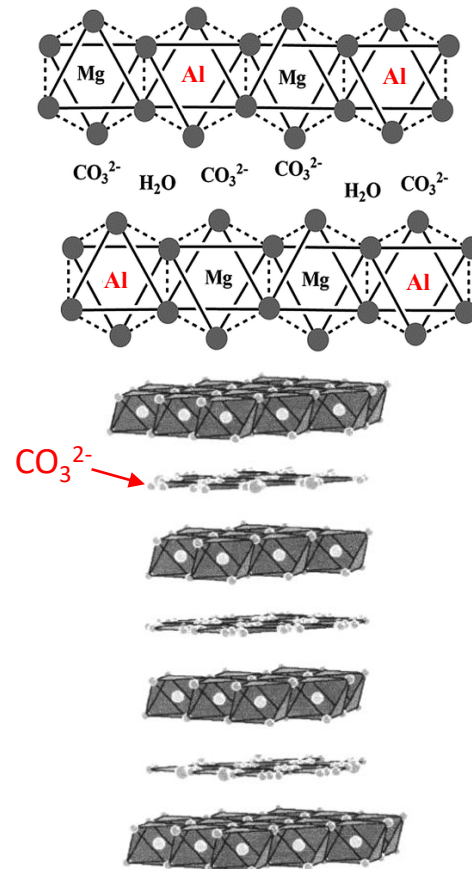
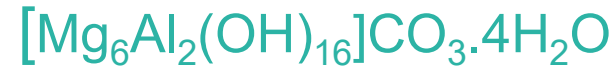


Layered Double Hydroxides (LDH)

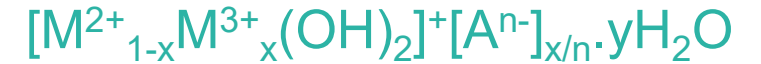
Brucite



Hydrotalcite



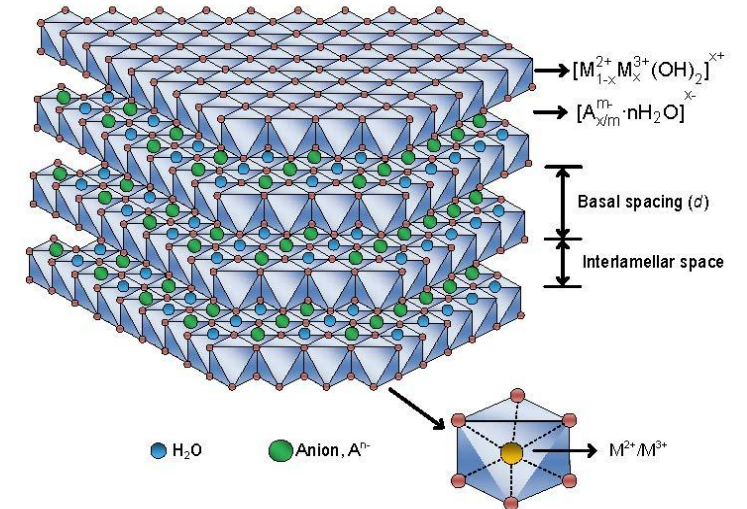
LDH



$\text{M}^{2+} = \text{Mg}^{2+}, \text{Ca}^{2+}, \text{Zn}^{2+}, \text{Ni}^{2+}, \text{Mn}^{2+}, \dots$

$\text{M}^{3+} = \text{Al}^{3+}, \text{Fe}^{3+}, \text{Cr}^{3+}, \text{Ga}^{3+}, \dots$

$\text{A}^{n-} = \text{CO}_3^{2-} < \text{OH}^- < \text{Cl}^- < \text{NO}_2^- < \text{NO}_3^-$

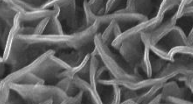


RSC Adv. 5 (2015) 98853

Proc. Indian Acad. Sci. (Chem. Sci.) 113 (2001) 671

J. Tronto *et al.*, Conducting Polymers / Layered Double Hydroxides Intercalated Nanocomposites, *in* Materials Science - Advanced Topics, Y. Mastai (Ed.), InTech Pub, 2013.

The diagram illustrates a crystal lattice structure, likely representing a mineral or a specific type of ion exchange. The lattice is composed of blue and green spheres, which represent different ions or atoms. A green arrow points to the right, labeled "Inhib-", indicating an inhibitory effect. A red arrow points to the left, labeled "Cl-", indicating the presence of chloride ions.


c1cc[nH]c2ccccc12[O-]C(=O)ONC[C@H](CS)C(=O)O[illegible]

SU8600 15.00kV 9.7mm x30.0k UD

1 μ m



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Advancing Sustainable Surface Treatments

Layered double hydroxides (LDH) as a versatile approach to protect metallic surfaces



Dr. Frederico Maia
General Manager
frederico.maia@smallmatek.pt

Organized:

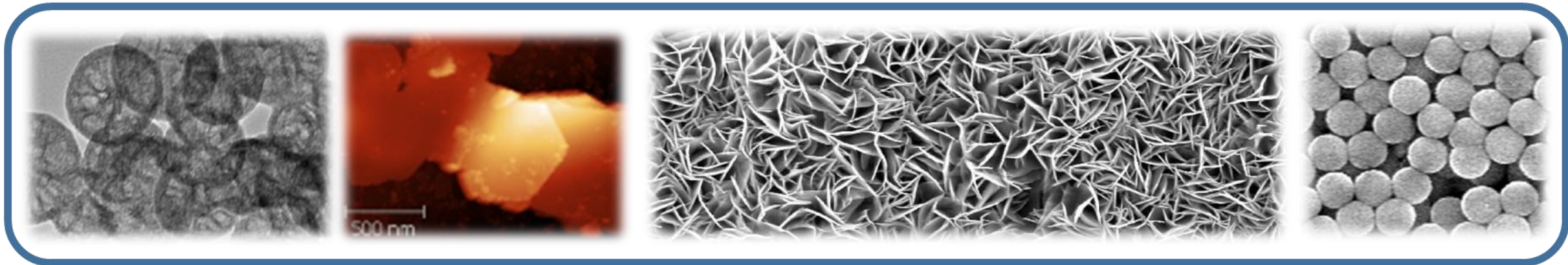


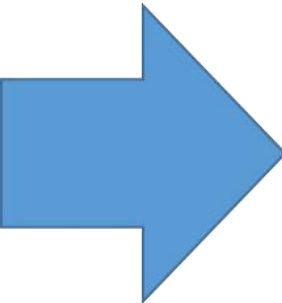
Co-financed:



SMT Encapsulation Platform

Based on the physicochemical properties of the active compound and on their application, the most suitable carrier is selected



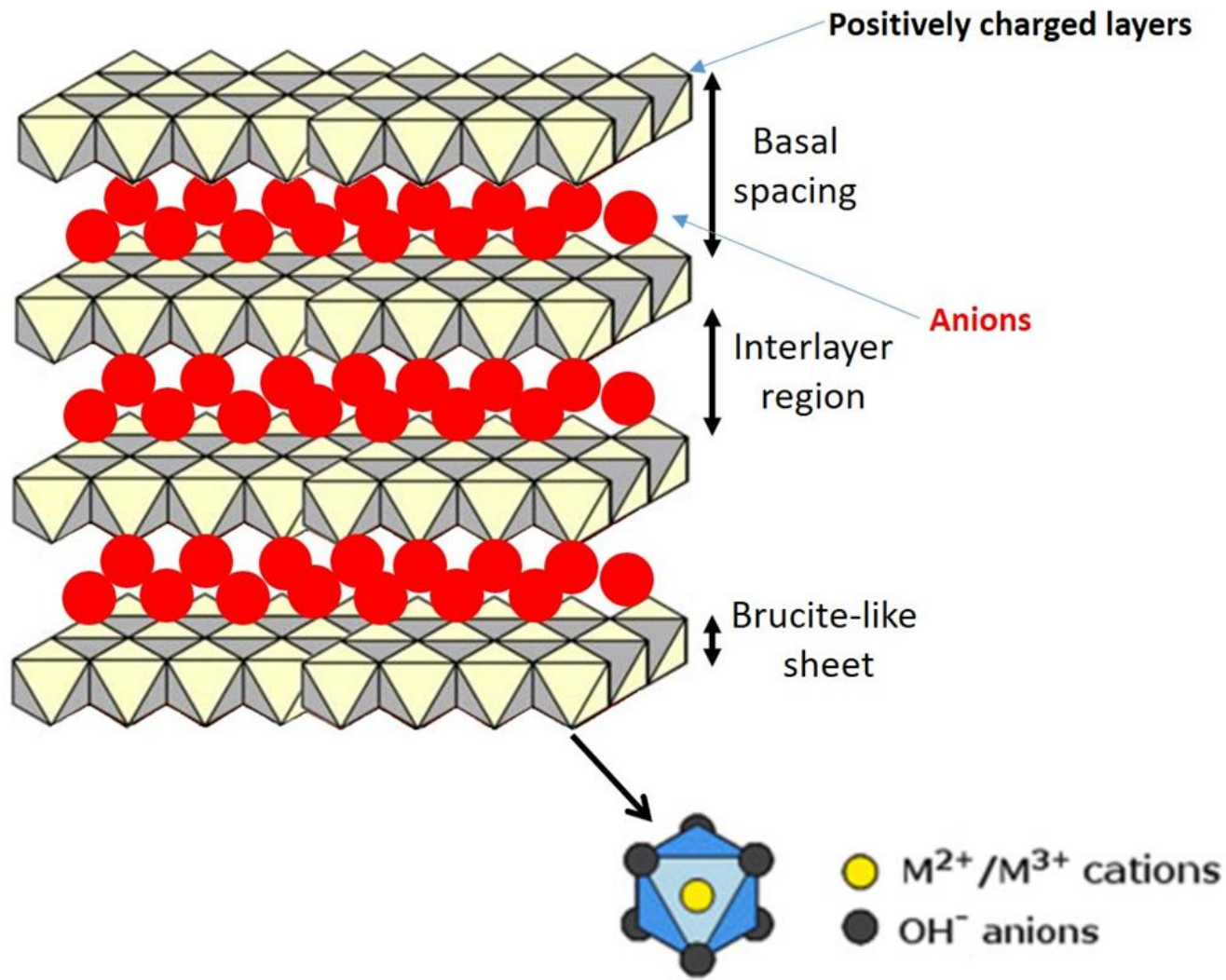
- 
- ✓ Specific release profiles.
 - ✓ Provide mechanical and temperature protection.
 - ✓ Prevents degradation or spontaneous leaching.
 - ✓ Might decrease toxicity

Applications:

- ✓ Multifunctional coatings
- ✓ Food packaging
- ✓ Drug release
- ✓ Water purification/pollutants removal
- ✓ Fertilizers

Layered double hydroxides (LDH)

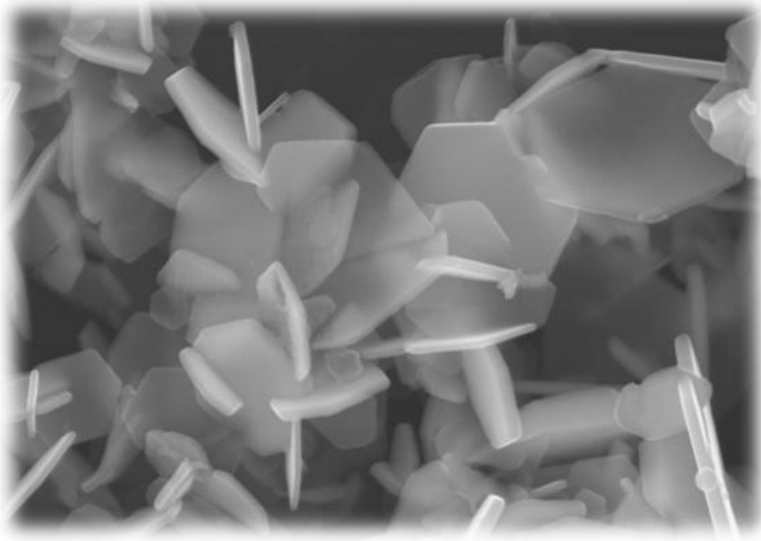
General properties and structure



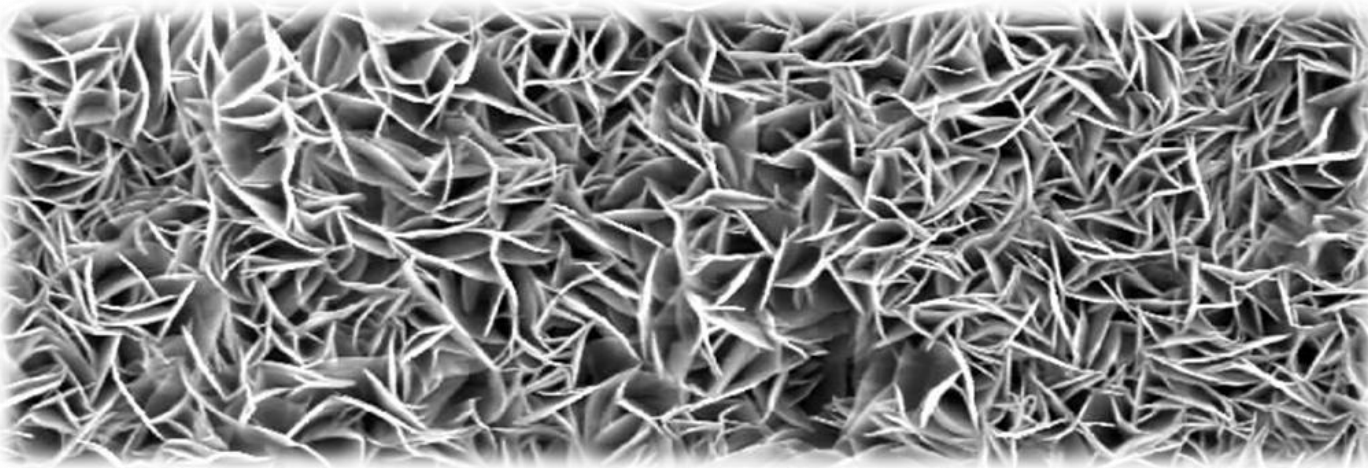
- Brucite ($Mg(OH)_2$) modified material
- Clay type and lamellar material
- Crystalline material
- Anion-exchange ability
- Variable chemical composition
- Temperature and mechanically stable
- Low or no toxicity (*for traditional compositions*)

Layered double hydroxides (LDH)

SEM images

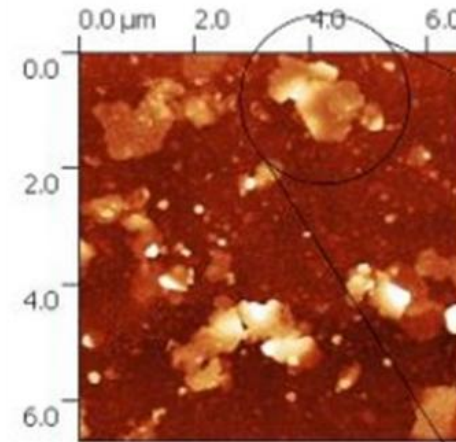


particles



film

AFM images



1

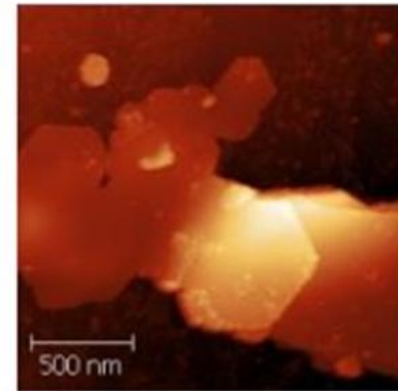
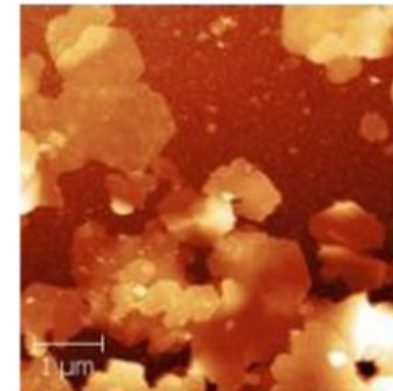
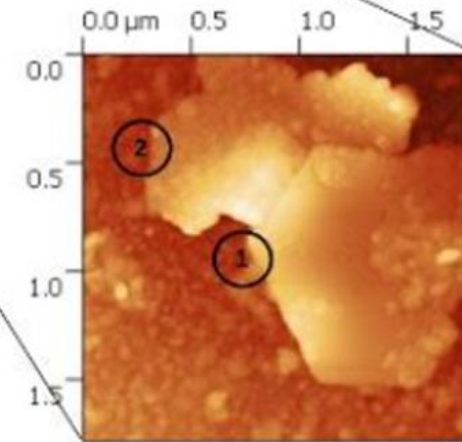
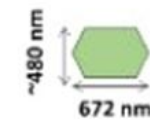
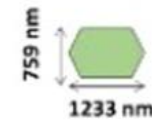
Altura: 56.8 nm

Largura/Comprimento:

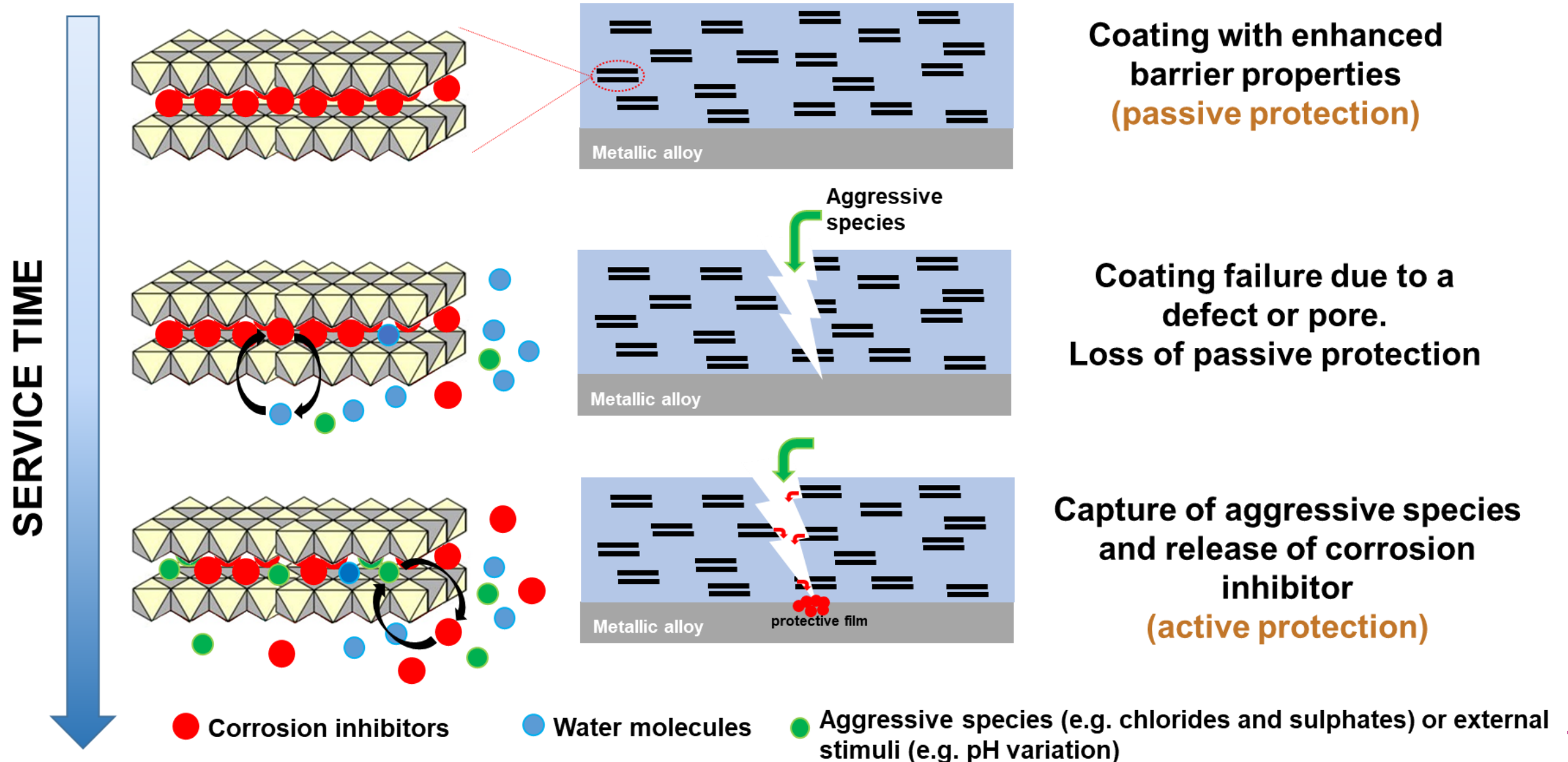
2

Altura: 26.62 nm

Largura/Comprimento:

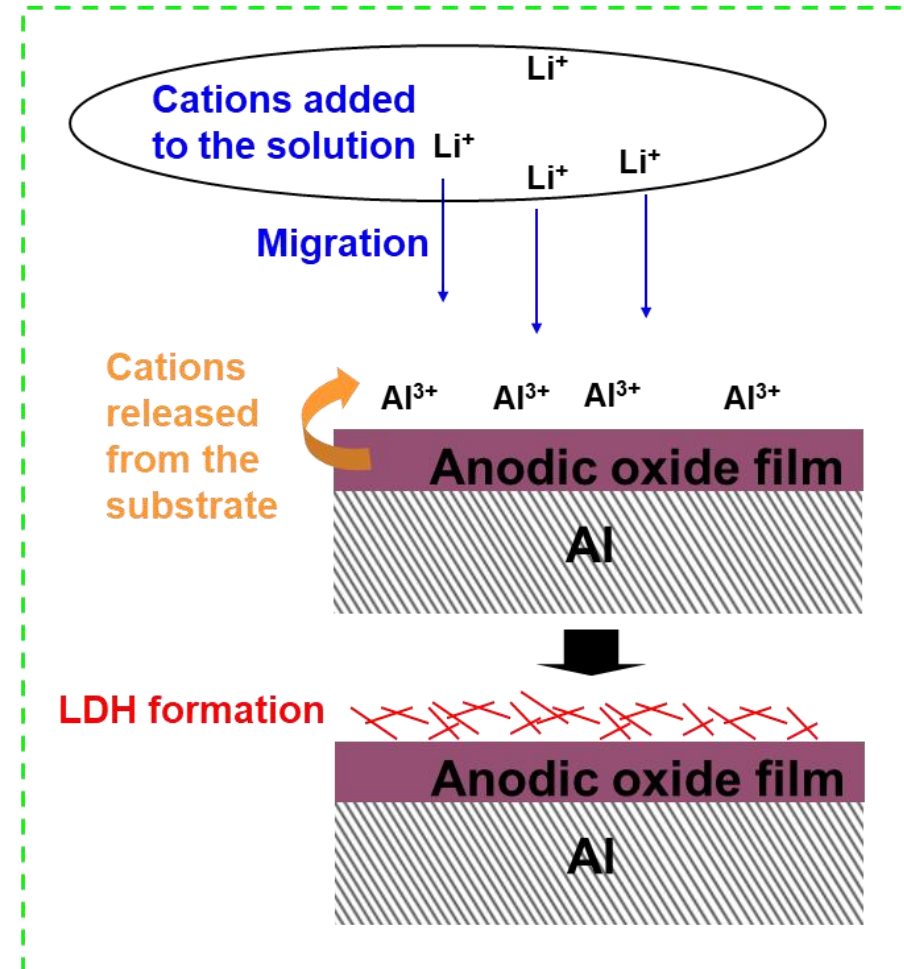
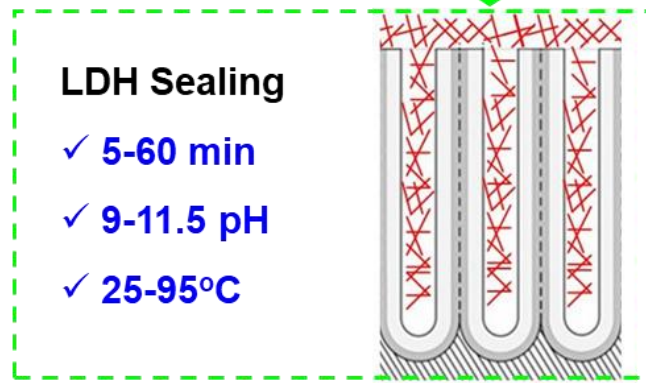
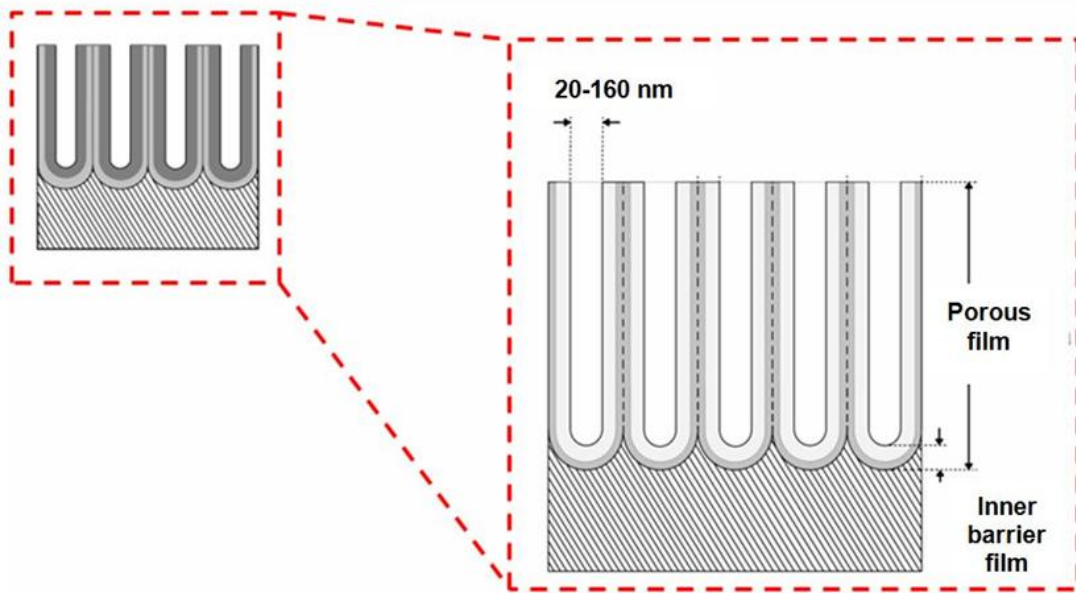


Mechanism of LDH pigment activity

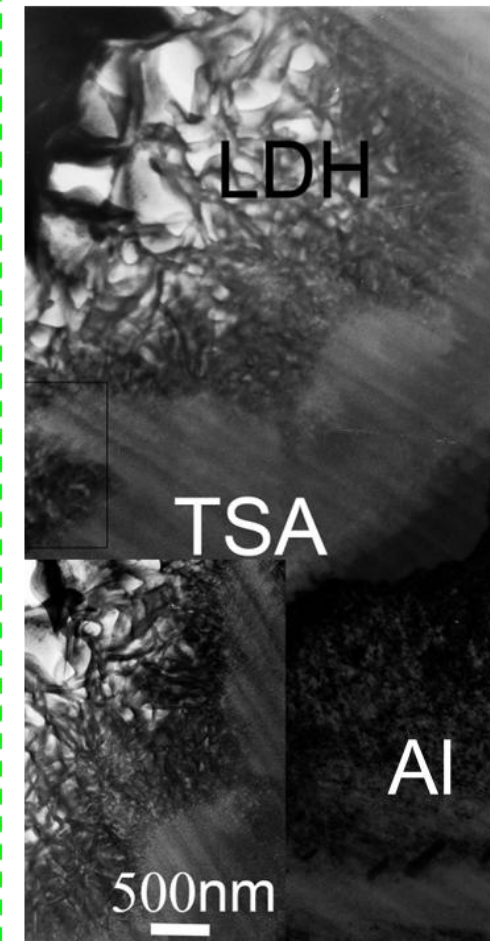


LDH film for TSA sealing and corrosion inhibitor incorporation

LDH sealing process – conversion coating



HRTEM



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Advancing Sustainable Surface Treatments

Electrophoretic Coatings:

A Sustainable and Cr-Free Technology for Corrosion Protection of Aeronautical Aluminium Alloys.

cidetec >
surface engineering



Dr. Rosalina Pérez
Researcher and Project Manager

Organized:



Co-financed:





A great technological complex

cidetec➤

MEMBER OF BASQUE RESEARCH
& TECHNOLOGY ALLIANCE

**Key
Data**

30 M€

Turnover in 2025

300

People in the workforce

> 100

European projects
(> 25 as coordinator)

35 M€

Invested
(2012-2025)

6

Spin-offs

cidetec➤
energy storage

cidetec➤
surface engineering



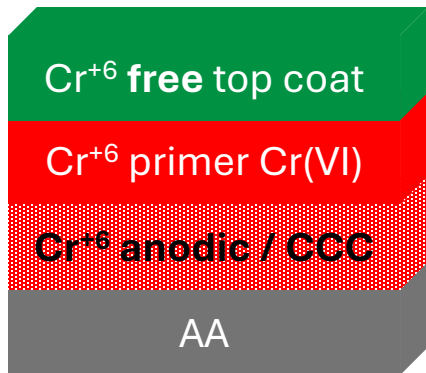
A big player in Surface Engineering

+100
people

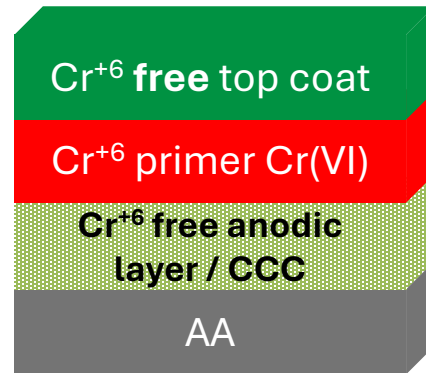
+220
customers in 2025

Electrophoretic Coatings

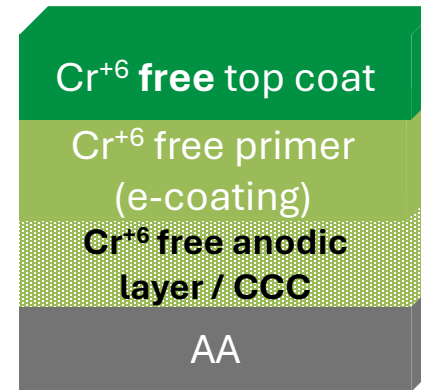
Conventional Cr^{+6} -based
coating systems for
Aeronautical Applications



Current Cr^{+6} partially free
coating systems

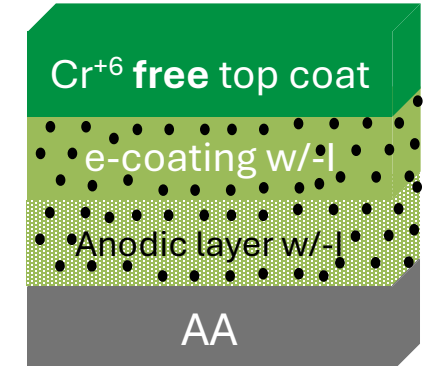
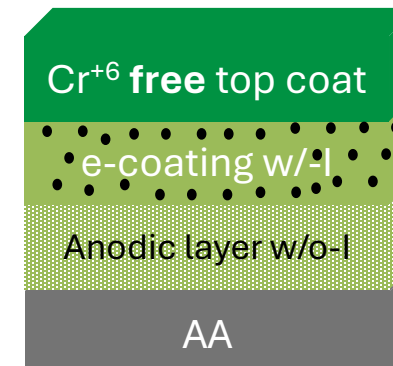
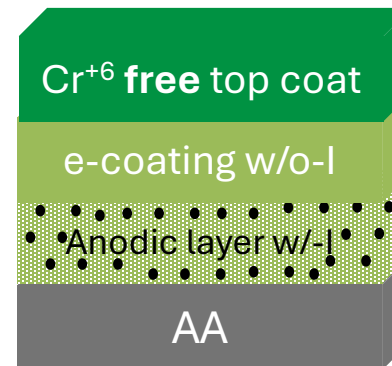


RESINSURF



Advantages:

- Green technology
- Production capability
- Ability to incorporate corrosion inhibitors
- Excellent corrosion & chemical resistant system

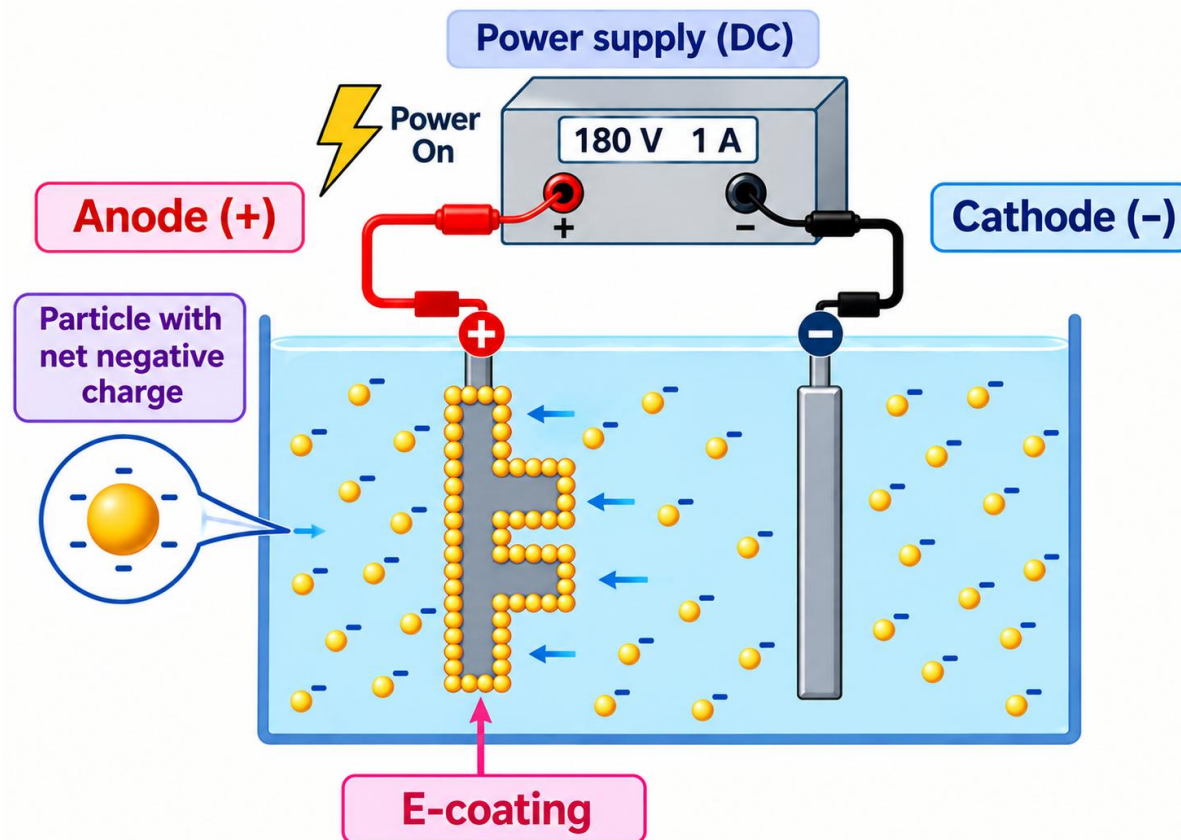


Electrophoretic Coatings

How are coatings developed at CIDETEC?

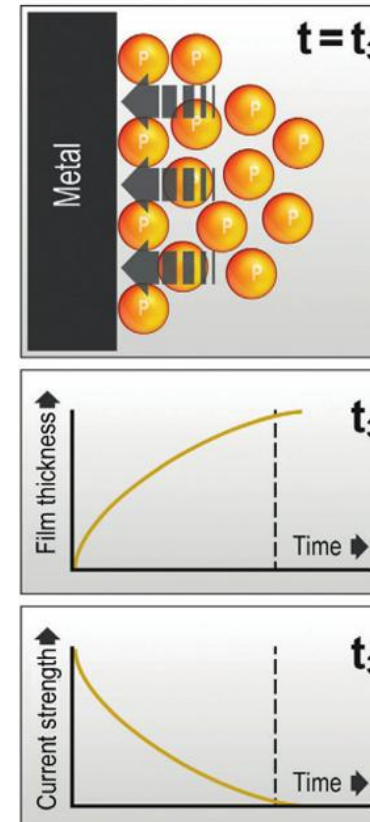


Anaphoretic deposition: A coating process (e-coating) in which electrically charged paint particles are deposited onto a conductive metal surface under the influence of an applied electric field between two electrodes.

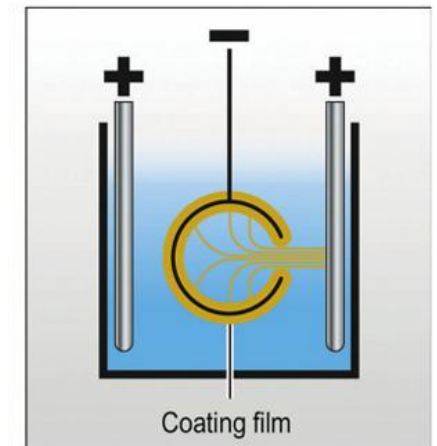


L. Besra, M. Liu / Progress in Materials Science 52 (2007) 1–61

Coating thickness



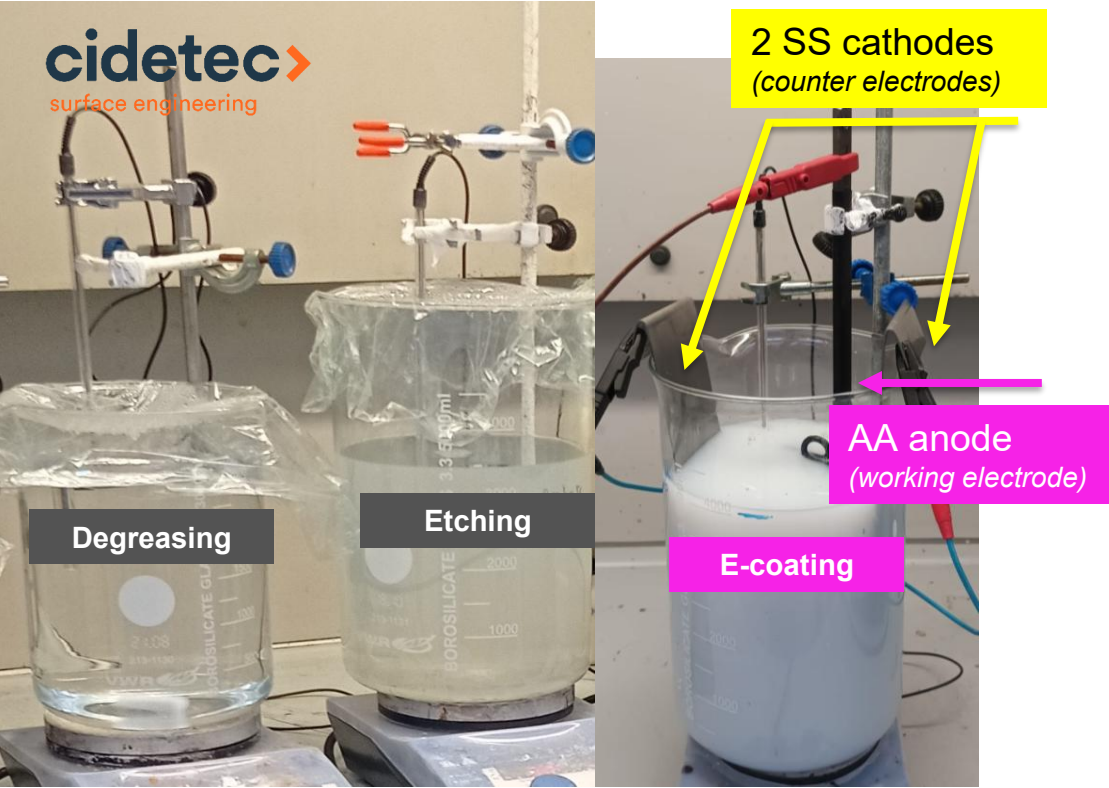
Throw power



c) Final phase

- 1) Current seeks the way of the lowest resistance.
- 2) Outer surface the electrical resistance increases.
- 3) The current seeks for a path with less resistance.

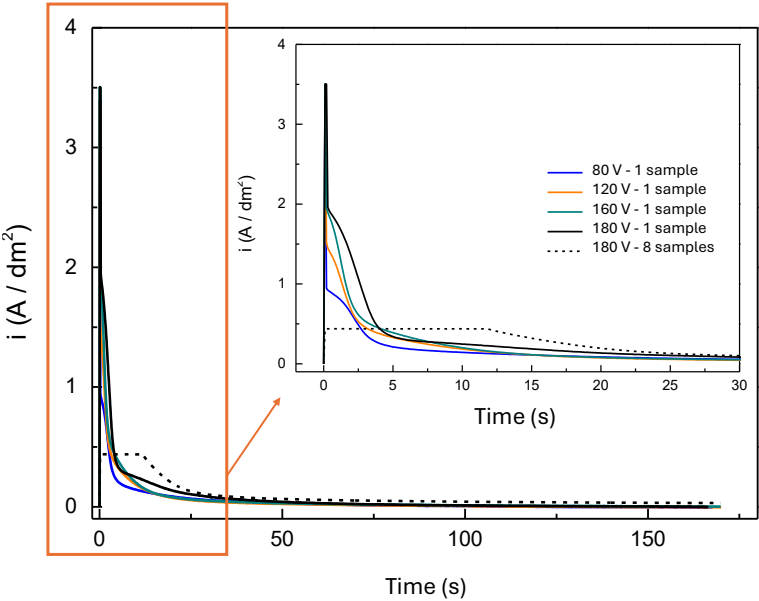
Electrophoretic Coatings



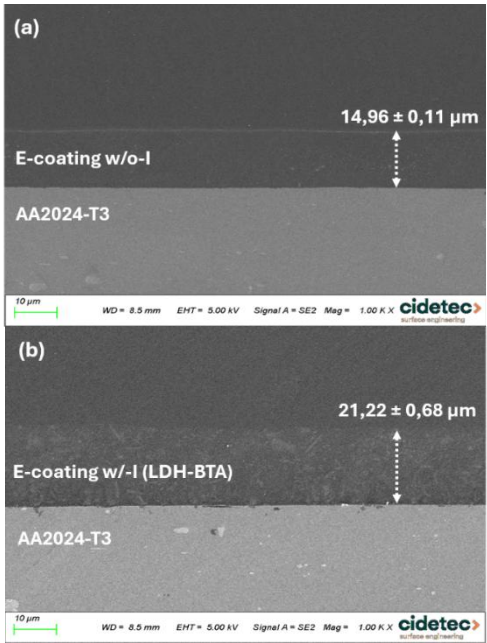
Optimisation of **bath** (ZP, PS, conductivity) and **process** (voltage applied, deposition time, others) **parameters**.

Surface/cross-section characterisation (microstructure, corrosion and chemical resistance, adhesion, others).

Monitoring of voltage applied & current response:



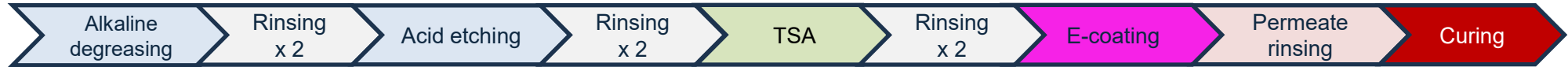
Cross-sectional FESEM analysis:



Electrophoretic Coatings

“Scale-up”

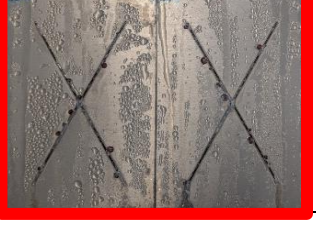
200 L – 400 L



Aluminum test panels (AA2024-T3) before (a) and after (b) electrophoretic lacquering.

Electrophoretic Coatings

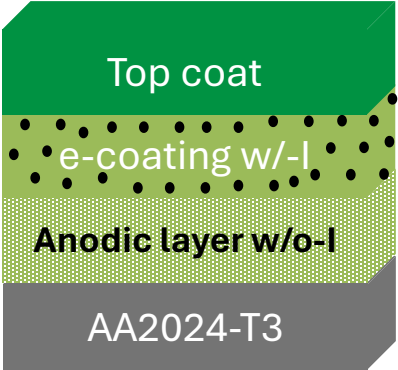
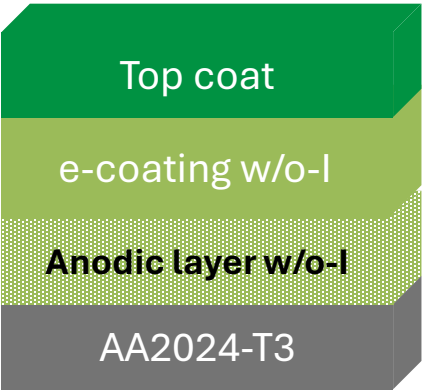
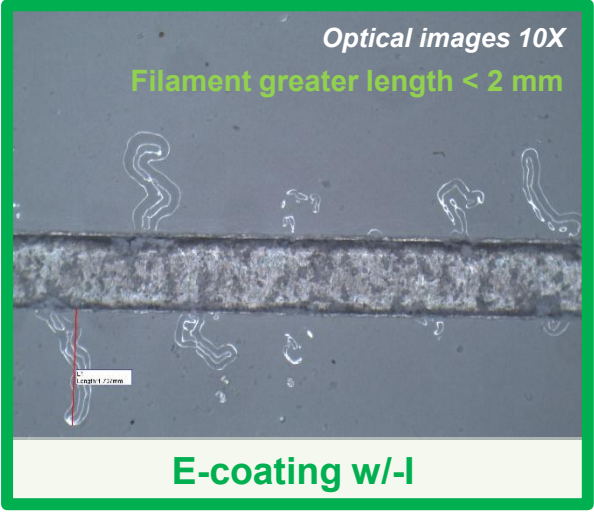
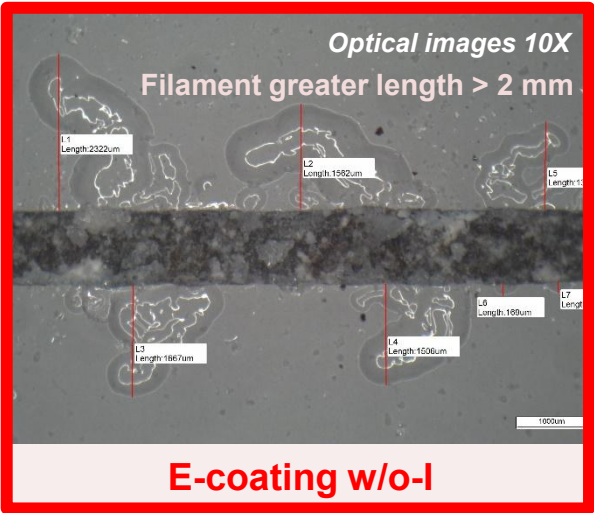
Neutral Salt Spray (NSS) exposure: ISO 9227

	(a) without inhibitor	(b) with LDH-BTA	(c) with LDH-BTA-50 µm
500 h			
1000 h			
2000 h			
3000 h			

Filiform Corrosion Test:

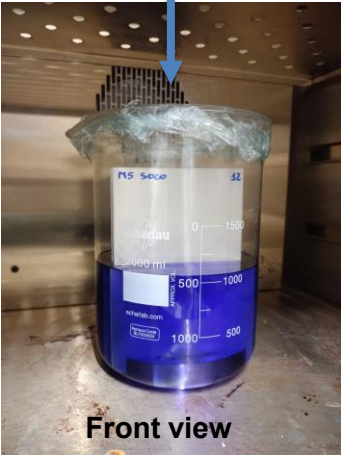
ISO 4623-2 / EN 3665

A complete Cr⁺⁶ **free** system was tested:



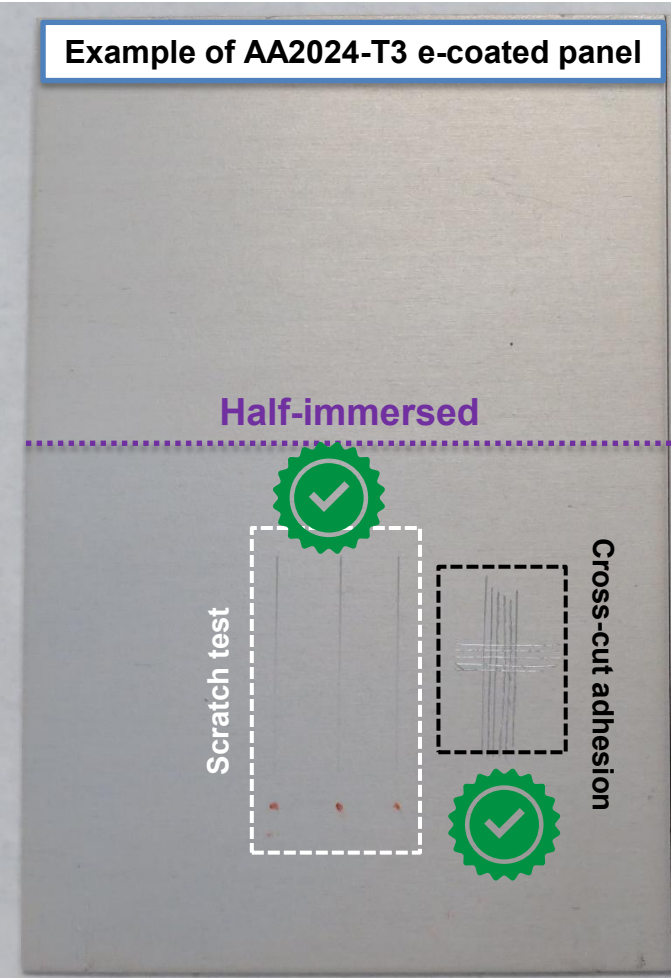
Electrophoretic Coatings

Chemical Resistance Test → ISO 2812-1: Determination of resistance to liquids Part1: Immersion in liquids other than water



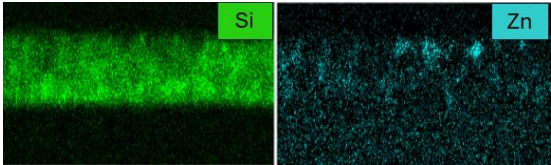
cidetec
surface engineering

The 2024-T3 aluminium coated panels were half-immersed in skydrol.

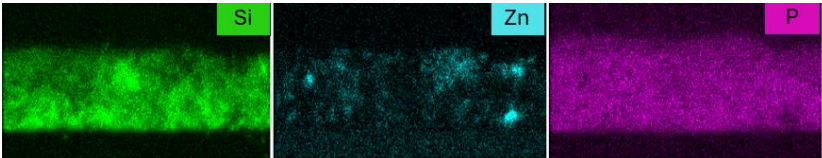


Cross-sectional FESEM analysis: **cidetec**
surface engineering

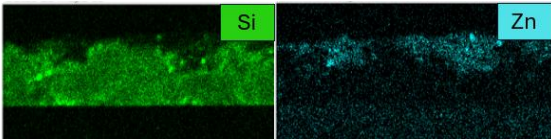
A1. E-coating w/-l (20 µm):



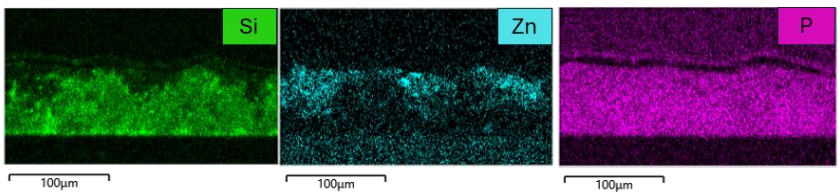
A2. E-coating w/-l (20 µm) after Skydrol:



B1. E-coating w/-l (50 µm):



B2. E-coating w/-l (50 µm) after Skydrol:



Electrophoretic Coatings

Summary RESINSURF results obtained:

AA2024-T3 panels tested: 150 x 100 x 2 mm

Test	ISO	Assessment Criteria	RESINSURF systems:
Dry adhesion test	ISO 2490	Grade 0	All systems → Grade 0
Neutral salt spray	ISO 9227	1) No blisters after 1000 h 2) No blisters after 3000 h	Most of the systems → 500 – 1500 h w/o defects 3000 h achieved → e-coating w/-l (50 µm)
Filiform corrosion test	ISO 4623-2 EN 3665	Filament greater length < 2 mm after 1000 h at (40 ± 2) °C and RH (82 ± 3) %	1) TSA w/o-l + e-coating w/-l + top-coat 2) CCC1 + e-coating w/-l + top-coat
Humidity resistance by condensation	ISO 6270-2 ISO 4628-1/-2 ISO 2490	No delamination nor blistering, adhesion grade ≤1 after 500 h of immersion at (40 ± 3) °C and RH of 100 % aprox.	All systems → No delamination or blistering and Grade ≤ 1
Chemical resistance by Skydrol immersion	ISO 2812-1 ISO 4628-1/-2 ISO 2490	No delamination nor blistering, adhesion grade ≤1 after 336 h of immersion at (70 ± 5) °C	All systems → No delamination or blistering and Grade ≤ 1



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Advancing Sustainable Surface Treatments

Chromium-free coatings:

Validation of Chromium Free Surface Protection Systems for Aerospace Aluminium Alloys



Raúl Páez
Researcher and Project Manager

Organized:



Co-financed:



Validation of Chromium Free Surface Protection Systems

It is a center specialized on materials and processes, highly focused in aerospace industry



Validation of Chromium Free Surface Protection Systems



Aluminium
substrate

Cr⁺⁶ Free
Anodic layer

Cr⁺⁶ primer



CURRENTLY

Aluminium
substrate

Cr⁺⁶ Free
Anodic layer

Cr⁺⁶ Free primer
(E-coating)

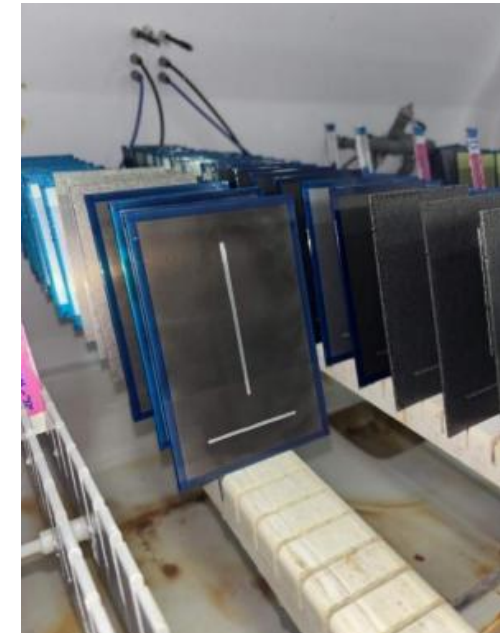
RESINSURF



Corrosion inhibitors?

Validation of Chromium Free Surface Protection Systems

Processing of aluminium alloys using **TSA anodizing**, **E-coating** and **corrosion inhibitors**, followed by **characterization tests** according to **aerospace requirements**

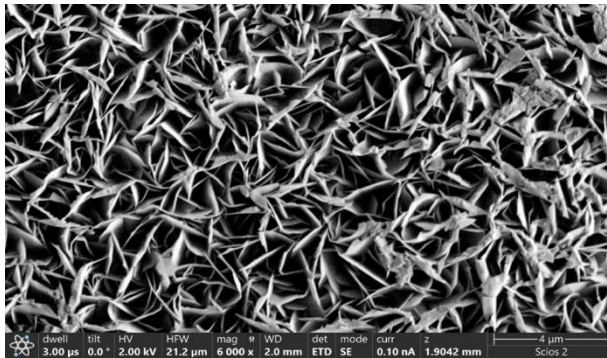


Validation of Chromium Free Surface Protection Systems

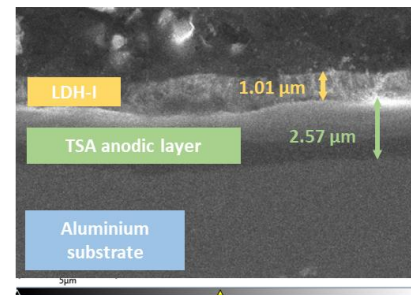
Anodizing TSA + Inhibitors (NaVO_3)



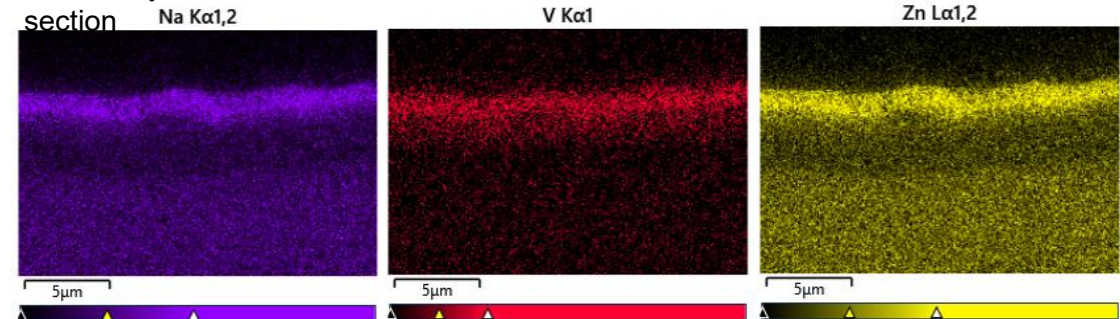
SEM. Top view



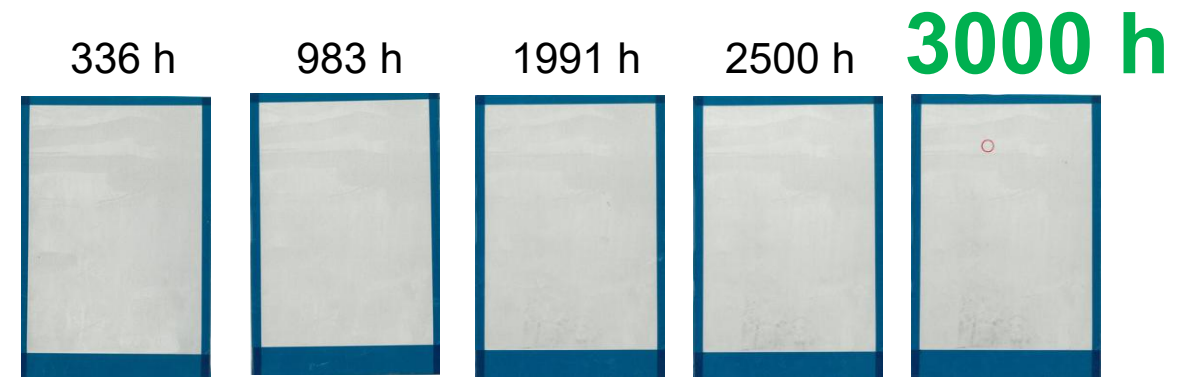
SEM. Cross-section



EDS analysis. Cross-section



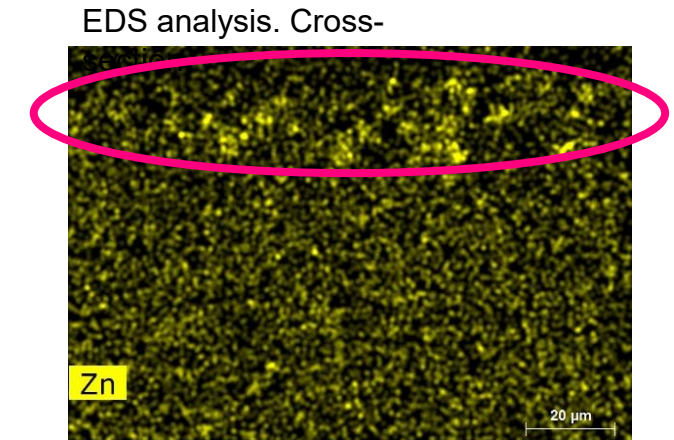
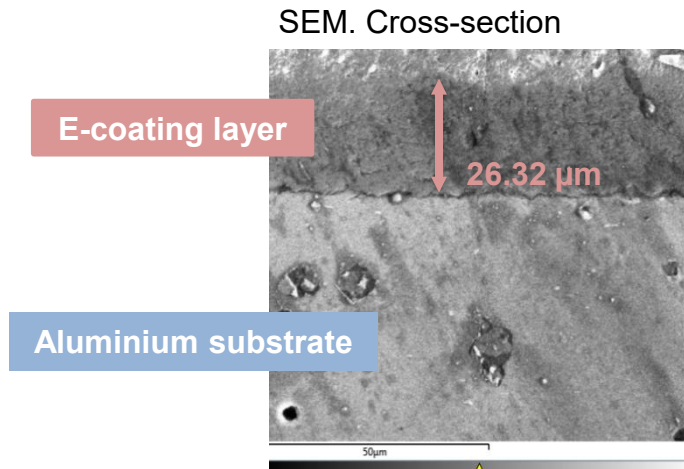
**Corrosion resistance test.
Neutral Salt spray test
(ISO 9227)**



TSA anodizing **with**
corrosion inhibitors

Validation of Chromium Free Surface Protection Systems

E-coating + Inhibitors (ZnAl-BTA LDH)



Corrosion resistance test.
Neutral Salt spray test
(ISO 9227)

168 h



E-coating **without**
corrosion
inhibitors

168 h



508 h



1008 h



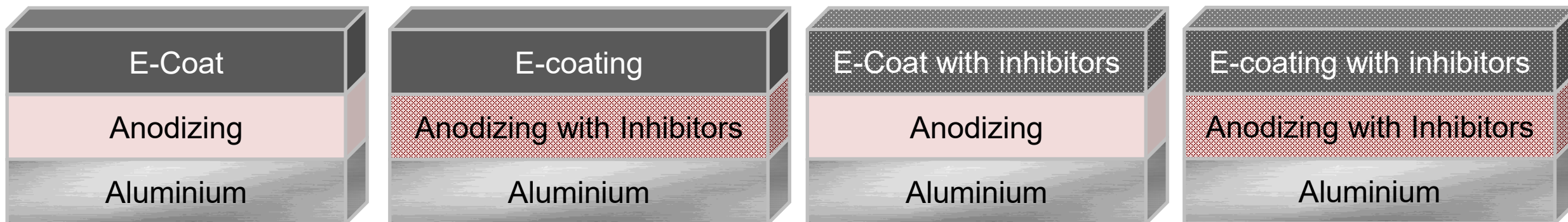
1508 h



E-coating **with**
corrosion inhibitors

Validation of Chromium Free Surface Protection Systems

Corrosion protection schemes



Aluminium alloys

- 2024T3 BARE
- 2024T3 CLAD
- 7075T6 BARE

Validation of Chromium Free Surface Protection Systems



Characterization Testing results

Tests

Layer Thickness (SEM)

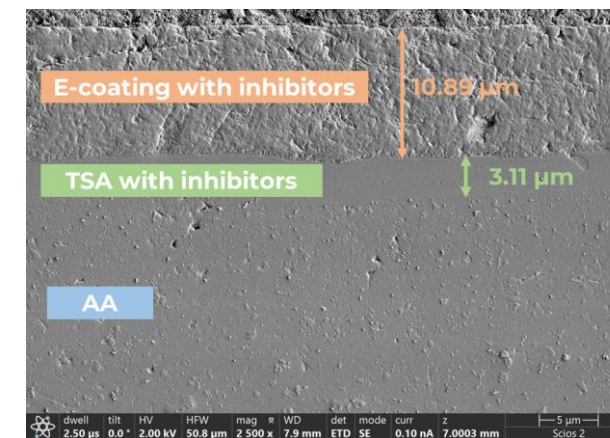
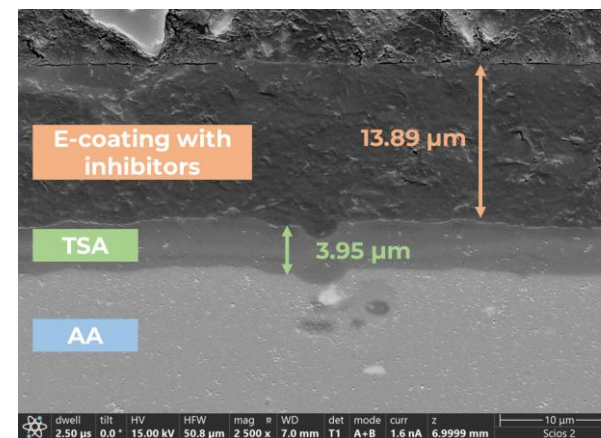
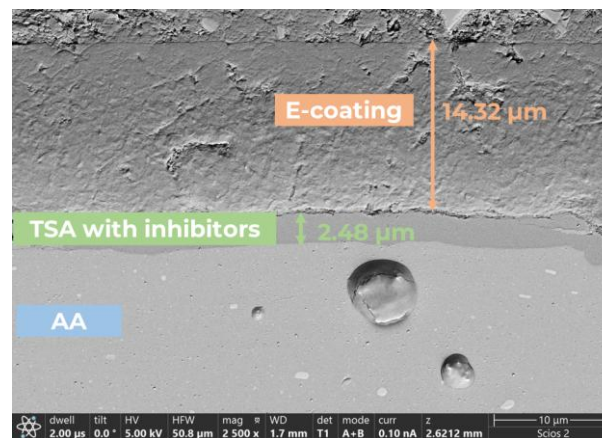
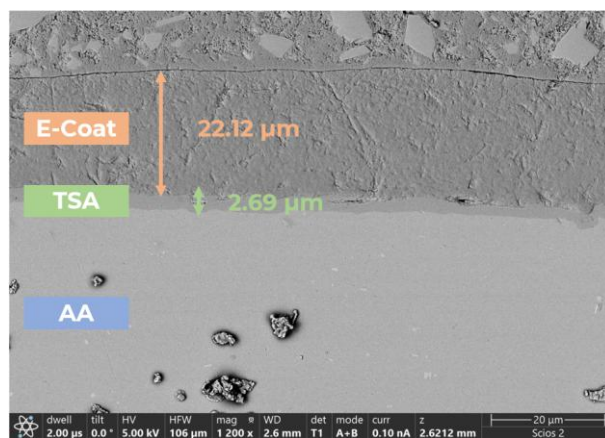
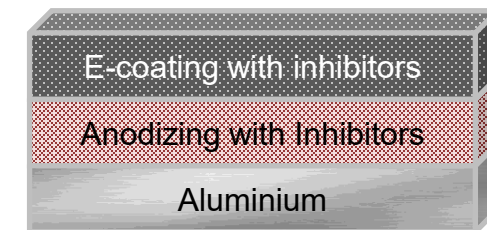
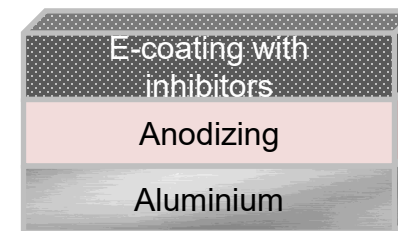
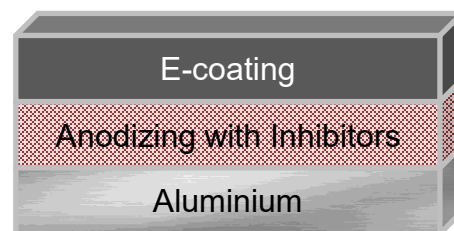
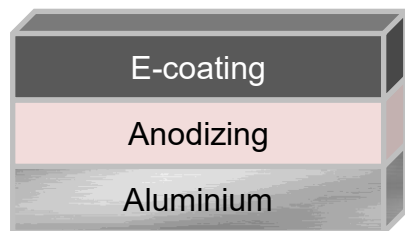
Paint adhesion (dry, water and skydrol)

Corrosion resistance (Neutral salt spray)

Paint compatibility (filiform corrosion)

Validation of Chromium Free Surface Protection Systems

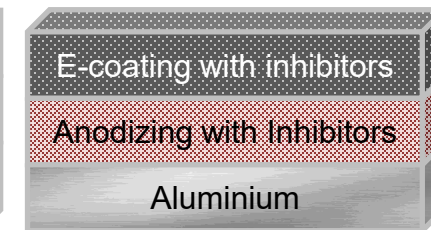
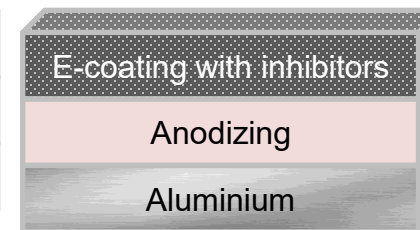
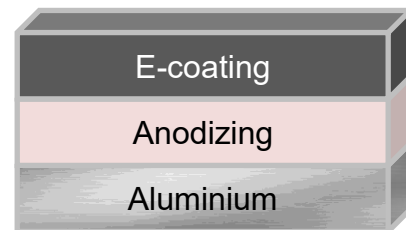
- Layer thickness



Anodic layer thickness requirement: **2-7 µm** ●

E-coating thickness requirement: **12-30 µm** ●

Validation of Chromium Free Surface Protection Systems

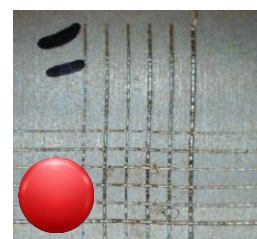


- Paint adhesión (dry)**
(ISO 2409)

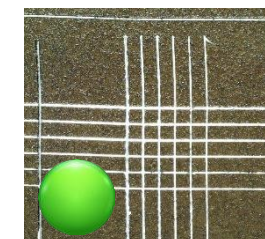
Requirement: $\leq$ Grade 0



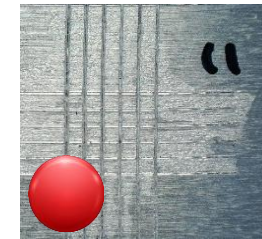
Grade 0



Grade 5



Grade 0

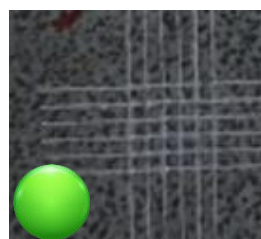


Grade 5

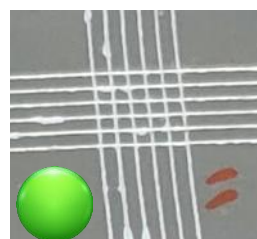
- Resistance to water**
(ISO 2409/ISO 2812-2)

Immersion time: 336 h
Temperature: 23 ± 2 °C

Requirement: $\leq$ Grade 1



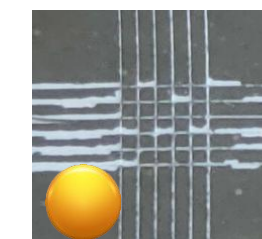
Grade 0



Grade 1



Grade 0

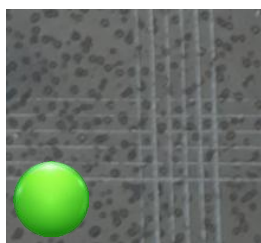


Grade 2

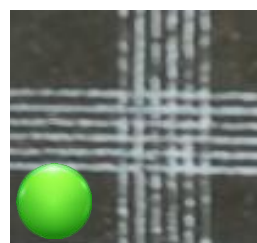
- Resistance to skydrol**
(ISO 2409/ISO 2812-2/ISO4628-2)

Immersion time: 336 h
Temperature: 70 ± 5 °C

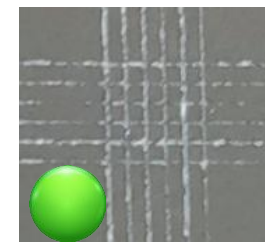
Requirement: $\leq$ Grade 1



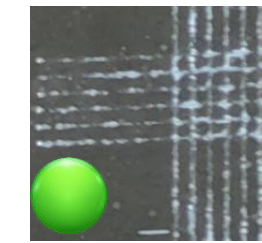
Grade 0



Grade 1



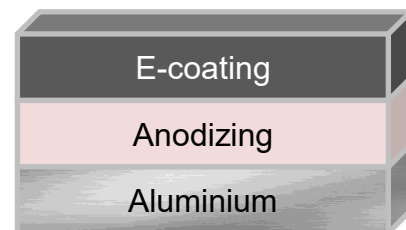
Grade 0



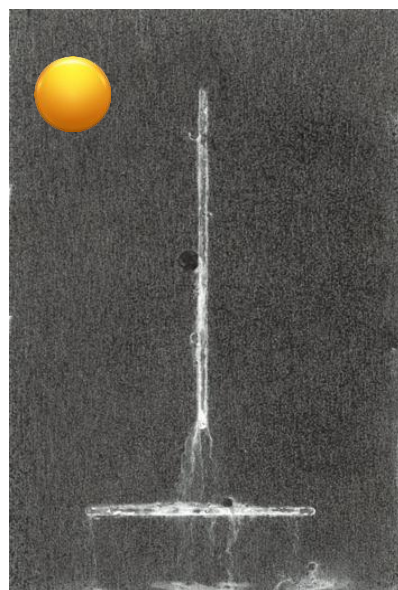
Grade 1

Validation of Chromium Free Surface Protection Systems

- Corrosion resistance.**
Neutral Salt spray test
(ISO 9227)



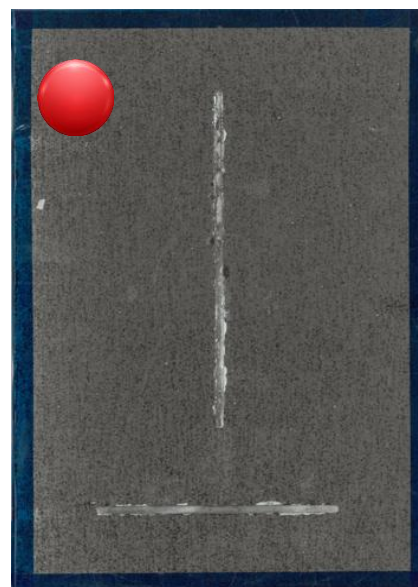
3000 h



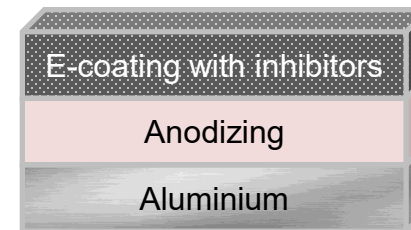
7075T6 BARE



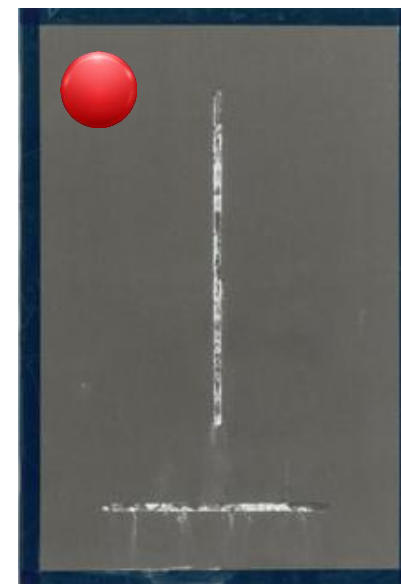
1508 h



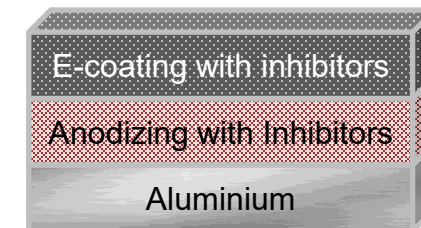
7075T6 BARE



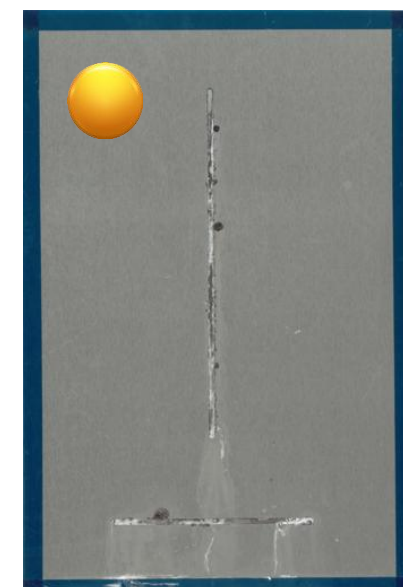
1008 h



2024T3 BARE
2024T3 CLAD
7075T6 BARE



3000 h

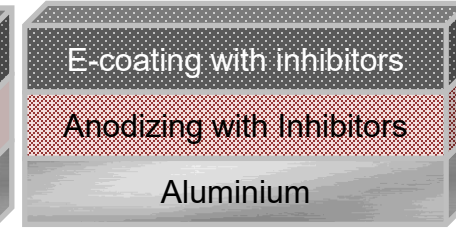
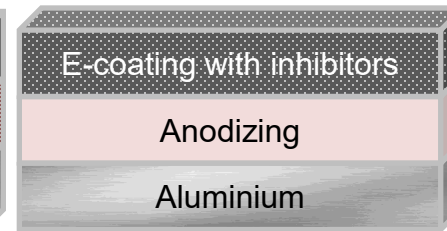
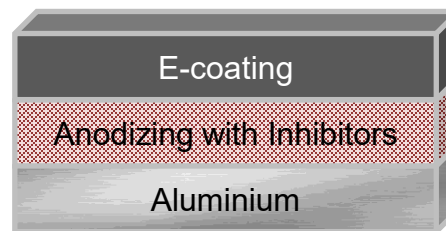
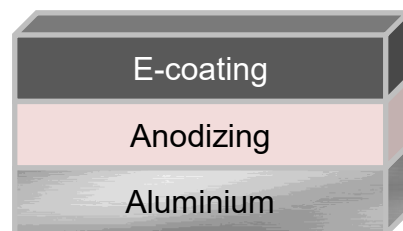


2024T3 CLAD

Requirement:
>3000 h

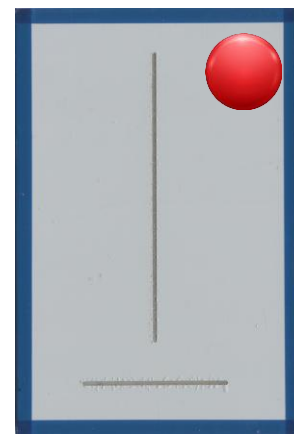
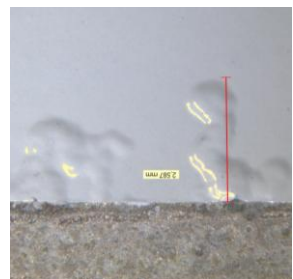
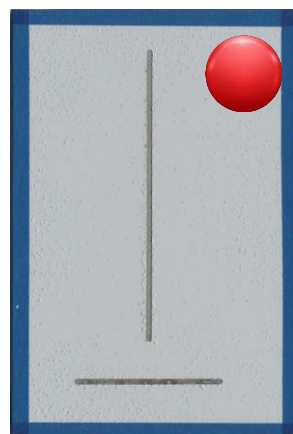
Validation of Chromium Free Surface Protection Systems

- **Paint compatibility.**
Filiform corrosion
(UNE-EN-3665)

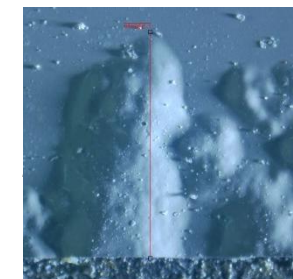
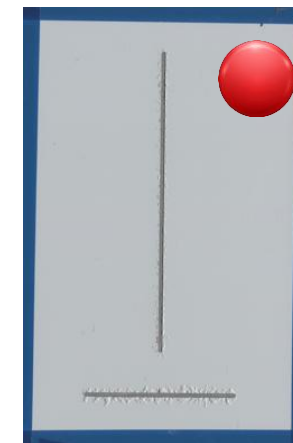
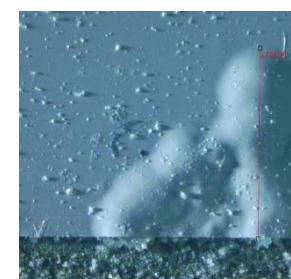
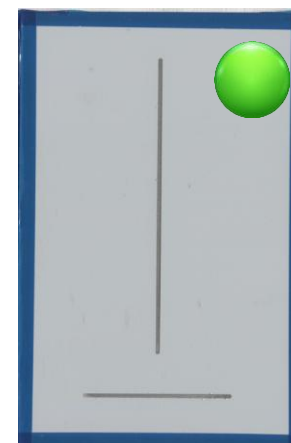


Requirement: **Maximum**
length of filaments on each
side of scratches: 2 mm

Exposure time: 960 h



1.840 mm



Validation of Chromium Free Surface Protection Systems

CONCLUSIONS



- ❖ **Corrosion inhibitors** improved the **corrosion performance** of both **TSA** and **E-coating**.
- ❖ When **both layers** were **combined**, **negative effects** were identified, affecting both **paint adhesion** and **corrosion performance**.

E-coating technology shows **strong potential** as a **chromium(VI)-free alternative**. The results achieved provide **valuable insights** for its further **development**.

Validation of Chromium Free Surface Protection Systems



Thanks for your attention!

Webinar Pilot 2 - September 16th, 2026.

Advancing Sustainable Surface Treatments

Q & A session



Organized:



Co-financed:



Webinar Pilot 2 - September 16th, 2026.

Advancing Sustainable Surface Treatments

Thank you very much for your attention



Project (GA number: S1/1.1/E0025) co-financed by the Interreg Sudoe Programme through the European Regional Development Fund (ERDF).

Ongoing project: 2024 – 2026

Organized:



Co-financed:

