Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

POLITECNICO MILANO 1863

UNIVERSITÀ DI TRENTO

(PRIN 2022, COD. PROTOCOLLO: 2022H3S28T, CUP MASTER: D53D23005410006) FINANZIATO DALL'UNIONE EUROPEA – NEXT GENERATION EU, PNRR - MISSIONE 4 "ISTRUZIONE E RICERCA" - COMPONENTE C2 INVESTIMENTO 1.1 "FONDO PER IL PROGRAMMA NAZIONALE DI RICERCA E PROGETTI DI RILEVANTE INTERESSE NAZIONALE (PRIN)" D.D. N. 104/2022 "BANDO PRIN 2022". PE11 Engineering of Metals and alloys.

Producing Plasma Electrolytic Oxidation (PEO) corrosion resistant coatings on aluminium 2024 texturized with a riblet-like surface for aeronautical applications

Matteo Gamba [1], Marco Ormellese [1], Andrea Cristoforetti [2], Michele Fedel [2], Andrea Brenna [1]

[1] *Dipartimento di Chimica, Materiali ed Ingegneria Chimica "Giulio Natta", Politecnico di Milano*

[2] *Dipartimento di Ingegneria Industrale, Università di Trento*

EMCR 2025

San Servolo (VE) | 15-19 giugno 2025

Producing Plasma Electrolytic Oxidation (PEO) corrosion resistant coatings on aluminium 2024 texturized with a riblet-like surface for aeronautical applications

M. Gamba[1], M. Ormellese[1], A. Cristoforetti[2], M. Fedel[2], A. Brenna[1]

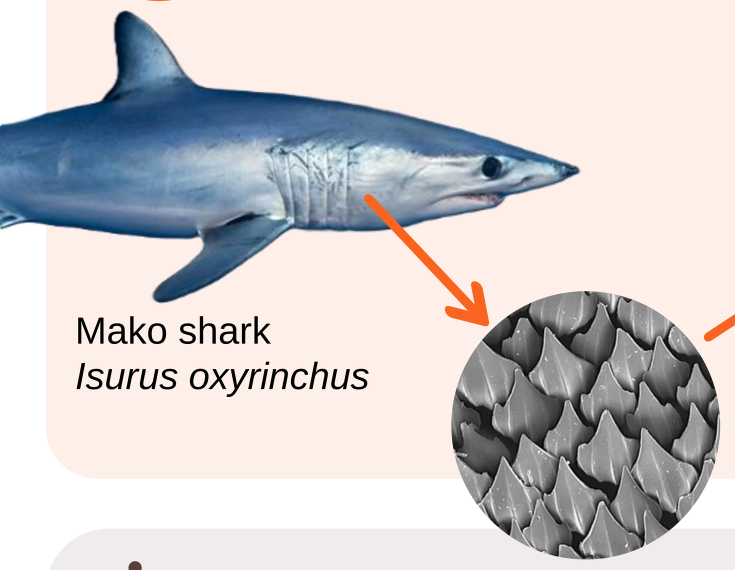
[1] Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta", Milano

[2] Università di Trento, Dipartimento di Ingegneria Industriale, Trento

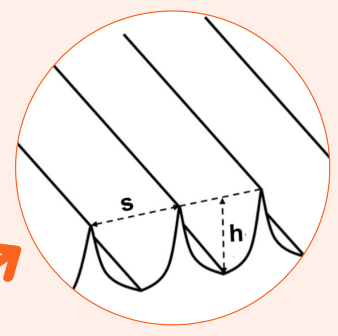
matteo.gamba@polimi.it

Project outline

- Sharkskin biomimetic textures are able to reduce fluid dynamic drag during motion.
- Plasma Electrolytic Oxidation (PEO) coatings proved to be effective for corrosion protection on aluminum alloys.
- Their combination would offer desirable surfaces for aeronautical vehicles.

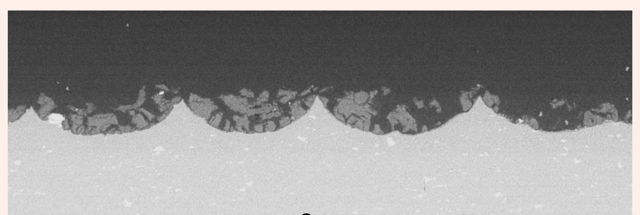


Mako shark
Isurus oxyrinchus



s = 200 µm
h = 75 µm

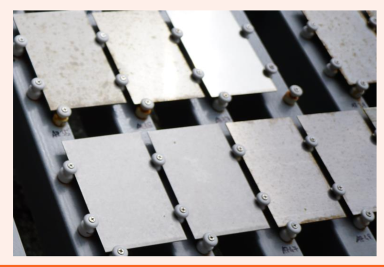
Biomimetic texture production by electrochemical etching



144 s at 2,5 A/cm^2 in 100 g/L $NaNO_3$

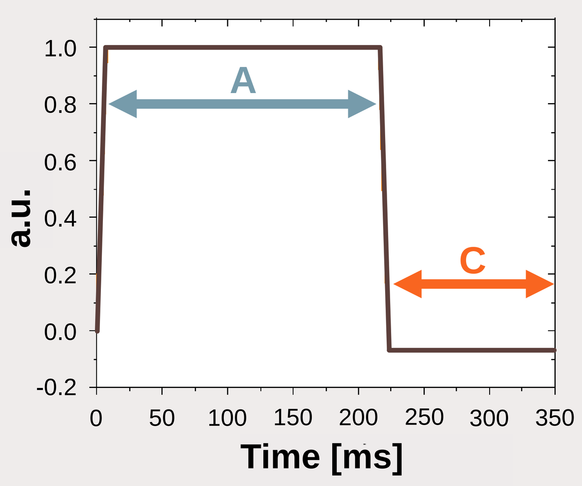
PEO coating optimization for textured surfaces

Corrosion testing of surfaces

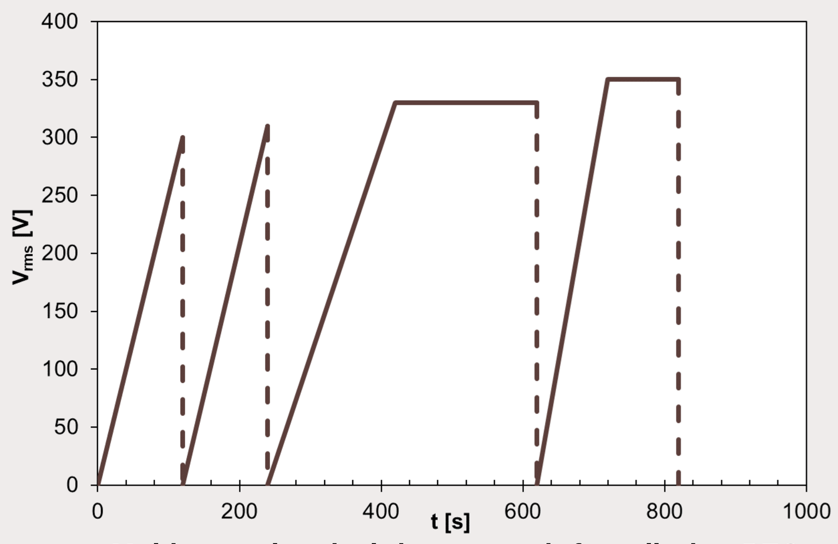


Materials Methods

- The PEO electrical process was fixed. A common silicate-alkaline electrolyte was used as a starting point, with glycerin for reducing splash-out.
- Different PEO electrolytic solutions were studied to optimize the **cationic composition**, the **alkali concentration** and the **organic additives**.
- Coating evaluated by **SEM microscopy** and **electrochemical testing.**



Waveform used for PEO electrical input. Square signal, 60% time in anodic polarization, cathodic amplitude 7% of anodic one.



Multistep electrical input used for all the PEO coatings. Four steps encompassing ramps and maintenance periods, with maximum voltage 350 V_{rms} and total duration around 15 min.

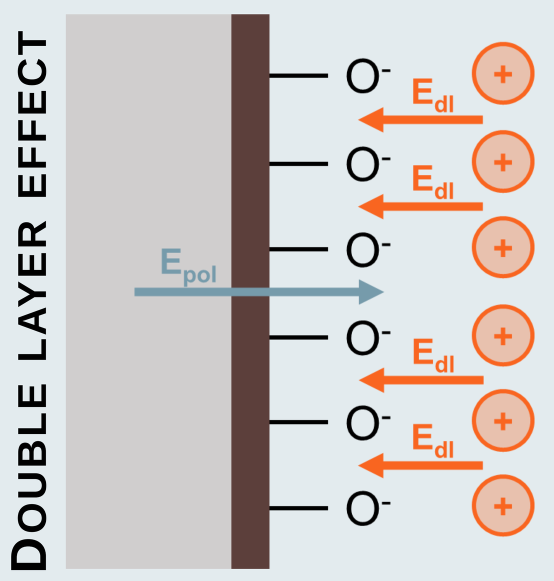
Electrolyte	Alkali			Additives	
	KOH, mol/L	NaOH, mol/L	CH_3COOH, g/L	Na_2SiO_3, g/L	Glycerin, g/L
0.20 KS	0.20	-	-	10	10
0.20 KNS	0.04	0.16	-	10	10
0.09 KNS	0.014	0.076	-	10	10
0.09 KNSA	0.014	0.076	10	10	10

Electrolytic solutions used for PEO coatings.

Discharge features

- More intense sparking corresponds to more defected, but thicker, coatings.
- Spark intensity depends on oxide thickness, electrolyte resistivity and double layer formation.
- Spark characteristics can be modified by acting on the electrolytic solution composition.

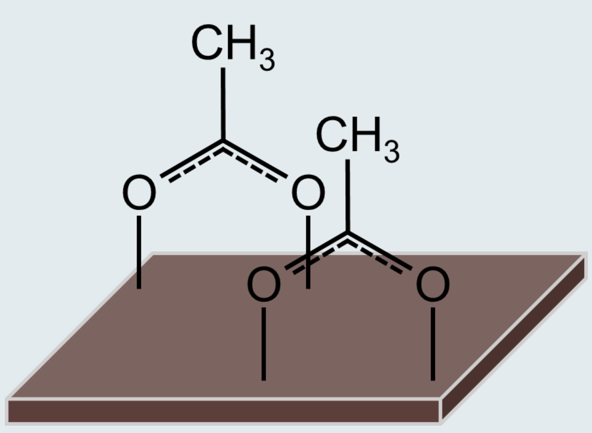
Double layer effect



Due to the lower mobility of Na⁺ with respect to K⁺, **double layer formation is slower in 0.20 KNS**, giving a stronger, but **more homogeneous, sparking**.

\+

Acetic acid effect



CH_3COOH adsorbs on the oxide, **increasing the dielectric thickness**, giving a **weaker sparking**.

\+

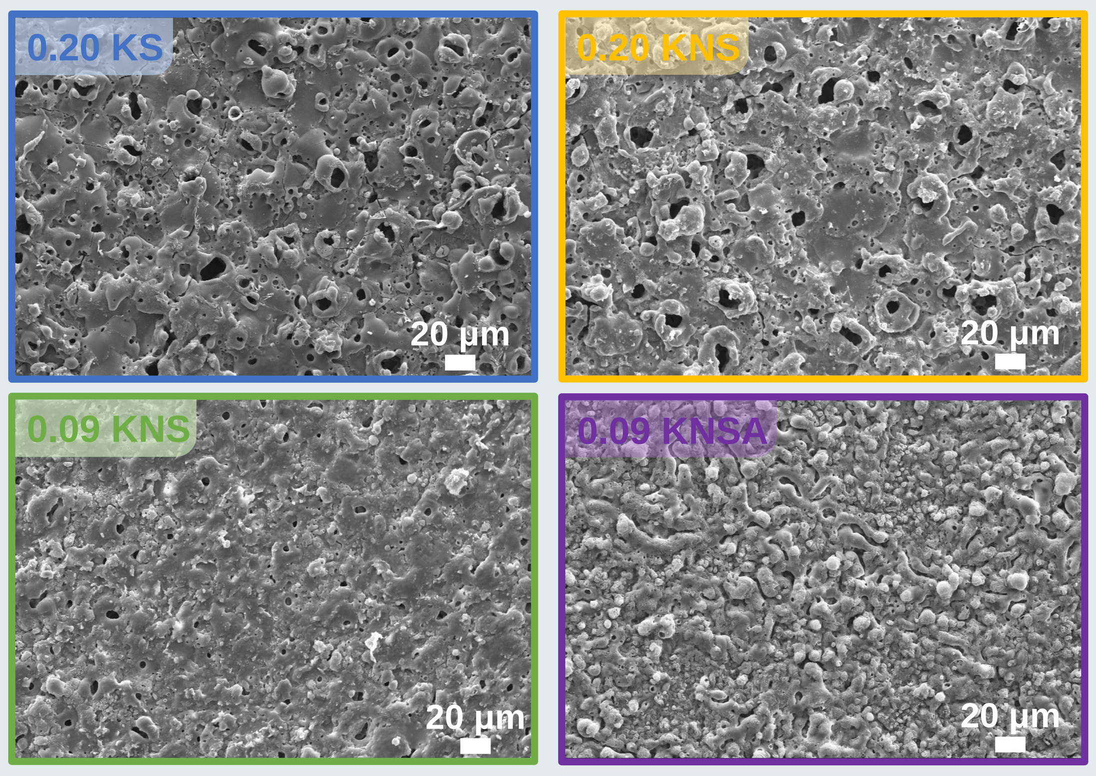
Alkali concentration effect

Reducing alkali concentration the **electrolyte becomes resistive**, obtaining **weaker sparks**.

Stronger plasma sparks
Thicker coating
Larger defects

0.20 KS
0.20 KNS
0.09 KNS
0.09 KNSA

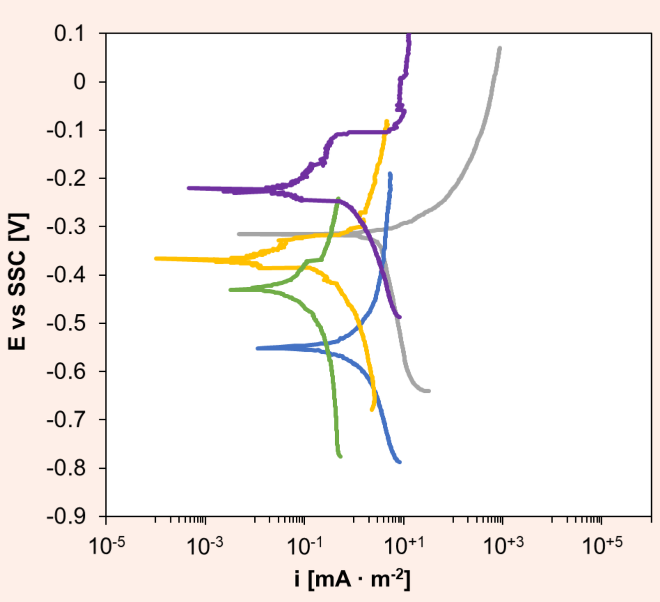
Weaker plasma sparks
Thinner coating
Smaller defects



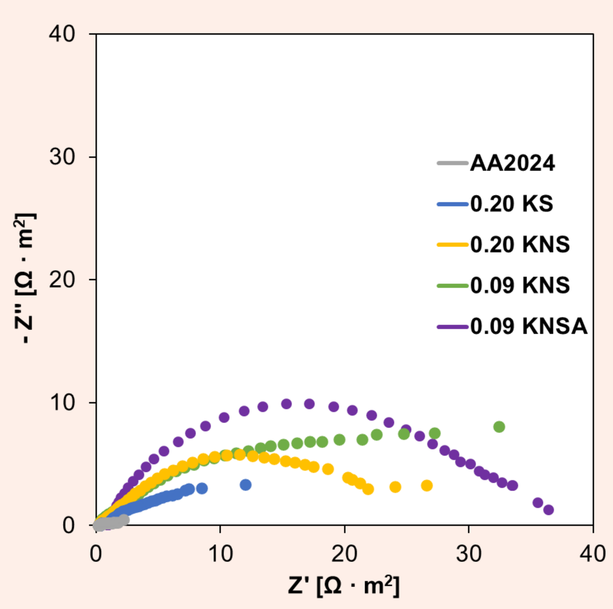
SEM 1000x magnifications of coatings. Pores and cracks amount decreases with spark intensity.

Corrosion resistance

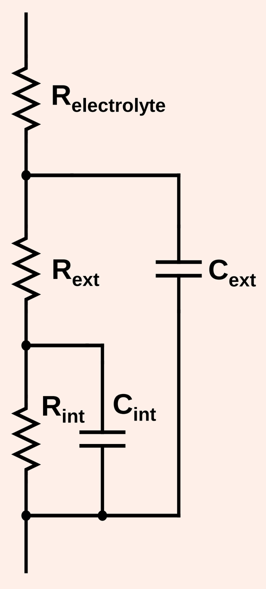
- All the coatings reduce i_{corr} of AA2024 by at least 10 times.
- Electrochemical testing shows that less defected coatings are more protective, irrespectively of their thickness.



Potentiodynamic polarization
20 ppm Cl⁻, 1 h immersion



EIS
20 ppm Cl⁻, 1 h immersion
10^5 to 10^{-2} Hz



All coatings are bilayered

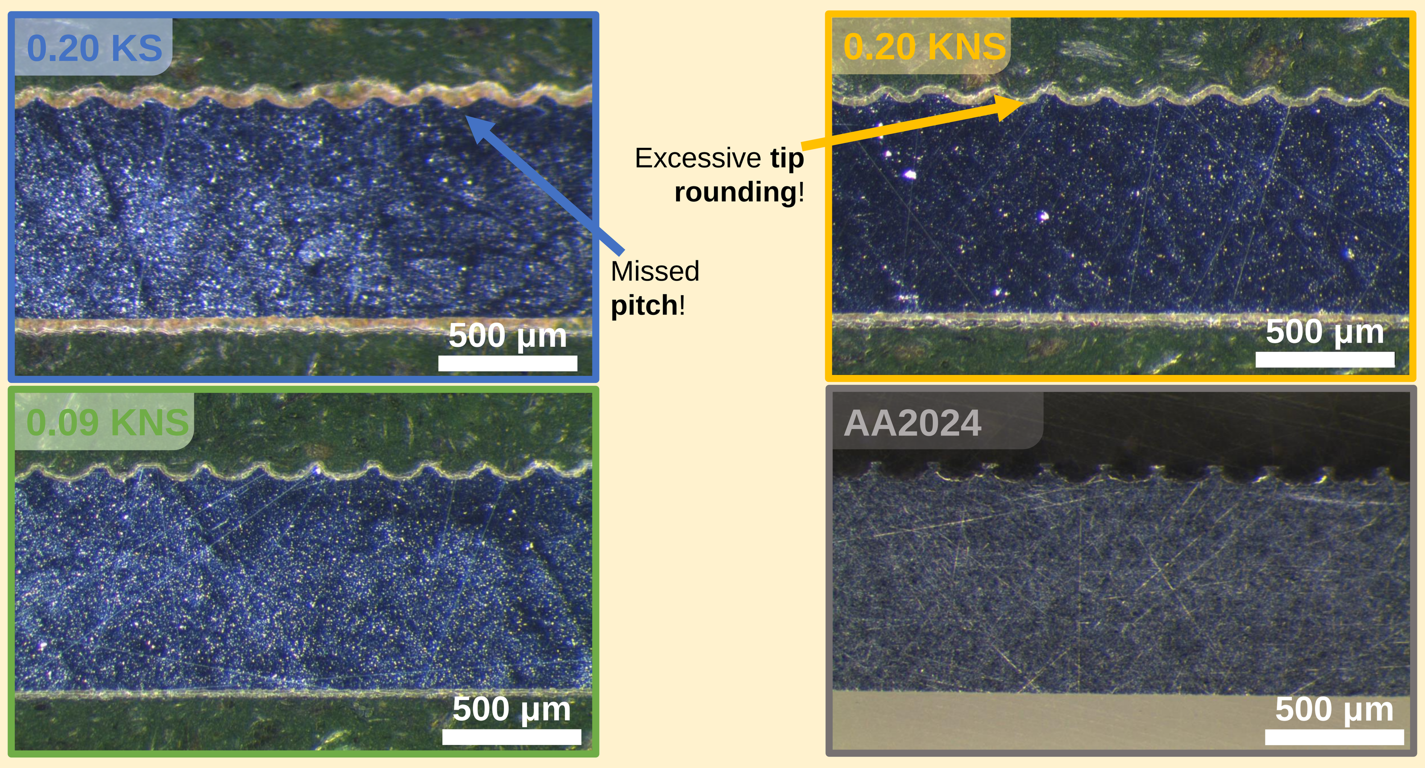
Larger defects
Higher i_{corr}
Lower R_p

0.20 KS
0.20 KNS
0.09 KNS
0.09 KNSA

Smaller defects
Lower i_{corr}
Higher R_p

Sharkskin Texture

- Not all the processes are accurate.
- Electrolytes able at reducing spark intensity give better reproduction.



Conclusions and future development

- The amount of coating defects decreases by **decreasing spark intensity** during PEO. Thus, coating homogeneity, **corrosion resistance** and **texture reproduction** are **improved**.
- Substituting K⁺ cations with **Na⁺** ones, reducing the amount of **alkali** and introducing **acetic acid** are effective strategies for **reducing discharge intensity**.
- Coating **pore sealing** for increasing the corrosion resistance of the PEO coatings.

Follow the shark!

@makoproject

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

EMCR 2025