Matchmaking riset dan kolaborasi UI dan APIK
11 Februari, 2021

Surface modification of metals by plasma electrolytic oxidation

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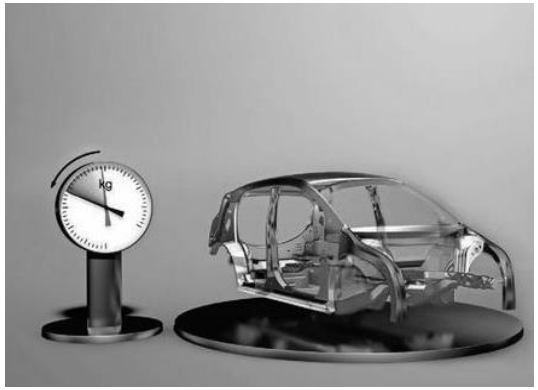
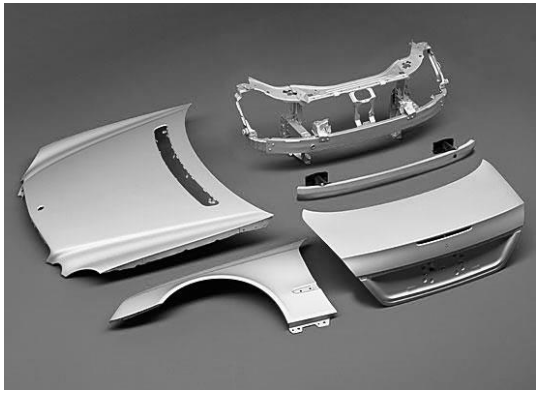
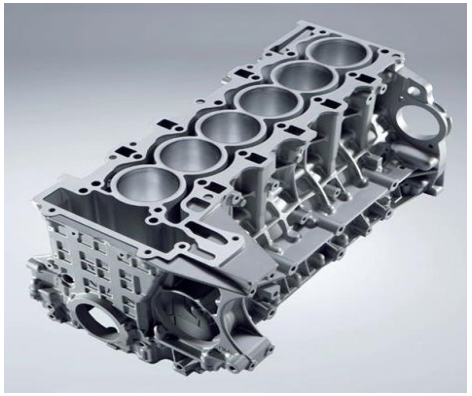
1. Introduction

- Light metals
- Surface treatment methods
- Plasma electrolytic oxidation (PEO)

Introduction: Light metals







Advantages

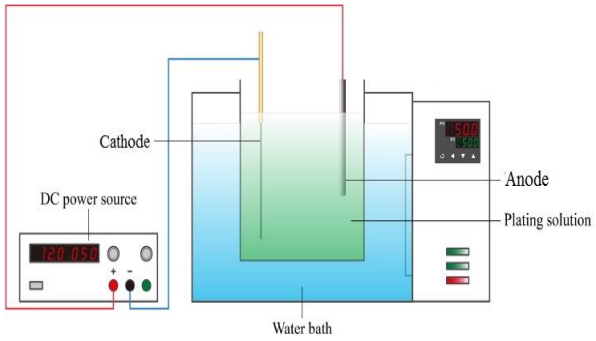
High specific strength (Al, Mg, Ti)
Good electrical and thermal conductivity (Al)
Electromagnetic shielding (Mg)
Biocompatibility (Ti)

Limitations

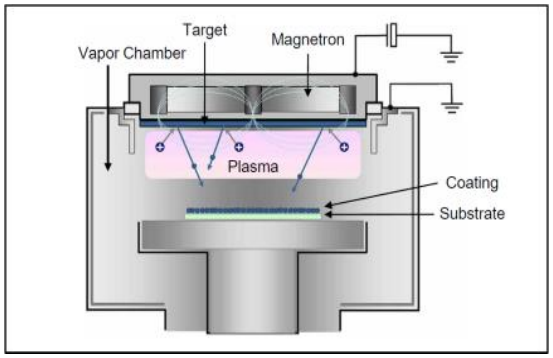
Relatively low strength (Mg, Al, Ti)
Low corrosion resistance (Mg and Al)
Poor surface hardness (Mg and Al)
Bio inertia (Ti)

1-2 Introduction: Surface treatment methods

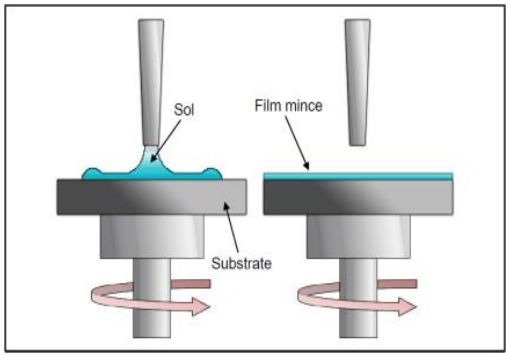
Electroplating



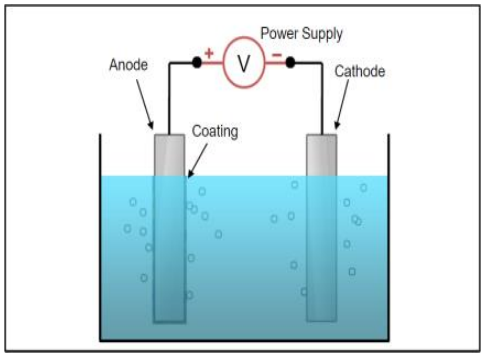
Chemical Vapor Deposition



Sol-Gel



Anodizing

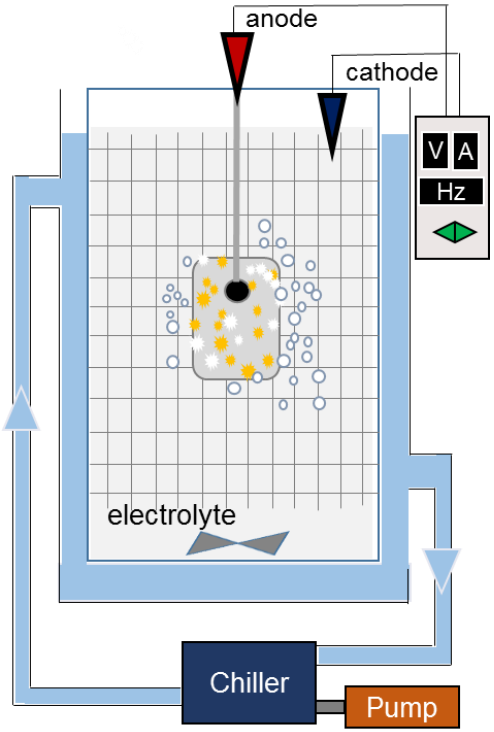


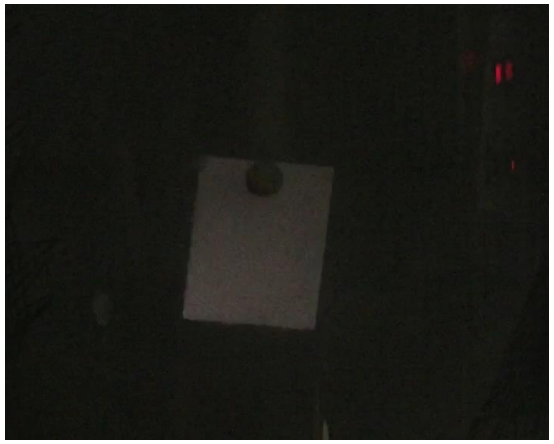
Important Features

- Eco-friendly
- Excellent adhesion
- High performance
- Functional properties
- Cost-effective
- Simple process

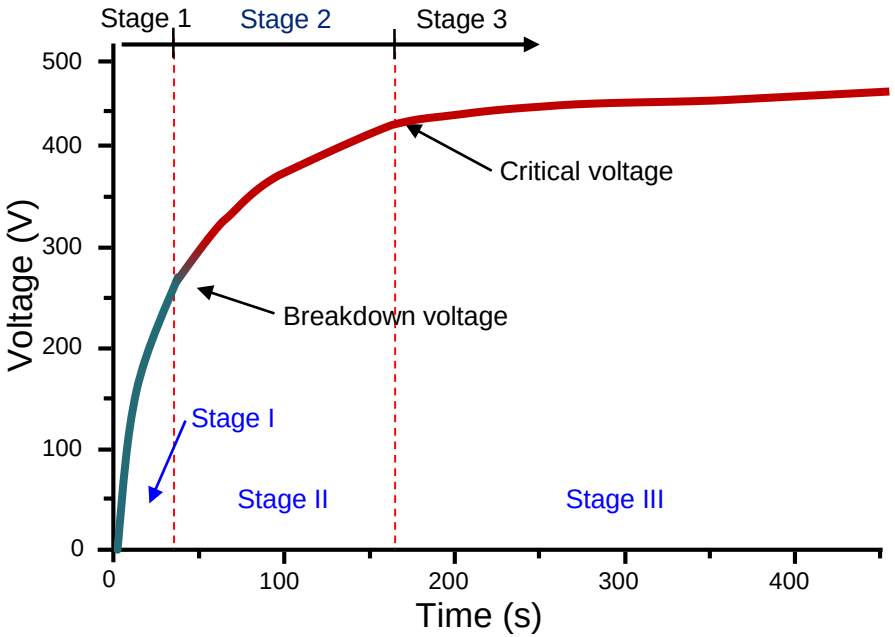
1-3 Introduction: Plasma electrolysis oxidation (PEO)

Schematic illustration of PE





Time-Voltage Curve



Electrochemical reactions at the anode

$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$

$Mg(OH)_2 \longrightarrow MgO + H_2O$

} Oxide formation

$Na_2SiO_3 + H_2O \longrightarrow SiO_2 + 2NaOH$

$2MgO + SiO_2 \longrightarrow Mg_2SiO_4$

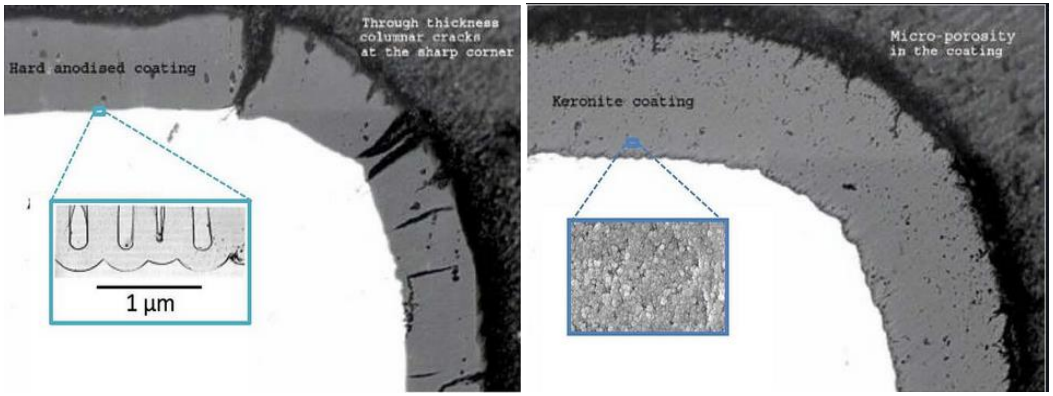
} Incorporation

Electrochemical reaction at the cathode

$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

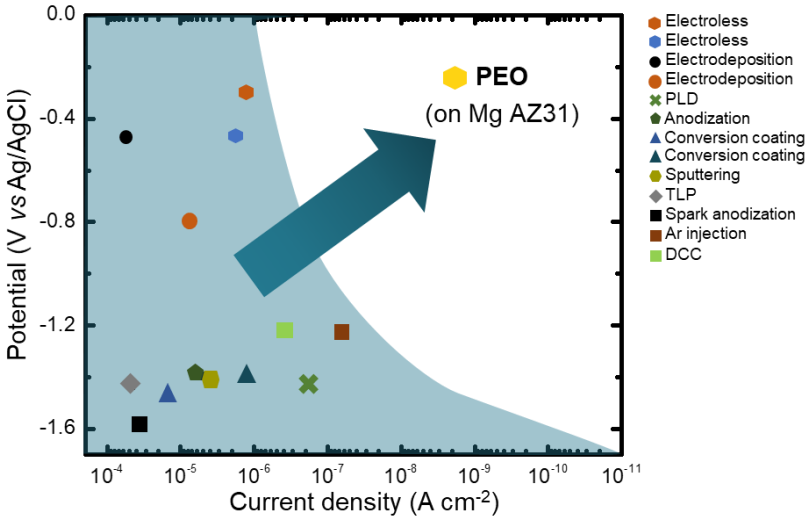
1-4 Introduction: Plasma electrolysis oxidation (PEO)

Microstructure

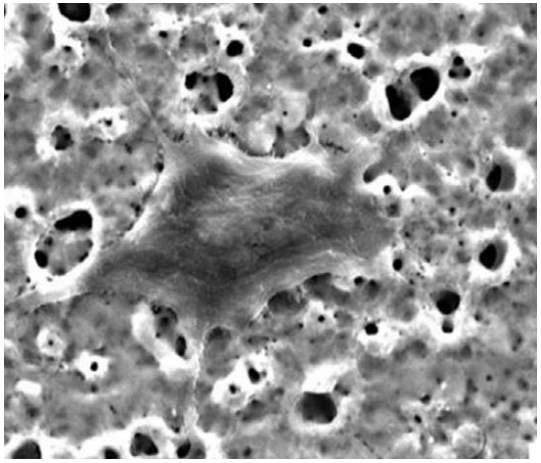


Hard-anodization PEO

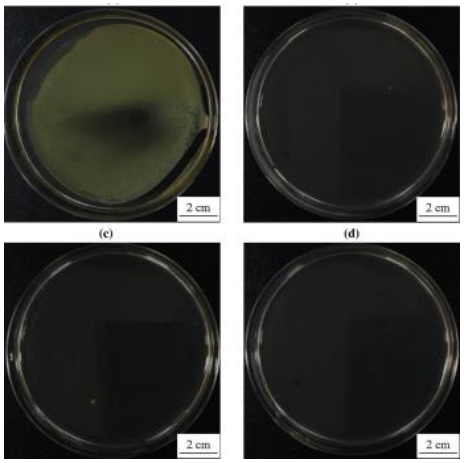
Corrosion resistance



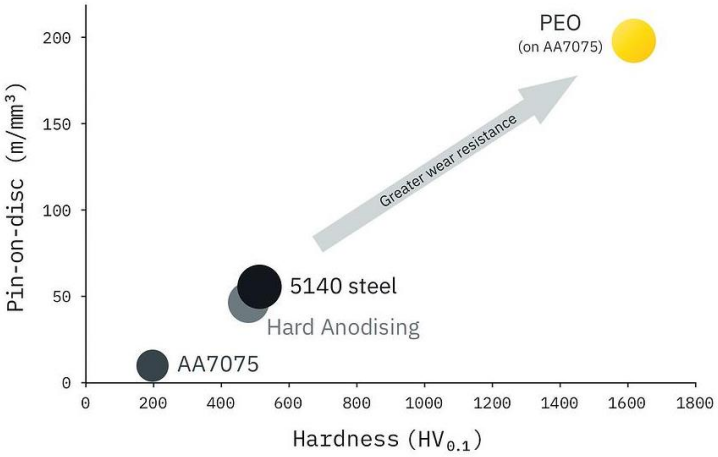
Biocompatibility



Anti-bacterial activity



Hardness and Wear



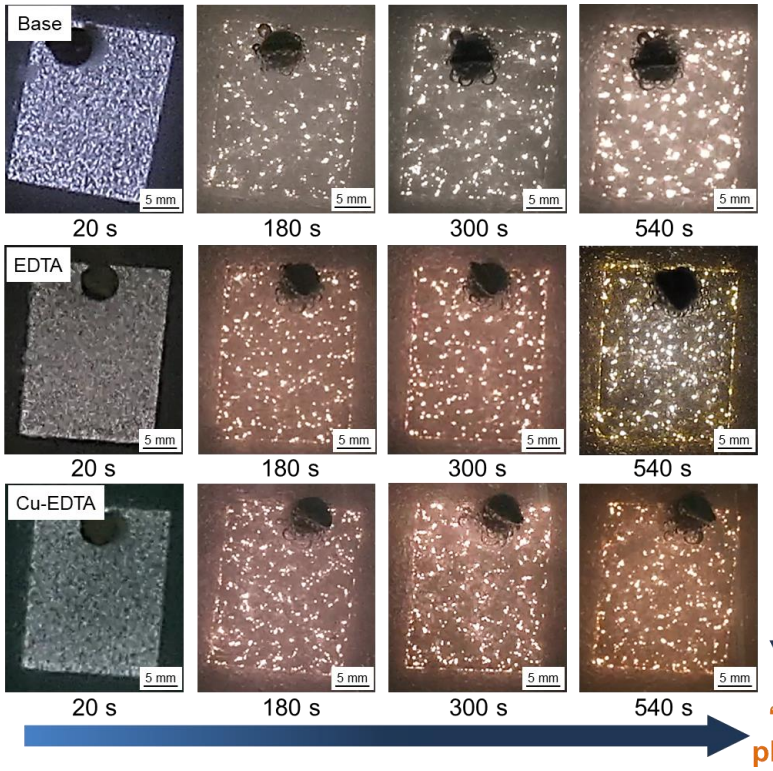
2. Research experience

- Fundamentals of PEO
- Structural properties
- Functionalization

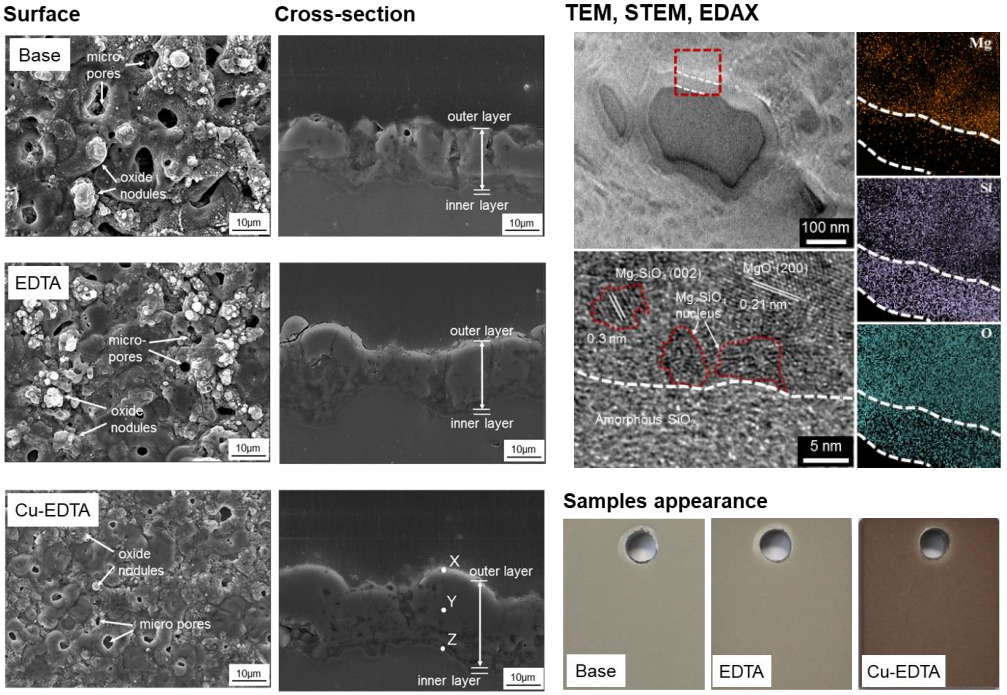
Fundamentals of PEO

Processing-structure relationship

Control of plasma discharges[1]



Structural characterizations[1,2]



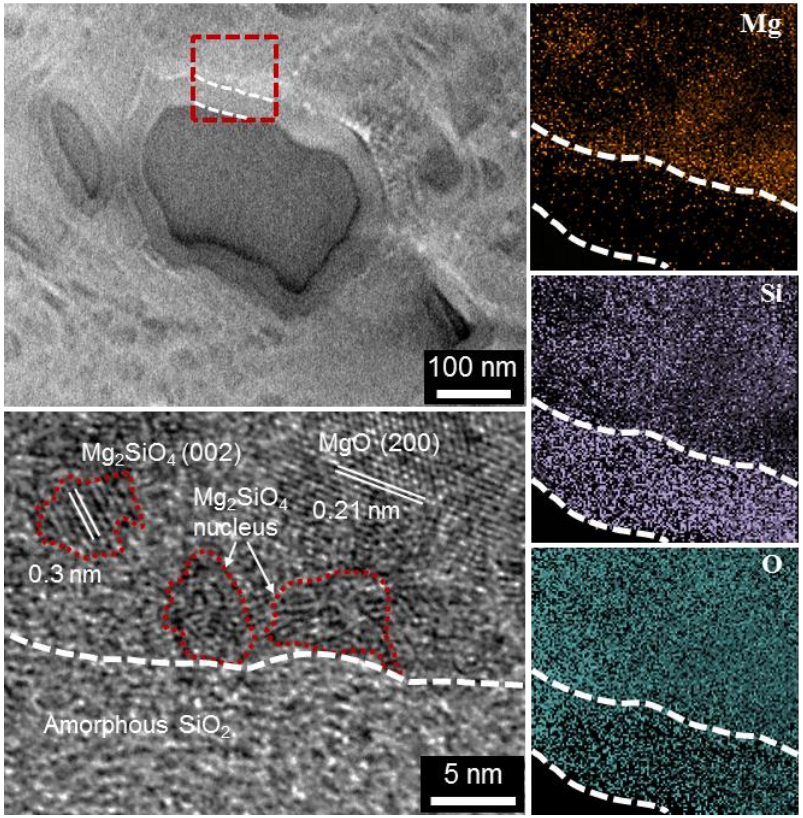
[1]Kamil et al. **Scientific Reports** (2017)

[2]Kamil et al. **Electrochemistry Communications** (2018)

Fundamentals of PEO

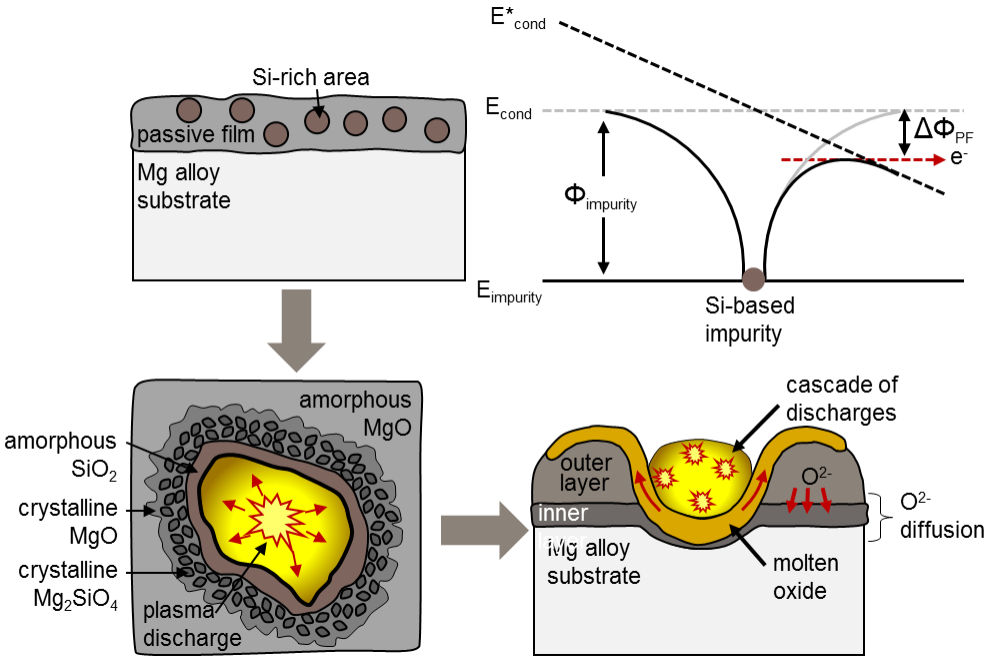
Mechanism of plasma discharges[1]

STEM, HRTEM, EDAX analyses



Impurity-rich area as ignition sites for plasma discharges

Impurity-induced discharges



Formation of plasma discharges on impurity sites

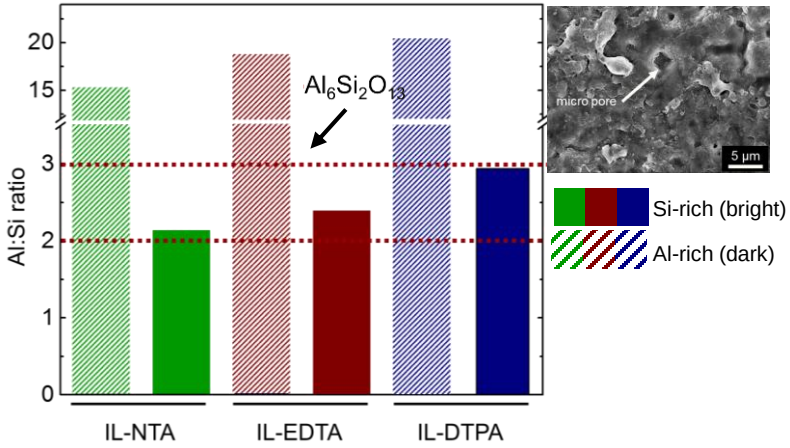
Reduction of potential barrier by Poole-Frenkel effect

[1]Kamil et al. **Electrochemistry Communications** (2018)

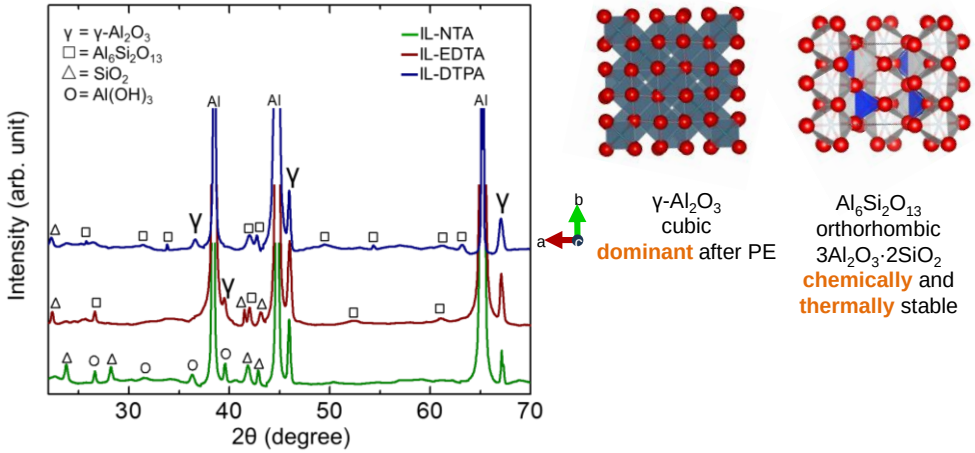
Fundamentals of PEO

Chemical characterizations

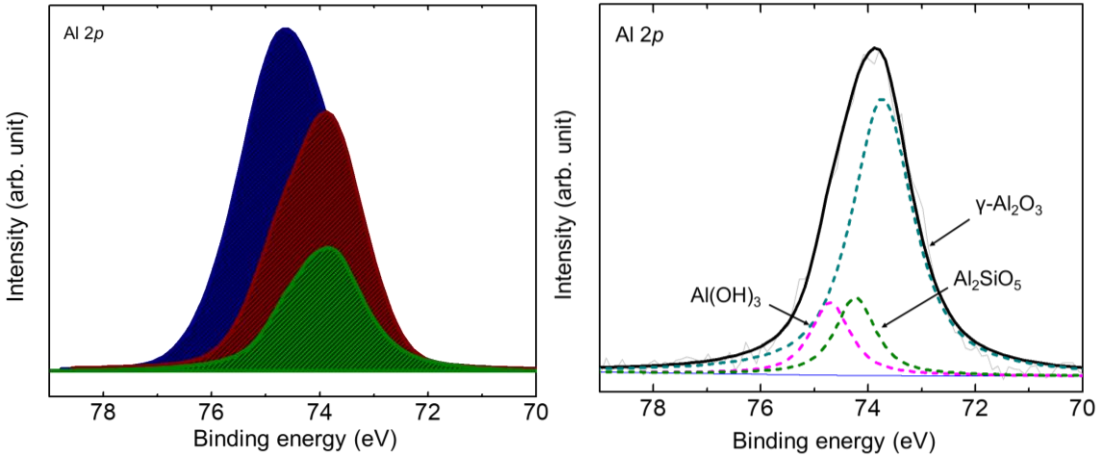
EDS analysis



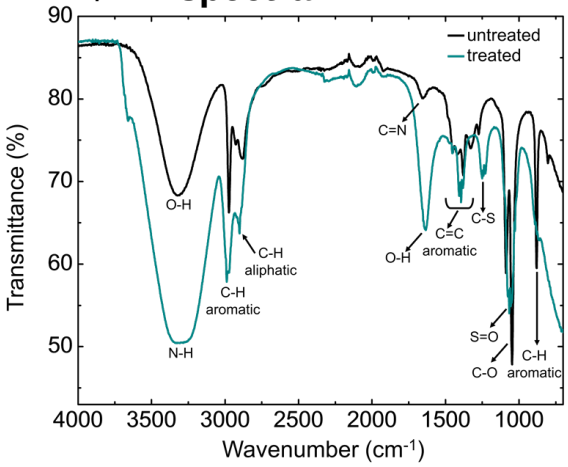
XRD spectra



XPS analysis



FTIR spectra

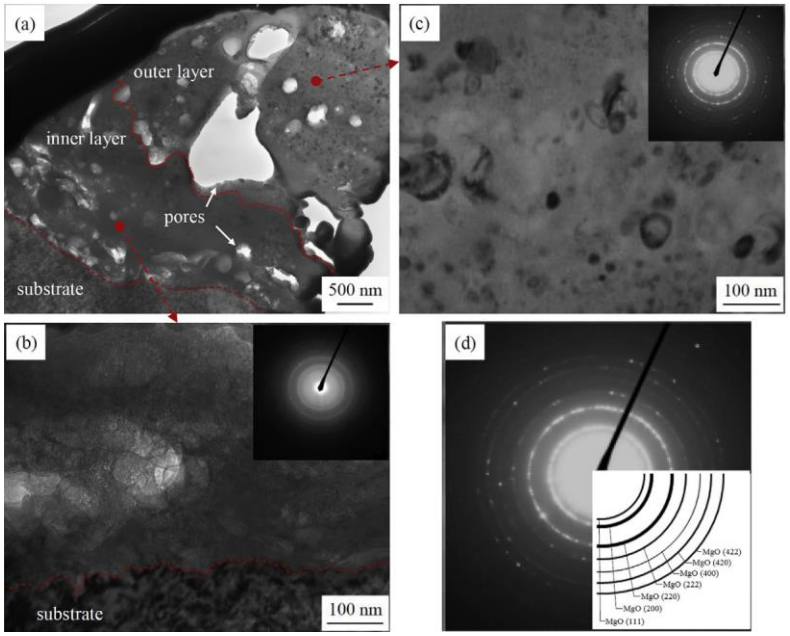


Kamil et al. **Chemical Engineering Journal** (2020)

2-2 Structural properties

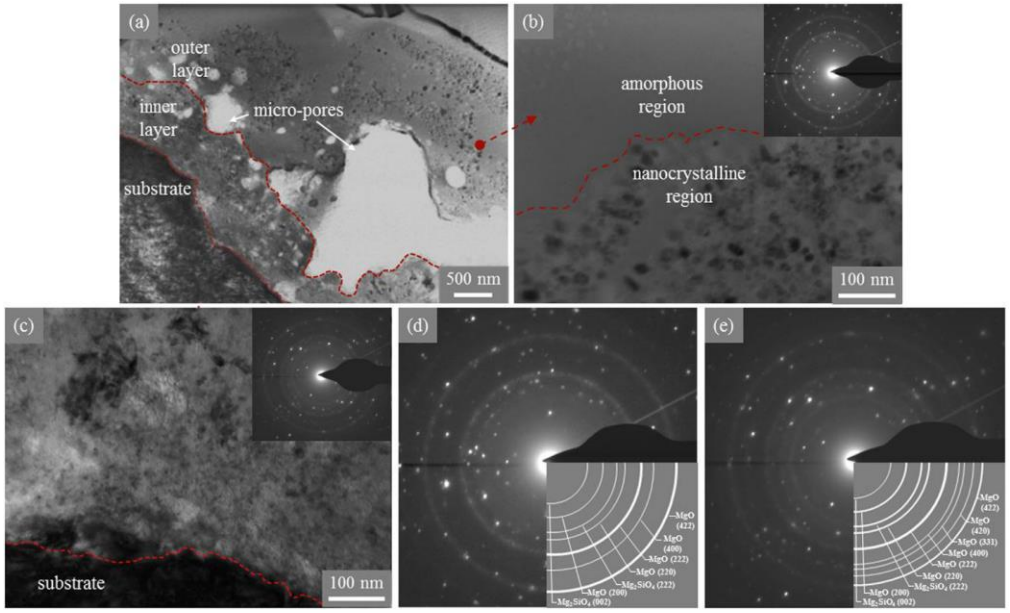
Sub-layered structures of PEO

Pure metal oxide[1]



MgO
Inner layer : amorphous
Outer layer : nanocrystalline

With incorporation of modifiers[2]



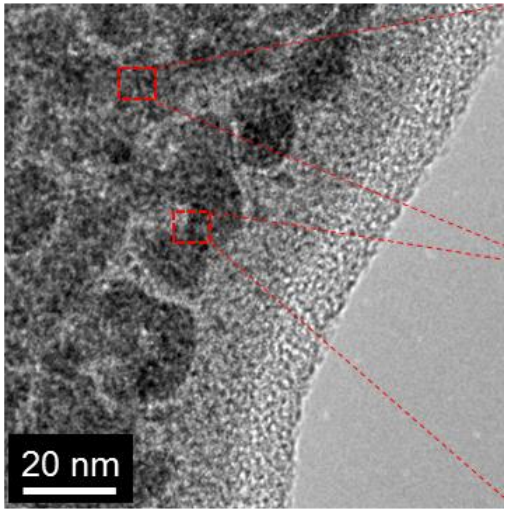
MgO + Mg_2SiO_4
Inner layer : nanocrystalline
Outer layer : amorphous + nanocrystalline

[1]Kamil et al. **Journal of Alloys and Compounds** (2017)
[2]Kamil et al. **Electrochemistry Communications** (2018)

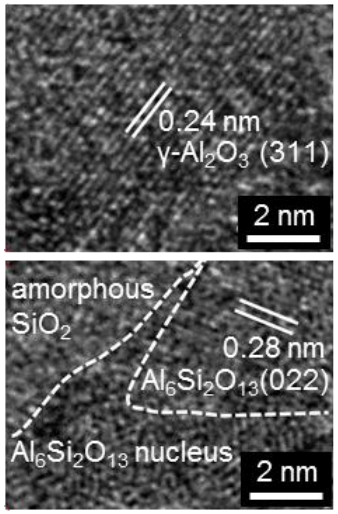
2-2 Structural properties

Structure-corrosion properties relationship[1]

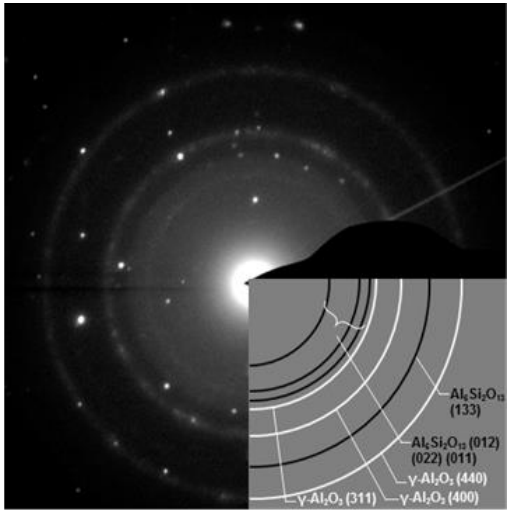
TEM



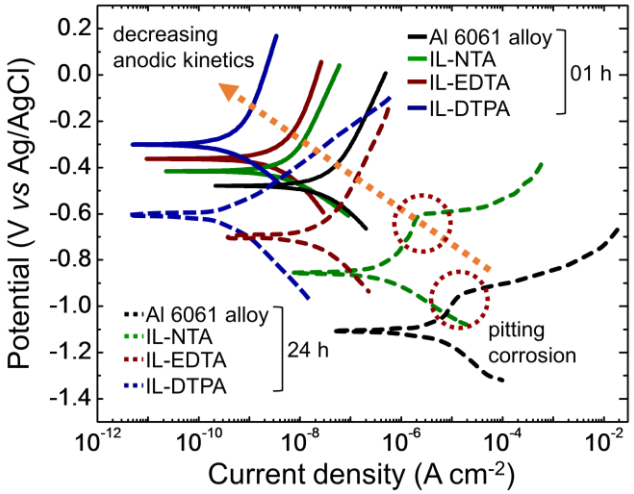
HRTEM



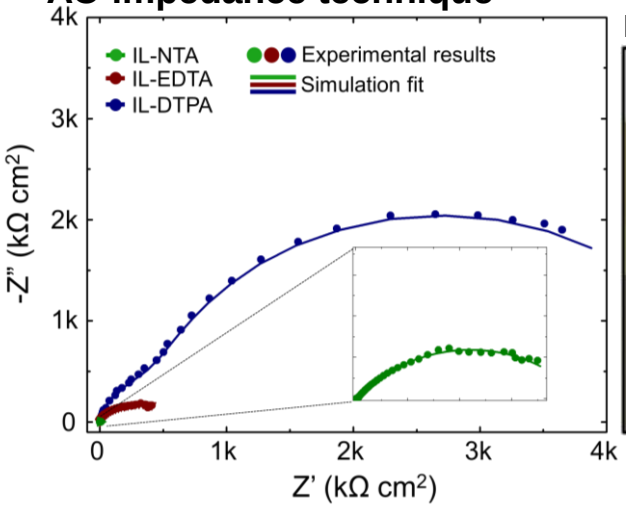
SAED pattern



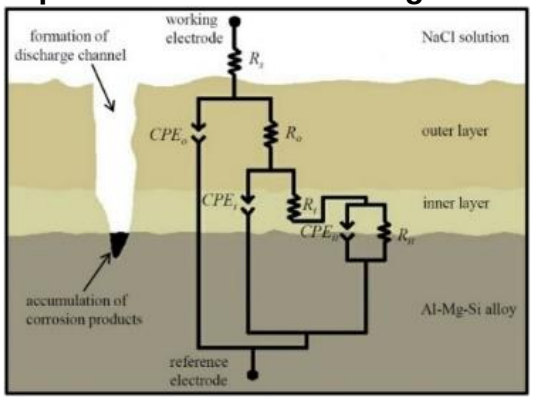
DC-polarization technique



AC-impedance technique



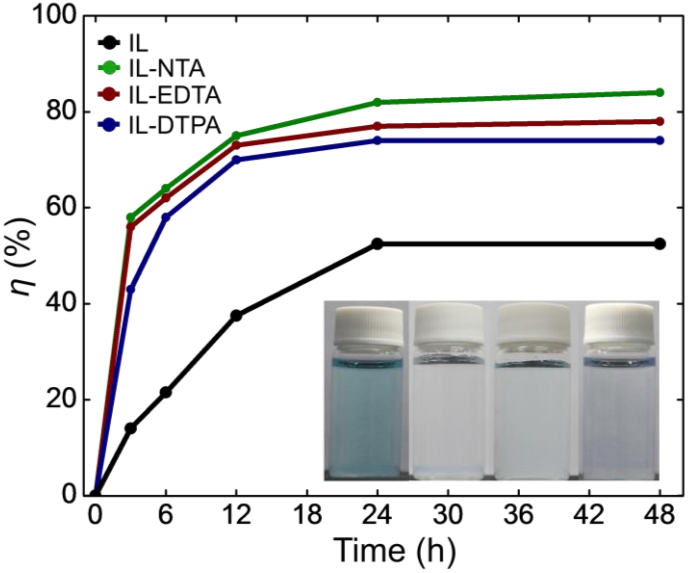
Equivalent circuit modeling

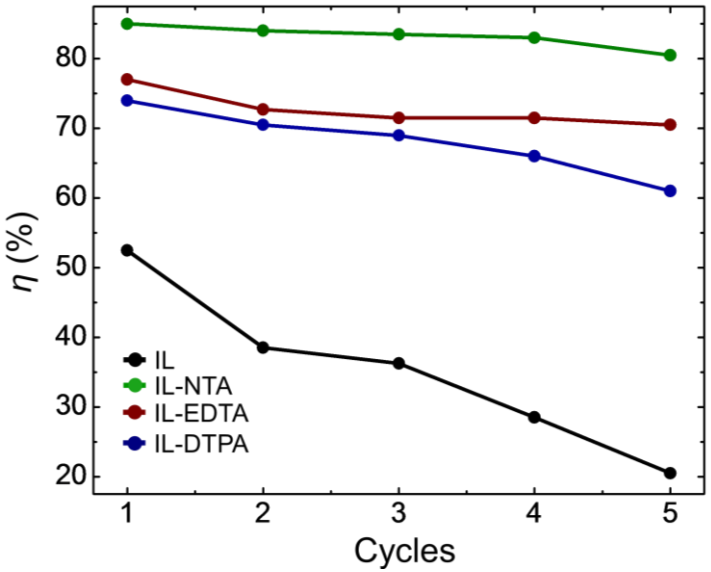


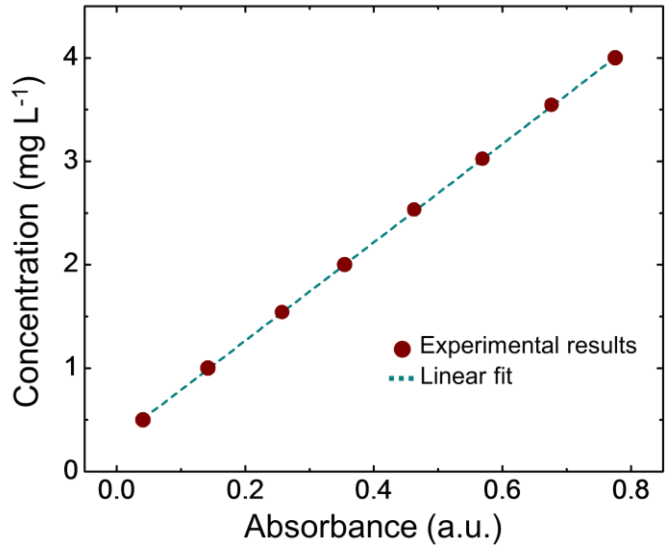
[1]Kamil et al. **Chemical Engineering Journal** (2020)

Functionalization

Exploration of new coating properties







Catalytic efficiency

$$\eta = \frac{C_0 - C_t}{C_0} \times 100\%$$

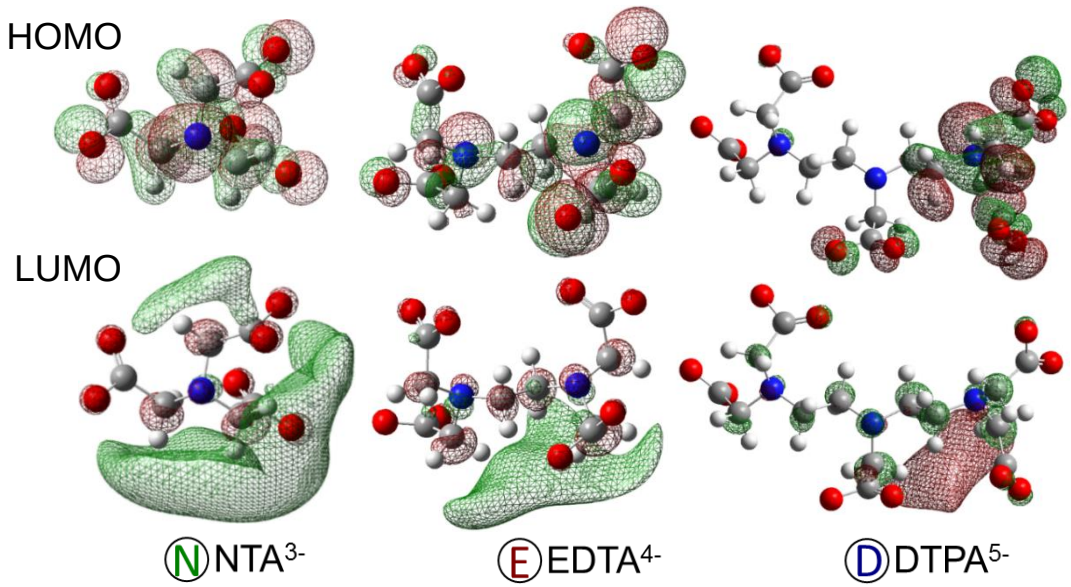
η = catalytic efficiency
C_0 = initial concentration of MB
C_t = concentration of MB at a given time

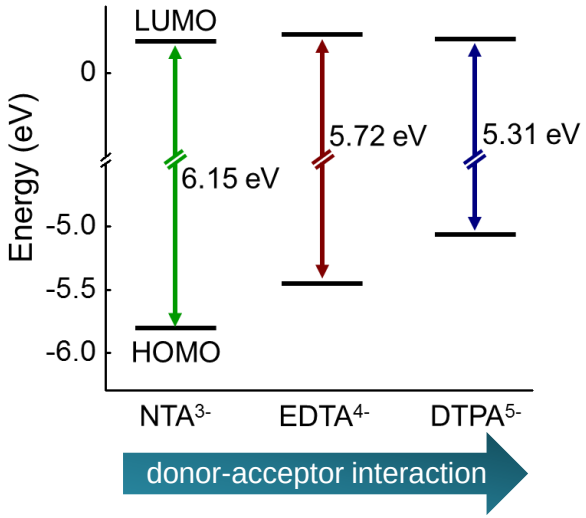
Plateau starts from **24 h**
Long-term stability is confirmed by reusability test

[1]Kamil et al. **Chemical Engineering Journal** (2020)

Functionalization

Theoretical calculations for modifier compounds





$$\Delta N = \frac{X_{Al} - X_{mol}}{2\,(\eta_{Al} + \eta_{mol})}$$

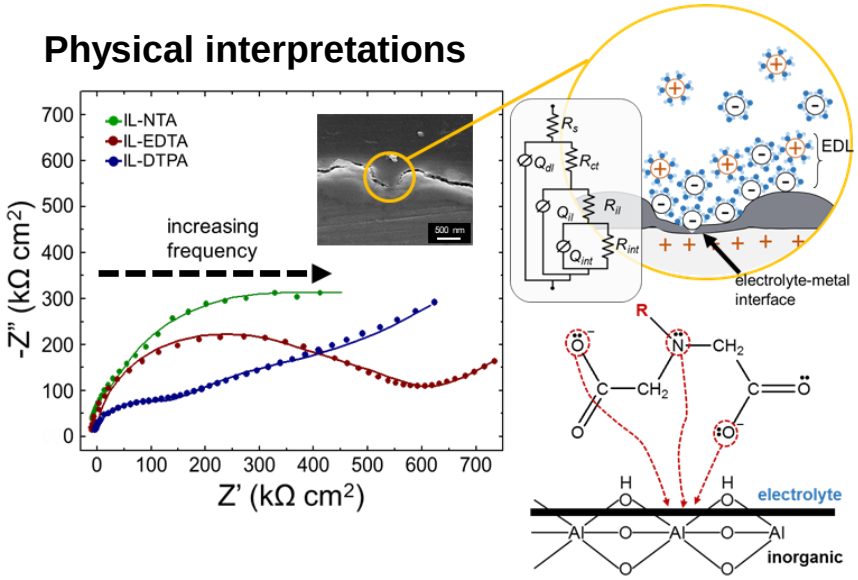
$$I = -EHOMO \qquad A = ELUMO$$

$$X = \frac{I + A}{2} \qquad \eta = \frac{I - A}{2}$$

I = ionization potential
A = electron affinity
X = Mulliken electronegativity
η = absolute hardness

ΔN = fraction of electron transferred

Physical interpretations



[1]Kamil et al. **Chemical Engineering Journal** (2020)

3. Future potential

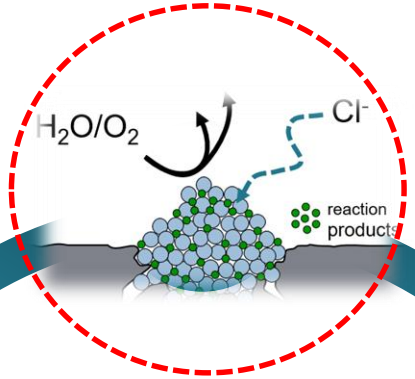
Metallic device with multiple functional properties

3 Exploration and improvement of practical applications

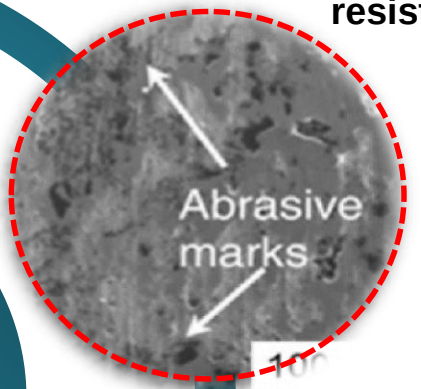
Improve the performance

Metallic materials w/ multiple surface functions

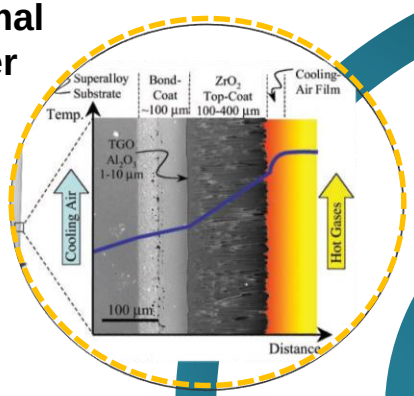
Corrosion resistant



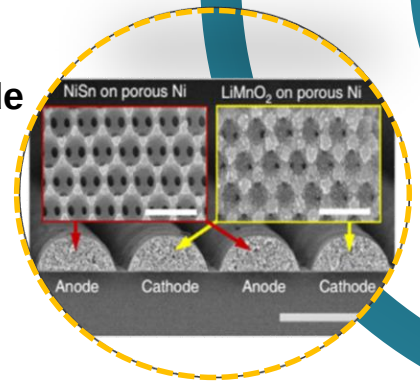
Wear resistant



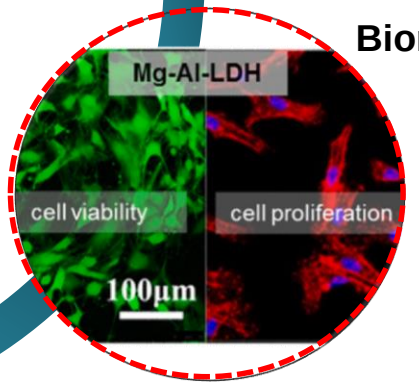
Thermal barrier



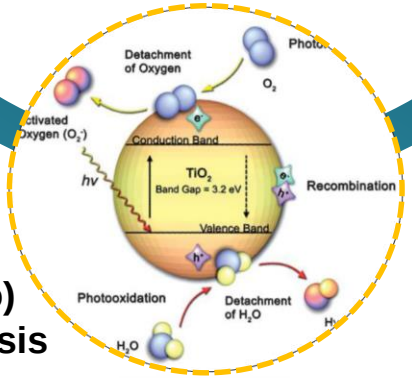
Porous electrode



Biomaterials



(Photo) Catalysis



Explore new ideas

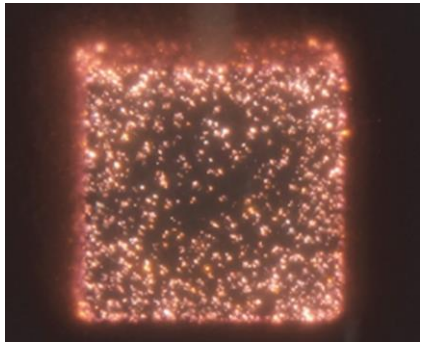
감사합니다

Thank you

Yeungnam University

ii In-house apparatus

1. Processing devices



2. Characterization devices