

Aqueous electrodeposition of Titania for superior corrosion resistance, durability and improvement in engine emissions

Dr. Christian Rosenkranz
Engine Expo Stuttgart, 19.05.2011



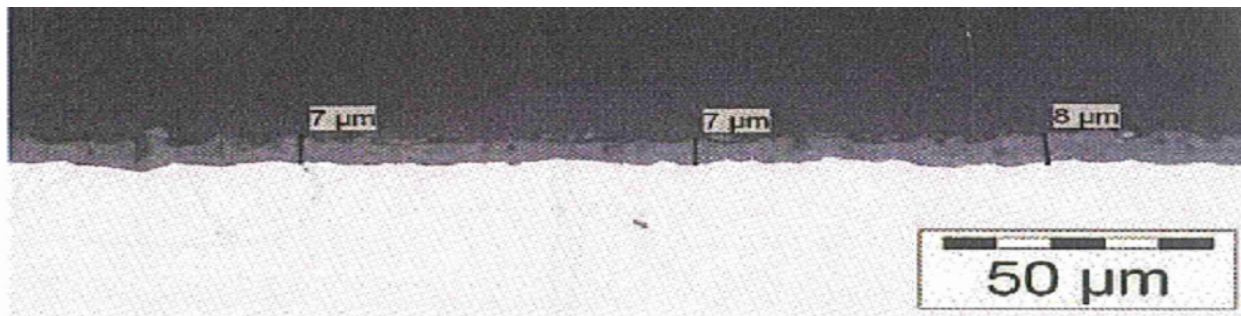
Excellence is our Passion

Contents

1. Alodine EC² - What is it?
2. Alodine EC² - Properties
 - Corrosion Performance
 - Physical Properties
 - Chemical Properties
 - Influence on Combustion Processes
3. Potential Future Applications for Alodine EC²
4. Summary

Alodine EC² - What is it?

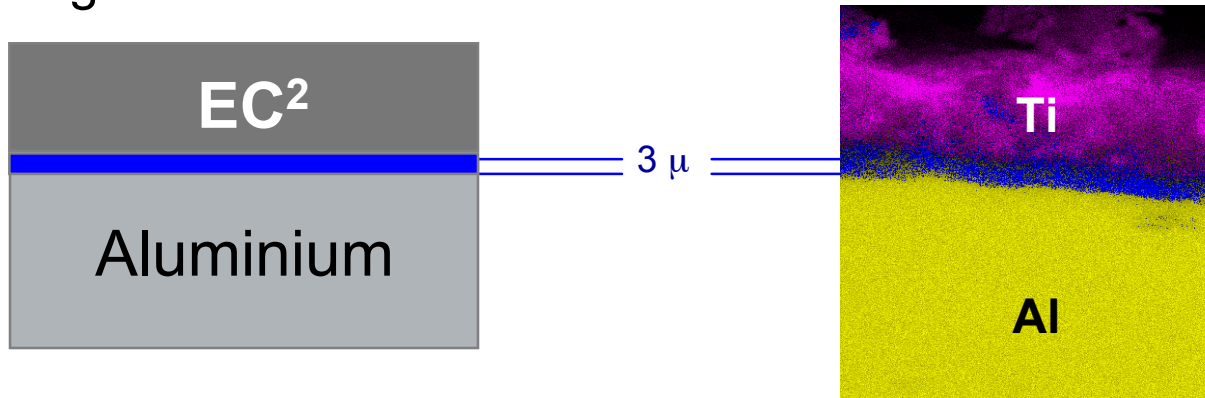
- Galvanic plasma-deposition of TiO₂ from aqueous electrolytes
- Standard coating thicknesses 3-12 µm
- Coating forms on light metals:
 - Aluminum and its alloys
 - Titanium and its alloys
 - IVD Aluminum
 - Aluminized steels
 - Alodine MgC for Magnesium



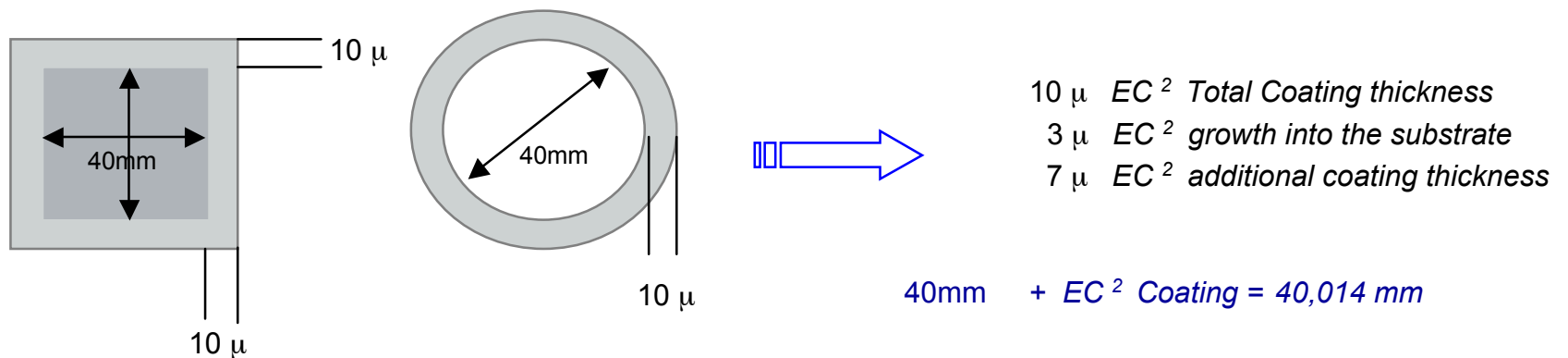
Alodine EC² - What is it?

Galvanic deposition - no conventional anodizing

- Coating formation



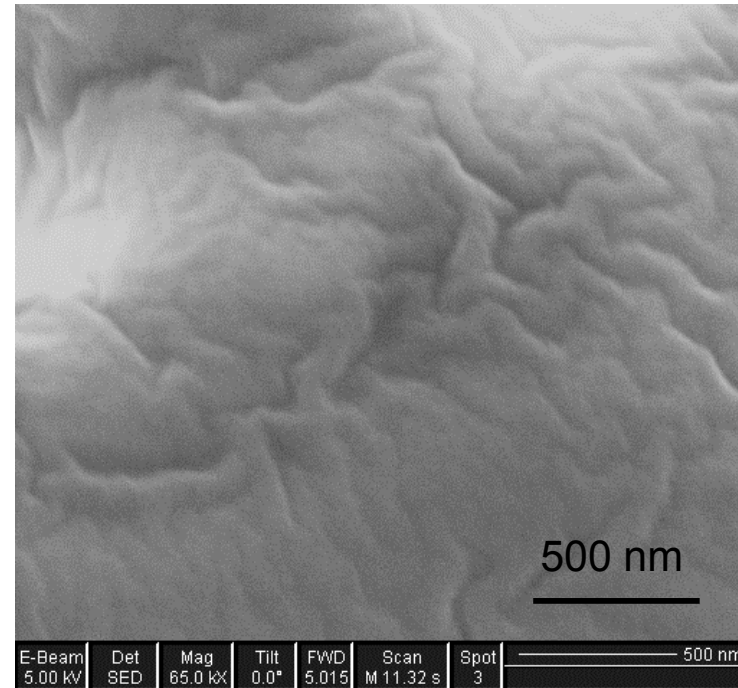
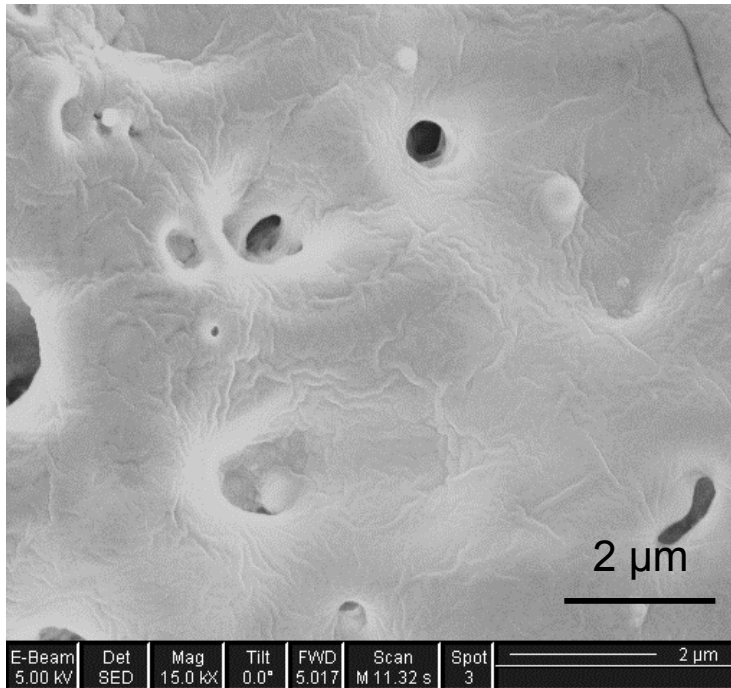
- Coating thickness



Alodine EC² - What is it?

Coating morphology

- Scanning Electron Microscopy

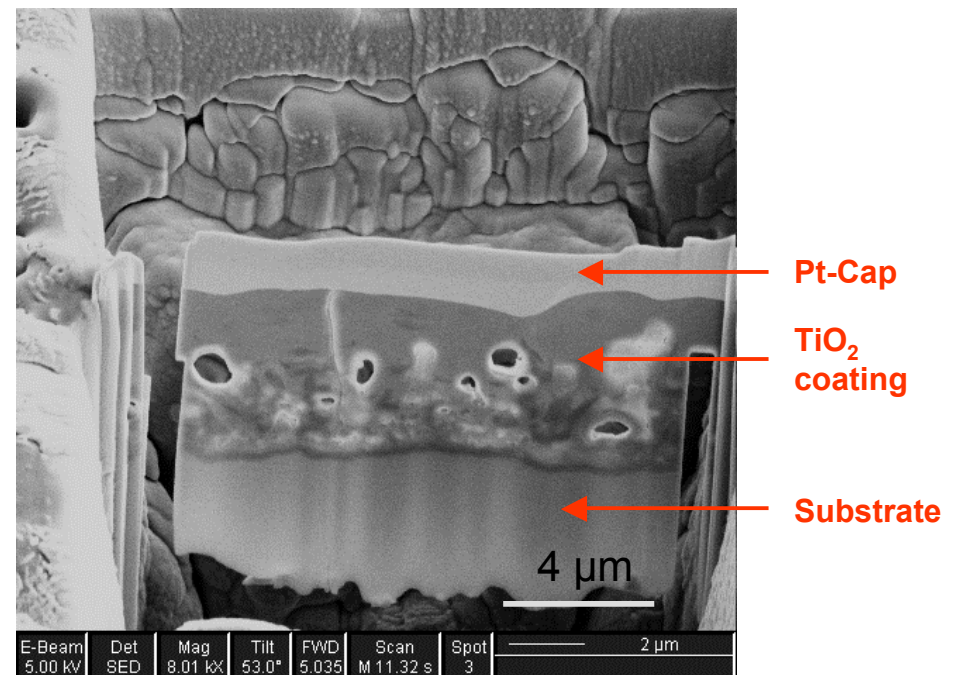
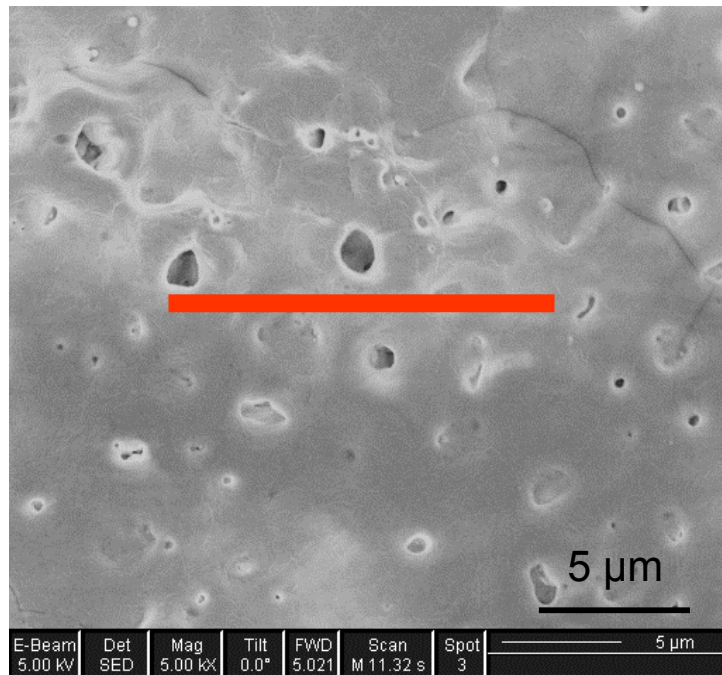


Porous coating structure, main component is TiO₂

Alodine EC² - What is it?

Coating morphology

- Transmission Electron Microscopy and FIB-X-Cut



Sample Size: Length: 15 μm; Width: 10 μm; Thickness: 100 nm

Alodine EC² - Properties

Corrosion Performance

- Comparison of different standard pretreatments on Aluminum

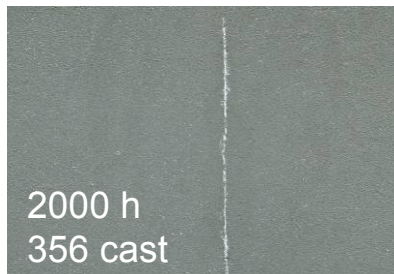
Pretreatment	NSS according to DIN 50021 SS		Acetic Acid SS acc.DIN 50021 Painted + Scribe
	bare	Paint + scribe	
Degreased	< 24 h completely corroded	100 h strong delamination	100 h strong delamination
Chromate Cr(VI)	1000 h no delamination	1000 h no delamination	1000 h delamination < 1 mm
Green chromate Cr(III)	500 h no delamination	1000 h no delamination	1000 h delamination < 1 mm
Transparent Chromate	300 h no delamination	1000 h no delamination	1000 h delamination < 1 mm
Chrome-free	200 h no delamination	1000 h no delamination	1000 h delamination < 1 mm

Alodine EC² - Properties

Corrosion Performance

- Corrosion Performance of Alodine EC² on bare Aluminum

Alloy	Composition	Hours (ASTM B117)	Scribe creepage
356	AlSi ₅ Mg	2000	Nil
5052	AlMg ₃	4000	Nil
6061	AlMgSiCu	4000	Nil
6063	AlMgSi _{0,5}	5000	Nil
7005	AlZnMgCu ₂	1000	Nil
2024	AlCuMg ₂	300 - 1000	Nil
2024 - Clad	AlCuMg ₅	3000	Nil



Alodine EC² - Properties

Corrosion Performance

- Example Marine Industry – Results after 6 months sea water exposure



Cr(VI)-pretreatment, Primer and
Topcoat (no Anode)



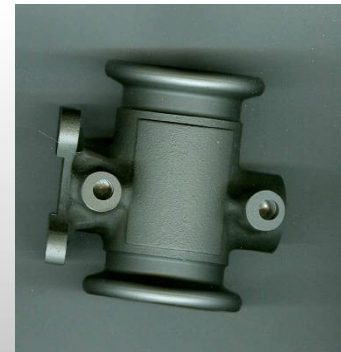
Alodine EC² and Topcoat
(no Anode)

Alodine EC² - Properties

Chemical Properties

Alodine EC² offers excellent chemical resistance!

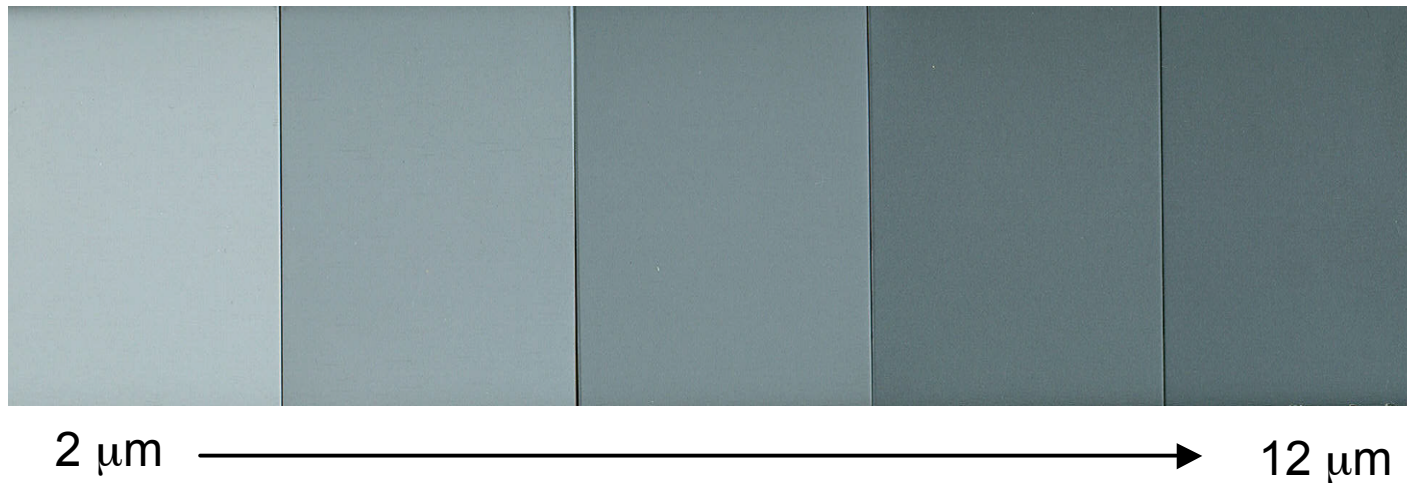
- Boiling Ethylenglycole/water-mixture (30-70%)
at 110-130°C for 3 weeks
 - ↳ No visible changes
- Immersion in 10% sulfuric acid for 48 h at RT
 - ↳ No loss of adhesion
- Immersion in 10% Acetic Acid for 30 days
 - ↳ No visible changes
- Immersion in 32.5% urea solution (AdBlue®)
for 18 months at RT
 - ↳ No visible changes
- Hot and cold paint strippers do not attack the coating.



Alodine EC² - Properties

Physical Properties

- Coating Color and UV-Stability
 - Color depends on coating thickness



Alodine EC² - Properties

Physical Properties

Abrasion resistance (CS-10 Wheel, 10,000 cycles)

↳ Alodine® EC²

⇒ TWI 1.5

↳ Comparison with Electroless Nickel Plating

⇒ TWI 5-15

Hardness (HV 0.001)

↳ 100- 150 Hv (Al-uncoated)

↳ 637-800 H_v

Roughness

↳ < 0.6 µm

Alodine EC² - Properties

Physical Properties

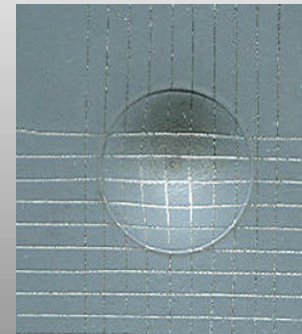


Temperature resistance (> 600°C)

- Temperature resistance
 - ↳ 600 °C, 84 hours
 - ⇒ No delamination



- Temperature shock
 - ↳ 600 °C
 - ↳ Followed by 5°C water quench
 - ⇒ X-Cut und Impact test
 - ⇒ No delamination!



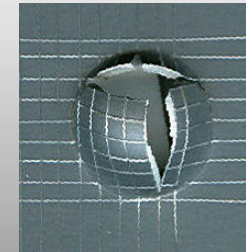
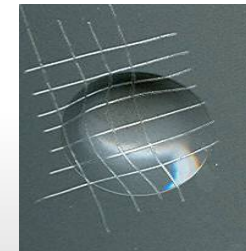
Alodine EC² - Properties

Physical Properties



Coating adhesion is higher than substrate stability

- Passes 1-2T T-bend-test (ASTM D 4145)
- Impact performance comparable to best paint systems (ASTM 2794)
- Cross cut followed by impact test
 - ⇒ Substrate fails
 - but coating remains intact



Alodine EC² - Properties

Physical Properties

Use of Alodine EC² as primer for Thermal Spray Coatings

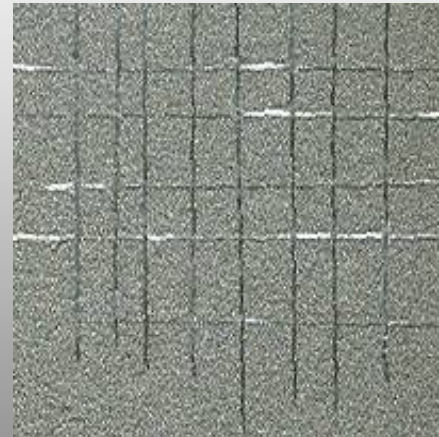
Current Process

- Clean & shot blast
- Fe/Mo/C composite
- 3-4 mil thermal spray



Improved process with EC²

- Alodine EC²
- No shot blast!
- Fe/Mo/C composite
- 3-4 mil thermal spray

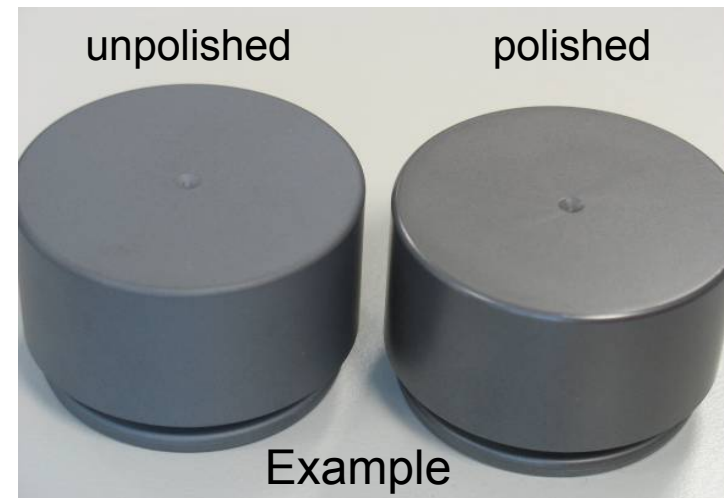
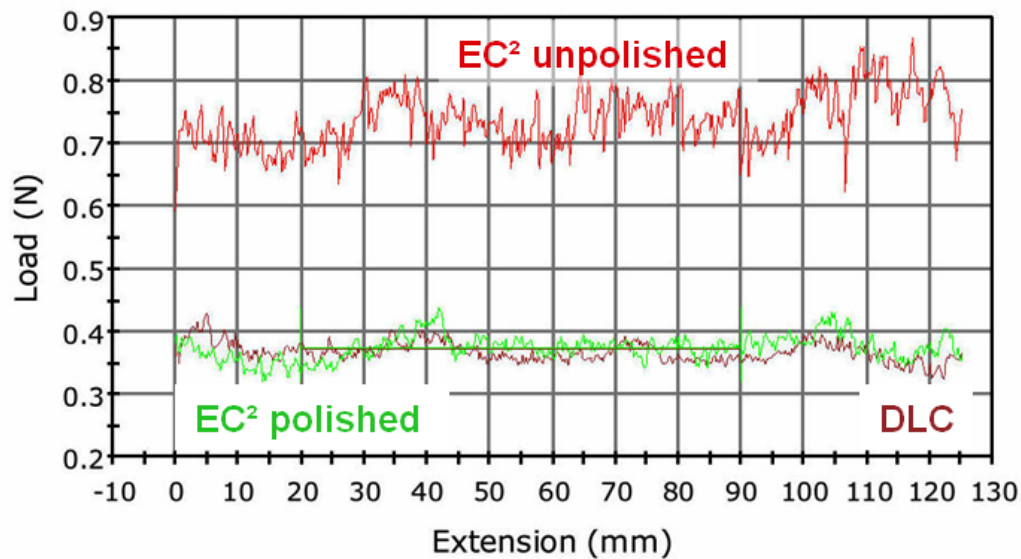


Alodine EC² - Properties

Physical Properties

- Very low coefficients of friction can be obtained with polished EC²-coatings!
- Pin-on-disk geometry, dry measurement

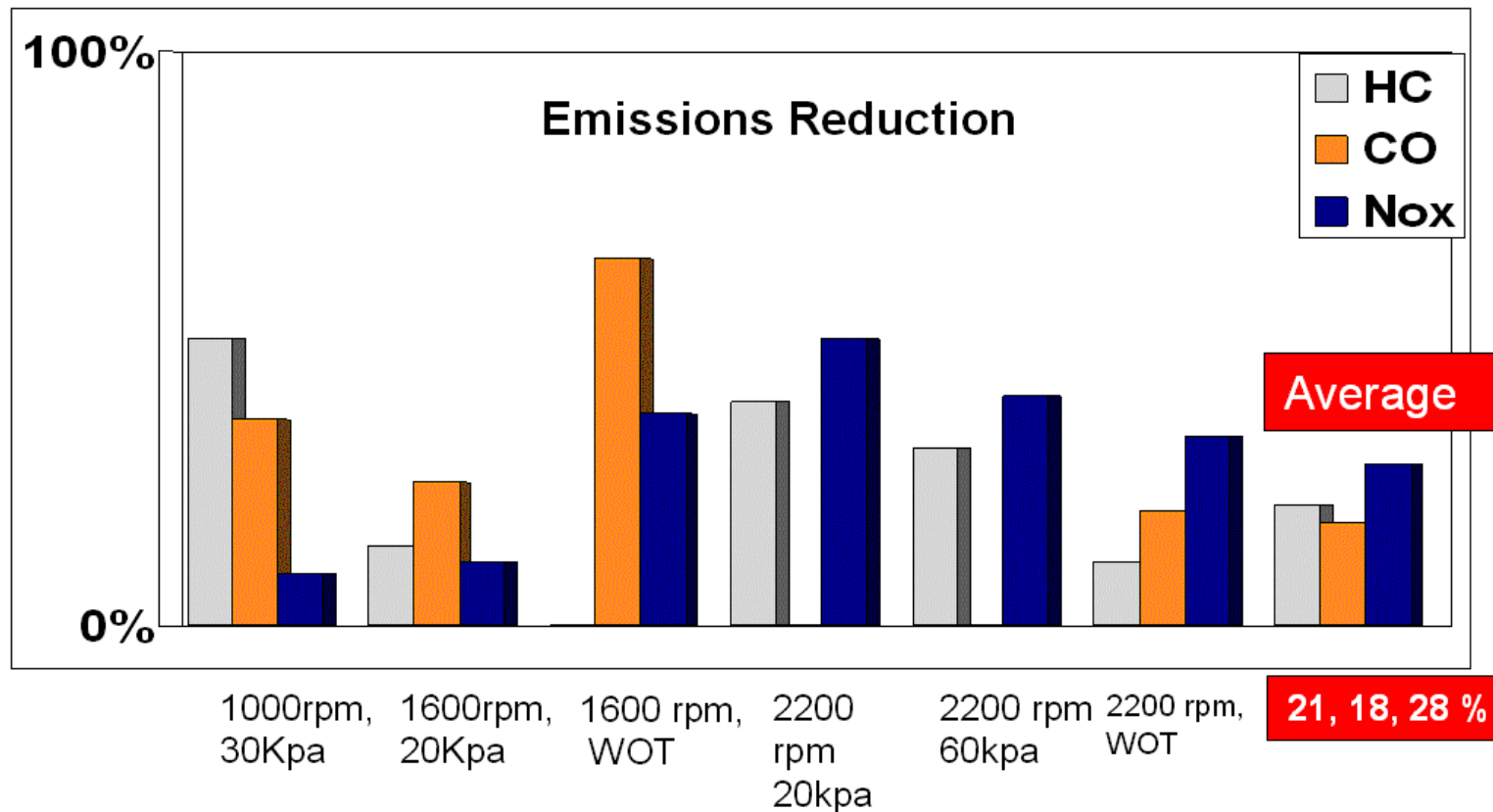
Coating	Static Friction	Dynamic Friction
EC ² - unpolished	0.3925	0.3786
EC ² -polished	0.1991	0.1948
DLC	0.2039	0.2003



Alodine EC² - Properties

Catalytic influence on combustion processes

- Gas engine – 2.4 Liter GM
- EC²-coated cylinder head and piston dome; Fully warm engine;

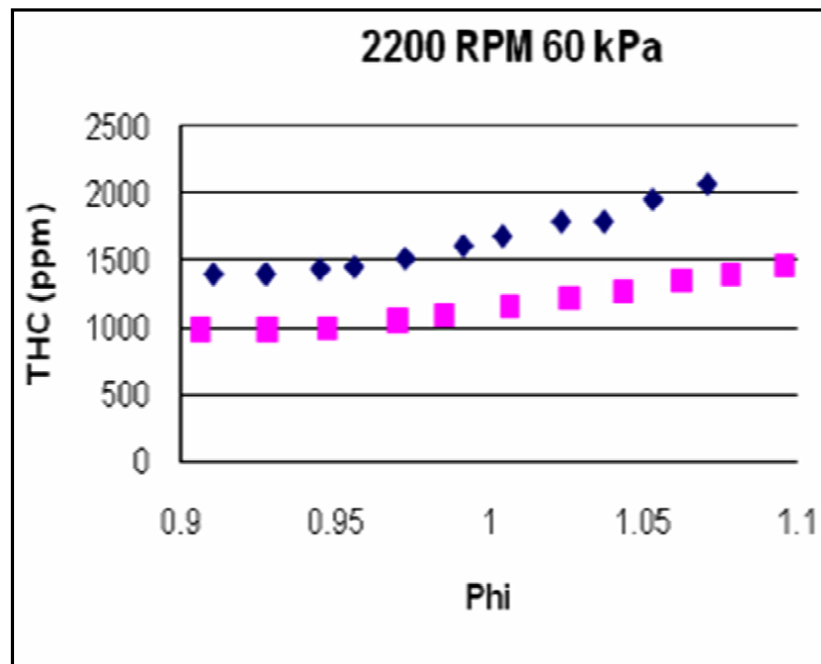


Alodine EC² - Properties

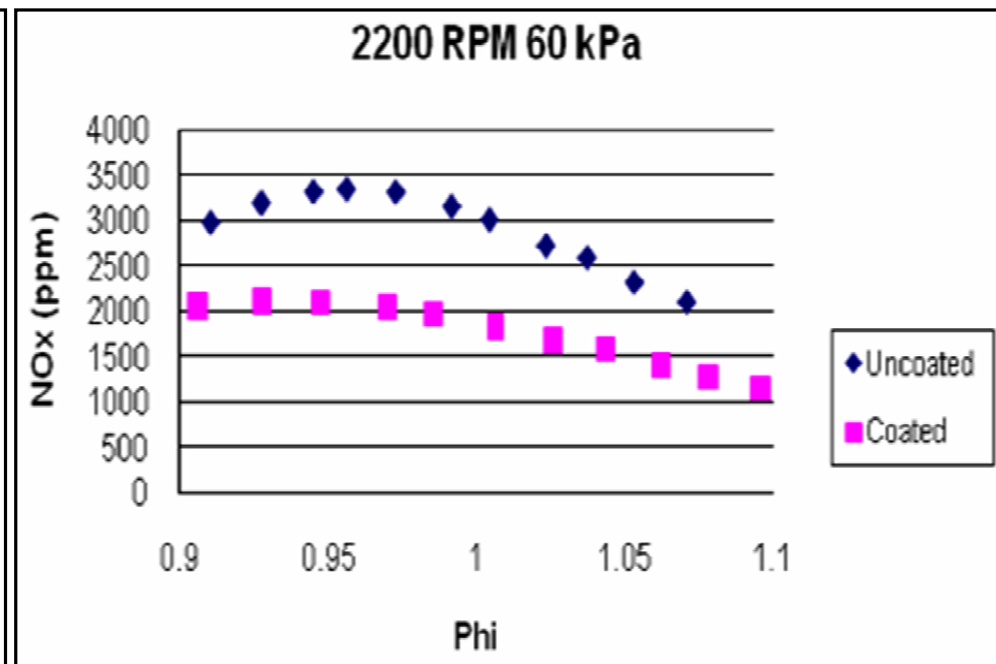
Catalytic influence on combustion processes

- Emission improvement over various stoichiometries

HC-emissions



NOx-emissions

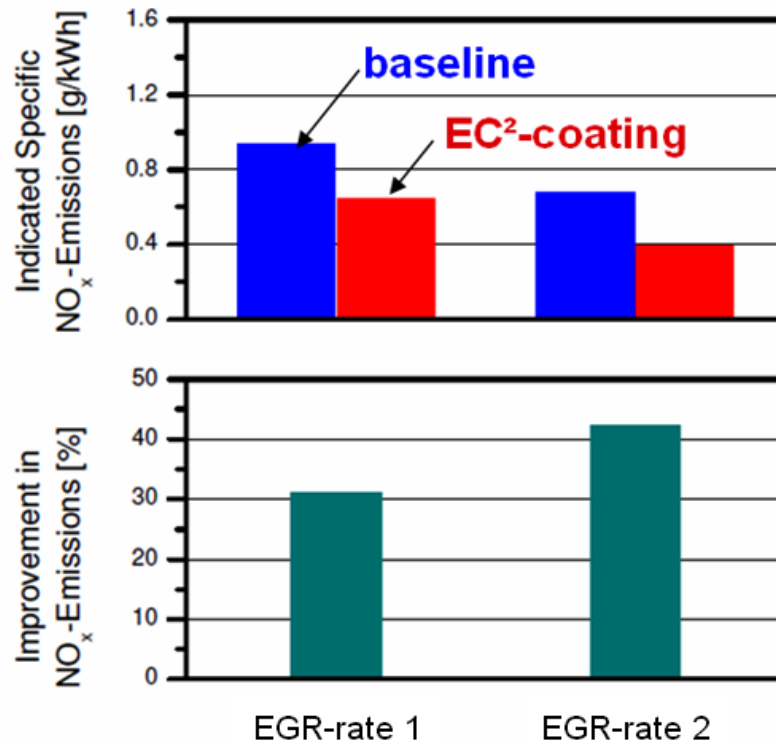


Alodine EC² - Properties

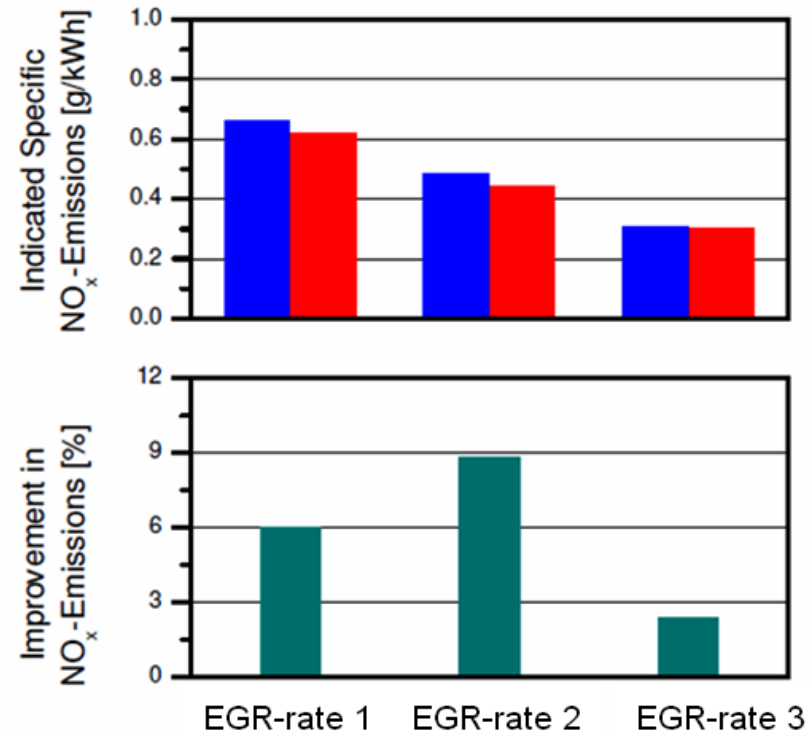
Catalytic influence on combustion processes

- Single Cylinder Diesel Engine (“HECS”, FEV)
- EC²-coated cylinder head and piston dome; Fully warm engine;

1500 rpm, 6.8 bar



1500 rpm, 4.3 bar



Alodine EC² applications

Target/Focus Applications in the Future

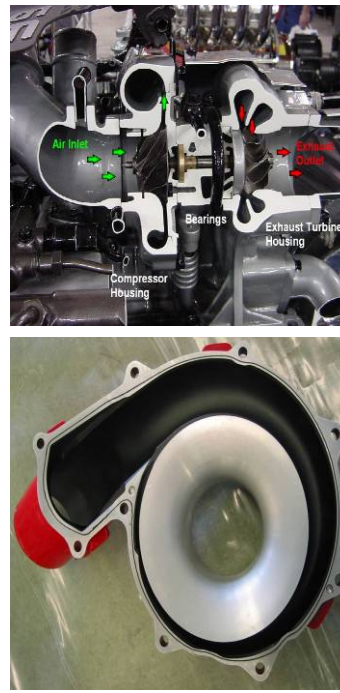
Piston



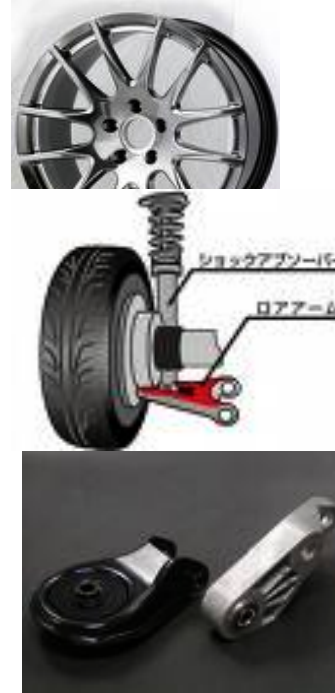
Intake
Manifold



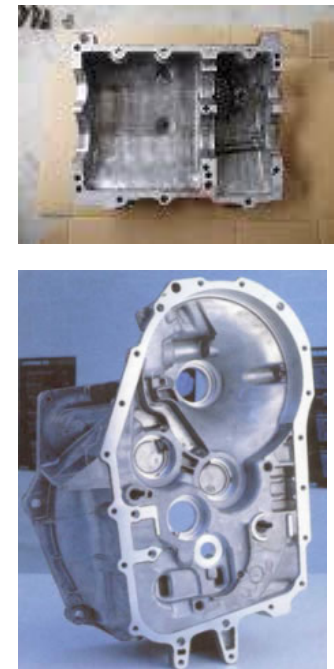
Turbo-Super
Charger



Chassis



Housings



Summary

- Alodine EC²
 - Is deposited by a galvanic plasma process from aqueous electrolytes
 - Is heavy metal free and environmentally friendly
 - Offers a simple coating process with outstanding corrosion resistance
 - Has unique physical properties, i.e. adhesion and flexibility
 - Offers high wear resistance and low coefficients of friction
 - Improves regulated emissions in combustion processes

Thank you!