Coating of Automobile Structural Components from Ultra-High Strength Steels

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Content

Corrosion Protection of Ultra-High Strength Steels

Motivation, Goal of the Project

Motivation

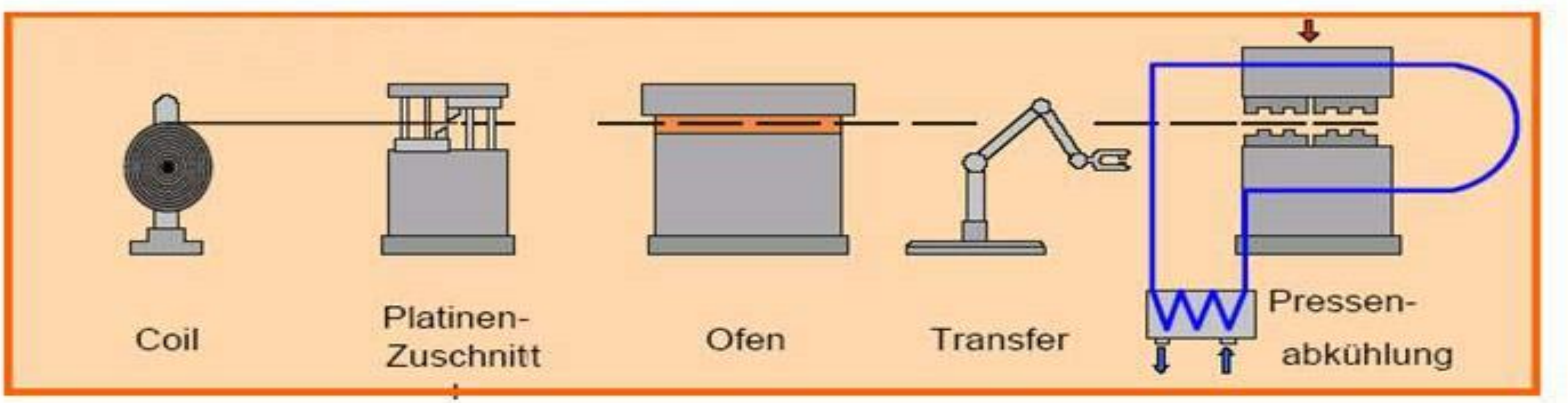
- Increasing lightweight applications of hot-stamped steel in automotive structure parts
- Due to manufacturing process no suitable corrosion protection of parts available
- Established corrosion protection for steel with Zn-Al or Zn-Mg alloys
- Increased corrosion protection with Zn-Al-Mg vgl. ZAM®

Goal of the project

- Development of a new corrosion protection system based on hot dip galvanizing in the Zn-Al-Mg system for high-strength steels without annealing effects for substrate

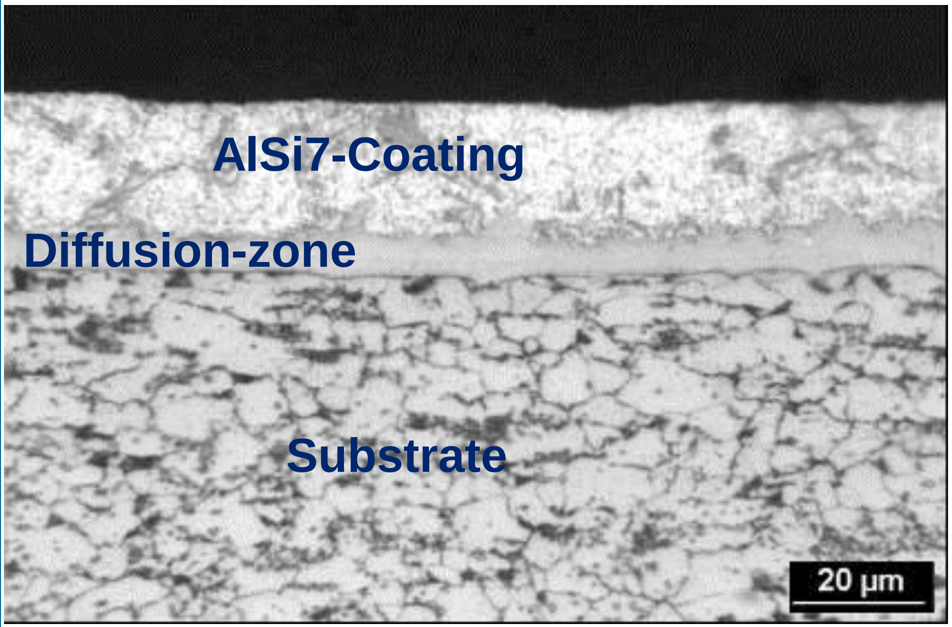
Process Description – In-Mould Hardening

- Austenitisation in furnace 9 min, 950 ºC
- Die quenching with a cooling rate of 50 K/s
- Transformation to final parts with martensitic microstructure

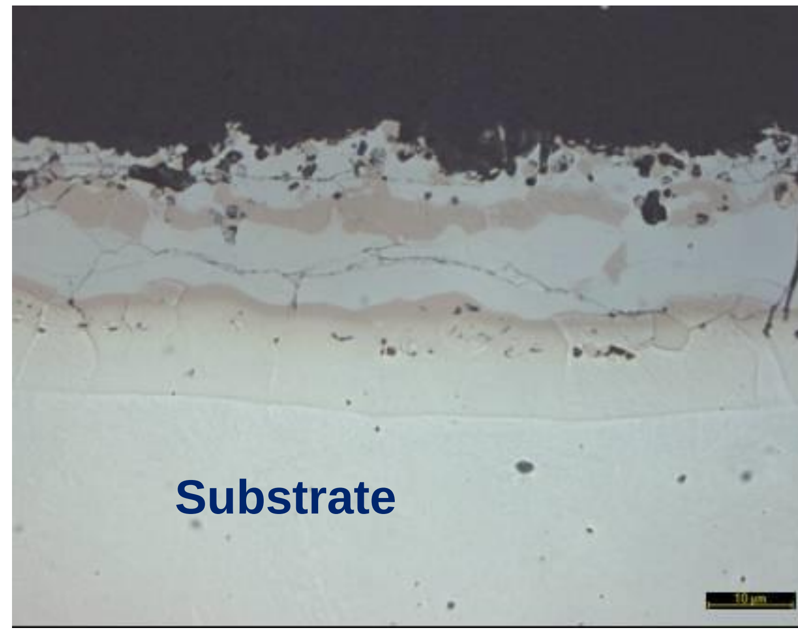


Problem: Which coating survives this treatment?

State of the Art



Usibor 1500 P – original structure



Usibor 1500 P - hardened

Corrosion Protection of High-Strength Steels
Alloy Development Zn-Al-Mg System

Problem

Problem:

Decreasing tensile strength due to heat treatment

• Original state:	R_m 1800 MPa	ε_{Bruch} ~ 4,5 %
• 350 °C	R_m 1250 - 1350 MPa	ε_{Bruch} 2,7 - 3,5 %
• 375 °C	R_m 1280 - 1320 MPa	ε_{Bruch} 2,7 - 3,2 %
• 400 °C	R_m 1200 - 1300 MPa	ε_{Bruch} 2,7 - 3,0 %
• 620 °C	R_m 850 - 900 MPa	ε_{Bruch} 6,5 - 7,5 %

• Best dip temperature: 350 to 390 °C

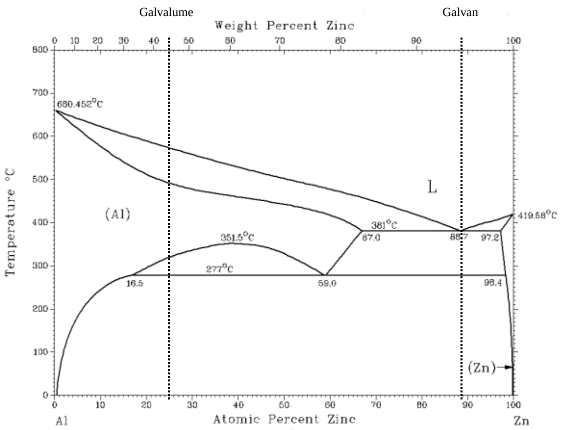
Solution
Low Temperature Galvanizing

Solution LTG:

Low **T**emperature **G**alvanizing

- Melting process
- Hot dip galvanising
- Reduction of melting point temperature by eutectic alloy

Alloy Development
Phase Diagram Zinc-Aluminium-Magnesium



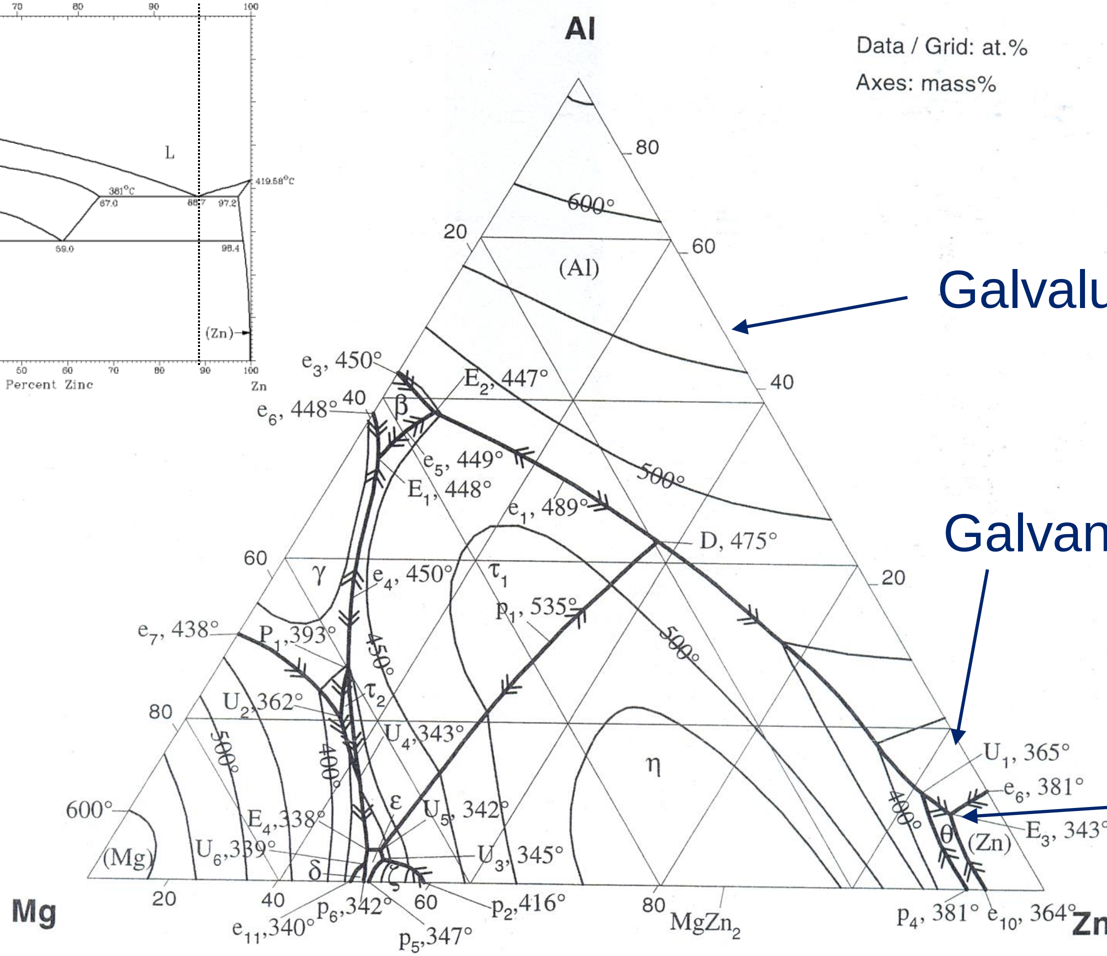


Figure 1: Liquidus surface

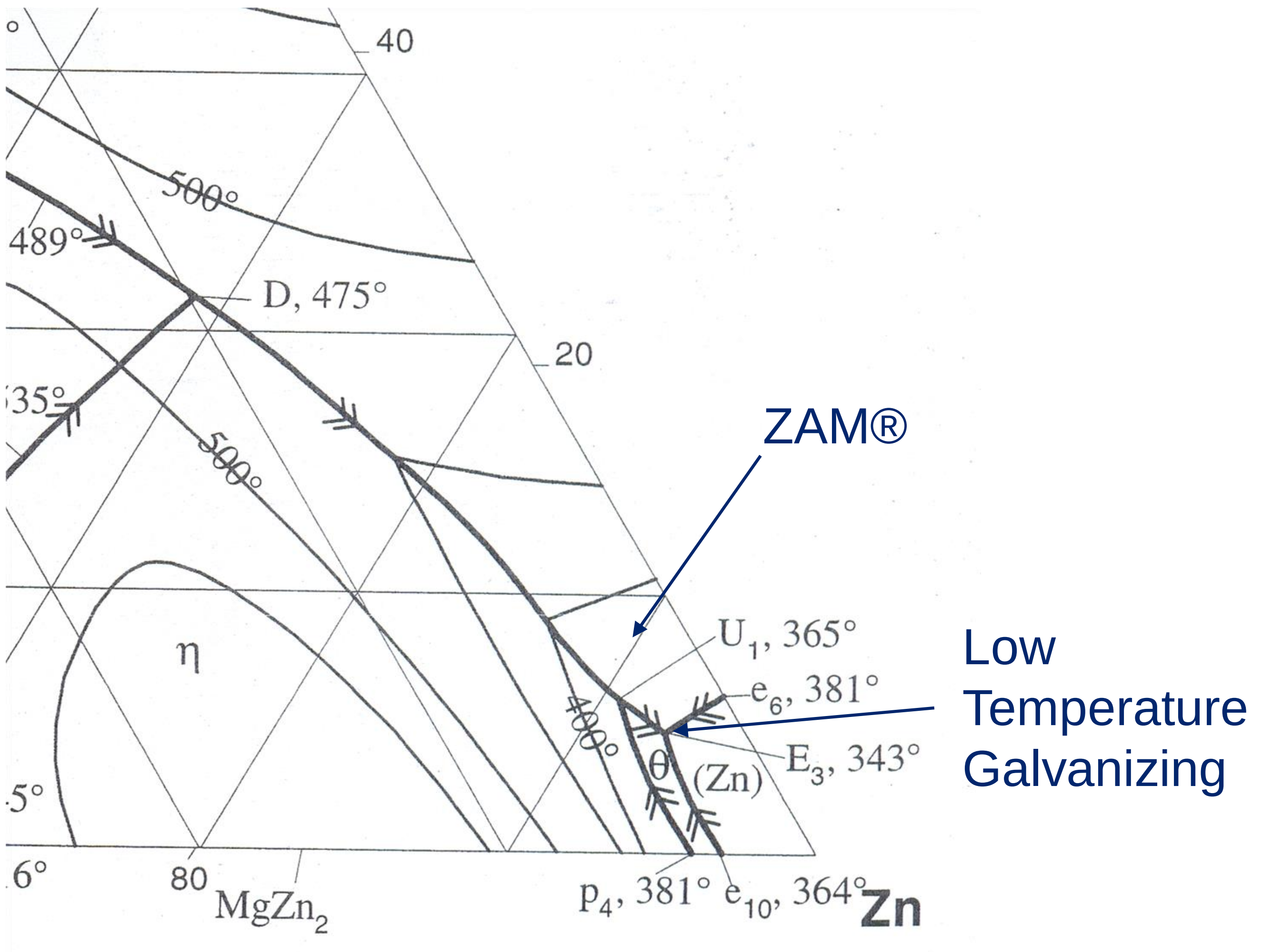
Galvalume

Galvan

Low **T**emperature **G**alvanizing

Alloy Development

Phase Diagram Zinc-Aluminium-Magnesium



Alloy Development
Comparison ZAM / LTG

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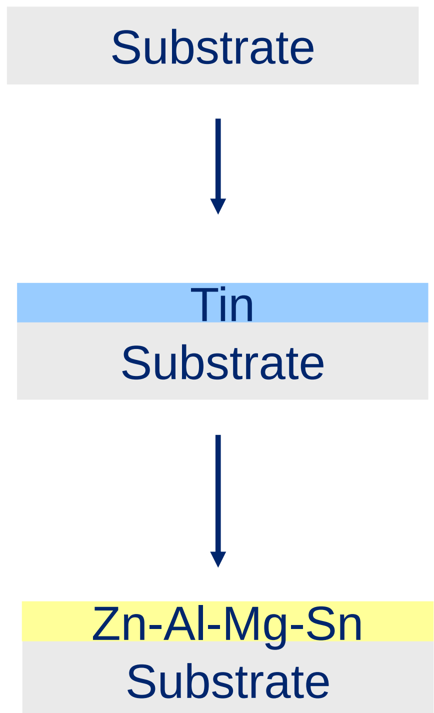
	ZAM® Existing alloy in Japan	LTG – new System
Composition of melting bath	91 % Zn 6 % Al 3 % Mg	92,95 % Zn 4,08 % Al 2,97 % Mg
Coating temperature	> 420 °C	< 400 °C
Application process	Continuous Coil Coating	Hot dip galvanizing of press hardened parts
Substrate material	Mild Steel	High and Ultra-High Strength Steels
Application	Structural parts for architecture and civil engineering	Structural parts for crash elements in automotive and BIW

Application process for new system



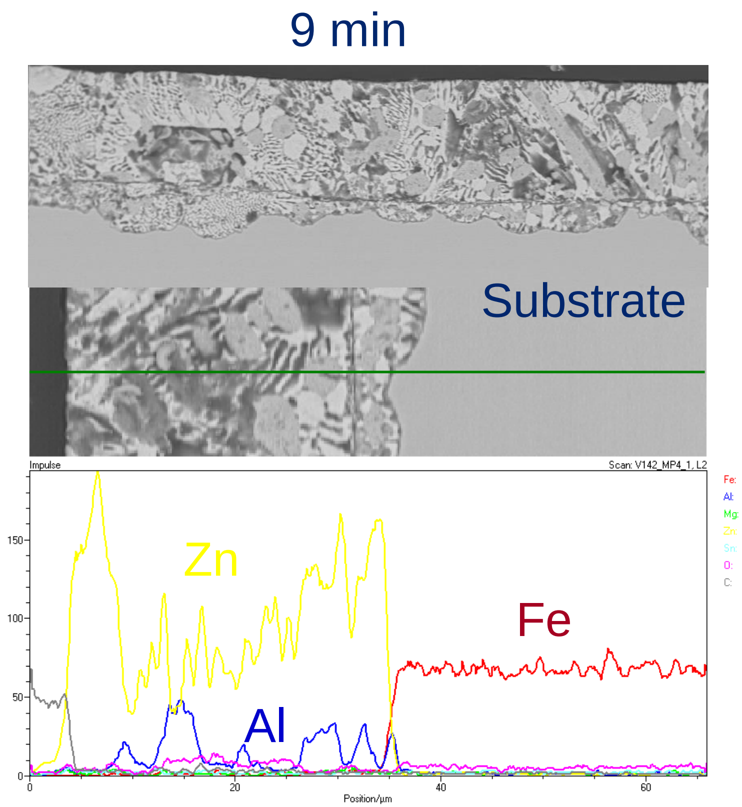
- Cleaning steel surface

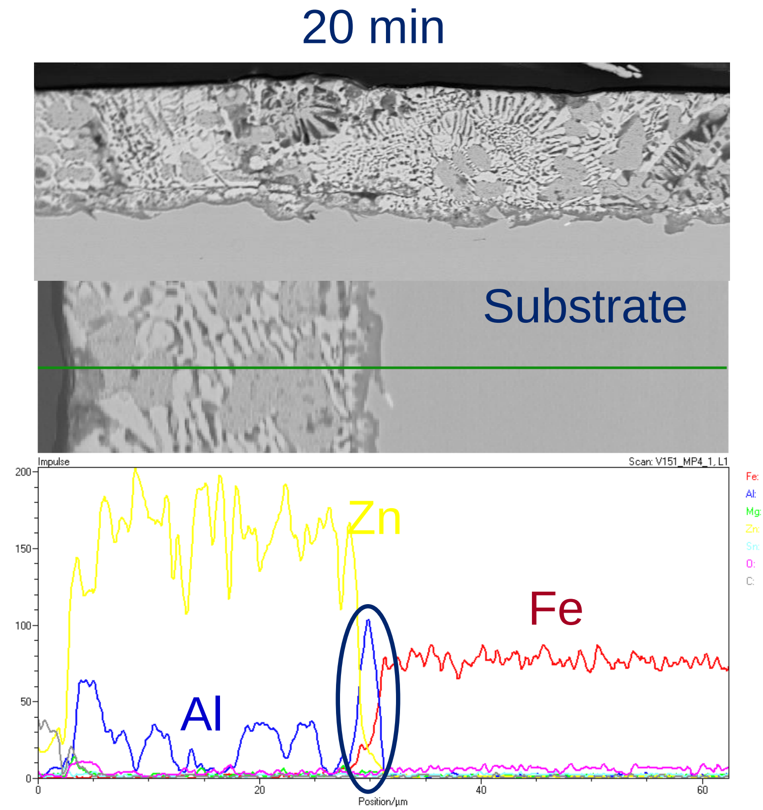
- Pre-coating with tin
- Hot dip galvanizing process Zn-Al-Mg

- Diffusion of tin during hot dip galvanizing
- Change of ternary system in a quarternary system Zn-Al-Mg-Sn
- Influence to the melting process and phase creation

Corrosion Protection of High-Strength Steels
Characterization Microstructure

Microstructure Characterization
Influence of Exposure Time





- Temperature 370 °C; ternary alloyed melting bath
- Ternary eutectic alloyed matrix
- Precipitations of Mg-Zn and Al-Zn
- Al is bonding layer between steel surface and coating
- Intermetallic compound of Fe-Al-Zn on the steel boundary layer

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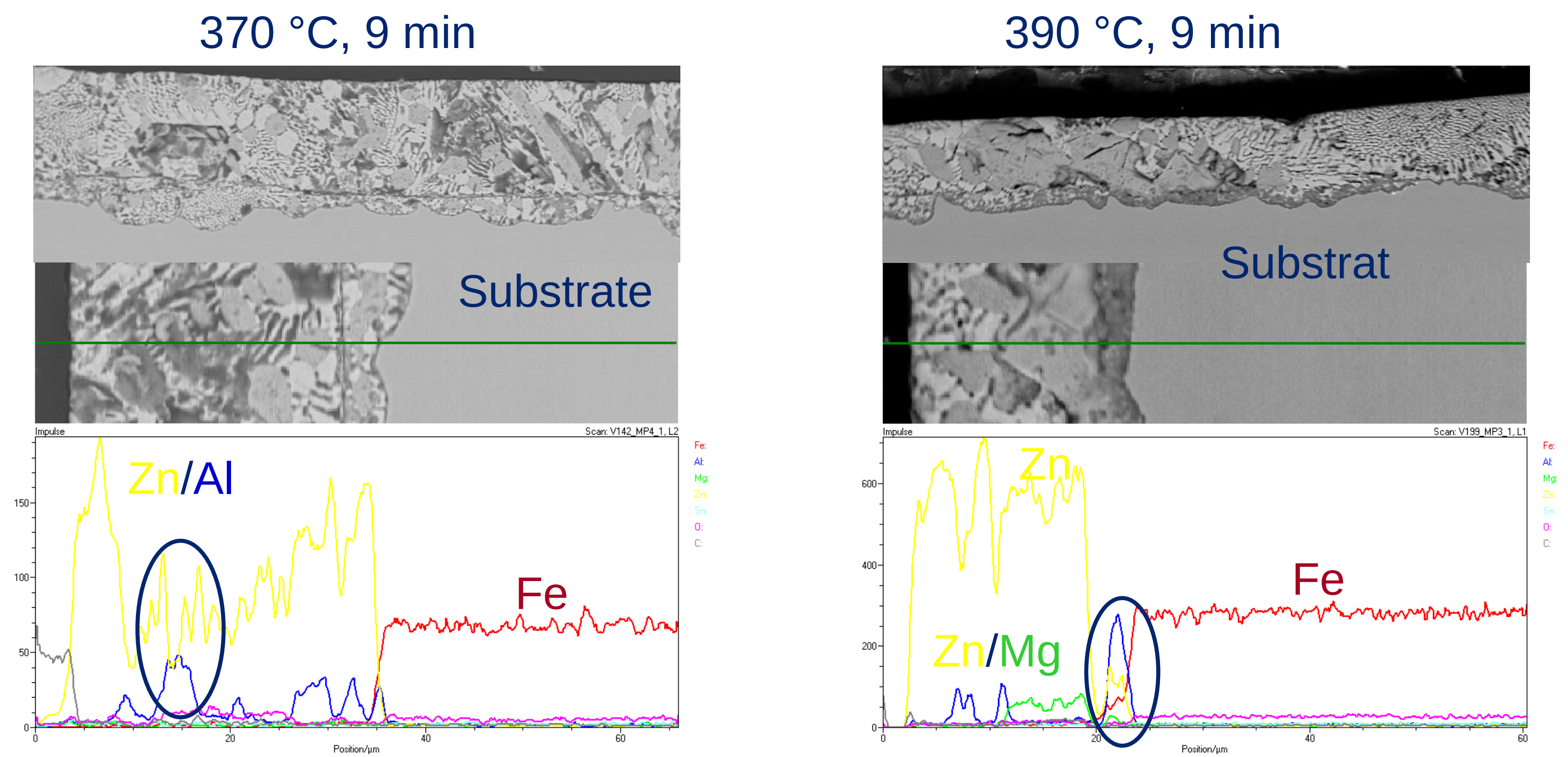
Microstructure Characterization
Influence of Temperature

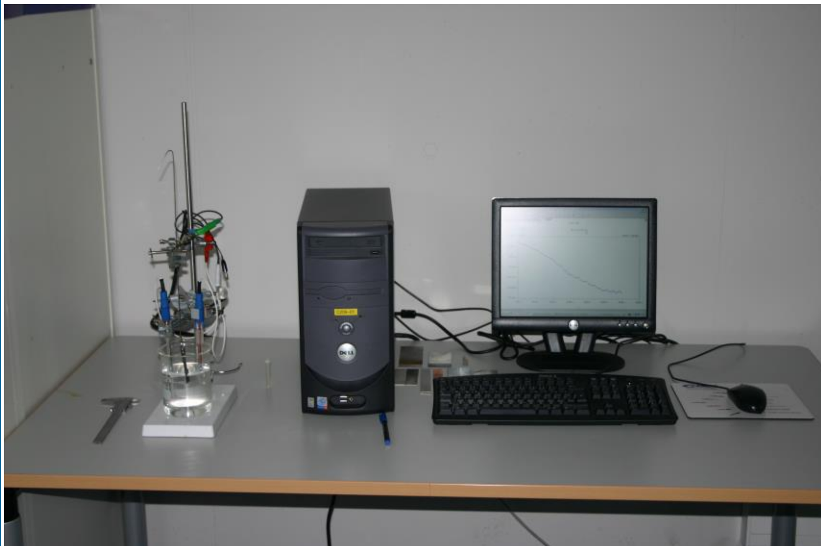


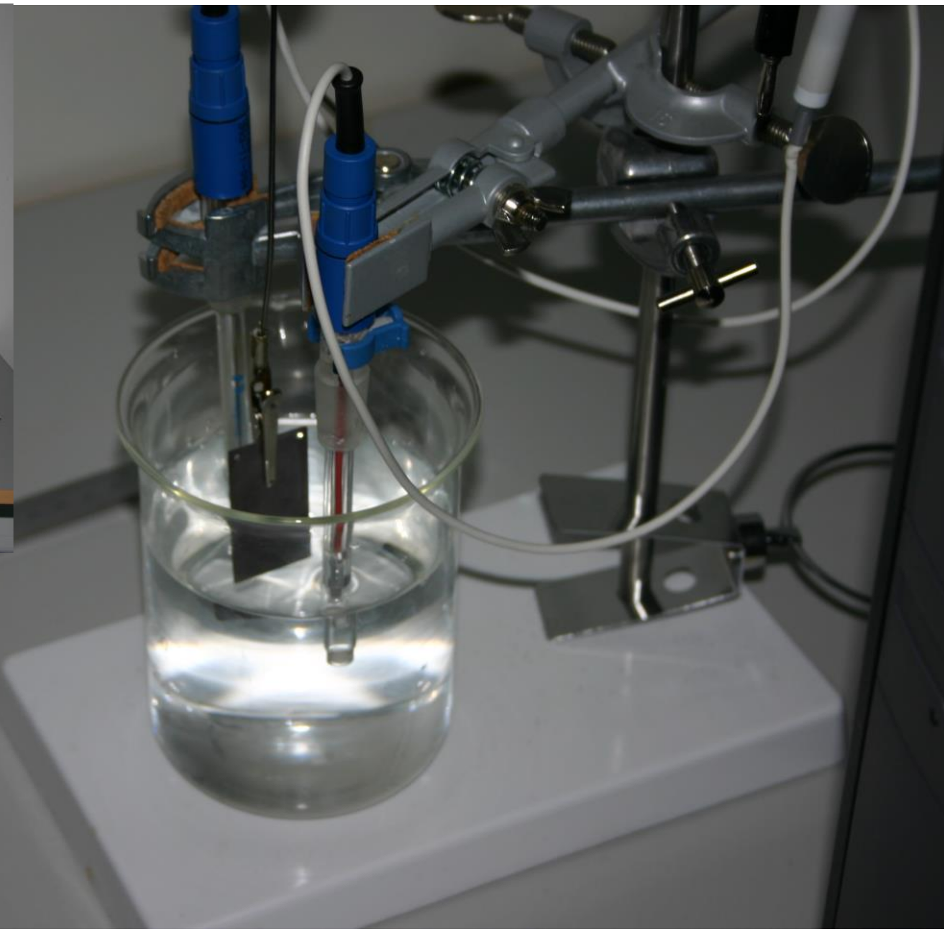
- Ternary melting bath
- Different compounds of Mg-Zn-Al bzw. Al-Zn, $MgZn_2$
- Thickness of coating layer at 370 °C higher, ~35 µm
- Thickness of coating layer at 390 °C smaller, ~ 20 µm
- More intermetallic compounds on the steel surface as bonding layer

Corrosion Performance

Corrosion Performance

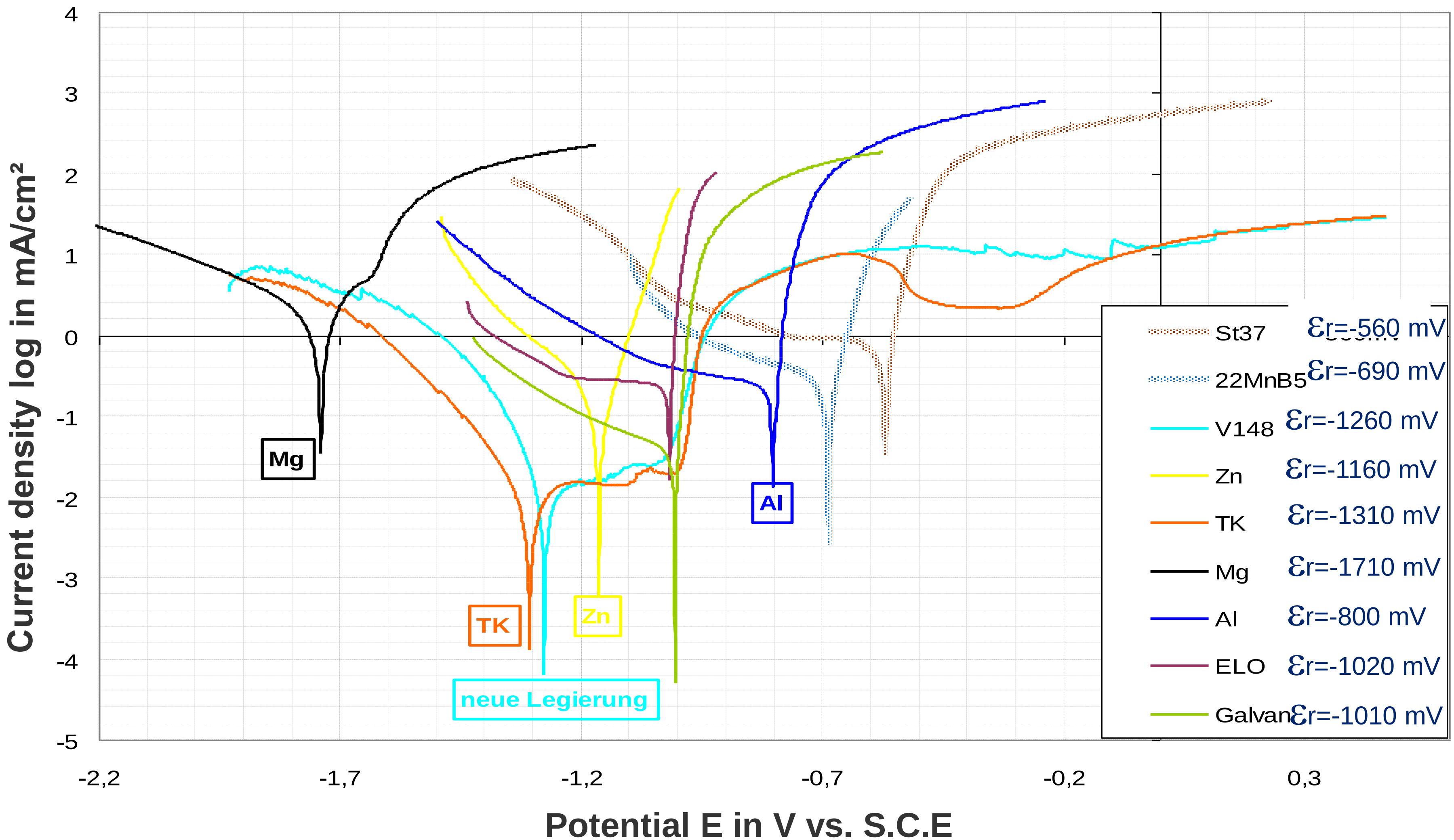
Corrosion Cell



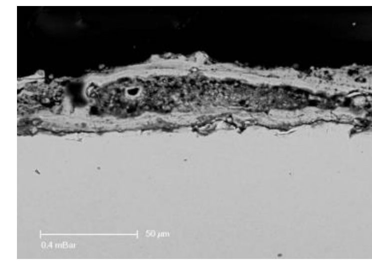
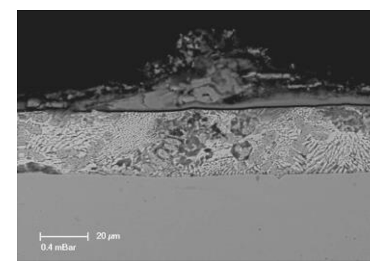


- Potentiostatic Polarisation Test
- Electrolyte: 3,5 % NaCl

Corrosion Performance
Potentiostatic Polarisation Test



Corrosion Protection
DIN EN ISO 9227

	Original State	96 h	240 h	480 h	
Hot dip galvanizing					
Zn-Al-Mg-Coating					

5 % NaCl
Temperature 35 °C

Corrosion Protection of High-Strength Steels

Summary

Summary

- Low coating thickness possible – depends on temperature (10 to 40 µm)
- Influence of temperature to the coating microstructure and phases
- Less influence of exposure time to the coating microstructure
- Low Temperature Galvanizing – Coating layer ignoble compared to Zinc
- Cathodic corrosion protection for Al and steel substrate
- Good compatibility of coating with other coatings like Zn or Mg compounds
- Process without acid cleaning $\Rightarrow$ no H_2-embrittlement
- Tin detectible only on single areas or phase boundary
- No bad influence of tin for the corrosion protection
- Higher corrosion resistance of the new alloy

Thank you for your Attention

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