REPLACEMENT OF CADMIUM COATINGS FOR AIRCRAFT INDUSTRY

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ABSRACT: Cadmium coating is used in the aircraft industry for the corrosion protection of medium and high strength steels. However, cadmium toxicity causes the restriction of its use as a result of US and EU legislations. Alternatives to cadmium coating include the binary coatings Zn-Ni, Sn-Zn, Zn-Co and Ion Assisted Deposition (IVD) of Aluminum .

We will present the results of investigation of Zn-Polymer composite coating on high strength steels as Cd alternative..

The newly developed Zn-polymer coating on high strength steel withstood standard adhesion and hydrogen embrittlement tests. The passivated coating showed high corrosion resistance in salt spray test (> 300 hrs for white corrosion).

SEM and XRD show that the presence of polymer in the Zn matrix results in modification of microstructure and texture of the coating as compared to pure Zn coating. Coating composition was evaluated by Glow Discharge Emission Spectroscopy (GDOES) and Auger Electron Spectroscopy (AES) . The amount of polymer embedded in the Zn matrix was found to depend on current density and polymer concentrations in the solution.. The results of the on-going investigation indicate that the Zn-polymer coating is probably suitable for Cadmium replacement on high strength steel alloys, but further investigation has to be carried out.

EXPERIMENTAL :

Types of Coatings:

Double layer coating : Zn/ Zn+ polymer A
Zn/ Zn+polymer B

Reference coatings: pure Zn and and pure Cd

Substrates: High strength steels : 4340, 4130

Polymers : Polymer A –cationic surfactant
Polymer B- cationic surfactant

Electrodeposition process:
- Surface pretreatment : according to ASTM B183
- Electrodeposition
- Standard chromate passivation

Measurements and Characterization:

Corrosion: Salt spray cabinet according to ASTM B117
Electrochemical measurements

Hydrogen embrittlement tests: According to ASTM F 519 on notch cylinders

Composition : EDS analysis, GDOES, Auger , TOF-SIMS

Morphology : SEM

Adhesion: Bending of test panels made of steel 4130 according to ASTM B571, SEM of cross-section

RESULTS

1. Corrosion Resistance – Salt Fog Test ASTM B117

Coating Type	Deposition solution	Current Density A/dm2	Heat treat. 190°C, 3Hrs	Hours to white corrosion
Cd	IAI samples		NO	**336**
Zn	Zn	20	NO	**216**
Zn/ Zn+B	Zn/Zn+10gr/l B	20/60	YES	**312**
Zn/ Zn+B	Zn/Zn+10gr/l B	20/60	NO	**356**
Zn/Zn+A	Zn/Zn+7gr/l A	20/20	NO	**192**

SST results: A higher corrosion resistance was achieved for Zn -Polymer coating as compared to the pure metal coatings.

2. ADHESION TEST - ASTM B571

Coating Type	Deposition solution	Current Density A/dm2	Adhesion
Zn	Zn	20	**good**
Zn/ Zn+B	Zn/Zn+7gr/l B	20/60	**good**
Zn/Zn+A	Zn/Zn+7gr/l A	20/20	**good**

Adhesion test: A very good adhesion of the Zn-polymer coating on 4340 steel

3. HYDROGEN EMBRITTLEMET TEST – ASTM F519

Testing conditions:200hrs under load of 75% of the material strength - 278,436 PSI

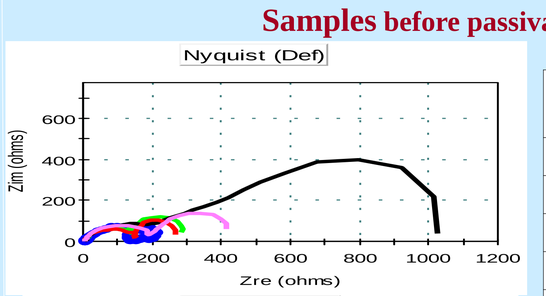
Sample	Plating solution	RESULTS
15	Zn	CONFORMS. No hydrogen embrittlement failures recorded. Samples were visually inspected after test. No embrittlement cracks noted.
16	Zn	
19	Zn/ Zn+Polymer A	CONFORMS. No hydrogen embrittlement failures recorded. Samples were visually inspected after test. No embrittlement cracks noted.
20	Zn/ZN+Polymer A	
17	Zn/Zn+Polymer B	CONFORMS. No hydrogen embrittlement failures recorded. Samples were visually inspected after test. No embrittlement cracks noted.
18	Zn/Zn+Polymer B	

Hydrogen embrittlement test: 4340 steel coated by Zn-polymer coating is not susceptible to hydrogen embrittlement

4. Electrochemical Impedance Spectroscopy - EIS

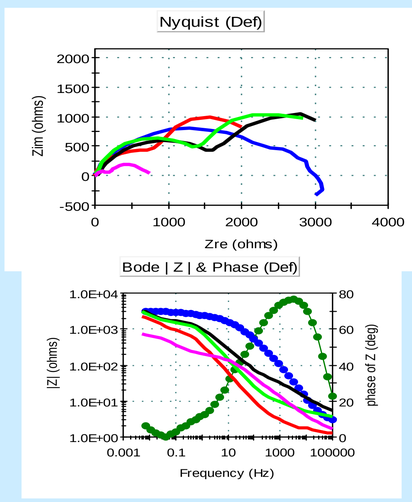
Test solution : 3.5% NaCl ; pH=7.5

Samples before passivation



A conc. gr/l	Current density A/dm²	Imp Ohm
0	20	244
2	20	300
2	60	400
4	40	300
7	40	1000

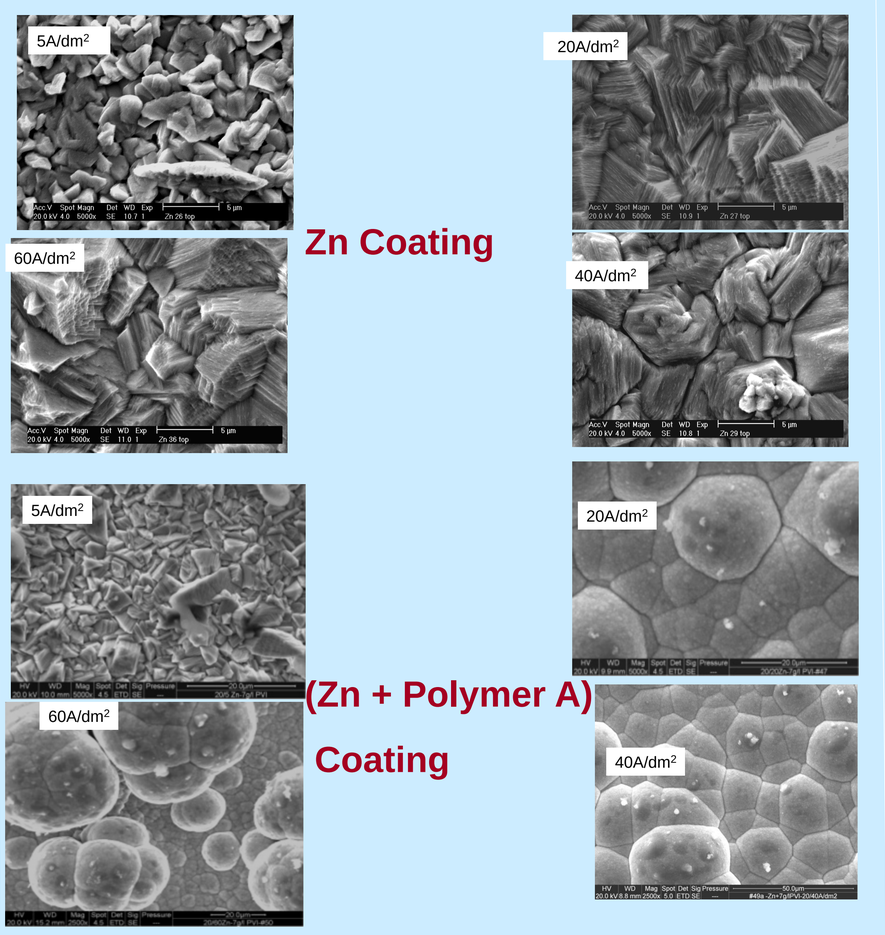
Samples after dichromate passivation



A conc. gr/l	Imp Ohm
Cadmium	3000
0	750
2	3000
4	3000
7	2000

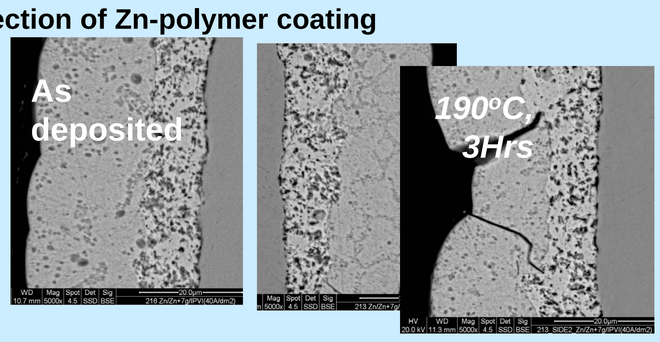
EIS results show that the Zn-polymer coating has a higher corrosion resistance as compared to pure metal coating.

5. MORPHOLOGY OF THE COATING EFFECT OF CURRENT DENSITY

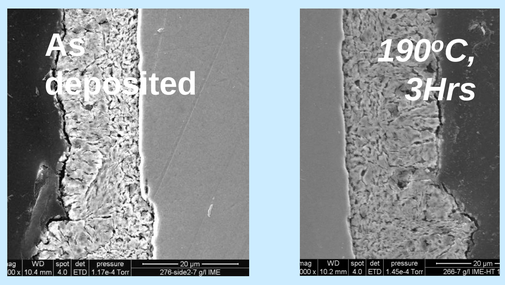


6. EFFECT OF HEAT TREATMENT

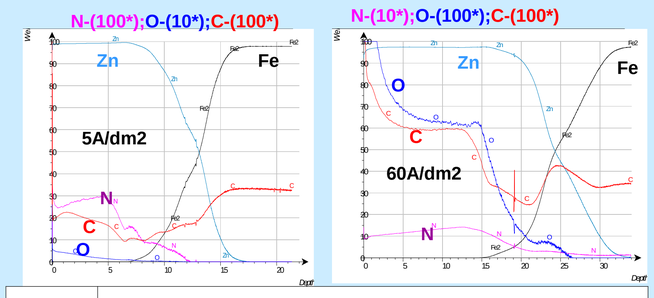
Cross- section of Zn-polymer coating



Zn+ polymer B coating is less dense than Zn+ polymer A coating , and as a result does not crack during heat treatment



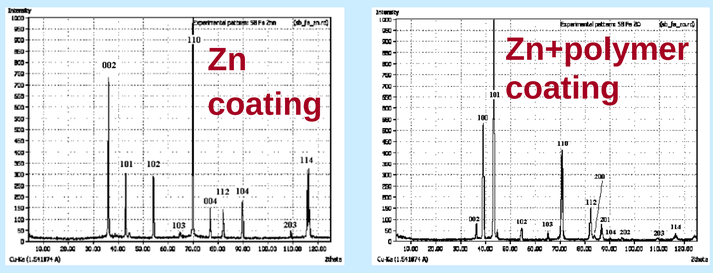
7. Coatings Composition –GDOES Depth Profile-Effect of Current Density



Polymer A conc. gr/l	current density(A/dm²)					
	5			60		
	O(%)	C(%)	N(%)	O(%)	C(%)	N(%)
4	0.5-0.2	0.2	0.3	0.6	0.6	1.3

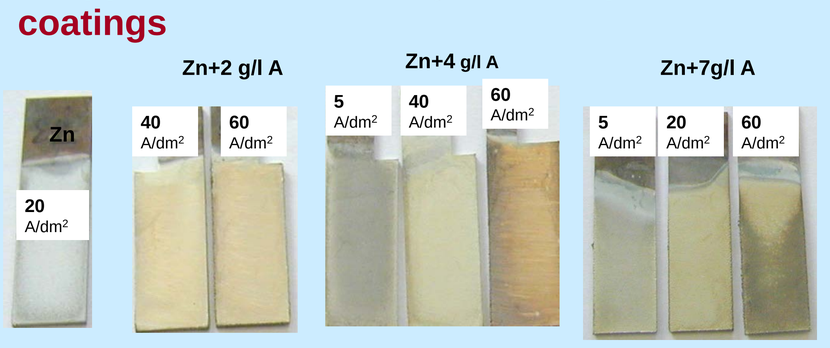
Increase in current density resulted in increase in polymer content in Zn coating

8.XRD –EFFECT of POLYMER on TEXTURE



- **Wider diffraction lines of sample with organic additive at (110) are a consequence of the smaller grain size.**
- **Crystallographic orientation of zinc changes from (110) for free-organic additive bath to (101) with organic.**

9. Appearance of Zn-Polymer composite coatings



SUMMARY AND CONCLUSIONS

- Composite Zinc- Polymer coating was evaluated as a possible alternative to Cadmium coating for High Strength Steel for Aircraft applications
- The Zn –Polymer composite coating withstands the requirements for Cadmium alternative to high strength steels:
  - Hydrogen Embrittlment Resistance (ASTM F519)
  - Corrosion Resistance - Exposure in Salt Fog Test (ASTM B117) – Appearance of white corrosion products on the passivated samples only after 300hrs or higher exposure period.
  - Adhesion test- bend test (ASTM B571)
- SEM and XRD investigation show that the presence of polymer in the Zn matrix results in modification of microstructure and texture of the coating as compared to pure Zn coating.
- Coating composition was evaluated by Glow Discharge Emission Spectroscopy (GDOES) and Auger Electron Spectroscopy (AES) . The amount of polymer embedded in the Zn matrix was found to depend on current density and polymer concentrations in the solution.