Aluminum Alloys Optimized for Sacrificial Protection

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Presented to: ASETSDefense
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Background

• Commercially pure (CP) aluminum (1100 series) is typically used as a source for the IVD AI process and emerging cold spray applied aluminum coatings intended for sacrificial protection of steel, aluminum and other metals

• CP aluminum is limited in its ability to provide sacrificial protection due to natural passivation and its relatively high potential which is essentially the same as typical structural aluminum alloys
CP Al data

- OCPs and Polarization curves for 1100 (CP) aluminum- bulk substrate and cold spray applied

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\begin{align*}
\text{OCP}_{\text{Sub}} &= -0.75 \text{ V vs SCE} \\
\text{OCP}_{\text{Al}} &= -0.91 \text{ V vs SCE}
\end{align*}
\]

Cold spray process induces delta in potential- literature suggests this is due to cold work (similar effect seen in peening studies)
Potential Solution

• “Active” aluminum alloys
  i. “Activator” alloying elements allow for the tailoring of the three important anode properties:
    i. Potential
    ii. Current
    iii. Efficiency
  ii. The result is that tailored aluminum anode alloys have the highest relative output (Amp-hrs/kg) of all alloys. This results in the lowest cost per Amp-hr.
  iii. Leading candidates are already available and commercialized for immersion protection of assets worldwide
  iv. Alloys are governed by MIL-DTL-24779
    i. “conventional”- Al-5%Zn-0.02%In used where hydrogen embrittlement is not an issue (V vs SCE= -1.05)
    ii. “low potential”- Al-0.02%Ga use in high-strength steel applications on subs, etc. (V vs SCE= ~-0.90)
Cold Spray CP Al vs Al-Zn-In

Same as bulk alloy - no effect of cold spray process on e-chem properties

OCP_{Sub} = -0.75 V vs SCE
OCP_{Al} = -0.92 V vs SCE
OCP_{AlZnIn} = -1.03 V vs SCE
Al-Zn-In Powder

- Inert gas atomized with particle size distribution:
  - D10: 13 um
  - D50: 23 um
  - D90: 43 um
CS Al-Zn-In Corrosion Performance

- Applied to 1010 steel
- Thickness ~1 mil. No other finishing.

As applied coatings

Type I conversion coating

Type II conversion coating
CS Al-Zn-In Corrosion Performance

- Applied to 7075-T6. 6” by 6” by 0.125”
- Thickness ~1 mil. No other finishing.
CS Al-Zn-In Corrosion Performance

- 1010 steel after 2 weeks ASTM B117

Type I conversion coating

Type II conversion coating
• 1010 steel after 6 weeks GMW 14872 (42 cycles)
CS Al-Zn-In Corrosion Performance

- 7075-T6 after 6 weeks ASTM B117 (1000 hrs)

Type I conversion coating

Type II conversion coating
CS Al-Zn-In Corrosion Performance

- 7075-T6 after 6 weeks GMW 14872 (42 cycles)
Shortcomings of Current Alloys

• **1100 Al**
  - Passivates
  - Low relative potential gap with Al substrate alloys
  - Susceptible to cold work effects on potential- likely reversible with heat exposure

• **Al-Zn-In**
  - Zinc- aquatic toxin, higher density, and higher cost than aluminum

• **Al-Ga**
  - Efficiency- only about 60%. Yields low relative current output compared to Al-Zn-In, which is about 90% efficient
Improved Alloys

- Al-X-Y-(Z)
  - No or very low zinc
  - X, Y, and Z total less than 0.3% of the alloy
  - Efficiency greater than 90%
  - ~7% less dense, therefore 7% higher output per unit weight compared to Al-5%Zn-0.02%In
  - Targeting -0.90 and -1.10 volts vs SCE to mimic current alloys
Improved Alloys

• Polarization curves for two candidates
Plans

• More thoroughly characterize cold spray applied Al-Zn-In for general use and Al-Ga for high strength steel
• Secure powders and characterize new cold spray applied Al-X-Y-(Z) alloys
• Establish partnerships with other interested organizations
• Mature powder properties, application parameters and coating performance requirements
• Modify MIL-DTL-83488 to enable desired applications