

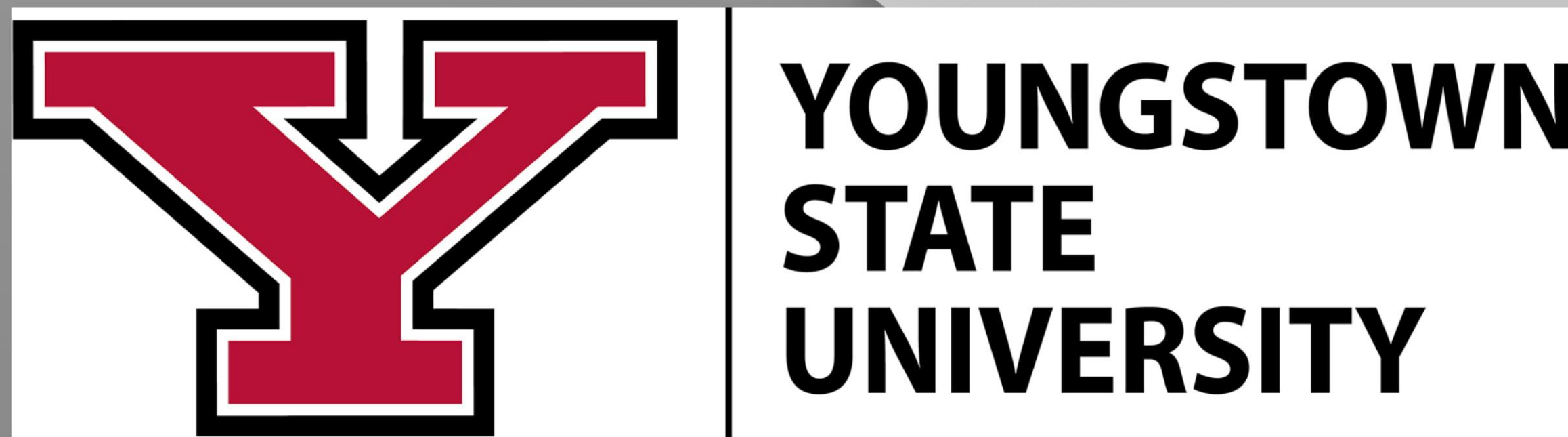
Reducing the Corrosion of a Potential Vehicular Structural Alloy

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The Purpose

Automotive Industry:



- Corrosion of structural steel on vehicles
 - Caused by salt treated roads
- Focused on increasing gas mileage
- Two ways to increase gas mileage using current technology
 - Improve efficiency of the engine
 - Reduce the overall weight of the vehicle
 - Engine cradles, control arms, bracing
- Change the structural material
 - Needs to be lighter than steel
 - Needs to be as stiff as steel
 - Needs to be easy to shape
- Possible Replacement Metals
 - Aluminum, Magnesium
 - Metals prone to corrosion



Why Use Magnesium?

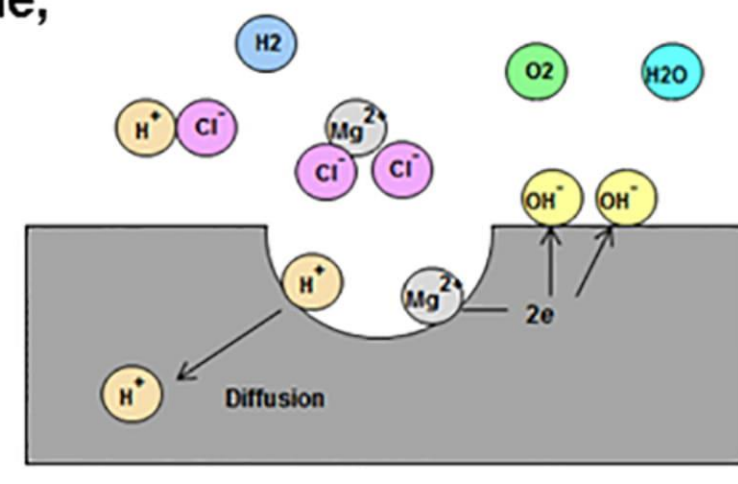
Magnesium Alloys:

- Feasible option for reducing the weight of vehicles
- High Stiffness to Weight Ratio
 - Steel: 25.7 GPa*cm³/g
 - Aluminum: 25.6 GPa*cm³/g
 - Magnesium: 25.9 GPa*cm³/g
- High Strength to Weight Ratio
 - Steel: 107.1 MPa*cm³/g
 - Aluminum: 114.8 MPa*cm³/g
 - Magnesium: 164.0 MPa*cm³/g
- Excellent Castability and Easy Machinability
- Low corrosion resistance

Corrosion of Magnesium


- Three Oxidation – Reduction Reactions
 - Magnesium, water, and oxygen
- Forms magnesium hydroxide precipitate
 - Magnesium and water
- Forms magnesium hydroxide precipitate and hydrogen gas
 - Magnesium, sodium chloride, and water
- Magnesium chloride, sodium hydroxide, and hydrogen gas
- Corrosion Locations
 - Surface Effects
- General corrosion
- Pitting Corrosion
 - Bulk Effect



Reducing the Corrosion of Magnesium

Magnesium Alloys:


- Addition of other elements to the magnesium
 - Changes the surface of the magnesium
 - Reduces corrosion
 - More expensive
- Magnesium Alloy AE44
 - 4% Aluminum
 - 4% Rare Earth Elements
 - 92% Magnesium



Other Problems With Magnesium

Galvanic Corrosion:

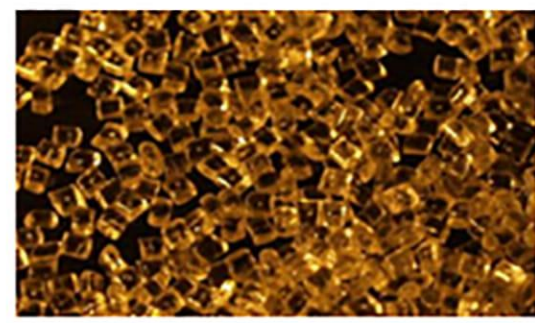
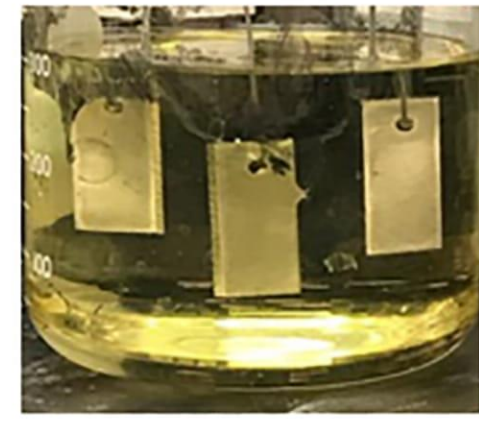
- Two metals in contact
 - One metal can corrode preferentially to another metal
- Magnesium corrosion can be accelerated if in contact with other metals on vehicle



Coatings to Reduce Corrosion of Magnesium

Polyetherimide (PEI):

- Amber colored and Amorphous
 - No distinct crystalline structure
- Glass transition temperature – 217°C
- Density – 1.27 g/cm³
- Hydrophobic and solvent resistant
 - Repels water
 - Not easily dissolvable by salt and other chemicals on the road
- Prevents direct contact with other metals
- Two Methods Tested
 - Polymer Solution Casting
 - 3D printing a polymer coating (JuggerBot)


Procedure

Solution Casting:

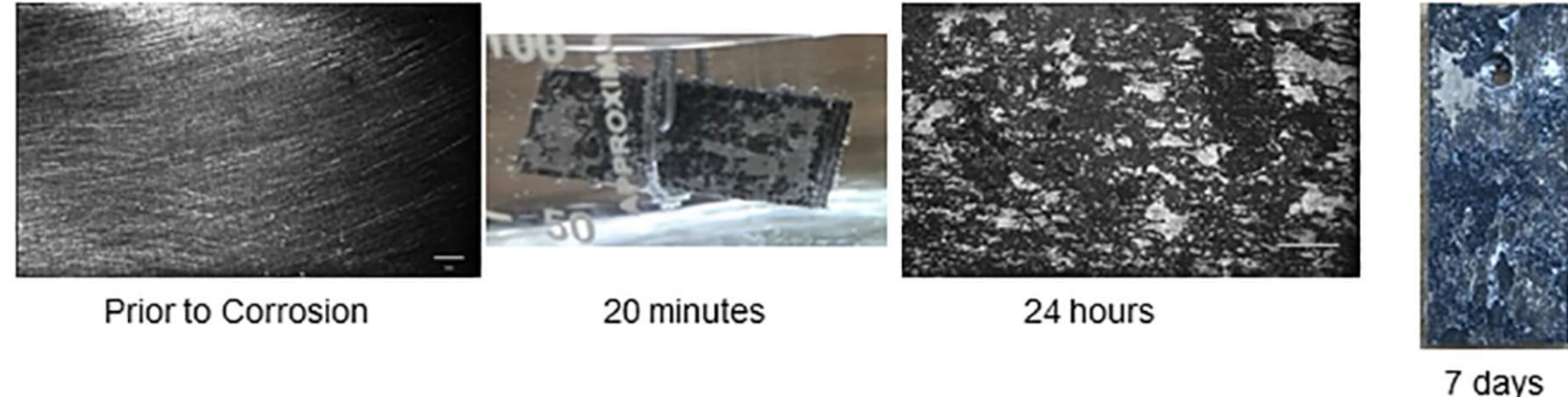
- Preparing magnesium samples
 - Sanded with 600, 800, and 1200 grit sandpaper.
 - Wash with Acetone, Acetone Semicongductor, and Ethyl Alcohol.
- Preparing polymer solution
 - Dissolve 5.985 g of PEI in 145.5 mL of Dichloromethane (DCM).
- Dip samples in solution
 - Samples were hung via paper clips from a glass stir rod atop the solution's beaker.
 - After 24 hrs, the solution solidifies and samples are left with a polymer coating.

Samples were coated through 3D printing

- Six samples were taken to JuggerBot (YBI)
- Samples were then coated by 3D printing.



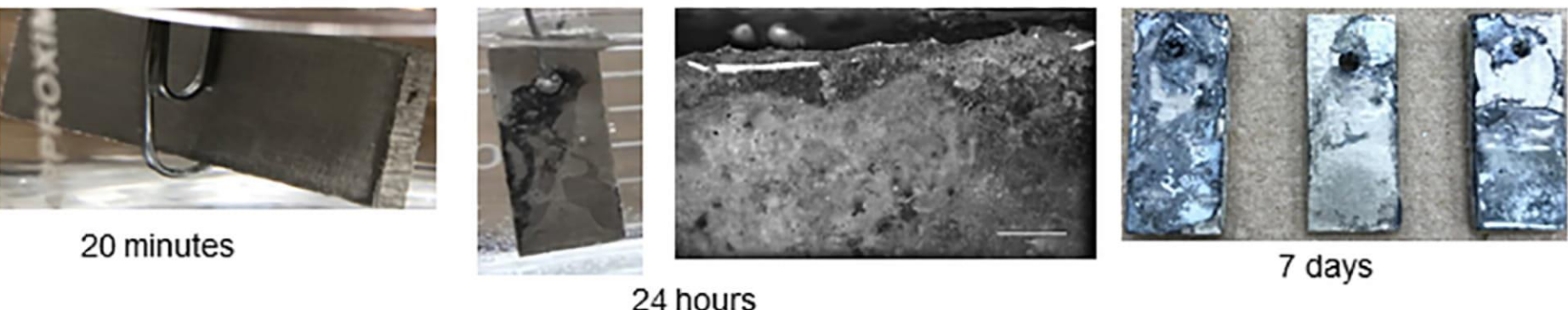
Results: Uncoated Magnesium



Prior to Corrosion, 20 minutes, 24 hours, 7 days

- Corrosion is visible within 10 seconds
 - Indicated by dark grey area forming
- Large amounts of corrosion visible after 24 hours
 - Indicated by a large portion of the surface covered by dark grey area with minimal light areas of the original magnesium surface
- Complete removal of the magnesium surface after 7 days
 - Indicated by the complete disappearance of the light colored areas that would indicate a magnesium oxide film

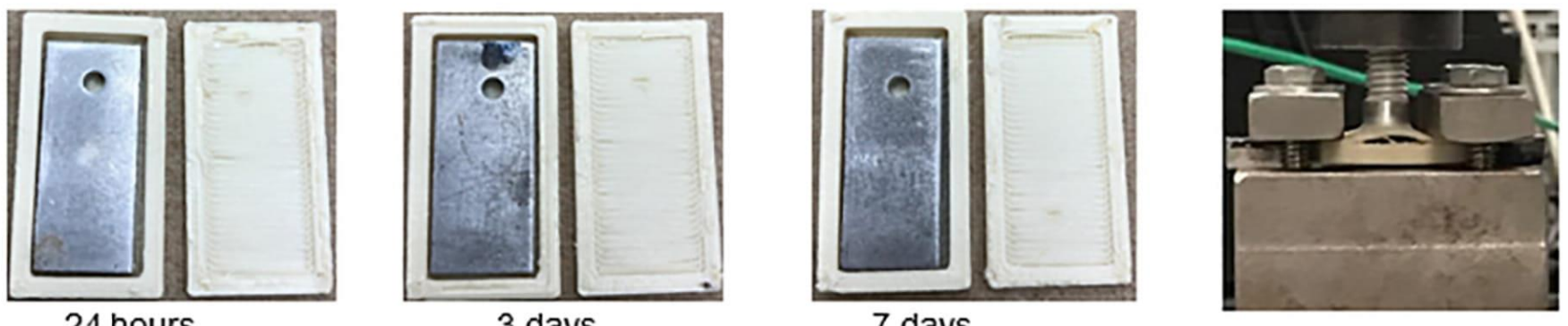
Results: Solution Cast Magnesium



20 minutes, 24 hours, 7 days

- No corrosion seen after initial exposure
 - No dark grey area formation, smooth around edges
- Some corrosion visible after 24 hours
 - Indicated by the presence of the dark grey area
 - Aqueous solution penetrated coating at edges
- Distinct corrosion after 7 days
 - Indicated by the formation of large areas of grey
 - Coating did offer some protection and was less than no coating

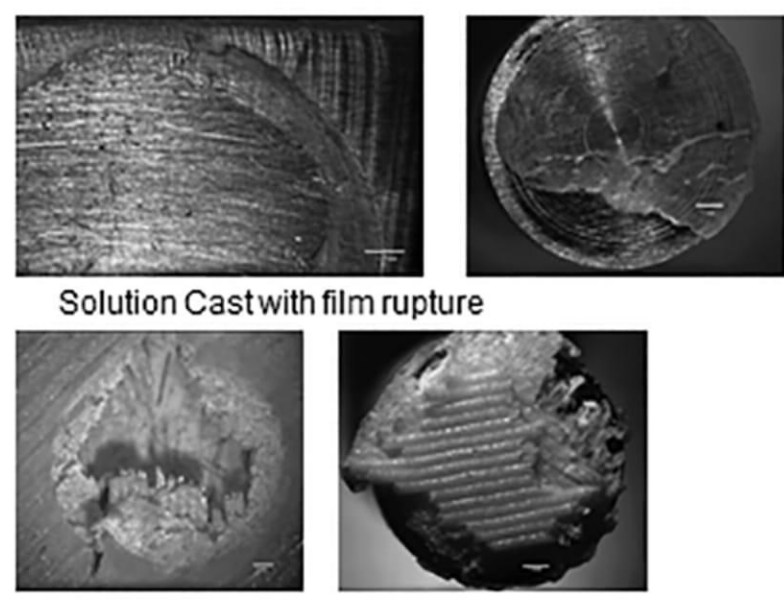
Results: 3-D Printed PEI and Magnesium



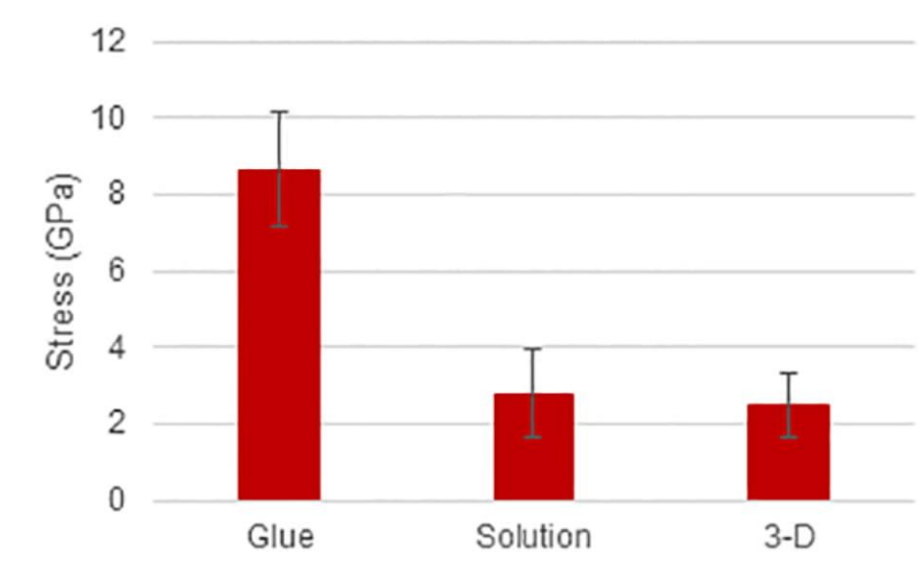
24 hours, 3 days, 7 days

- No corrosion seen after 24 hours
 - No dark grey area formation, smooth around edges
- Some corrosion visible after 3 days
 - Indicated by the presence of the dark grey area
 - Aqueous solution penetrated likely through the connecting groove
 - As seen with adhesion testing, failure occurred at the connecting groove
- Distinct corrosion after 7 days, although less than solution cast samples
 - Indicated by the formation of medium grey across the surface
 - Likely not enough aqueous solution inside the cavity to cause large amounts of pitting
 - Coating offered more protection than solution casting, likely because of thickness

Results: Adhesion Testing



Solution Cast with film rupture, 3-D printed with container rupture



Stress (GPa)

- Stress results indicate the polymer did not actually bond to the Magnesium surface
 - If bonded, break would have occurred at glue – coating interface
 - Occurred at metal – coating interface
- Glue – metal interface is stronger than the coating – metal interface
- No distinct difference between solution casting and 3-D printing adhesion strength

Conclusions and Future Work

- Polymer Solution Casting
 - Significantly reduces corrosion
 - Not a perfect process
 - Imperfections in coating leads to corrosion
- 3D Printed Coating
 - Better corrosion reduction
 - Particular polymer was not transparent
 - Can't see if corrosion has begun without destroying coating
 - Difficult to implement on actual vehicle parts
- Improving Polymer Solution Casting process
 - More reliable corrosion prevention
- Further testing with transparent 3D printed coating
- Developing a chemical bond between alloy and polymer
 - Stronger adhesion

