# Corrosion Reduction Using Two Coating Methods on Magnesium


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## Motivation for Research

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

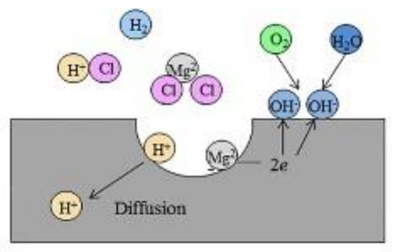
## Why Use Magnesium?

Magnesium Alloys:

- Desireable for use to replace heavy engine parts
- 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
- Easily corroded in the presence of salt-water

## Magnesium Corrosion

- Two Oxidation – Reduction Reactions
  - Magnesium and water
    - Forms magnesium hydroxide precipitate and hydrogen gas
  - Magnesium, sodium chloride, and water
    - Magnesium chloride, sodium hydroxide, and hydrogen gas
  - Unlike other metal corrosion reactions, oxygen not needed
- Corrosion Locations
  - Surface Effects
    - Total corrosion
    - Pitting Corrosion
  - Bulk Effect
    - Hydrogen Diffusion




## Magnesium Corrosion cont.

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

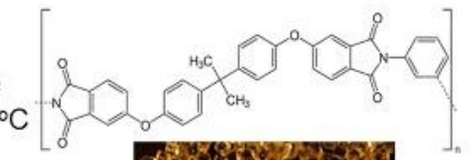
Magnesium Alloys:

- Addition of elements to the magnesium
  - Improve corrosion resistance
  - More expensive
- Magnesium Alloy AE44
  - 4% Aluminum, 4% Rare Earth Elements, 92% Magnesium

## Coating Magnesium - PEI

Polyetherimide:

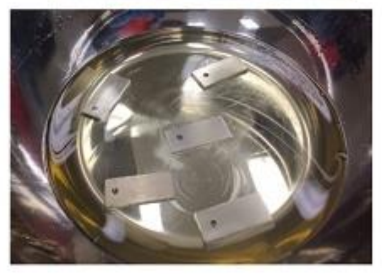
- Amber colored and Amorphous
  - No distinct crystalline structure
- Glass transition temperature – 217°C
- Density – 1.27 g/cm³
- Hydrophobic and solvent resistant
  - Repels water
  - Not easily dissolvable by salt and other chemicals on the road
- Prevents direct contact with other metals
- Two Methods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



## Procedure

Solution Casting:

- Preparing magnesium samples
  - Sanded with 600, 800, and 1200 grit sandpaper.
  - Wash with Acetone, Acetone Semiconductor, 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 to dry off.
  - After 24 hrs, the solution solidifies and samples are left with a polymer coating.



## Results: Uncoated Magnesium

- Untreated AE44 Sample
- Corrosion is visible within 10 seconds
- Significant corrosion after 24 hours

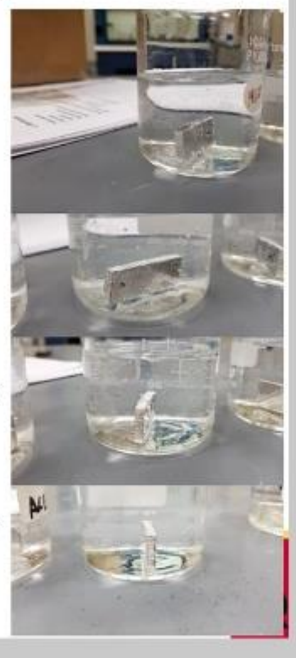
Prior to corrosion

24 hours

20 minutes

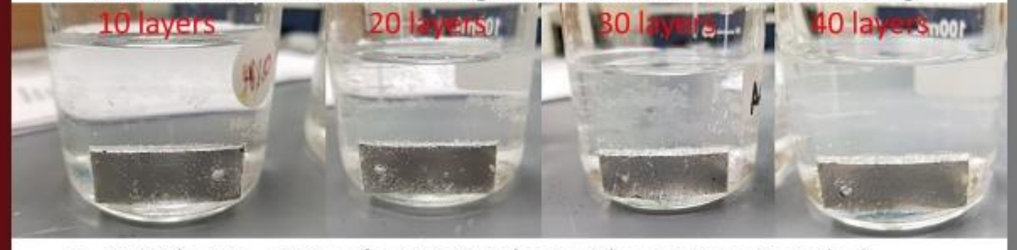
## Different Coating Layers

- 10 layers
  - Small amount of corrosion appeared at 5 minutes
  - Stream of bubbles began at 30 minutes
- 20 layers
  - Small amount of corrosion appeared at 5 minutes
  - Stream of bubbles began at 40 minutes
- 30 layers
  - Small amount of corrosion appeared at 30 minutes
  - Stream of bubbles began 40 minutes
- 40 layers
  - Small amount of corrosion appeared at 40 minutes
  - Stream of bubbles began at 50 minutes

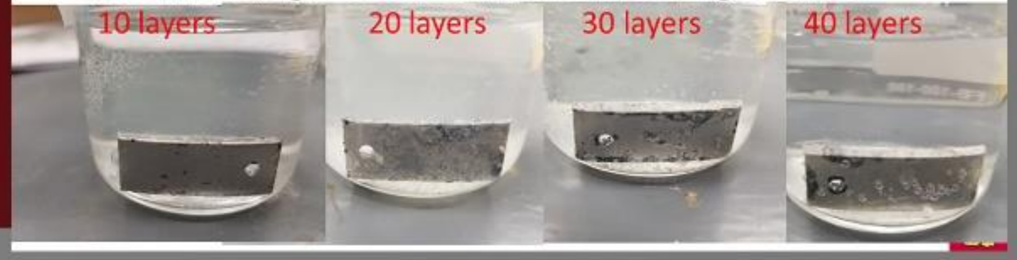


## Different Coating Layers

- At 90 minutes, all showed signs of corrosion beneath coating

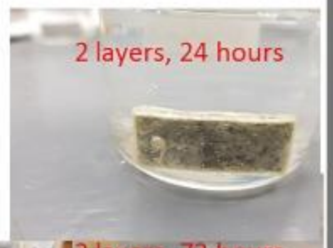


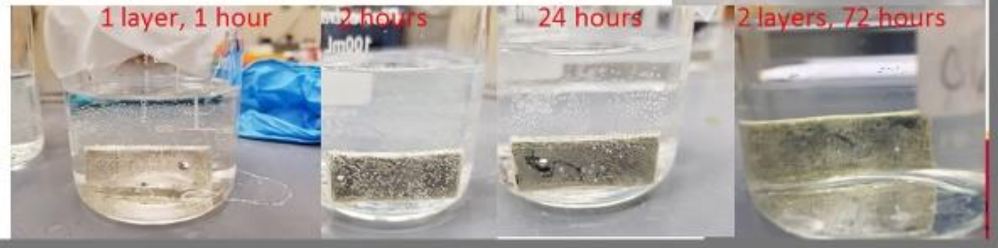

- At 24 hours, signs of corrosion beneath coating extended




## Film – Wrapped Magnesium

- One layer of film
  - No signs of corrosion occurred within 1 hour
  - Small amounts of corrosion began to occur on one side near the hole at 2 hours
  - At 24 hours, corrosion continued on one side, but not the other
- Two layers of film
  - No signs of corrosion occurred within 24 hours
  - Minimal corrosion at 72 hours




## Comparison of Methods

| Type of Coating | Thickness (mm) | Corrosion Signs (min) | Bubble Formation (min) | Destructive Corrosion (min) |
|---|---|---|---|---|
| Uncoated | 2.9 | 0.167 | 0.167 | 120 |
| 10 layers | 2.9 | 5 | 30 | 1440 |
| 20 layers | 2.9 | 5 | 40 | 1440 |
| 30 layers | 2.9 | 30 | 40 | 1440 |
| 40 layers | 3.0 | 40 | 60 | 1440 |
| Evaporated | 3.0 | 20 | 120 | 1440 |
| 1 Wrap | 3.2 | 120 | No stream formed | 2880 |
| 2 Wraps | 3.4 | 2880 | No stream formed | 4320 |

- In general, as thickness increased, corrosion initiation took longer
  - Evaporated coating showed corrosion at corners
    - Thinner PEI at corners
- As thickness increased, time to bubble stream formation increased
  - Thickness of coating prevented bubble stream for those using film and AM printed
- Minimum thickness needed to reduce destructive corrosion signs

## Conclusions and Future Work

- Polyetherimide increased time to corrosion
  - Thicker the coating, longer to initial corrosion bubble formation, and destructive corrosion
- Polymer film vs. pellet
  - Reduces corrosion
  - Compile more data on differences in layers
- Developing a chemical bond between alloy and polymer
  - Stronger adhesion