Modification of Aluminum using Organosilane Coatings to Prevent or Impede Corrosion

Tanya Miracle
Advisor: Bi-min Zhang Newby
The University of Akron
Department of Chemical and Bimolecular Engineering
Background

$400 Billion per year in the United States alone

Reaches into all industries:

• Causes equipments failures

• Becomes dangerous when failures are of bridges, levees, or power plant equipment

• Requires maintenance shut-downs of plants

Exfoliation corrosion due to paint coating failure

http://www.corrosionclinic.com/types_of_corrosion/aluminium_exfoliation_corrosion.htm
Experimental Method

Aluminum coupon in pH 4 sulfuric acid solution

Connect to a computerized video system

Power supply

Light source
Formation of SAMs

• SAMs are self-assembled monolayers that form on the substrate (solid aluminum surface in this study)

n-octadecyltrichlorosilane (OTS)
\[ \text{C}_{18}\text{H}_{37}\text{Cl}_3\text{Si} \]

Heptadecafluoro-1,1,2,2-tetra-hydrodecyldichlorosilane (FTS)
\[ \text{C}_{10}\text{F}_{17}\text{H}_4\text{Cl}_3\text{Si} \]
The molecules from the organosilanes are hydrolyzed onto the substrate using water found either in the atmosphere, in the solution itself, or imbedded on the surface of the substrate.

FTS formation of SAMs

OTS formation of SAMs
<table>
<thead>
<tr>
<th>Type</th>
<th>Average Contact Angle ($\Theta_{AVG}$)</th>
<th>Standard Deviation ($\pm 5^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-modified Al coupon</td>
<td>$\Theta_{AVG} = 75^\circ$</td>
<td>$\pm 5^\circ$</td>
</tr>
<tr>
<td>OTS modified Al coupon</td>
<td>$\Theta_{AVG} = 83^\circ$</td>
<td>$\pm 5^\circ$</td>
</tr>
<tr>
<td>FTS modified Al coupon</td>
<td>$\Theta_{AVG} = 112.72^\circ$</td>
<td>$\pm 5^\circ$</td>
</tr>
</tbody>
</table>

For each type of modified Al coupon, the images show varying degrees of contact angle, indicating the effectiveness of the modification process.
Water drop can only sit on top of FTS layer.

Fluorocarbon based organosilane structure

Water drop might “leak” into space between disordered chains

Hydrocarbon based organosilane structure
Evidence of Corrosive Changes to Aluminum Coupons after 3 Weeks Immersion in sulfuric acid diluted to pH 4.
non-modified

\[ \theta_{AVG} = 75^\circ \pm 5^\circ \]

OTS modified

\[ \theta_{AVG} = 83^\circ \pm 5^\circ \]

FTS modified

\[ \theta_{AVG} = 113^\circ \pm 5^\circ \]

Al coupon prior to immersion in dilute sulfuric acid

Al coupon after 3 weeks in pH 4 sulfuric acid

\[ \theta_{AVG} = 30^\circ \pm 5^\circ \]

\[ \theta_{AVG} = 25^\circ \pm 5^\circ \]

\[ \theta_{AVG} = 114^\circ \pm 5^\circ \]
Machining and scratches seen.

Original Al

860 µm

Machining and scratches seen.

Original FTS modified Al

860 µm

Pitting and surface changes easily noticed.

Al after submersion in dilute sulfuric acid (pH 4)

FTS modified Al after submersion in dilute sulfuric acid (pH 4)

No changes in surface can be seen.
Summary

- Water contact angles show that hydrophobic surface characteristics are achieved on aluminum by modifying the surface with a layer of fluorocarbon or hydrocarbon based organosilane.

- After exposing to the dilute sulfuric acid (pH 4), the change in water contact angle on the aluminum surface can be used to correlate to the extent of corrosion.

- Organosilane layers containing fluorocarbon yields both a highest contact angle and a best corrosion protection for a short term exposure of the aluminum to acidic water (pH = 4).

- A long term study is needed to evaluate the full extent of corrosion protection offered by organosilane coatings. However, this study is beneficial in that aluminum exposed only periodically to acidic conditions would greatly benefit from pre-treatment by a fluorocarbon based organosilane.
References


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Questions?