Modification of Aluminum using Organosilane Coatings to Prevent or Impede Corrosion

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Background

$400 Billion per year in the United States alone

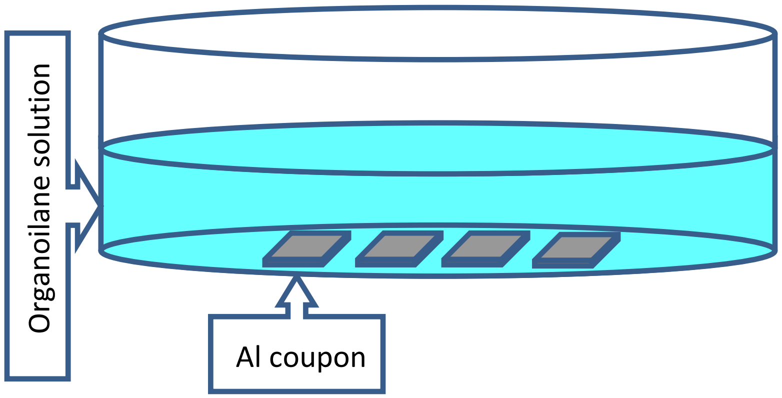
Reaches into all industries:

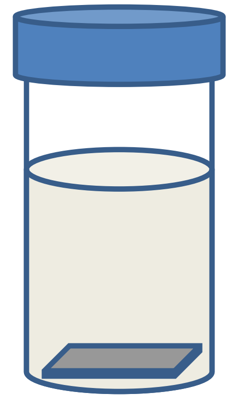
- Causes equipments failures
- Becomes dangerous when failures are of bridges, levees, or power plant equipment
- Requires maintenance shut-downs of plants

Exfoliation corrosion due to paint coating failure

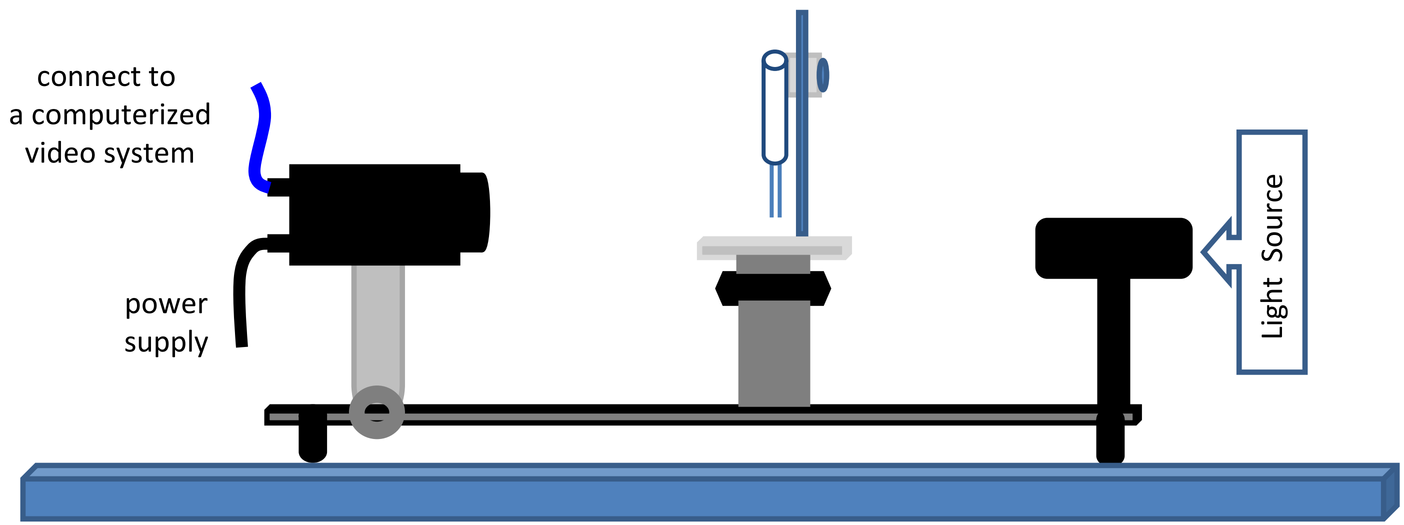
http://www.corrosionclinic.com/types_of_corrosion/aluminium_exfoliation_corrosion.htm

Experimental Method





Aluminum coupon in pH 4 sulfuric acid solution



Formation of SAMs

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

n-octadecyltrichlorosilane (OTS)

$C_{18}H_{37}Cl_3Si$

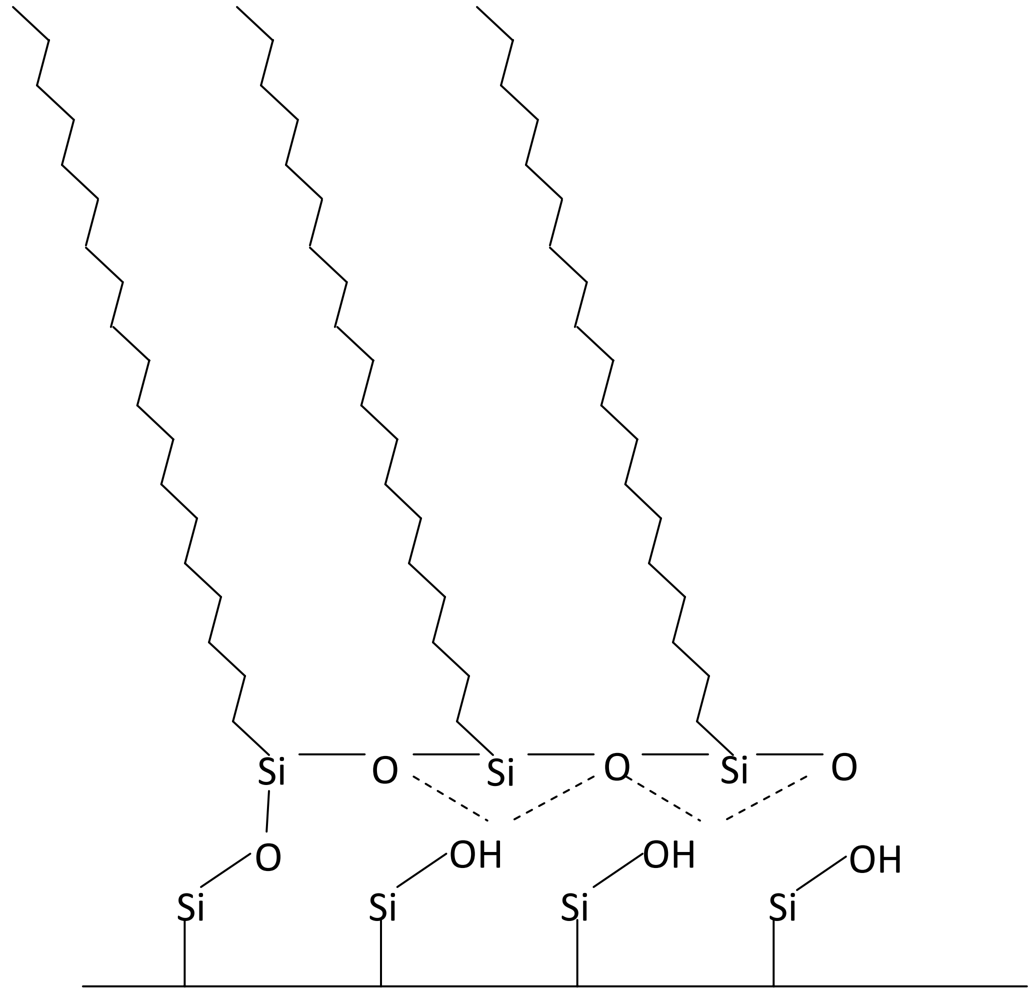
$$
\begin{array}{ccc}
 & Cl & \\
 & | & \\
CH_3(CH_2)_{16}CH_2 - & Si & - Cl \\
 & | & \\
 & Cl &
\end{array}
$$

Heptadecafluoro-1,1,2,2-tetra-hydrodecyltrichlorosilane (FTS)

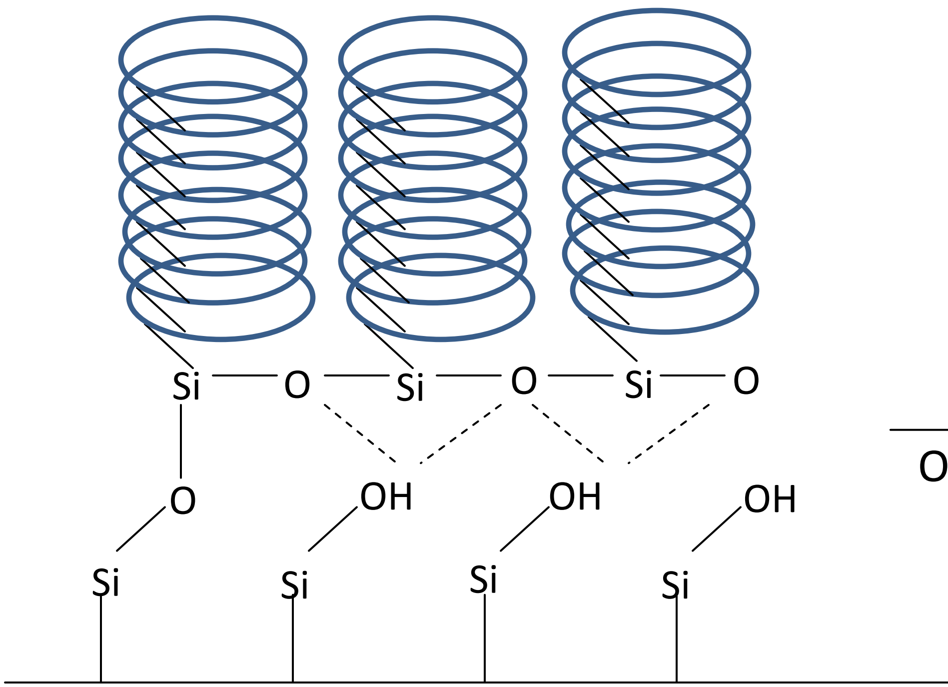
$C_{10}F_{17}H_4Cl_3Si$

$$
\begin{array}{ccc}
 & Cl & \\
 & | & \\
CF_3(CF_2)_7CH_2CH_2 - & Si & - Cl \\
 & | & \\
 & Cl &
\end{array}
$$

- 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 .

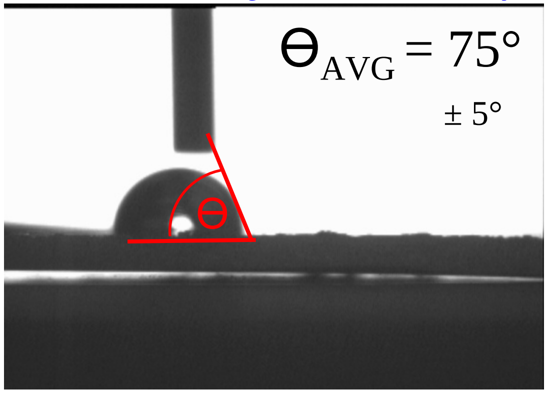


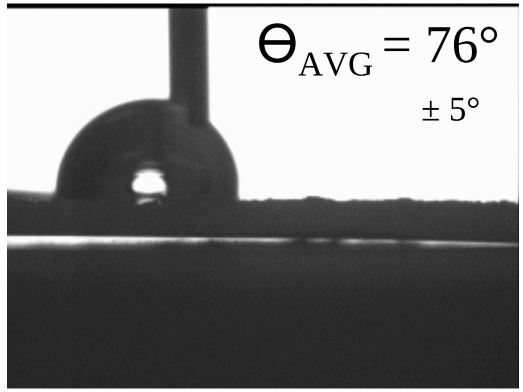
OTS formation of SAMs

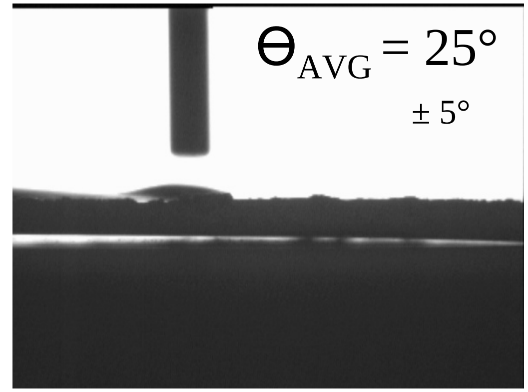


FTS formation of SAMs

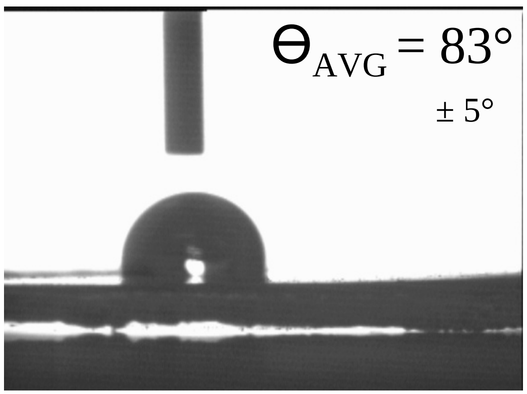
Non-modified Al coupon

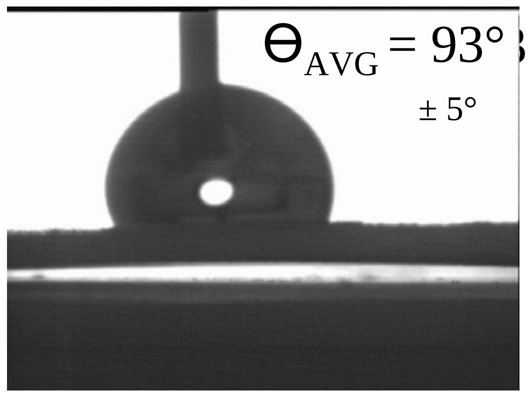


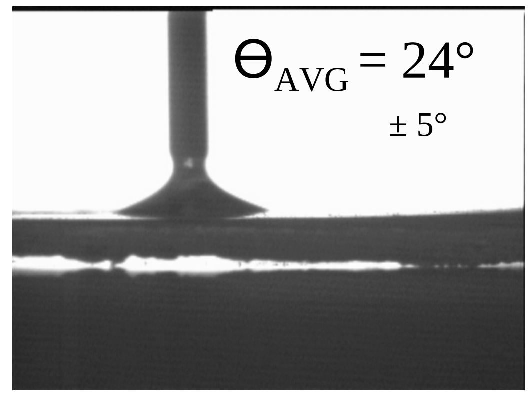




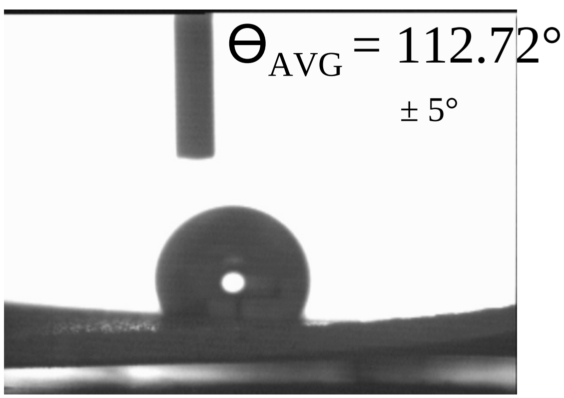
OTS modified Al coupon

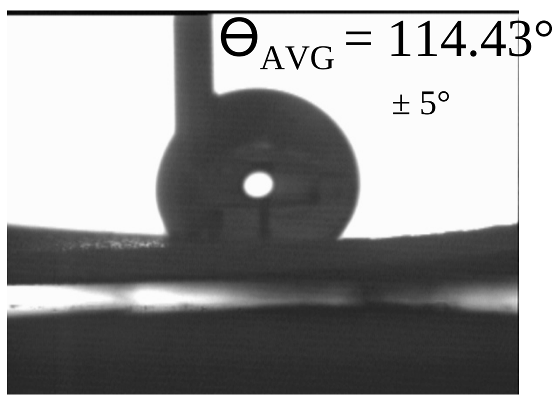


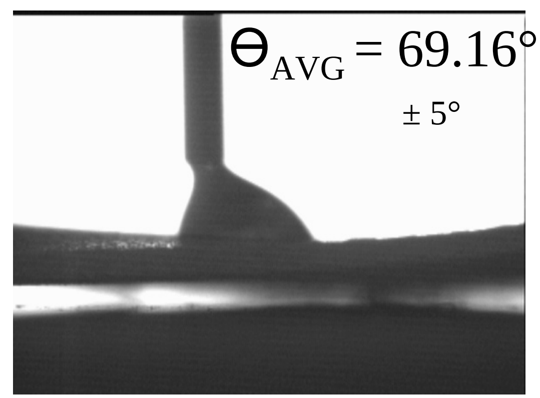


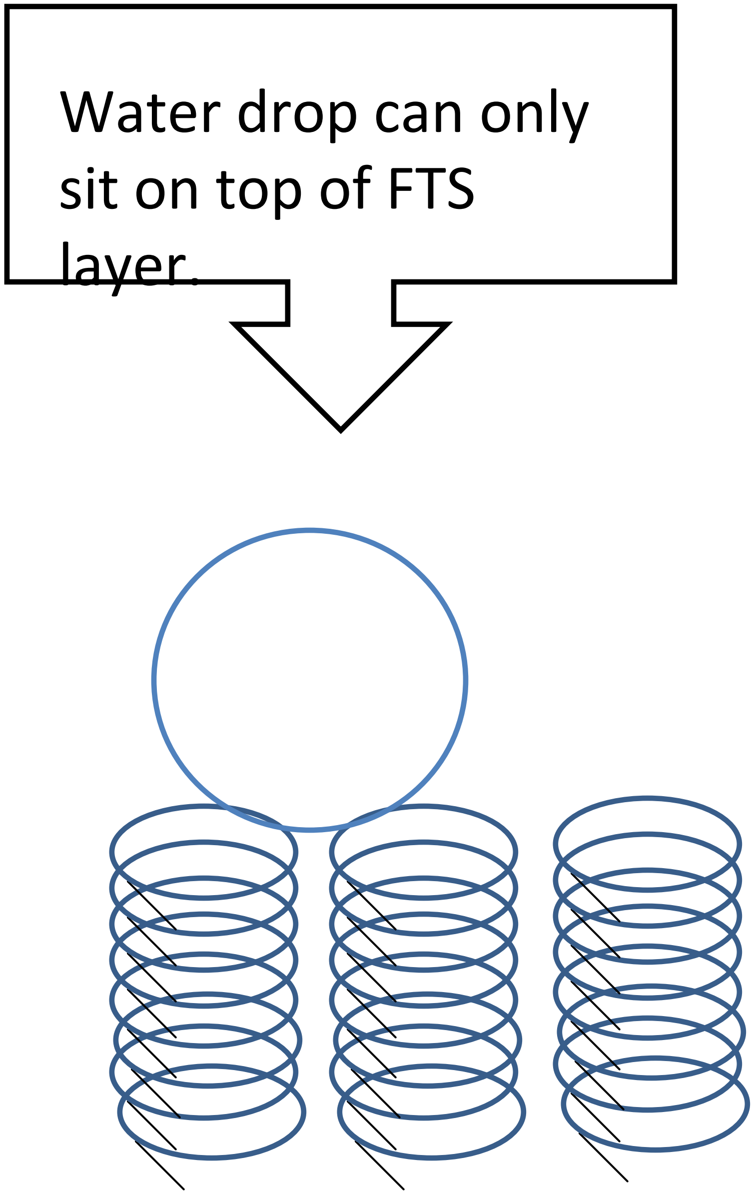


FTS modified Al coupon

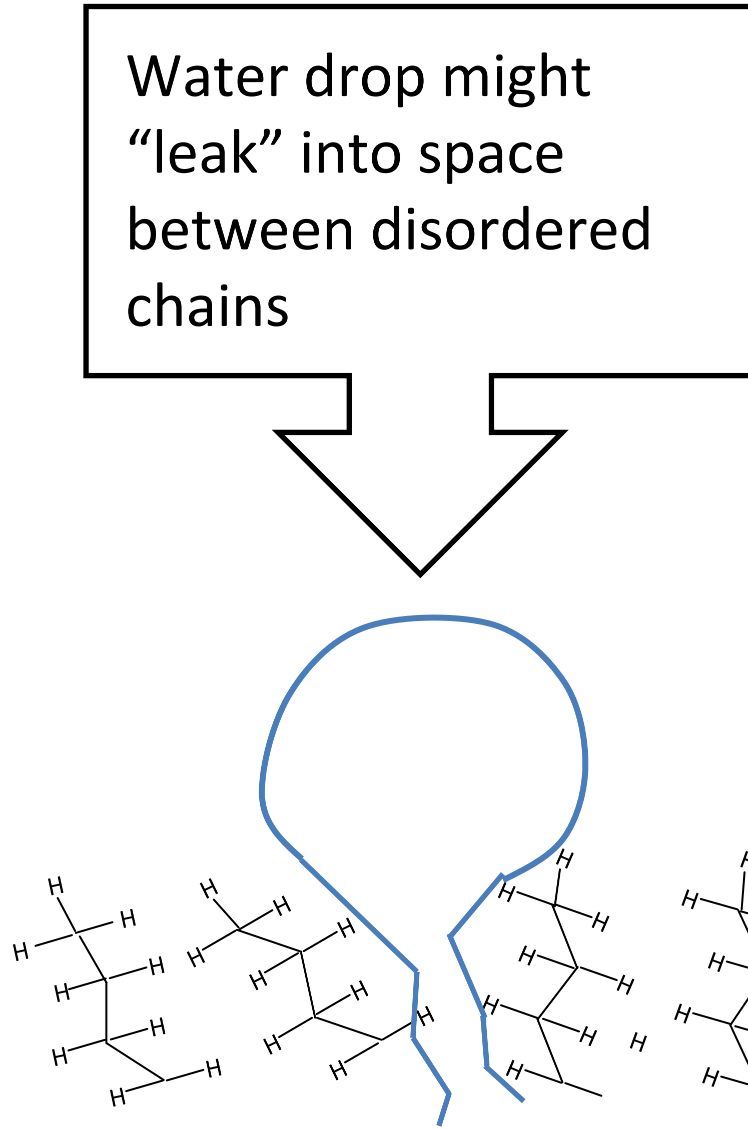








Fluorocarbon based organosilane structure



Hydrocarbon based organosilane structure

Evidence of Corrosive Changes to Aluminum Coupons after 3 Weeks Immersion in sulfuric acid diluted to pH 4.

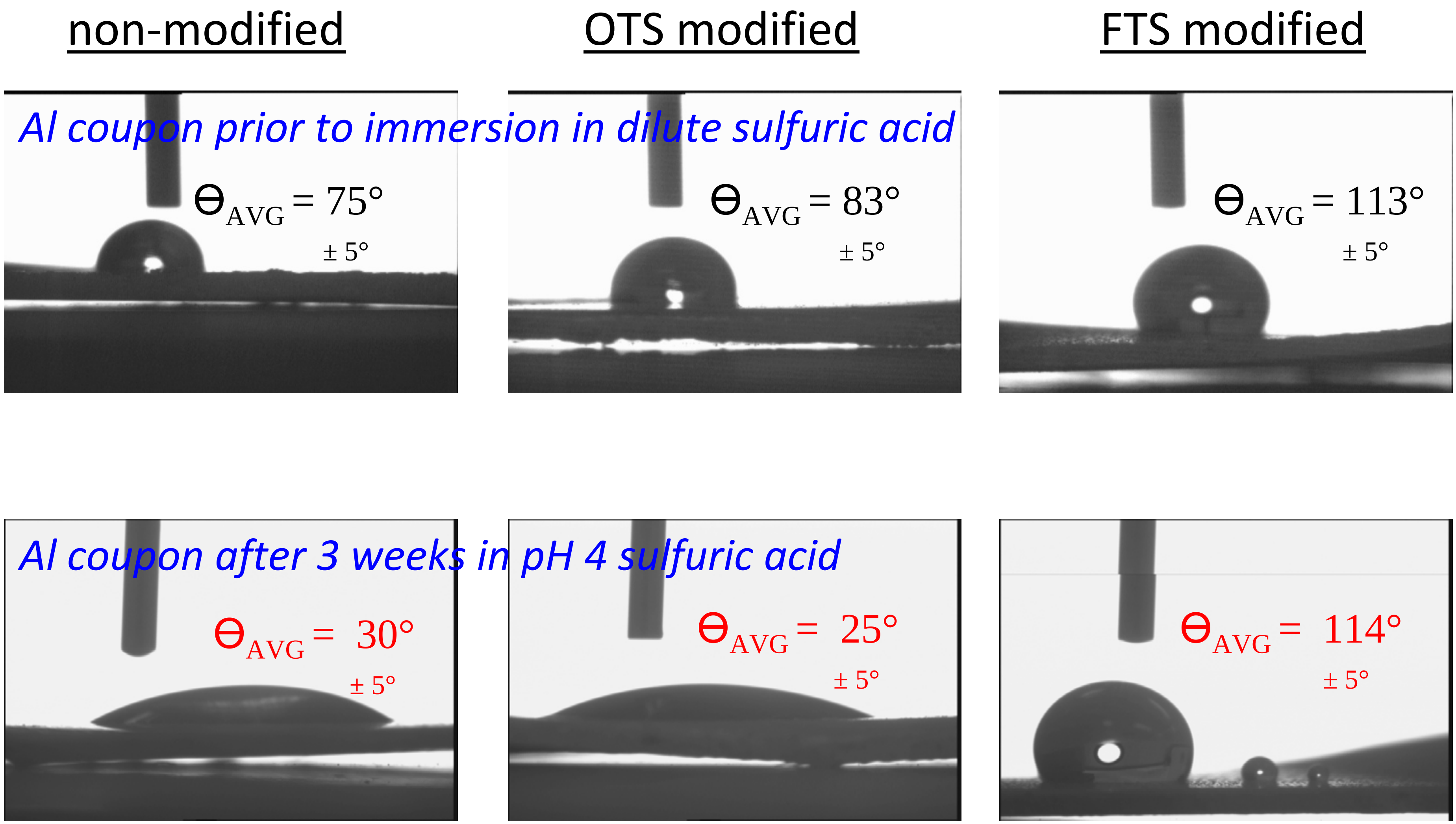
OTS on Al,
pH 4

Al,
pH 4

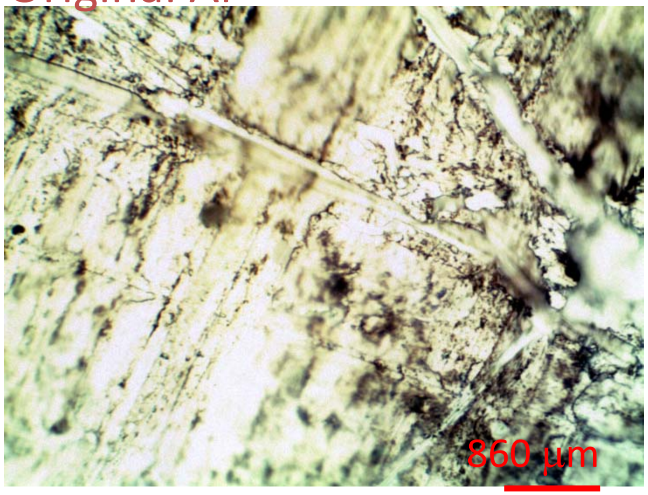
OTS on
oxidized
Al, pH 4

FTS on
Al, pH 4

FTS on
oxidized
Al, pH 4

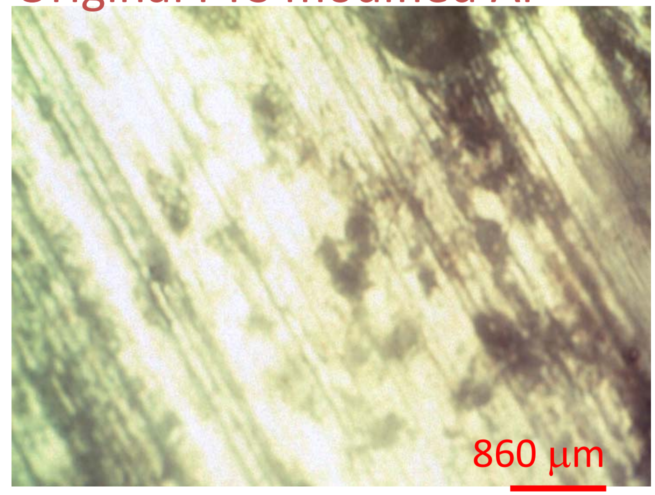

non-modified
OTS modified
FTS modified
Al coupon prior to immersion in dilute sulfuric acid
ϴAVG = 75° ± 5°
ϴAVG = 83° ± 5°
ϴAVG = 113° ± 5°
Al coupon after 3 weeks in pH 4 sulfuric acid
ϴAVG = 30° ± 5°
ϴAVG = 25° ± 5°
ϴAVG = 114° ± 5°

Original Al



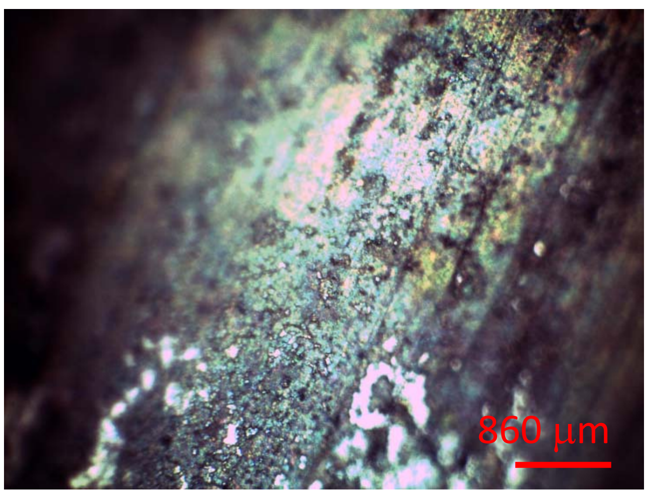
Machining and scratches seen.

Original FTS modified Al



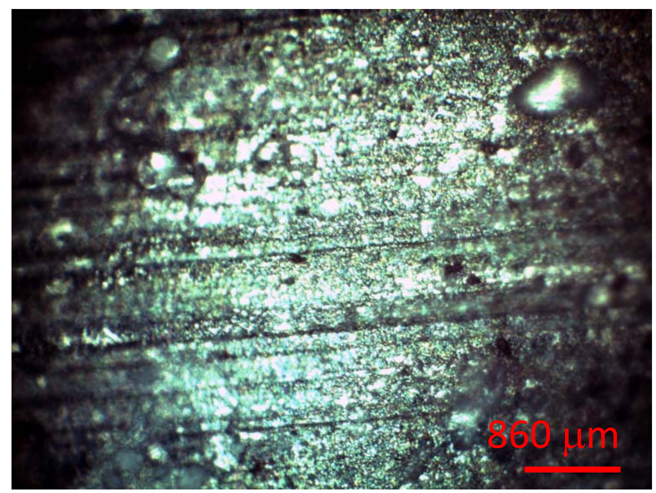
Machining and scratches seen.

Al after submersion in dilute sulfuric acid (pH 4)



Pitting and surface changes easily noticed.

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

1. Nanoscale Imaging of a Corrosion Reaction: Sulfuric Acid Droplets on Aluminum Surfaces, Qing Dai, Andrew Freedman, Gary N. Robinson, and Miquel Salmeron, J. Physical Chemistry, 1996, Vol. 100, No. 1, pp. 9-11

Acknowledgements

• Ohio Space Grant Consortium, project sponsor

•Dr. Bi-min Zhang Newby, Associate Professor of Chemical Engineering, University of Akron, Advisor to project

Questions?