Interactions of Aqueous Surface Treatments With Magnesium Alloy

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Substrate Protection

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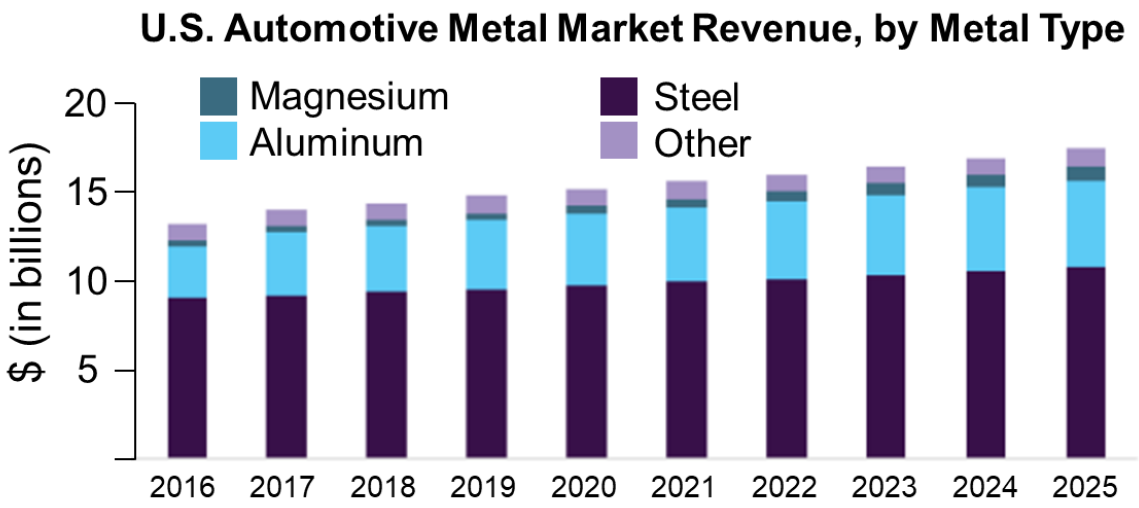
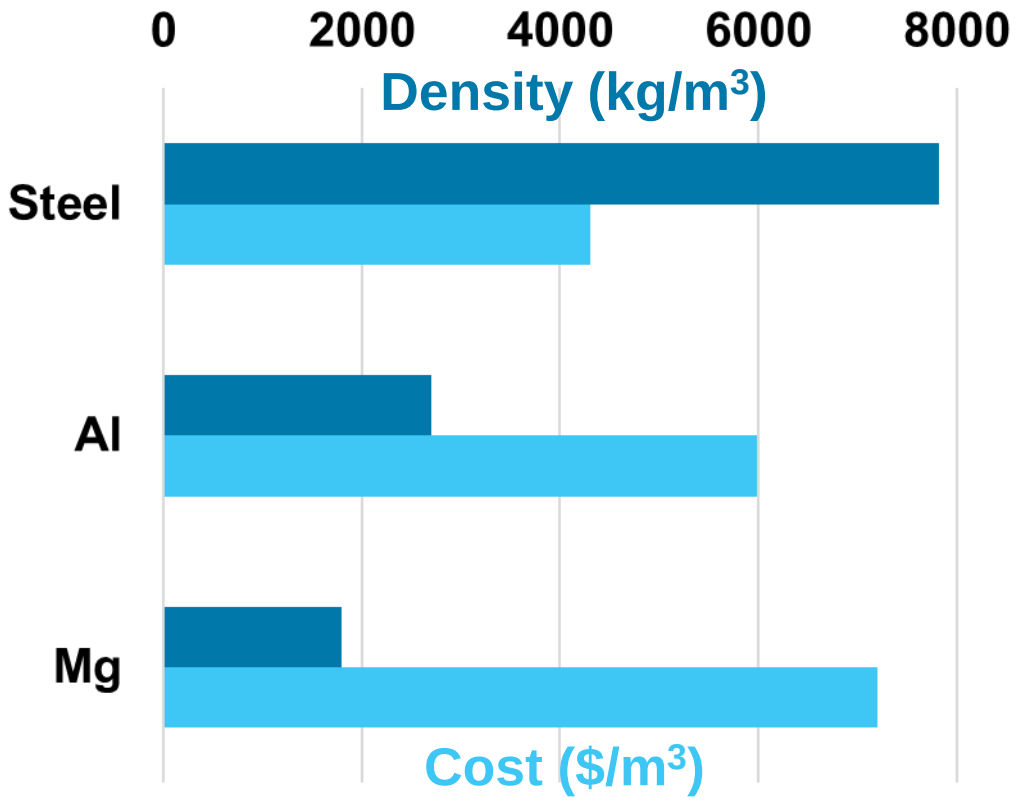
Lightweighting Drives Demand for New Substrates



Magnesium CAGR of 8.4%

https://www.grandviewresearch.com/industry-analysis/automotive-metal-market

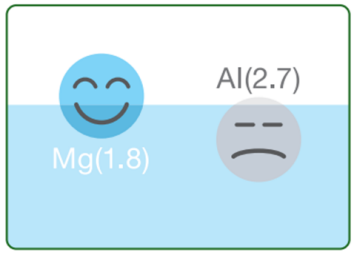


Density decreases faster than the increase in price!

Magnesium Components Yield Savings for the Customer

Fuel Savings per fleet of 100 aircraft	Small Aircraft	Large Aircraft
Annual	$1.57m	$10.3m
Lifetime (20 years)	$31.4m	$207m

http://tellitlikeitisnews.com/3d-printing-married-to-traditional-metal-casting-could-reshape-manufacturing/

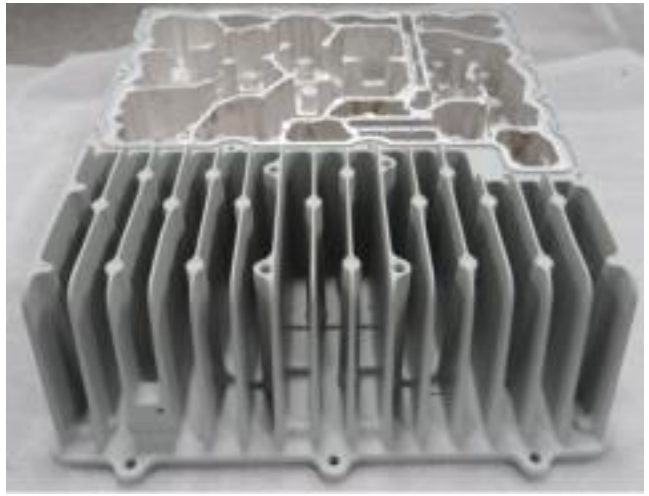


Magnesium Coatings Solutions are Needed in Many Sectors

Personal Electronics Casing - $500m

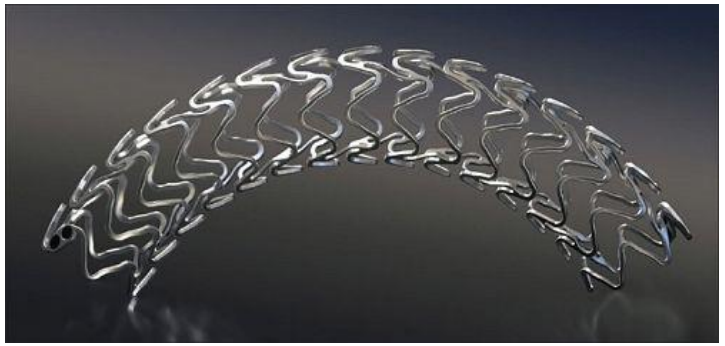
https://www.engadget.com/2016/01/05/samsung-notebook-9/

Heat Exchangers - $17b



Scale: 30 x 40 x 10 cm

Biomedical Implants - $22b



https://www.medicaldesignbriefs.com/component/content/article/mdb/features/27329

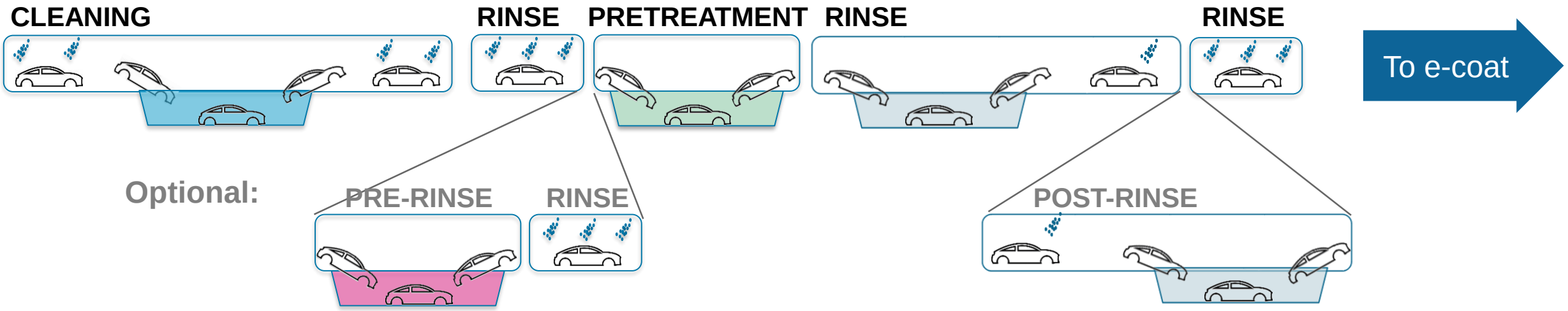
Aerospace Components - $80m

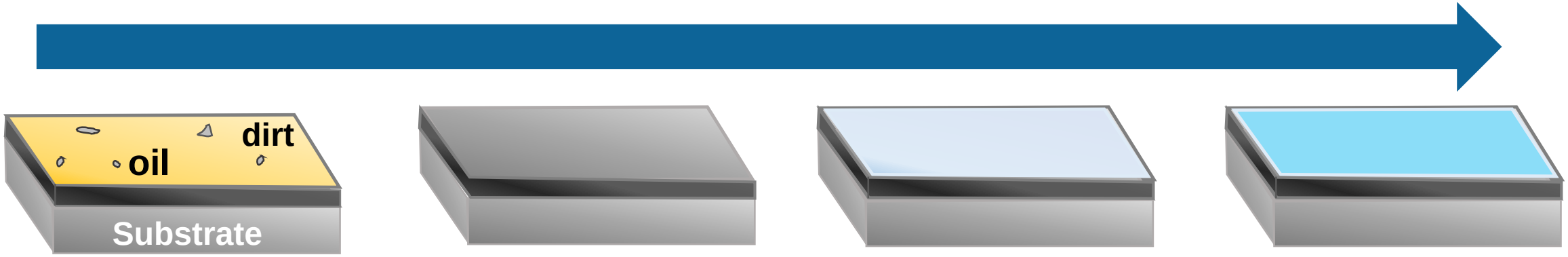
http://tellitlikeitisnews.com/3d-printing-married-to-traditional-metal-casting-could-reshape-manufacturing/

Cast Automotive Parts - $100b

https://www.wsj.com/articles/casting-the-future-of-lighter-vehicles-1455892867

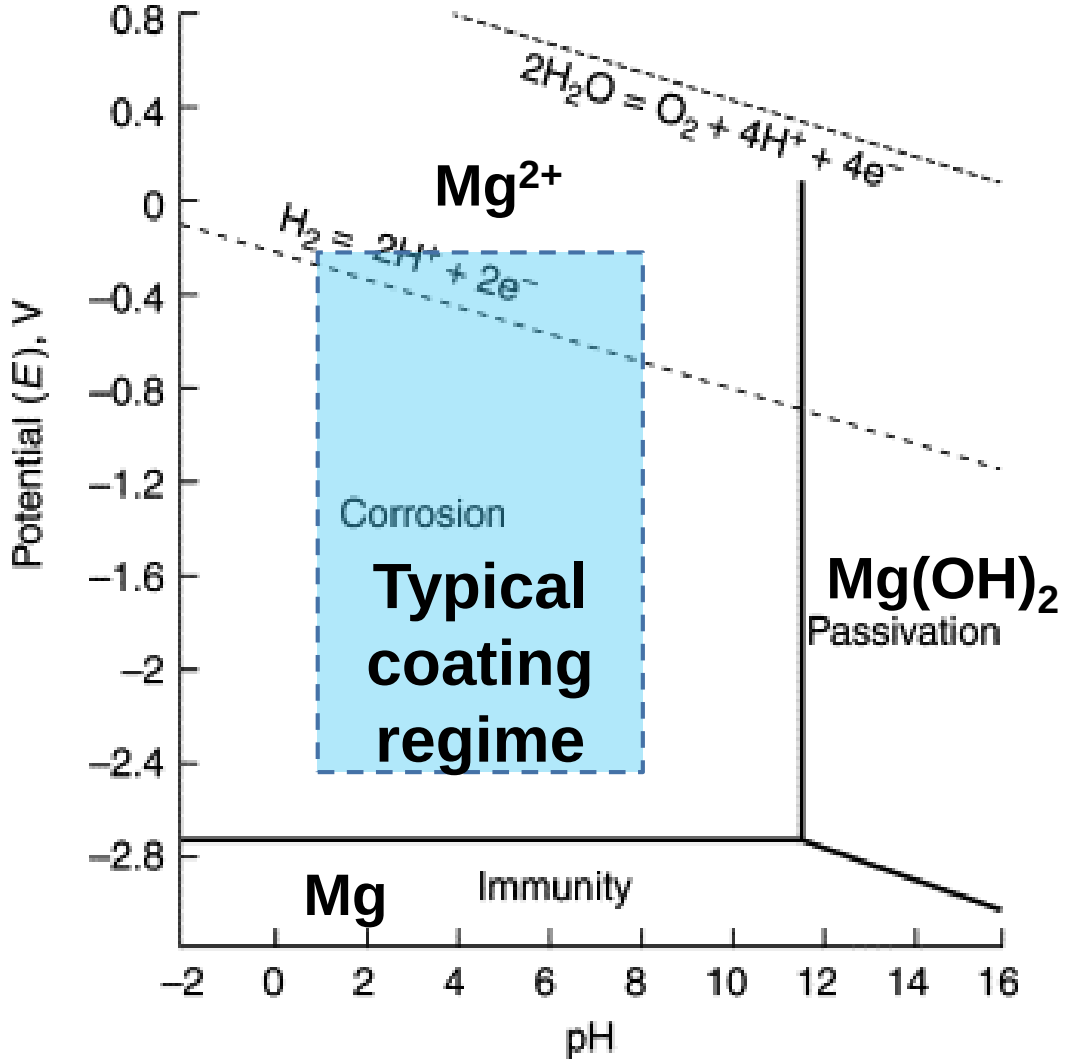
Cleaners are the Foundation of the Coatings Stack

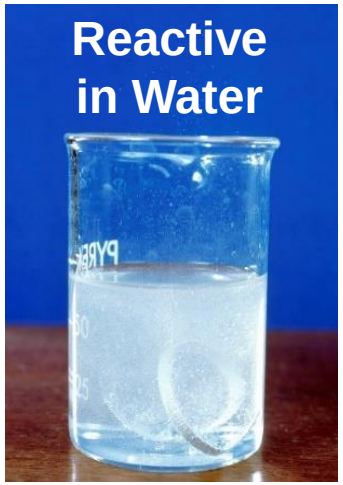


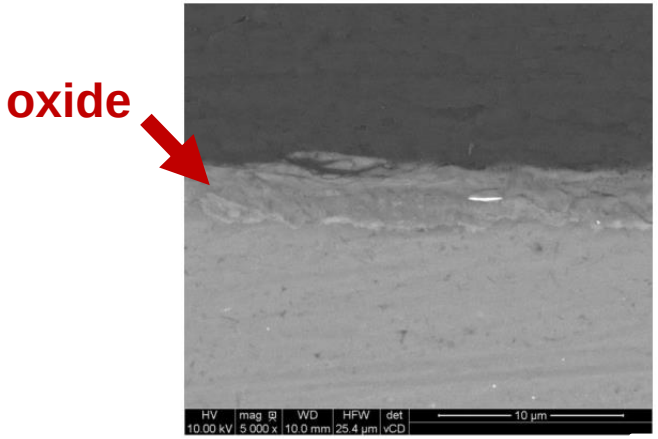


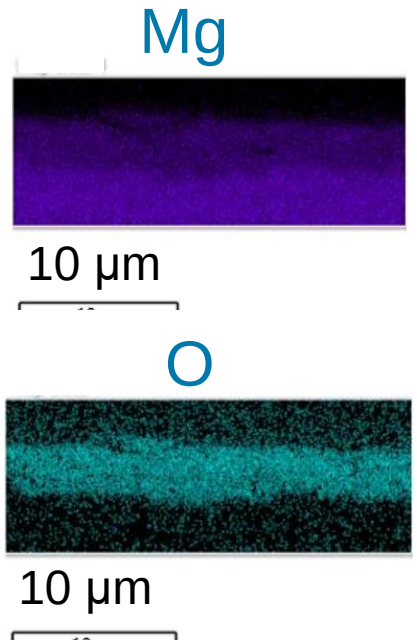
As Received | Fully Activated Surface | Uniform Deposition | Outer layer modification

Special Considerations for Cleaning and Protecting Magnesium









Overview of Cleaner Chemistry

Cleaner Formulation

Builders/Mineral Base

- Source of alkalinity or acidity
- Contribute to detergency
- Inorganic salts (phosphates, silicates, carbonates)

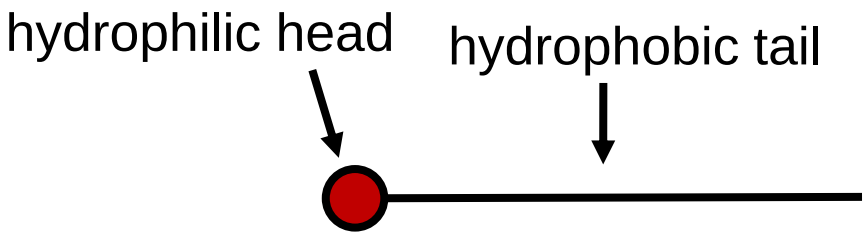
Surfactants

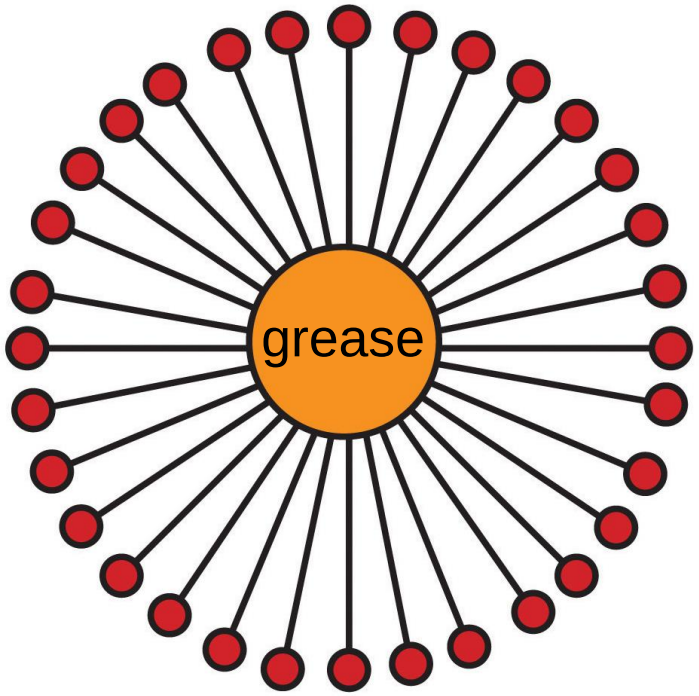
- Source of wetting
- Contribute to detergency
- Organic molecules with a hydrophobic end and a hydrophilic end

Additives

- Added for a variety of reasons (anti-oxidants, chelaters, defoamers)

Surfactants



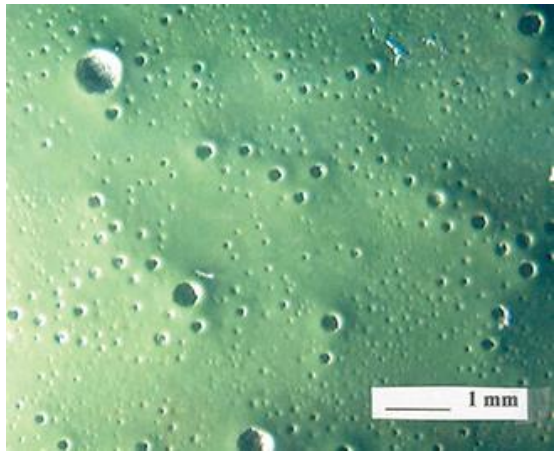


Consequences of Improper Cleaning

Adhesion Failure

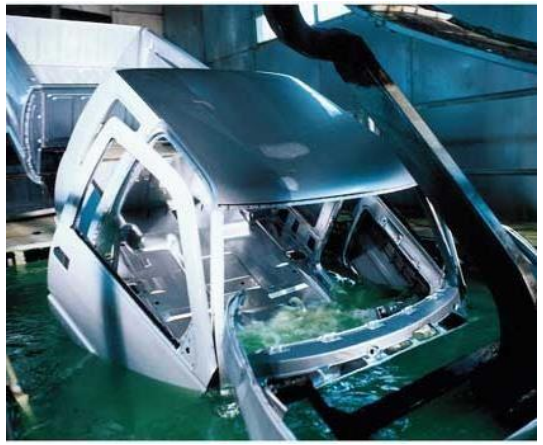
https://www.lpdlabservices.co.uk/problem_solving/typical_technical_expertise/interfaces_adhesion_adhesives_and_coatings.php

Coating Defects



https://www.paint.org/article/automotive-coatings-application-defects/

Bath Contamination



https://www.pfonline.com/articles/pretreatment-for-painting

Understanding Cleaner-Substrate Interactions

ICP-AES

- Dissolved ions in a sample
- Sample baths before and after panel immersion
- Panel etch rate and/or bath component deposition rate

SEM

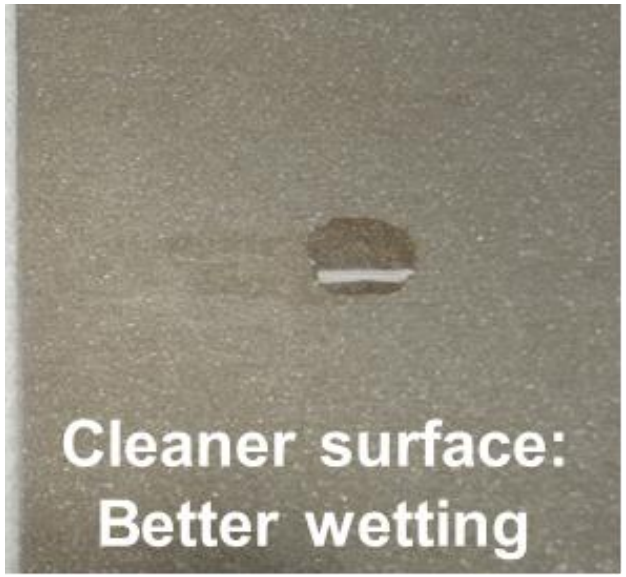
- High-resolution images of cleaned panel surface
- Understanding morphology
- Important for adhesion performance

Contact Angle

- Efficacy of cleaner for soil removal
- Low contact angles difficult to measure

Using the “Lazy Contact Angle” to Evaluate Oil Removal

- **We evaluated oil removal by observing a drop of water on the panel after cleaning.**
  - When the drop of water wetted the surface, this indicated the panel was clean.
  - If the water drop beaded, this indicated oil was still present on the surface.

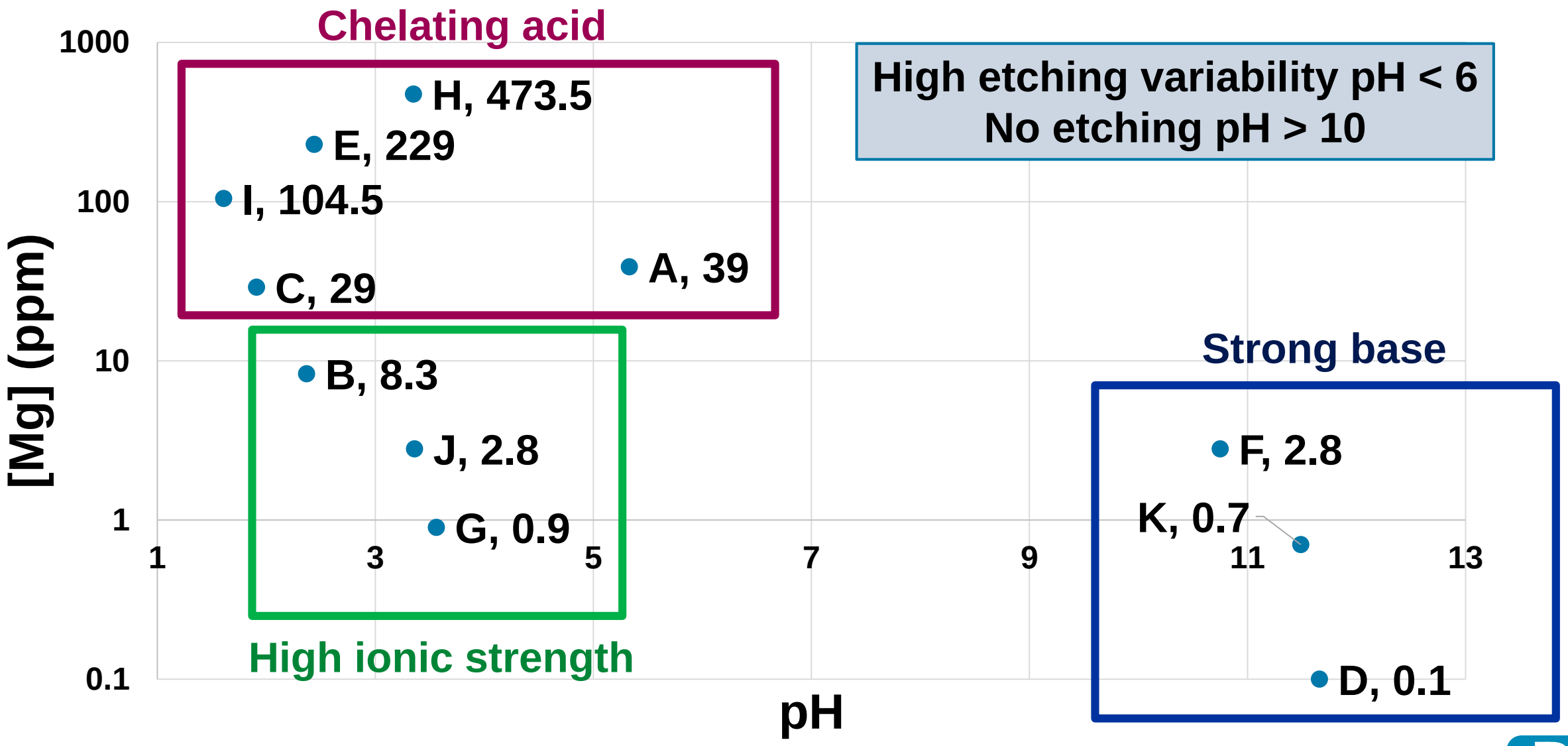


Oil removal was indicated by better wetting of the panel surface.

Soil Removal Efficacy is Not pH-Dependent

Cleaner	pH	Cleans bare panel	Cleans lubed panel	Time required (s)
A	5.3	Y	N	NA/NA
B	2.4	Y	N	30/NA
C	1.9	Y	N	30/NA
D	**11.7**	Y	Y	30/120
E	**2.4**	Y	Y	30/120
F	**10.8**	Y	Y	30/120
G	3.6	Y	N	60/NA
H	**3.4**	Y	Y	30/30
I	1.6	Y	N	120/NA
J	**3.4**	Y	Y	30/30
K	11.5	N	N	NA/NA

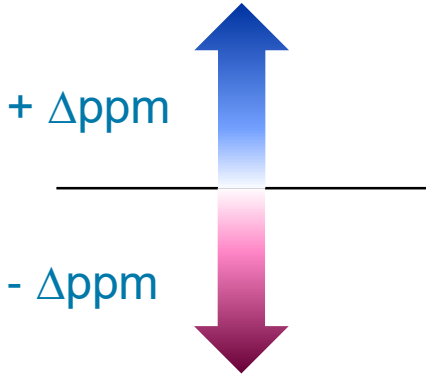
Cleaner pH Does Not Correlate with Degree of Mg Etching



Deposition from Cleaner onto Panel also Evaluable by ICP-OES

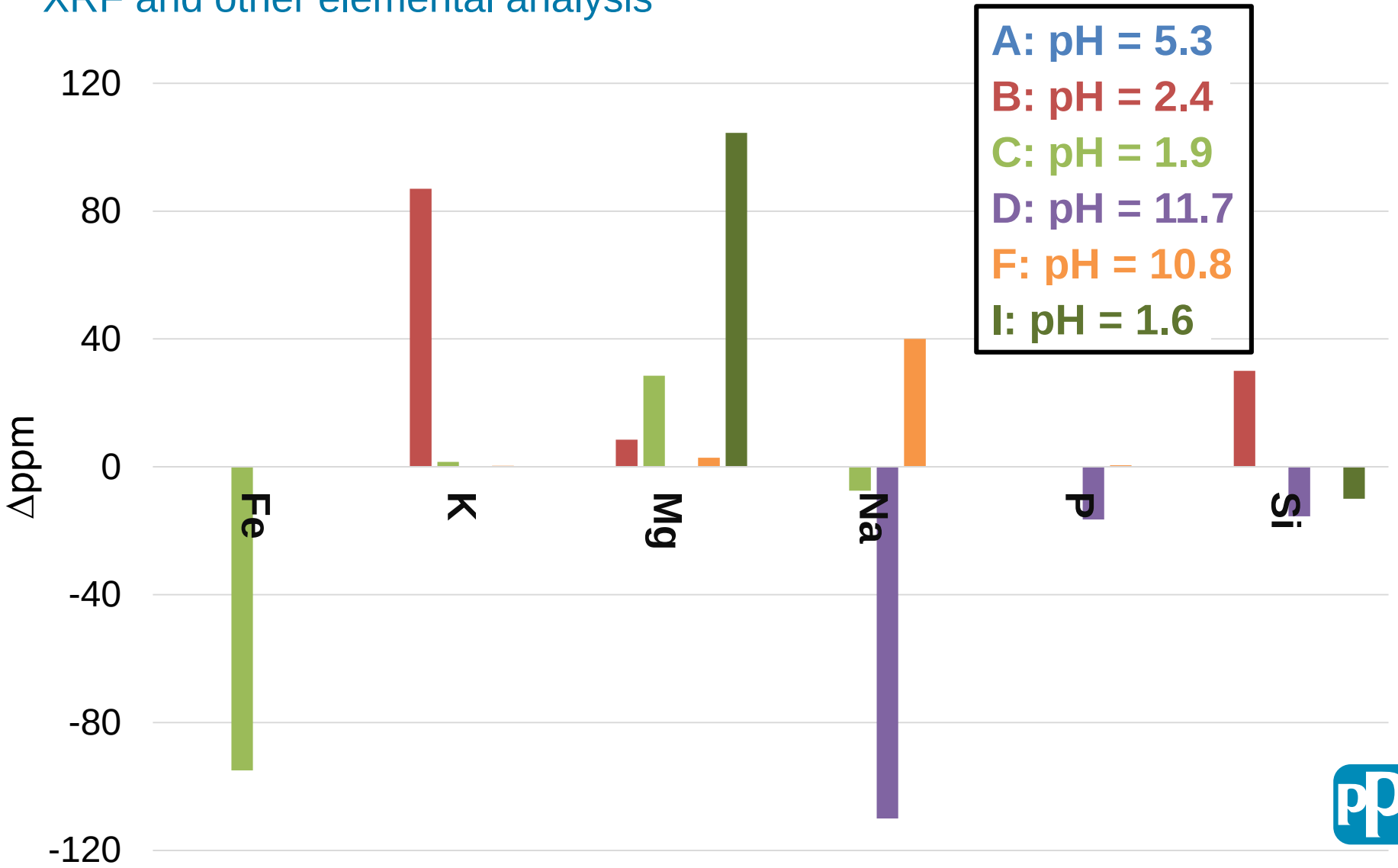
Relevant changes in concentration for elements of interest in the cleaner baths.

Dissolved in Bath



Deposited on Panel

- ICP-OES has been useful for testing deposition onto panel/correlating with XRF and other elemental analysis



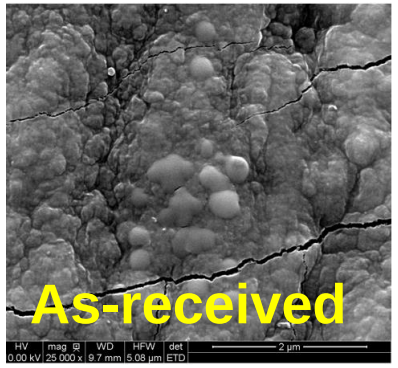
SEM of Panels Shows No Correlation between pH and Surface Texture

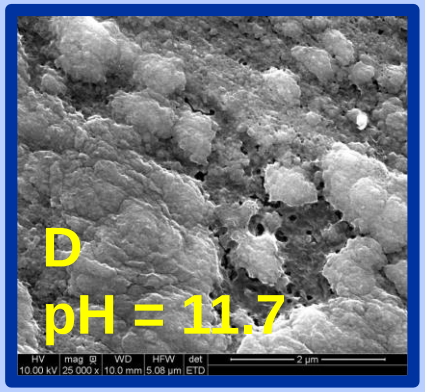
pH

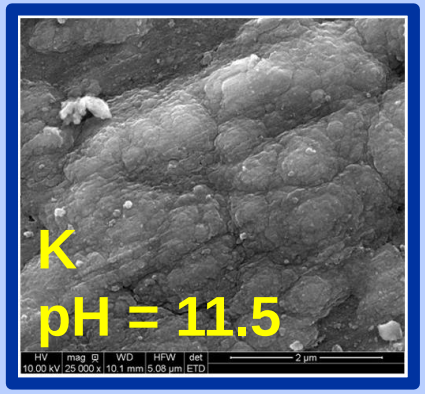
Alkaline

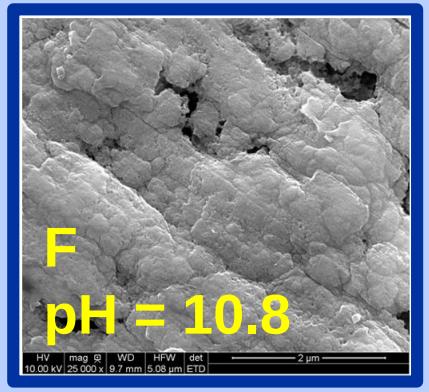
Mild Acid

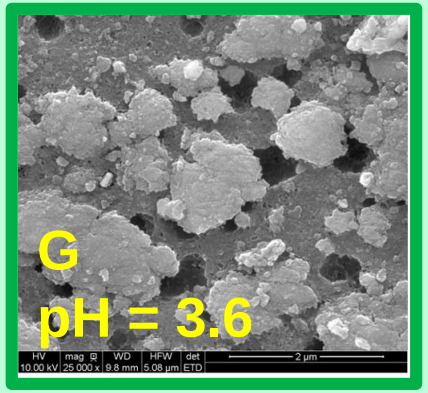
Strong Acid

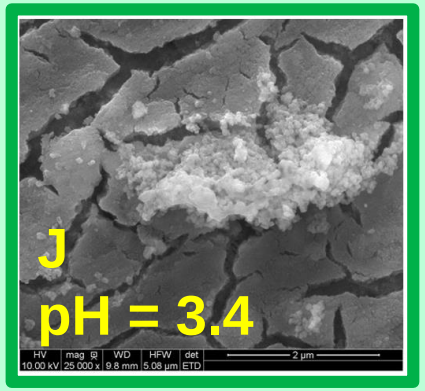


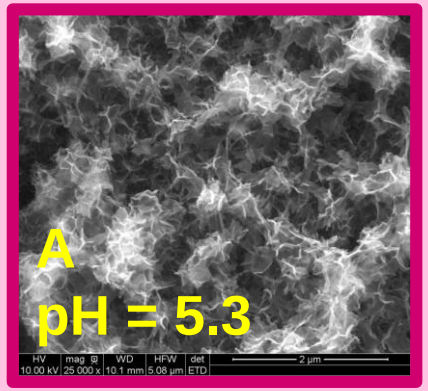


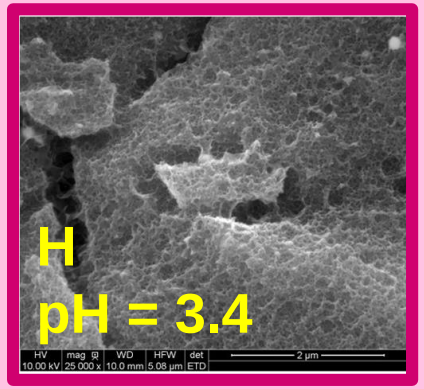


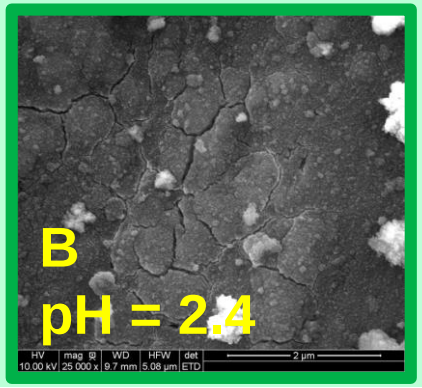


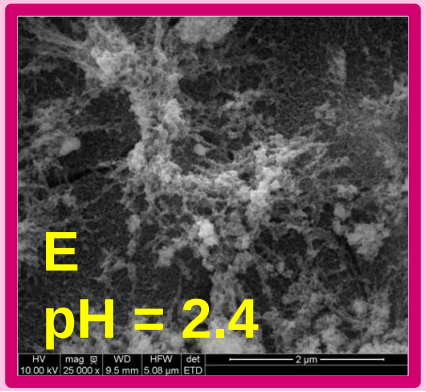


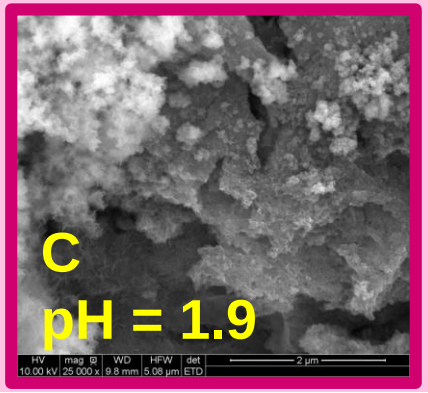






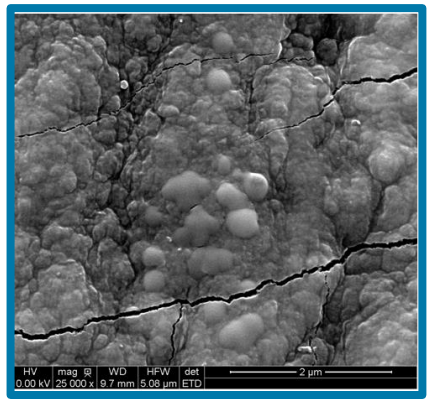


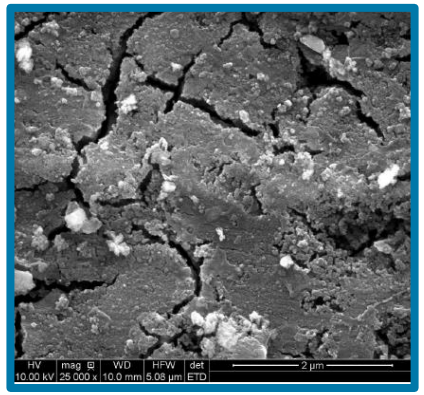
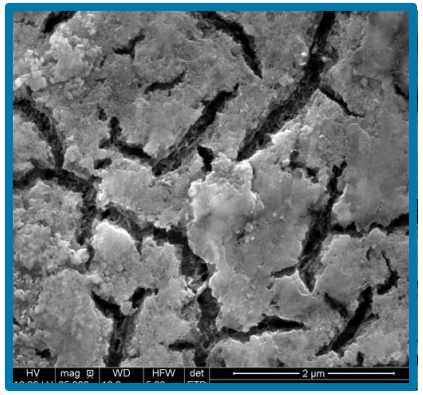
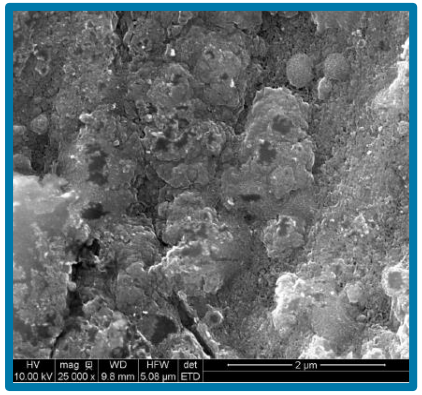
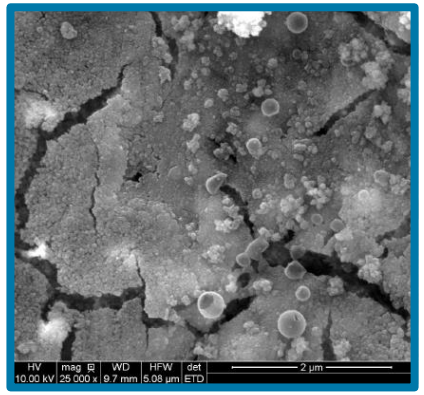
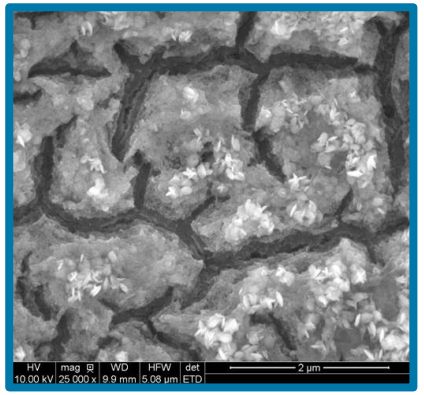
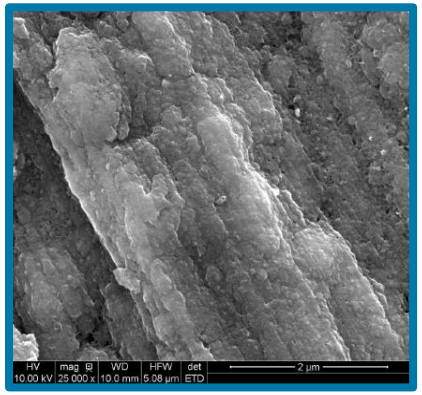
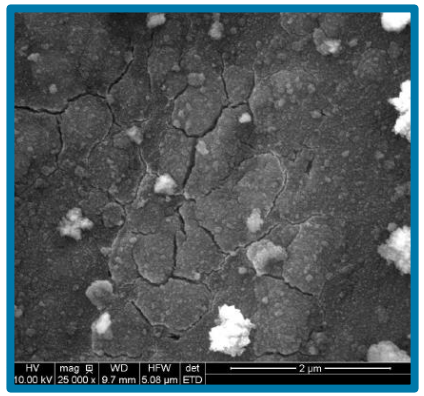
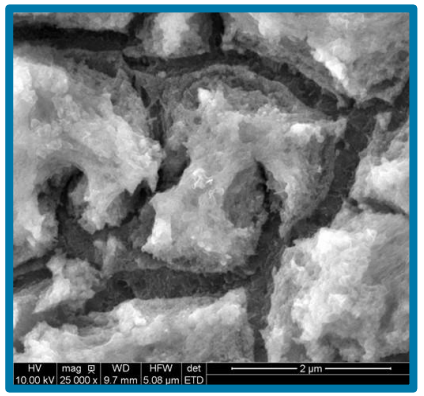
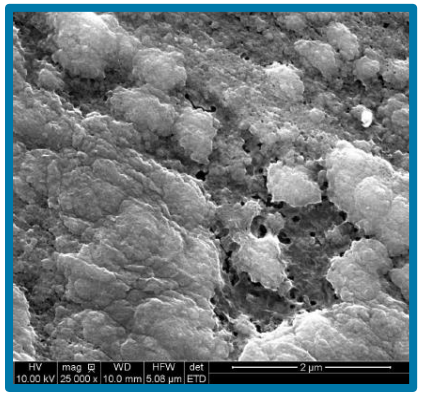




Etch Rate – Changes in Panel Morphology Over Time

Before Cleaning



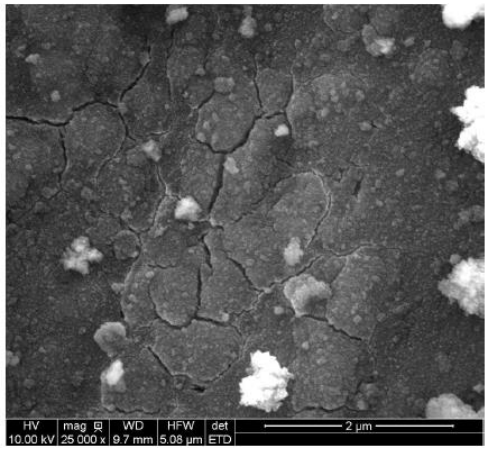
	Low pH/Low Etch - B	Low pH/High Etch - I	High pH - D
30 s			
60 s			
120 s			

Alkaline cleaners (pH > 9) show a smooth morphology that does not change over time.

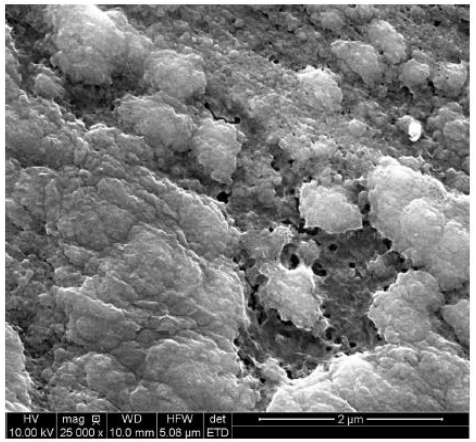
No single type of morphology that appears with etching; rather, the same morphology (mud cracks, pitting) may appear for different etching strengths.

Cleaners and Corrosion Performance

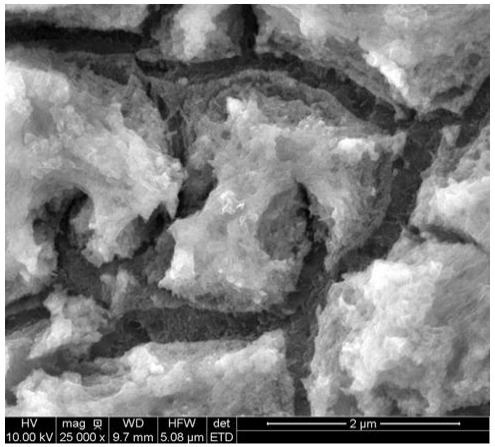
Cleaner B (pH = 2.4)



Cleaner D (pH = 11.7)



Cleaner I (pH = 1.6)



- Rougher surface appears to impart significant corrosion and adhesion benefits
- Additional corrosion protection from low-etch surface treatment

Conclusions and Acknowledgements

- **Cleaner baths with pH levels below 6 show a wide range of etching ability, but no strong correlation between pH and etching ability.**
- **No etching from baths with a pH > 9.**
- **Less chelation/higher ionic strength causes less etching of Mg substrate.**
- **Corrosion results depend strongly on cleaner used; highly morphology and deposition-dependent**

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Lu Chen
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