



P- and Si- Free Staining Inhibitors for Lightweight Metals

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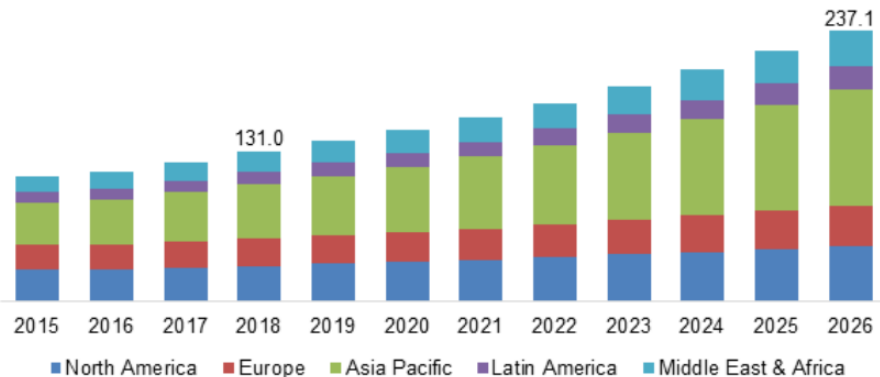


Agenda

- Light weight metals market trend
- Aluminum Staining Root Cause
- Anti-staining Mechanism
- Staining Inhibitor - Existing Technology
- Phosphorus and silicone free technology

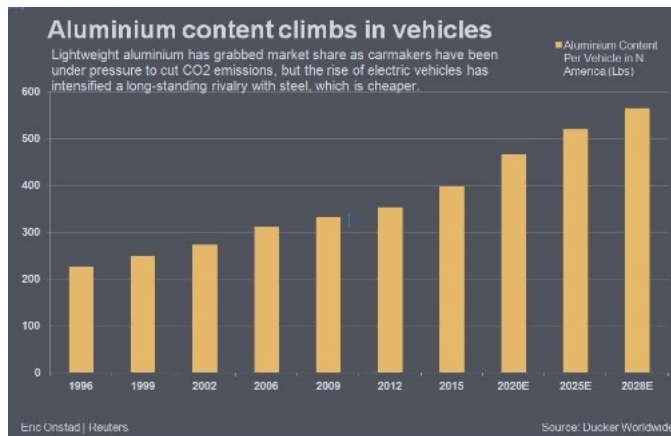
Lightweight Metals Market Trend

Lightweight Materials Market, By Region, 2015 - 2026 (USD Billion)



The global lightweight materials market is estimated to reach USD 237.1 Billion by 2026 with a CAGR of 7.9% - Polaris market research

Aluminum: More and more usage in various applications, especially in automotive industry



Aluminum Staining Root Cause

Aluminum reacts with oxygen and forms a stable oxide layer

- Filiform corrosion—imperfections of other metals used in various aluminum alloys.
- Galvanic or Bimetallic—exposure of aluminum to other metals in the presence of electrolytes
- Poulitice corrosion—natural aluminum oxide layer degrades

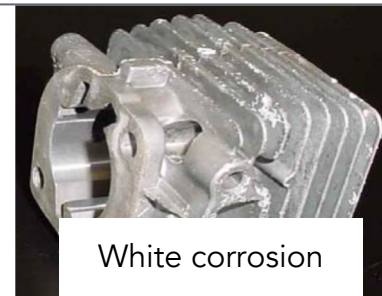
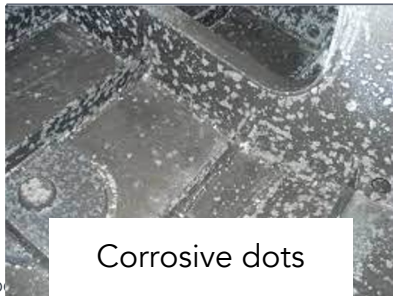
+

High alkalinity

Salts

Water

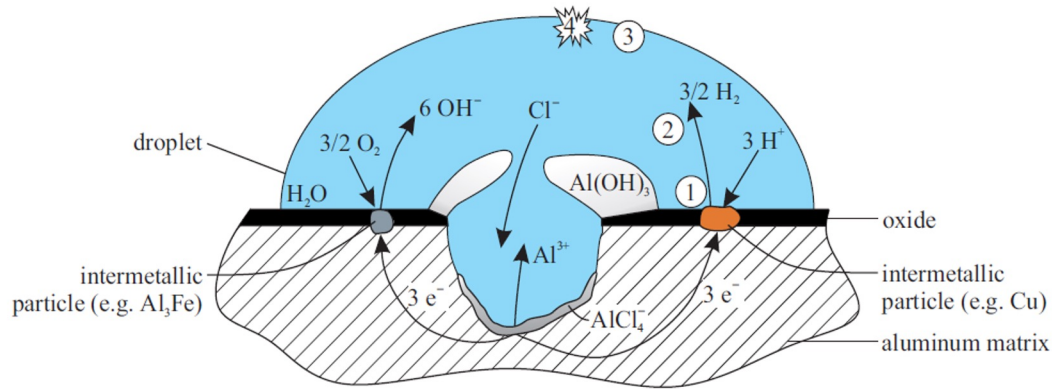
Oxygen



Normal corrosive presence of Aluminum

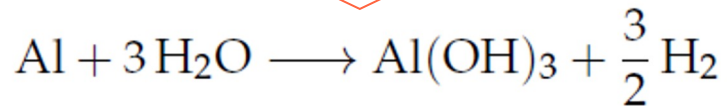


Al Corrosion Mechanism in Aqueous Solution



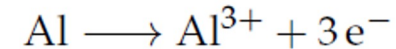
H₂ bubble activity is distinguished into the following phases:

- ① formation, ② detachment from metal surface and movement,
- ③ arrival at droplet surface and growth, and ④ bursting of H₂ bubbles.

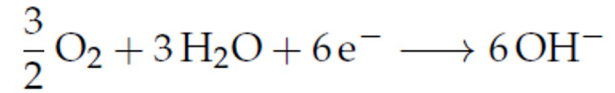


Electrochemical reactions

Anode : oxidation of metal (corrosion)



Cathode : reduction of depolarizing agent



Anti-Staining Mechanism

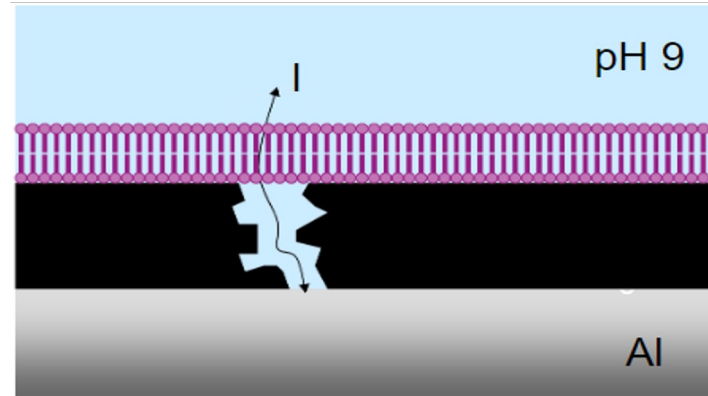
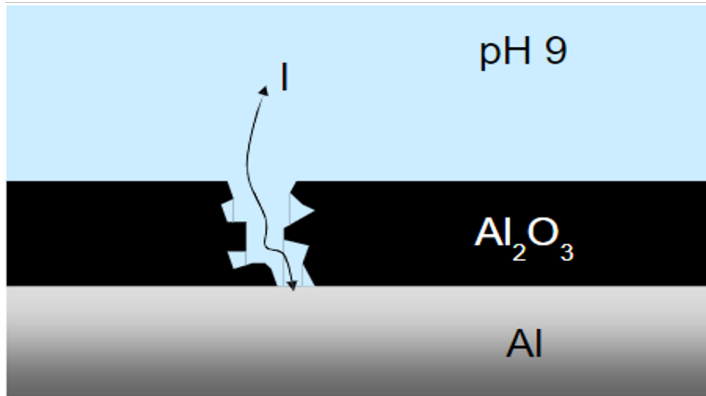
Three main mechanisms:

- Chemical absorption: inhibitors form a protective layer through chemical bonding on Aluminum surface
- Complex formation: inhibitors form a complex with corrosive agents to prevent them from staining the Aluminum surface
- Physical barrier: A protective film formed to protect the aluminum surface from staining

Type of Staining Inhibitors

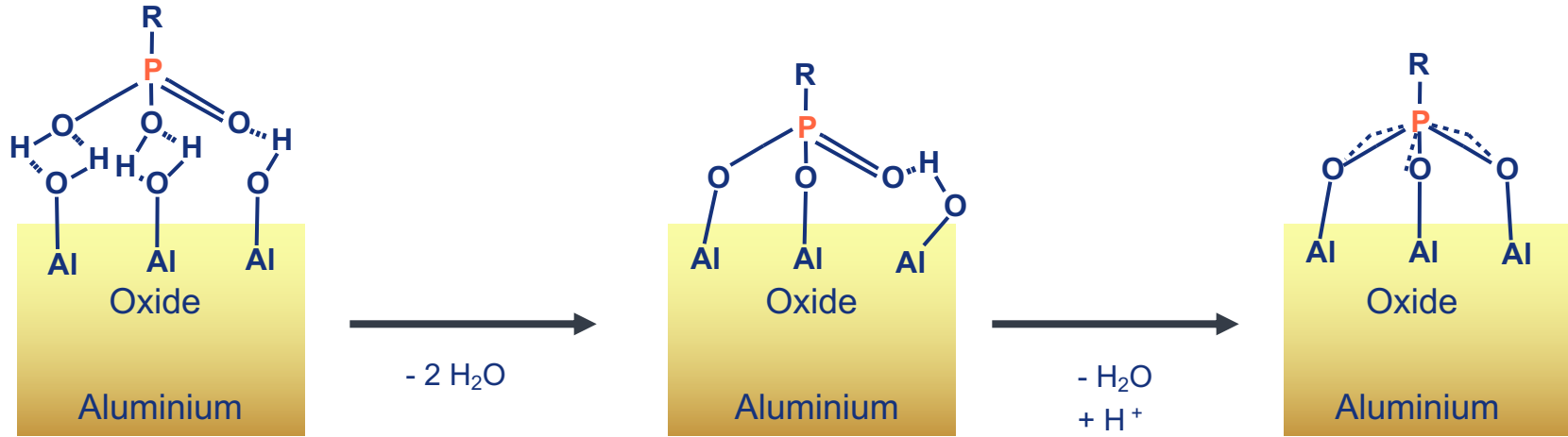
→ Technologies in the market

- Phosphorus based ones– Most effective ones with wide working pH range
- Sulfonates– Poor solubility in base oil
- Carboxylic Acid/amine salts– Narrow pH effective range and hard water sensitive
- Polymers–not to be compatible in synthetic fluids
- Silicates–Not stable enough. Hydrolysis reaction. Tend to form undesirable, tacky residue on the workpiece or the machine tool



Effective Al inhibition layer

Mechanism of Phosphate Ester as Inhibitors

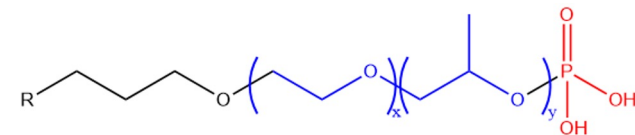
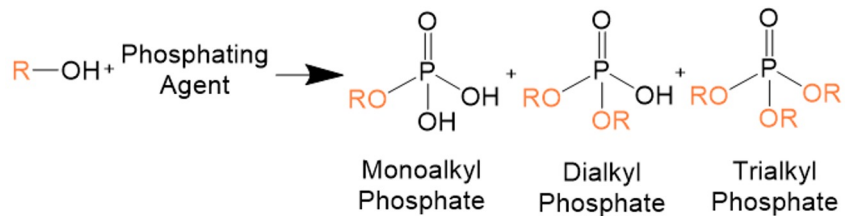


The adsorption and binding of Phosphate ester on the metal surface take place in 3 steps:

1. Acid H-bonded to hydroxylated surface
2. Condensation process
3. Formation of a resonance stabilized phosphonate complex

Phosphate Esters

Phosphate ester chemical structure varies and affects its performance



Fatty alcohol (ROH)

Ethylene oxide (EO)

Propylene oxide (PO)

MAP/DA P ratio

More favorable ecotox classification and labelling

Feedstocks availability and renewable raw materials

Hydrophilic/Hydrophobic balance

Performance: Foam, Staining, Tribology, etc.

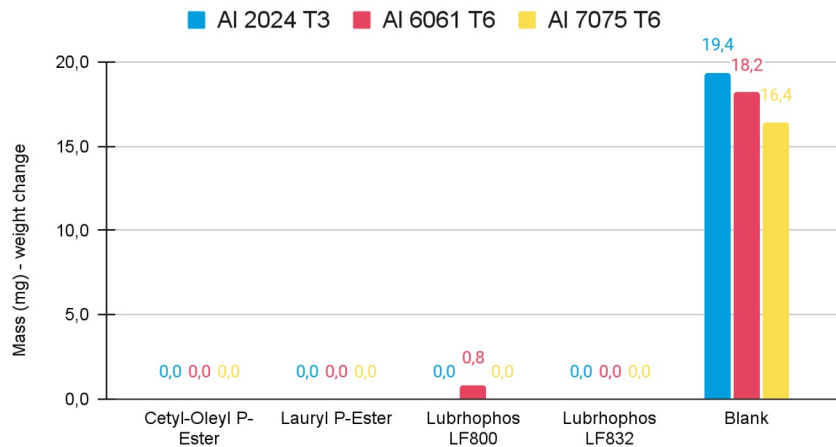
Parameters		Properties
Type of alcohols	<ul style="list-style-type: none"> - Natural or Synthetic - Degree of alkoxylation of alcohols: EO, PO - Length chain 	Surface activity/oil solubility balance
Phosphating agents	<ul style="list-style-type: none"> - P2O5 - Polyphosphoric acid - POCl3 - Hybrids 	Monoalkyl/Dialkyl/Trialkyl Phosphates ratio
Synthesis process	<ul style="list-style-type: none"> Molar ratio Temperature Type of catalyst 	<ul style="list-style-type: none"> - Monoalkyl/Dialkyl/Trialkyl Phosphates ratio - Purity



Aluminum Staining Inhibition – Different Phosphate Esters

DI Water, pH = 9.5

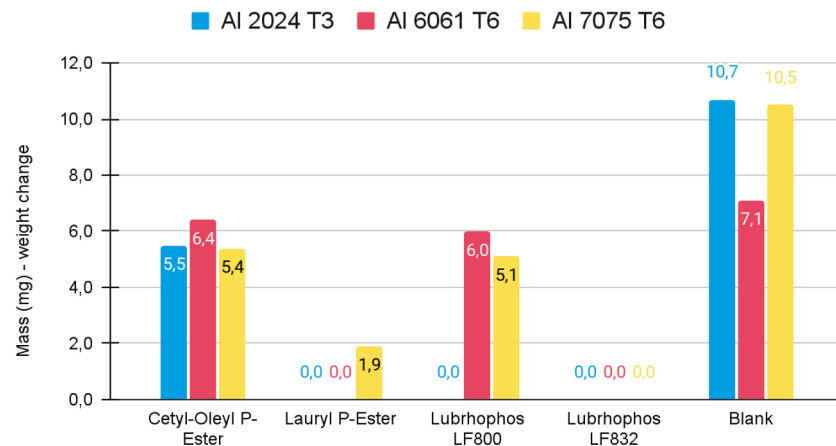
0.5% additive - pH = 9.5 - DI Water / 45°C - 7 days



Lubrhophos® LF 800 and LF 832: Lauryl based phosphate ester

440ppm Hard Water, pH = 9.5

0.5% additive- pH = 9.5 - Hard Water (440 ppm) / 45°C - 7 days












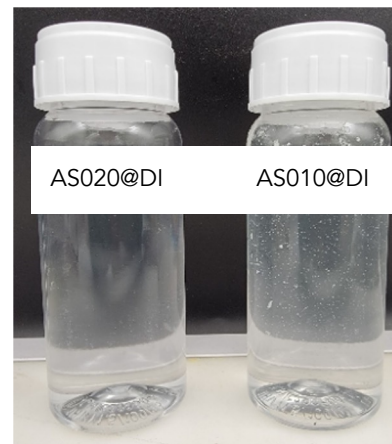
Lubrhophos® LF 832 provides the best staining inhibition across aluminium grades, even in hard water conditions



P - and Si - Free Technology: Geropon AS 020

New type of chemistry providing anodic protection to Aluminum surface and prevent staining

Al coupons half-immersion test								
Additive 0.15%wt@DI water-pH(MEA:TEA=1:3)=9.3, 96h@50°C								
Al 2024			Al 6061			Al 7075		
Blank	Geropon AS 020	Rhodafac AS 010	Blank	Geropon AS 020	Rhodafac AS 010	Blank	Geropon AS 020	Rhodafac AS 010
								
4.256			4.750			4.800		
Weight change,mg								
-	0.1	-0.7	-	0.4	0	-	-0.1	0.1










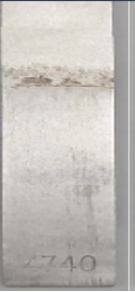
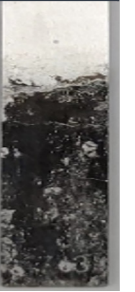
Geropon AS 020 dissolve in water to form a transparent aqueous solution

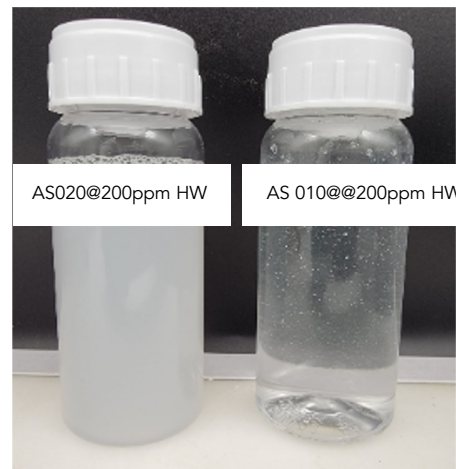
- Geropon AS 020 is an effective inhibitor like Rhodafac AS 010 to answer the rise in most of the Al(alloys) machining process at a low dosage level.

P - and Si - Free Technology: Geropon AS 020

New type of chemistry providing anodic protection to Aluminum surface and prevent staining

Al coupons half-immersion test
Additive 0.15%wt@200 ppm hard water-pH(MEA:TEA=1:3)=9.3, 96h@50°C

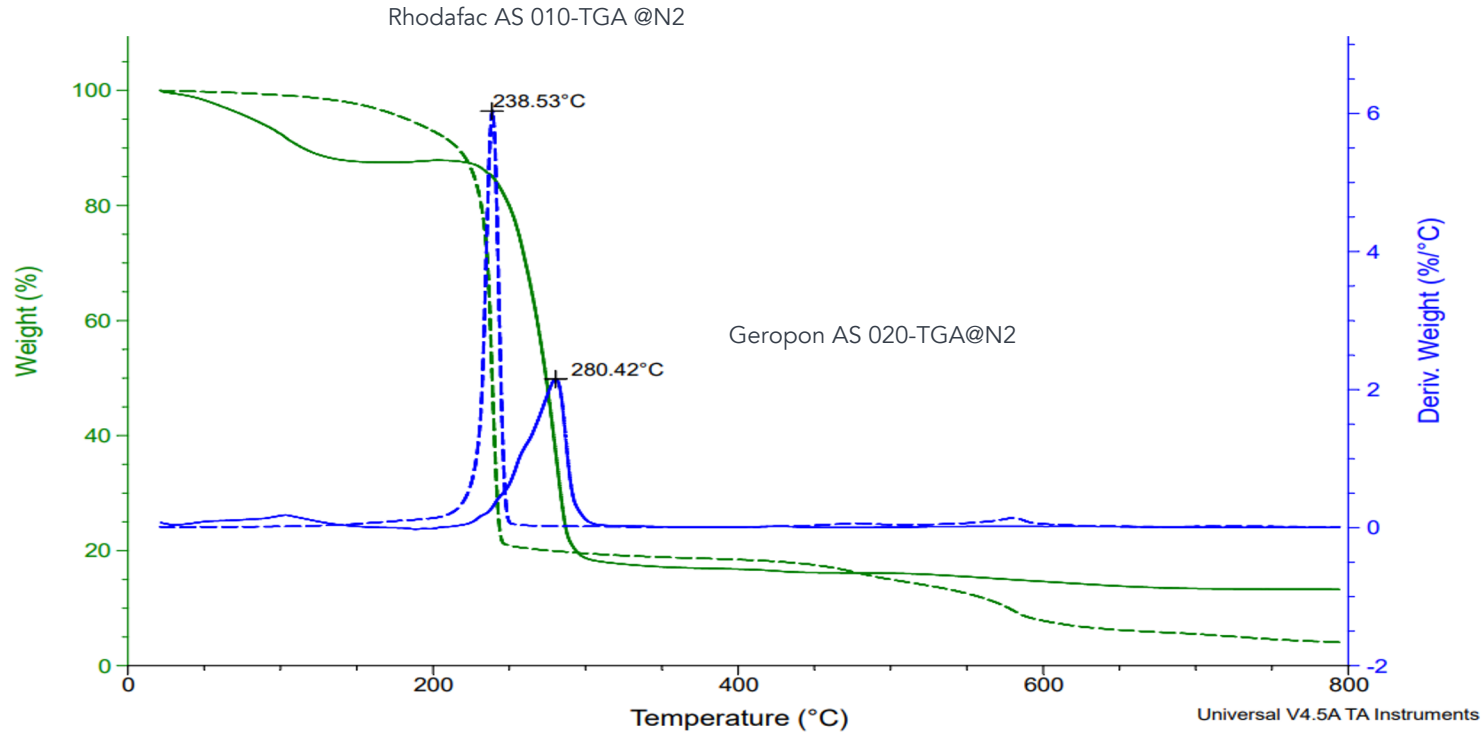
Al 2024			Al 6061			Al 7075		
Blank	Geropon AS 020	Rhodafac AS 010	Blank	Geropon AS 020	Rhodafac AS 010	Blank	Geropon AS 020	Rhodafac AS 010
								
Weight change,mg								
-	0.1	0.1	-	0.4	0.1	-	0.1	0.6



Geropon AS 020 can be dispersible in water to form a stable hazy aqueous solution.

- Geropon AS 020 provides Al(alloys) surface with efficient protection at low dosage.
- Geropon AS 020 shows much better hard water stability than Rhodafac AS 010 in both dispersibility and Al surface protection.

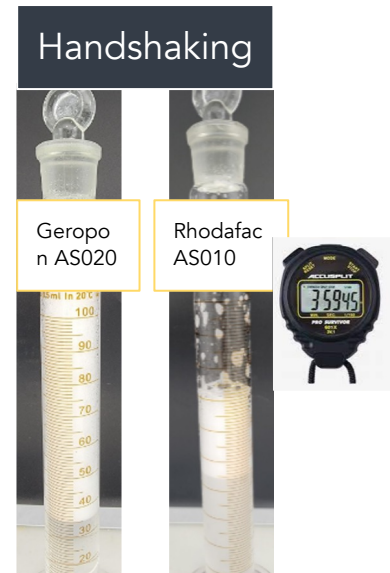
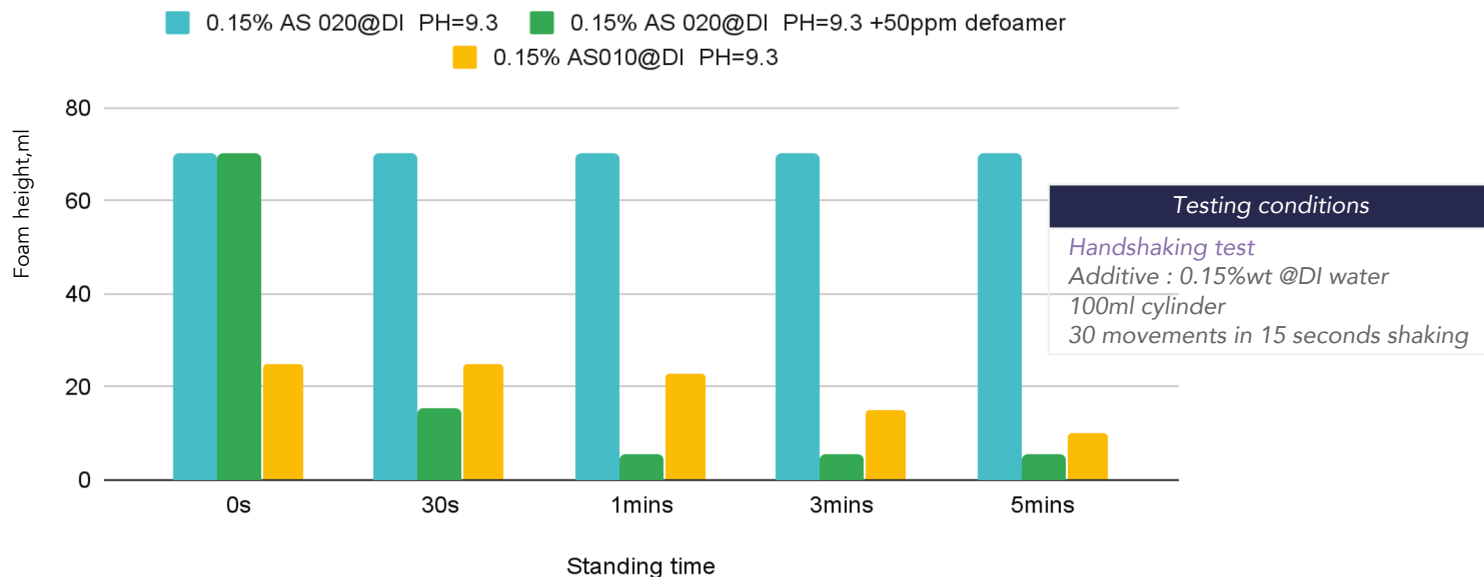
Geropon AS 020: Higher Thermal Stability for Modern Machining



- Geropon AS 020 has almost 40°C higher thermal decomposition temperature than Rhodafac AS 010 and other P esters. Superior solution for modern machining.

Geropon AS 020: Foam Tendency

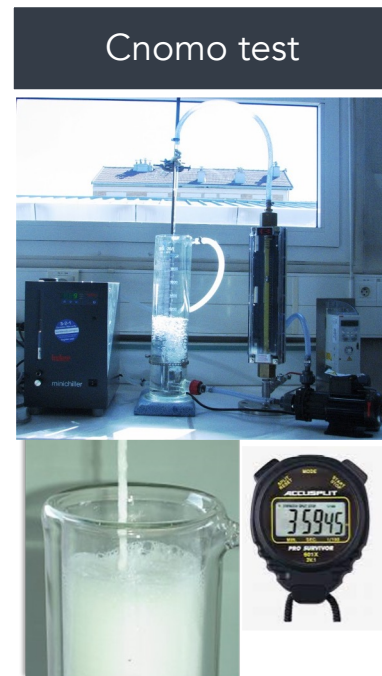
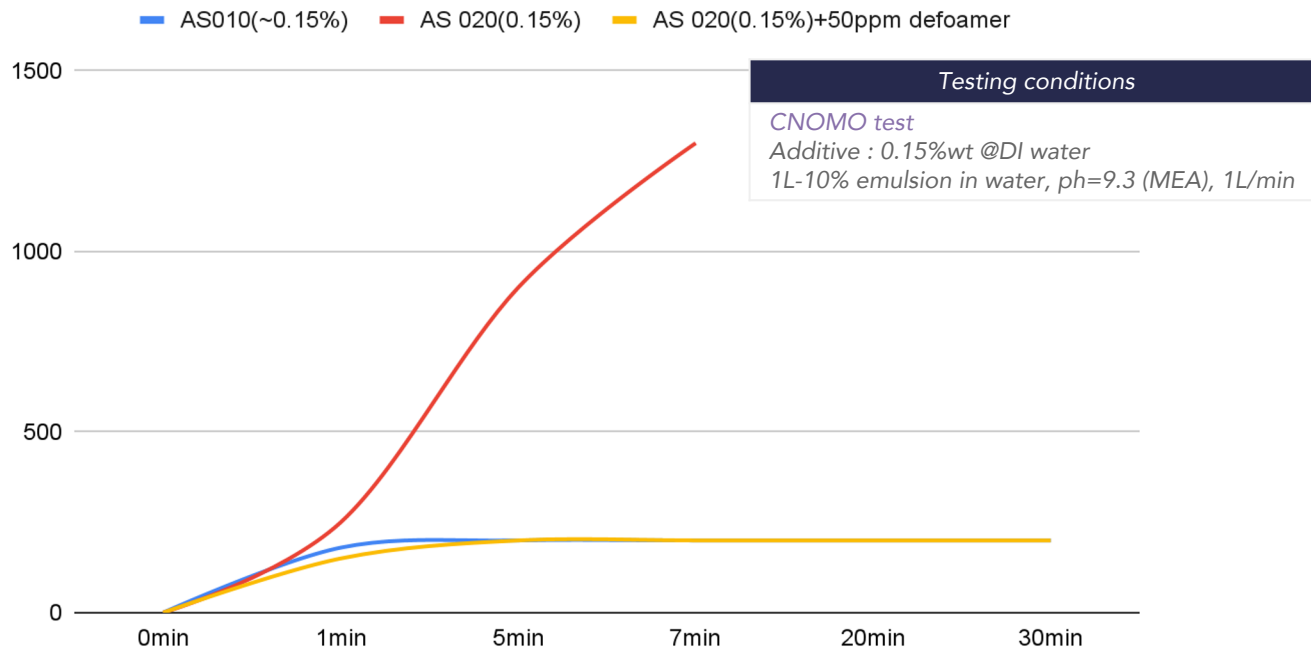
Foam properties of AI inhibitors-Handshaking



- The foam tendency of Geropon AS 020 could be suppressed by tiny amount of defoamer to a lower foam level.

*Rhodafac AS 010-Alkyl Phosphate Type Aluminum Corrosion Inhibitor of Solvay.

Geropon AS 020: Foam Tendency



- The foam tendency of Geropon AS 020 is higher than Rhodafac AS 010 but could be suppressed by tiny amount of defoamer to a lower foam level.

Conclusion

- Light metals like Aluminum and its alloy are susceptible to staining during machining
- Aluminum staining root cause: Filiform, Galvanic and Poulitice corrosion
- Anti-staining mechanism: Chemical absorption, complex formation and physical barrier
- Type of staining inhibitors: Phosphate esters, sulfonates, carboxylic amine, polymer, silicates, etc.
- Phosphate esters: chemical structure varies and affects its performance
- New P- and Si- free inhibitor: effective anti-staining additive, especially in hard water and higher temperature stability but needs to be combined with anti-foam

Thank You