

Development of a Nonchromate Structural Adhesive Bond Primer

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UTRC

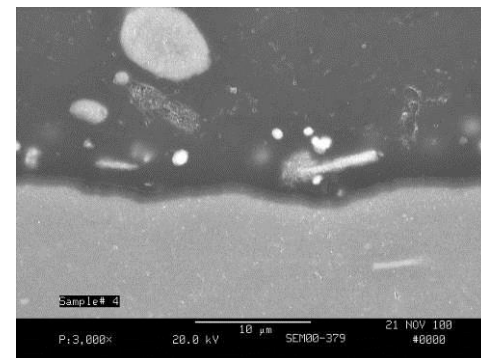
2014 AsetsDefense meeting

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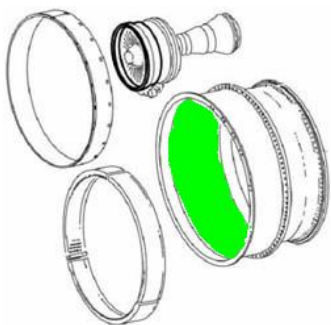
Overview: Chromated Structural Adhesive Bond Primers

- Nominally 5 microns thick
- Prevent corrosion of base metal
- Applied to porous anodized surface
- Overcoated with non-inhibited epoxy adhesive
- High adhesive bond strength required for life of product
- Used in **load bearing applications** in **flight-critical** hardware
- Anodized surface / primer interface stability is critical
- Typically 5% or less SrCrO_4 by weight as sprayed

Adhesive bond primer / anodize interface



Fan Case Internal Bonding



All-composite propellers



Helicopter main rotor, blade pockets, swashplate



Engine nacelles
Aerostructures



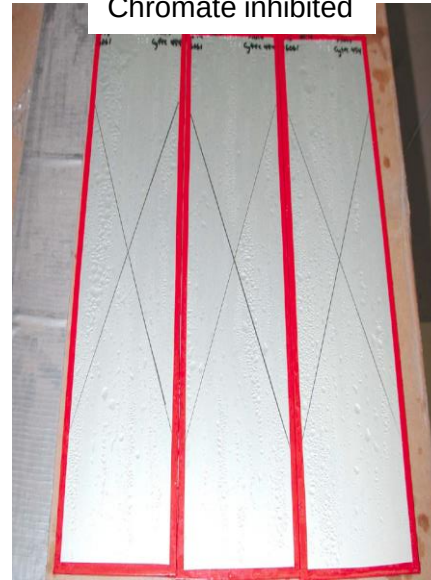
Previous testing of chromate free adhesive bond primers

- Three companies (3M, Cytec, Henkel) produce aerospace structural adhesive bond primers
- Long-running surveillance of chromate-free alternatives by UTC companies shows weak corrosion inhibition

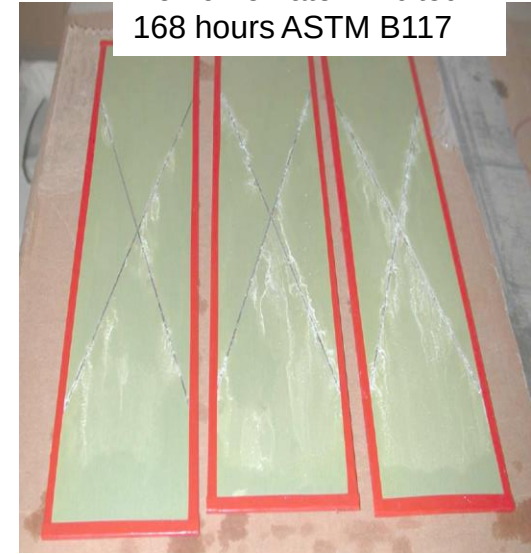
- (A) strontium chromate- inhibited bond primer, 2024 Al, 336 hours
- (B) Cytec BR6700-1, 2024 Al, 168 hours

- Inhibition technology appears “low tech”: alkali silicate, zinc phosphate

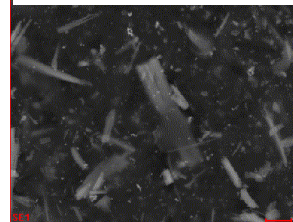
Chromate inhibited



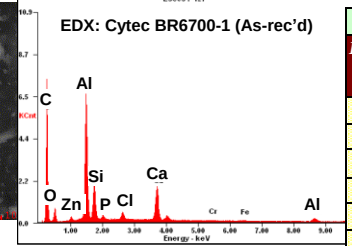
Non chromate inhibited
168 hours ASTM B117



SEM: Cytec BR6700-1 (As-rec'd)

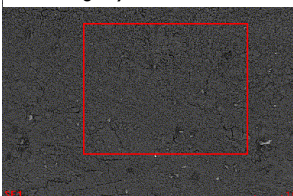


EDX: Cytec BR6700-1 (As-rec'd)

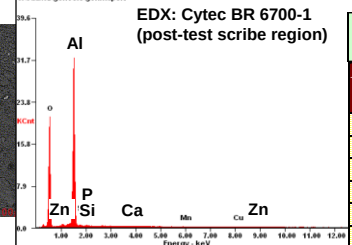


Cytec BR 6700-1 (As-rec'd)			
Element	At%	Atomic ratio	Possible component
AlK	3.92	43.56	Ca ₂ SiO ₄ , CaAlSiO ₃ , ZnO
SiK	1.09	12.11	
PK	0.09	1.00	
ClK	0.17	1.89	
CaK	0.79	8.78	
ZnK	0.19	2.11	

SEM: Cytec BR 6700-1 (post-test scribe region)

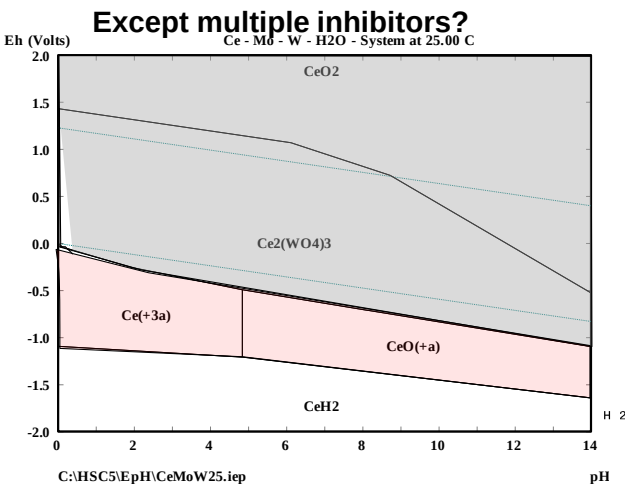
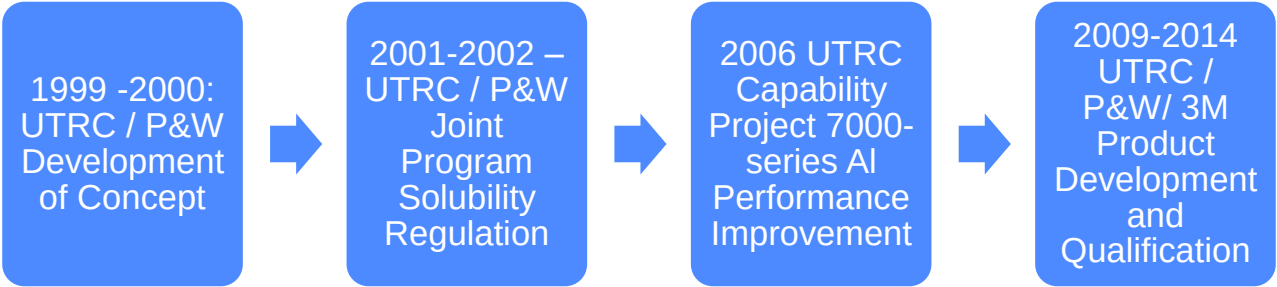
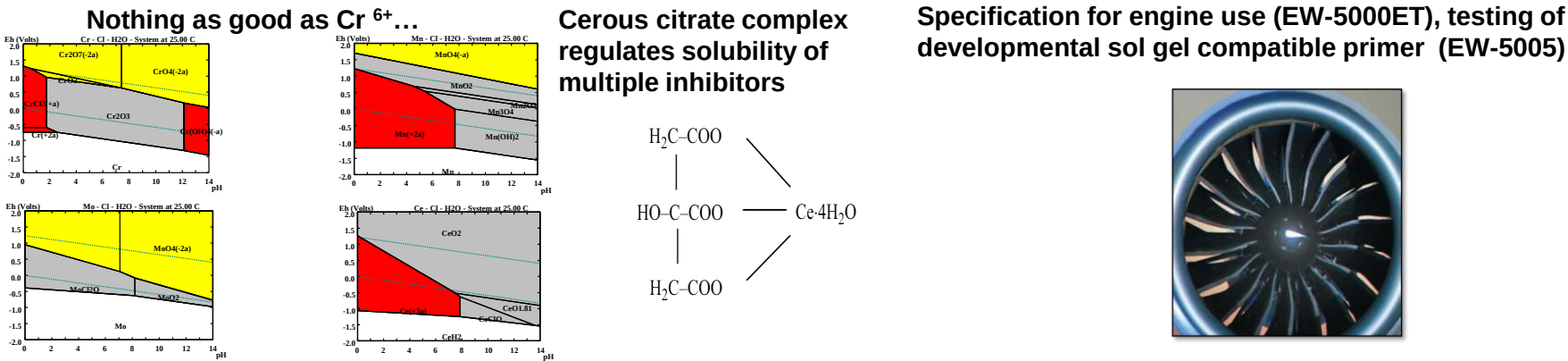


EDX: Cytec BR 6700-1 (post-test scribe region)



Cytec BR 6700-1 (post-test scribe region)			
Element	At%	Atomic ratio	Comment
AlK	33.14	552.33	Zn, P, Ca, and Si migrated
SiK	0.2	3.33	
PK	0.17	2.83	
CaK	0.09	1.50	
MnK	0.06	1.00	
CuK	0.24	4.00	
ZnK	0.21	3.50	

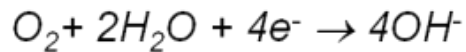
Development timeline for UTC Chromate-Free Adhesive Bond Primer



Corrosion Science Model used to Develop Non Chromate Inhibitor

Corrosion involves at least two electrochemical reactions: Anodic (metal oxidation) and cathodic (i.e., oxygen reduction)

Cathodic sites



Anodic sites: $\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$

Anodic $\rightarrow$ Cathodic ?

Al_2O_3 passive film

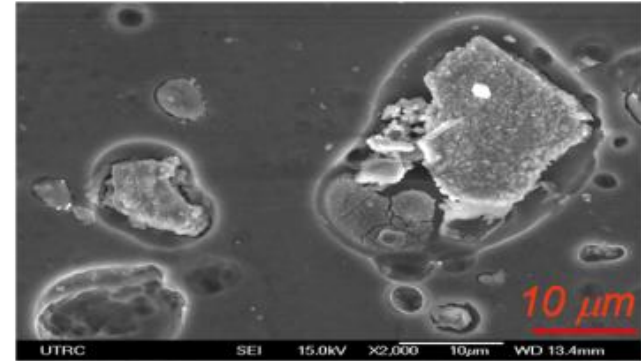
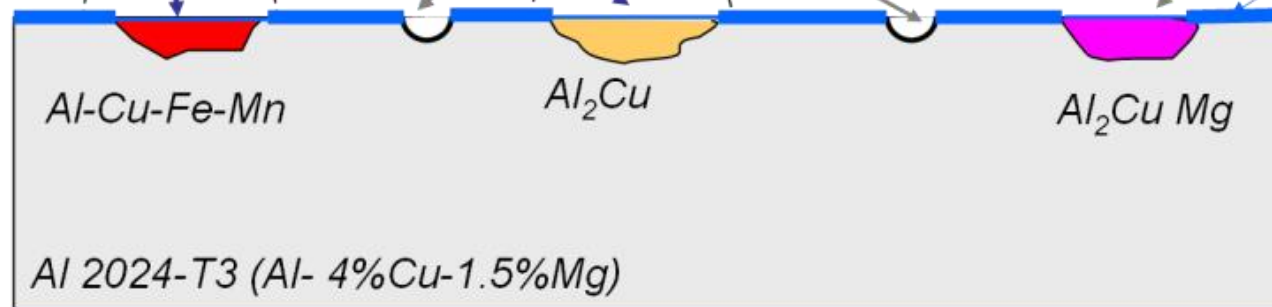


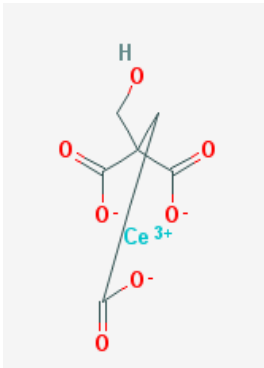
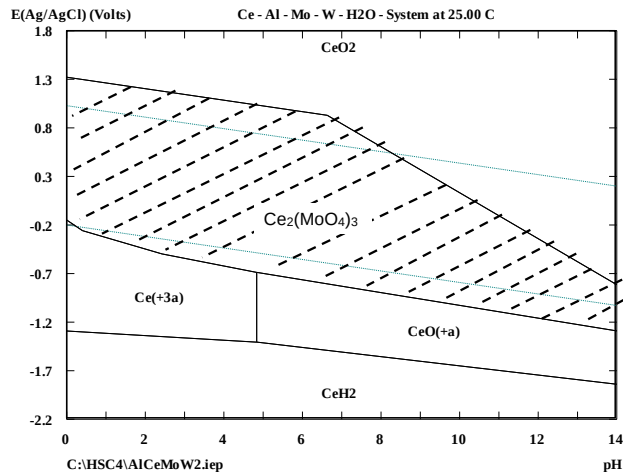
Fig.1 Corrosion of Al 2024-T3 in NaCl

An effective corrosion inhibitor system must demonstrate both anodic and cathodic inhibition in order to effectively prevent corrosion of Al alloys

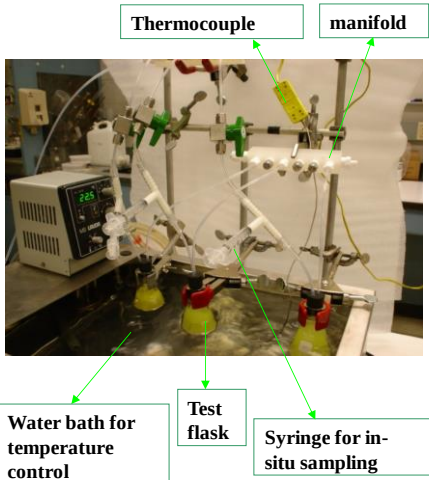
Thermochemical Strategy for Multimode Inhibitor

Thermochemical identification of inhibition system

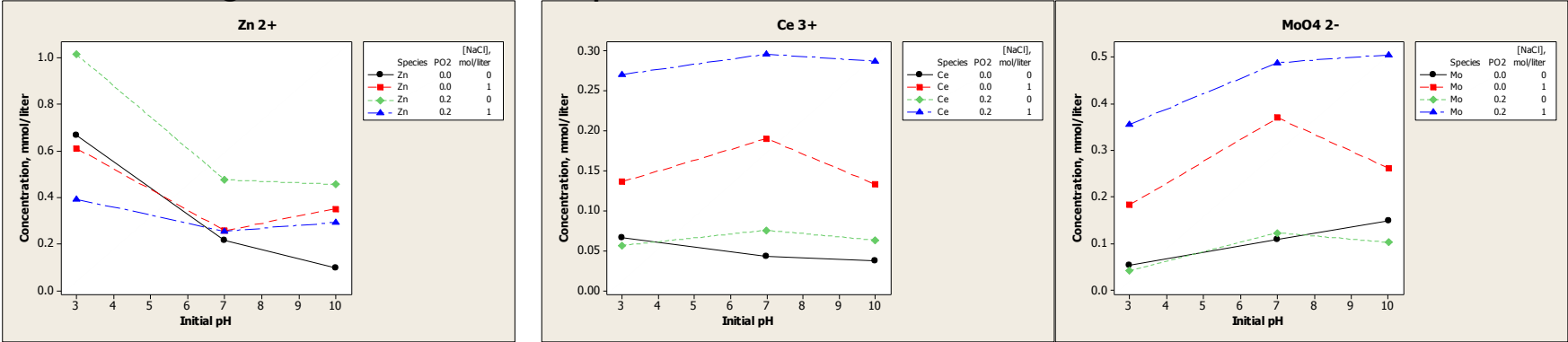
Cerous citrate chelation complex regulates solubility



Solubility test set-up

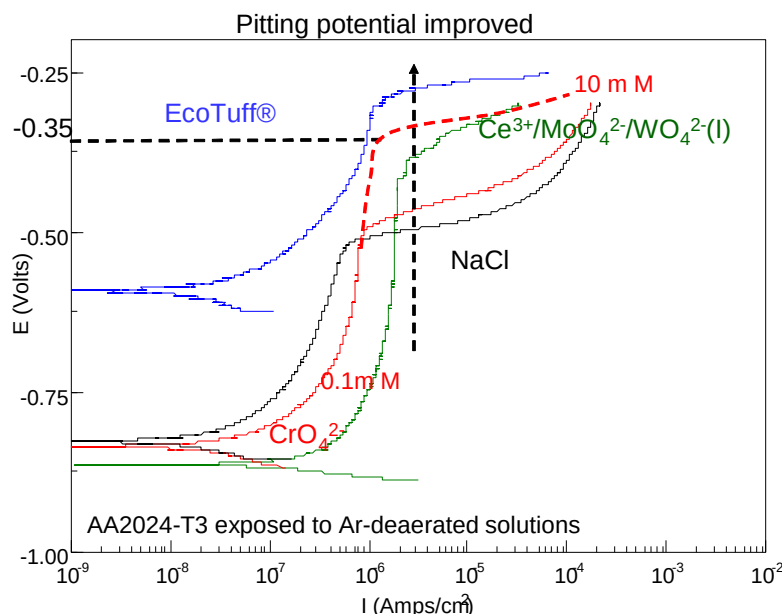


Target solubilities of separate corrosion inhibitor achieved

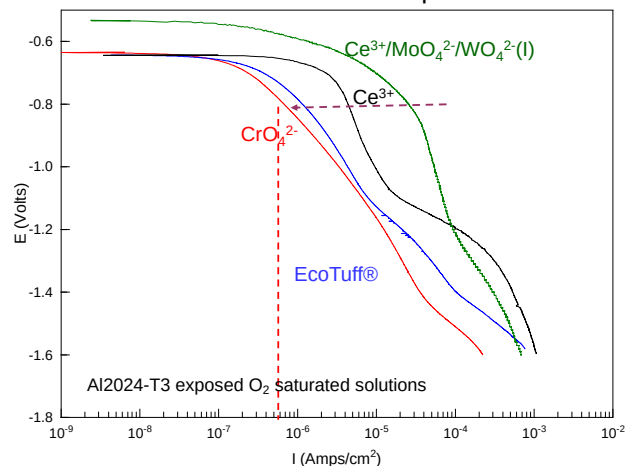


Electrokinetic Confirmation of Active Inhibition in Coatings

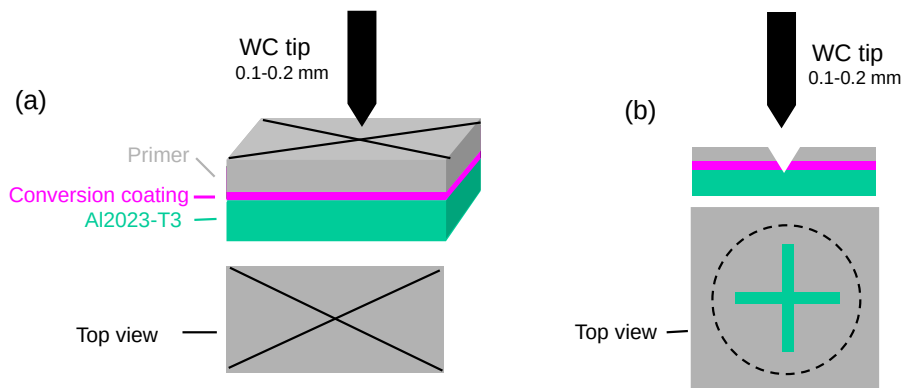
Static DC Testing on Bare Al



Cathodic inhibition comparable to Cr 6+



Dynamic damage testing of trial primers

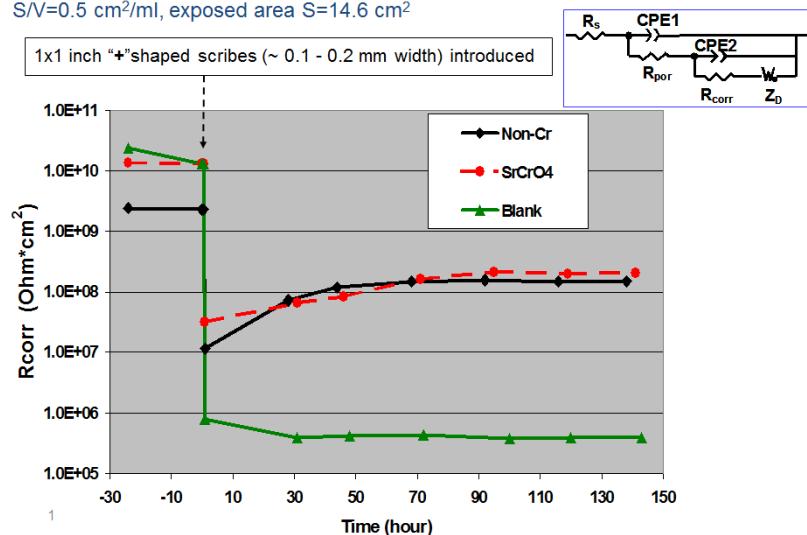


Schematic of defect production and samples for salt spray (a) and EIS test (b).

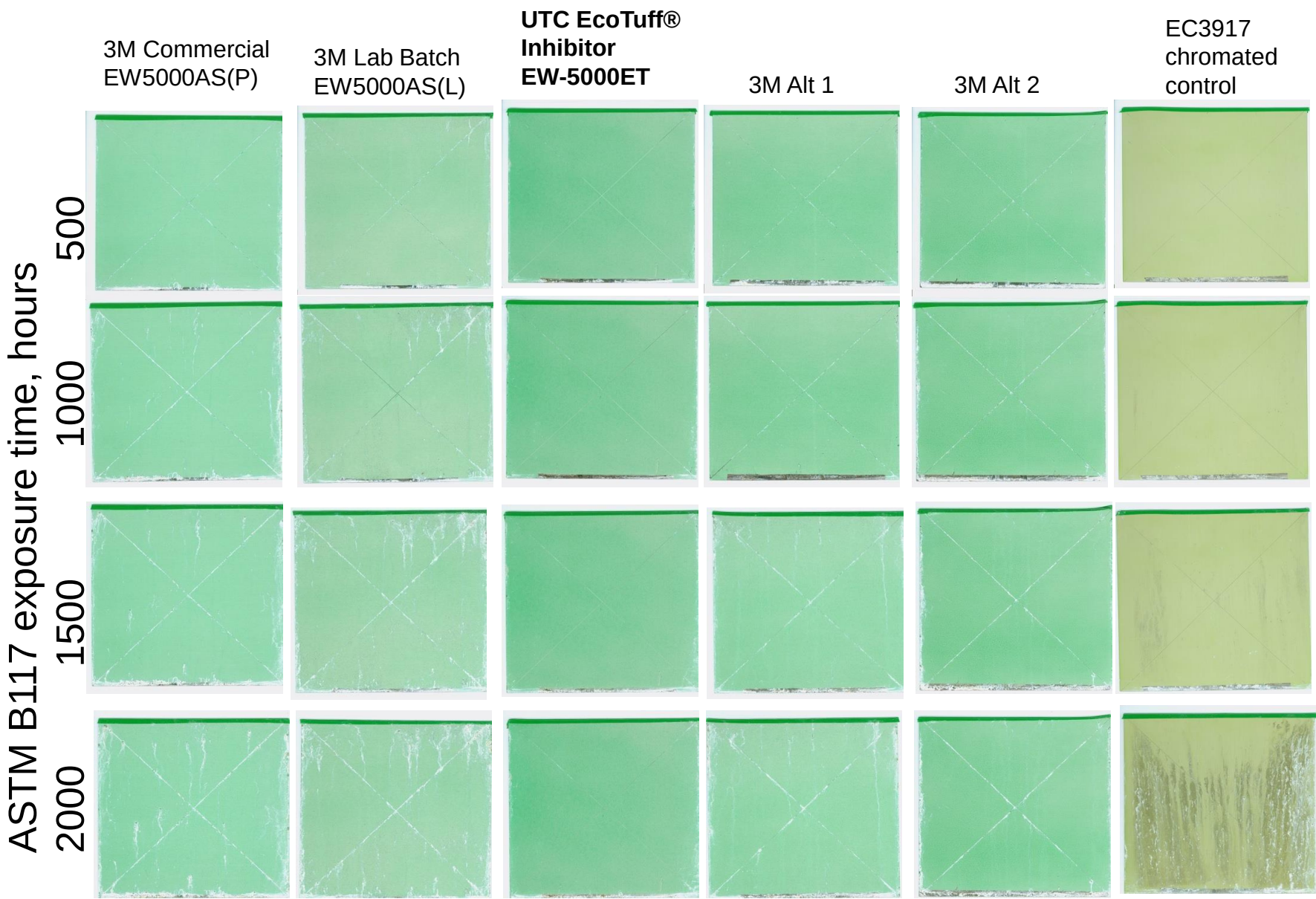
EIS-Based Damage Resilience Test

"Self-healing" is indicated for non-Cr inhibitors incorporated in epoxy primer

$S/V=0.5 \text{ cm}^2/\text{ml}$, exposed area $S=14.6 \text{ cm}^2$



3M / P&W / UTRC Corrosion Test Results PAA treated 2024-T3 Al



2014 R&D 100 Award to UTRC / P&W / 3M Team

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