When to use a SilcoTek® Coating in Corrosive Environments (and When to Consider Alternatives)

Your Presenter:

Dr. Min Yuan, PhD

Min is a Research and Development Scientist with SilcoTek who is focused on solving our customers' corrosion problems.

Today, she will help you learn more about corrosive applications where our coatings can increase lifetime and overall performance of your products and systems.

SilcoTek®

Welcome!

Webinar will be recorded and emailed to you

– You can find it any time on SilcoTek.com

#AskSilcoTek on Twitter (@SilcoTek)

?

Feel free to send questions at any time

This webinar will discuss:

- What corrosion is and how it occurs
- How SilcoTek coatings work and how they're different than typical solutions
- Coating benefits and performance
- When to use/when not to use our coatings

Our Speaker: Dr. Min Yuan

- Ph.D. in Materials Chemistry (Cornell University, 2005)

- Worked at IBM T.J. Watson Research Center and Varian Semiconductor Equipment Associates (now part of Applied Materials)

Our Speaker: Dr. Min Yuan

- Prior to joining SilcoTek, focused on thin film and silicon solar cell development

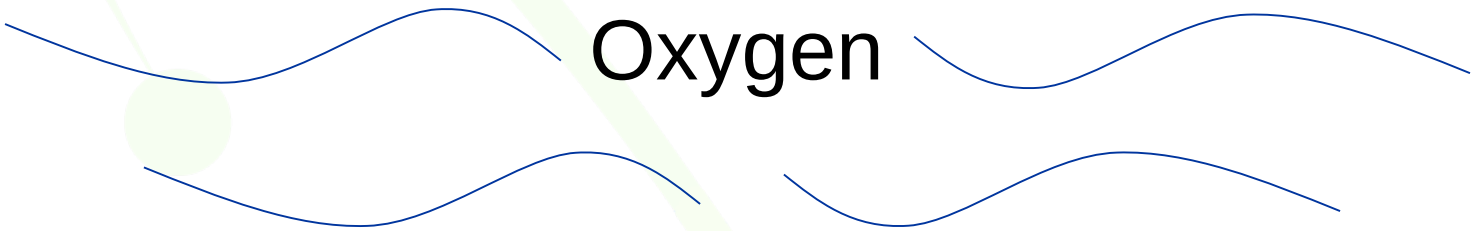
- Joined SilcoTek's R&D staff in 2013 and has a large focus on corrosion applications

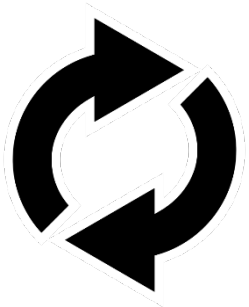
What is

What is Corrosion?

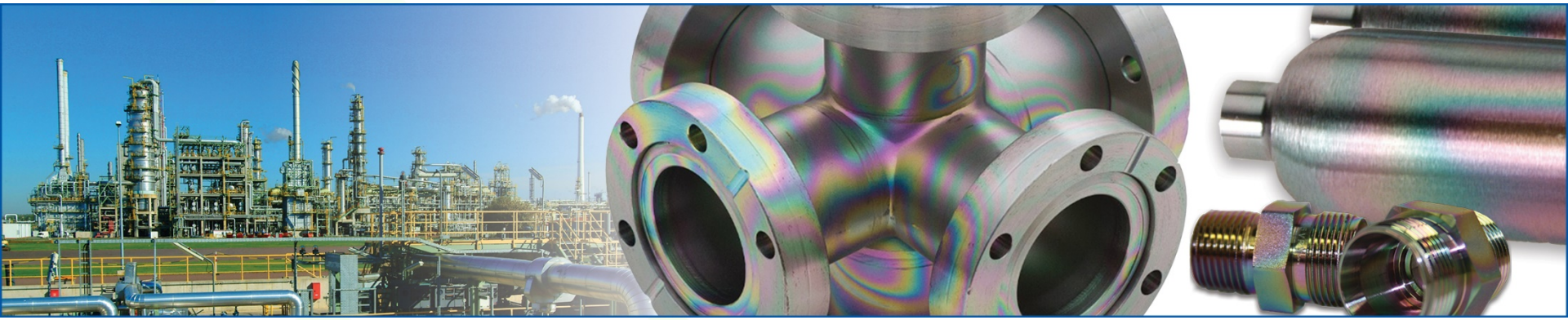
- Corrosion is a **chemical change** that takes many forms
- Corrosion can be very slow or rapid depending on the environment
- Base material selection is critical, even when using coatings

A General Corrosion Process





Metal Oxide

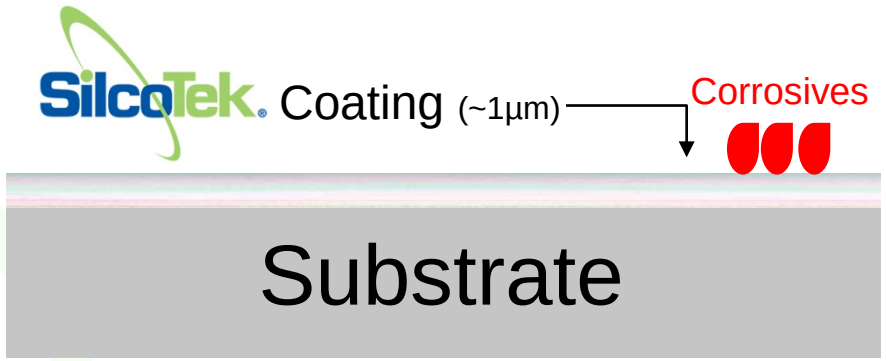


SilcoTek Coatings as a Solution

What are SilcoTek Coatings?

What are SilcoTek Coatings?

- Barrier coatings- prevent chemical interaction with the surface of a part



- Why?

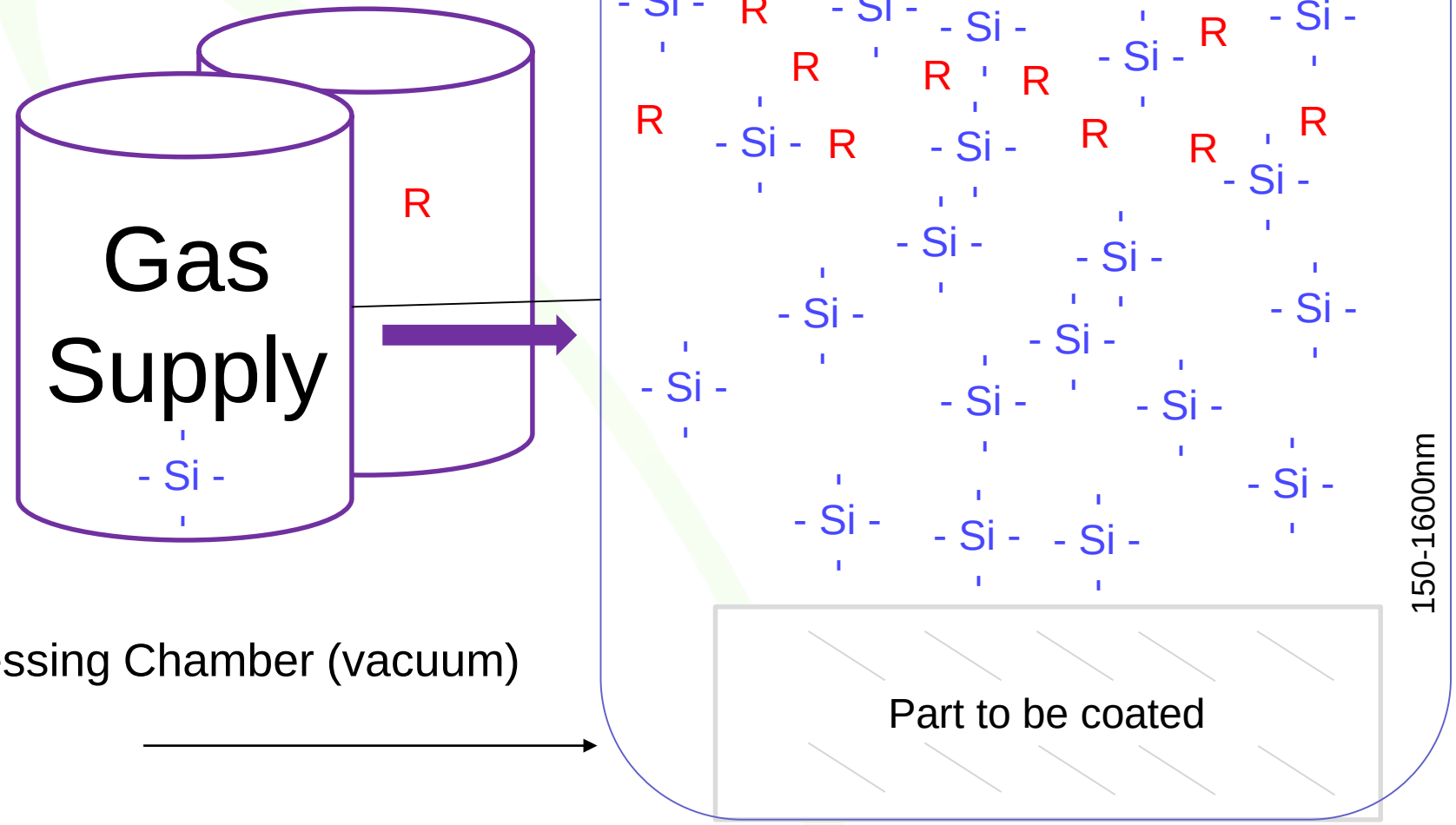
  → Improve the surface properties of **preferred** base materials e.g. stainless steel

The Coating Chemistry

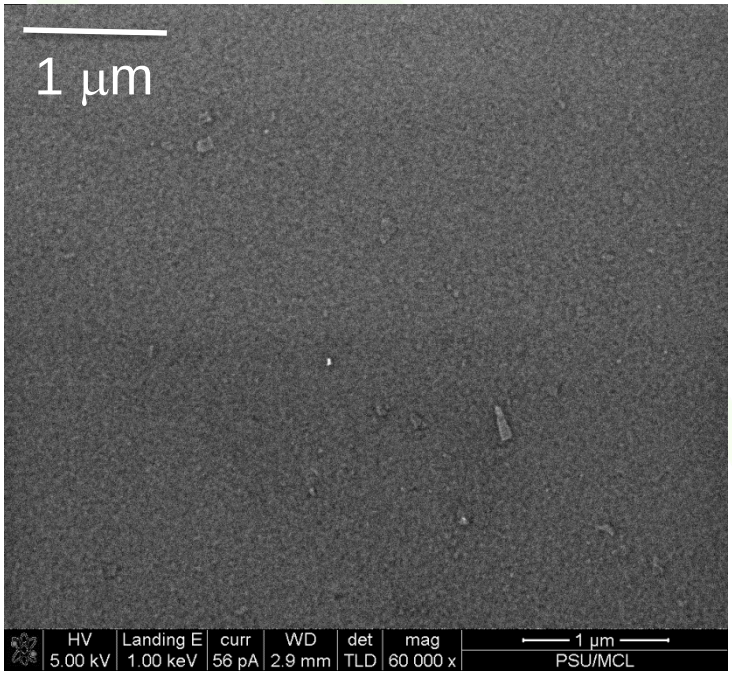
- Coatings consist of a Base Layer and a Surface Layer
  - Base is 150-1600nm of:
    - Si (Silco-) or
    - Si – O – C (Dur-)
  - Functionalized surface:

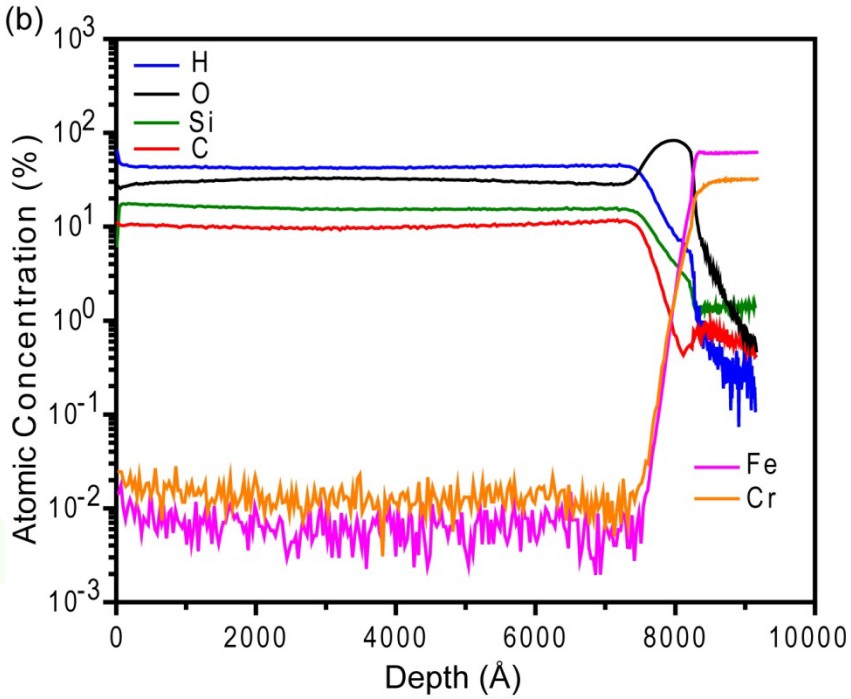
    chemistry is key to high performance

The Coating Process



Coating characteristics





- Amorphous dense coating
- Uniform elemental distribution throughout coating

SilcoTek's Coating Advantages

- Highly dense – few pinholes
- Very versatile corrosion resistance with few chemical limitations
- Can easily coat complex parts/geometries

Limitations

- Substrate limitations – no carbon steels
- Size of parts – relatively small (< 2m overall length)
- Process not easily transferable to the field

Special Considerations

- Focused on quality of layer – not thickness
- Base substrate does matter
- Work with SilcoTek to establish testing and validation plan
- Technology can be licensed to you

Comparisons

Property	Si-Based (Silcolloy)	Si_xO_y-Based (Dursan)	PTFE, PFA
Max Temperature	1400 ºC	550 ºC	260 ºC
Min Temperature	-196 ºC	-100 ºC	-240 ºC
Low pH limit	0	0	0
High pH limit	7	14	14
Thickness	0.12 to 0.8 um	0.3 to 1.6 um	25 um
Adhesion	Very Good	Very Good	Poor
Wear resistance	~90% of SS	2x SS	~10% of SS
Moisture contact	72-90°	104-140°	125°
Inertness vs. SS	Excellent	Good	Excellent

SilcoTek®

Benefits and Performance

SilcoTek®

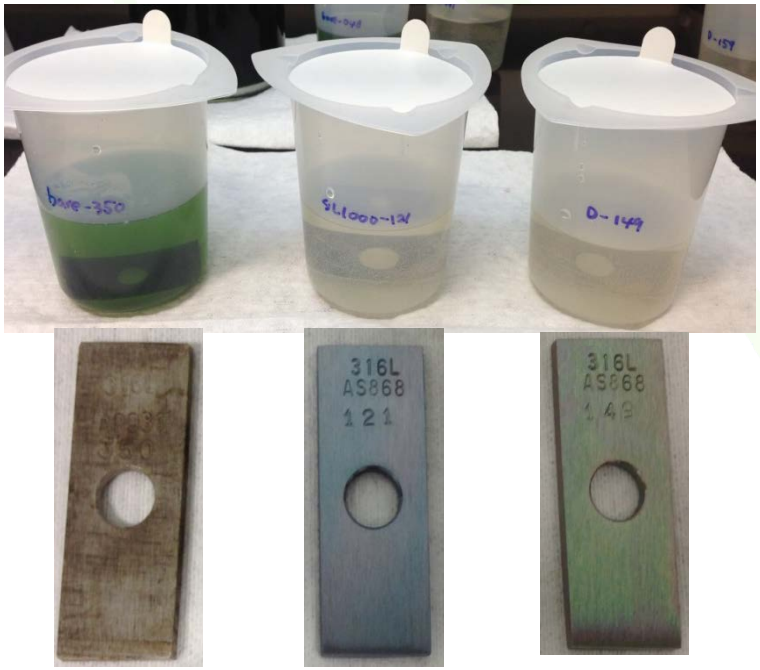
Petrochemical

- Instrumentation
- Tubing
- Small vessels
- Probes
- Fittings
- Pump components

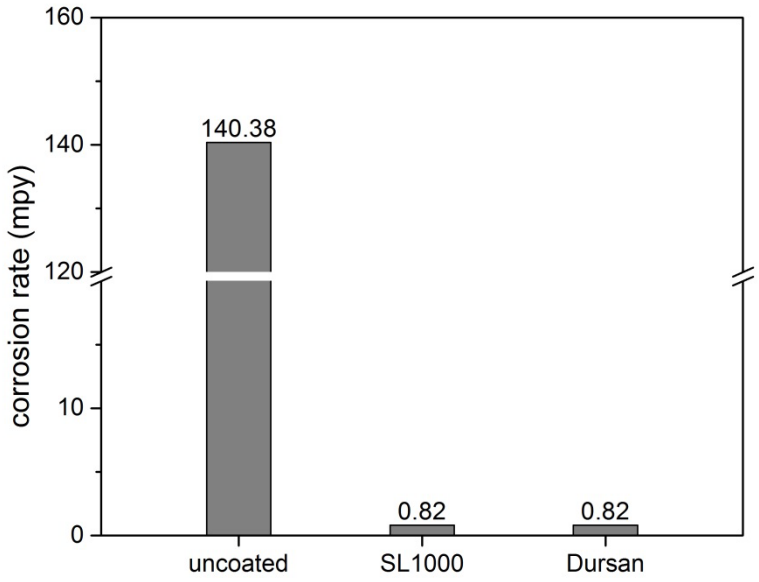
HCl, H_2SO_4, and more

Sulfuric acid

- ASTM G31 guidelines
- 50% (vol) sulfuric acid exposure
- 24 hours at room temperature



uncoated 316L | Silcolloy-coated 316L | Dursan-coated 316L



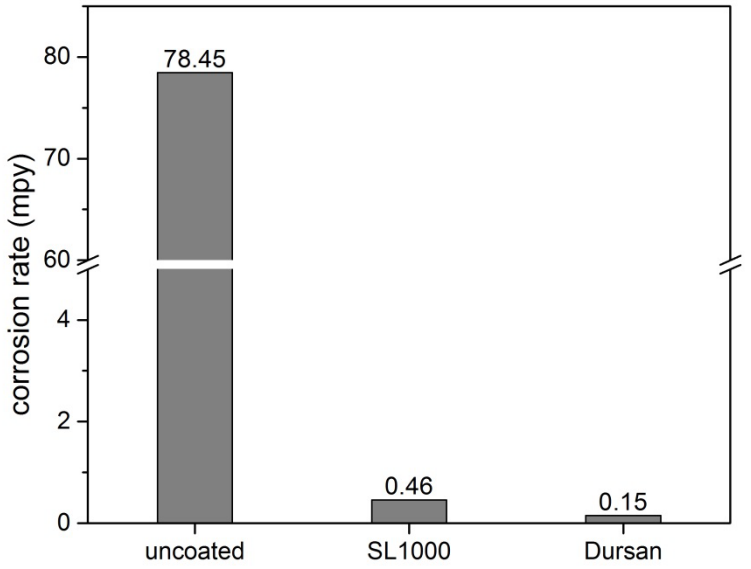
Sulfuric acid

- ASTM G31 guidelines
- 85% (vol) sulfuric acid exposure
- 24 hours at room temperature

uncoated 316L

Silcolloy-coated 316L

Dursan-coated 316L



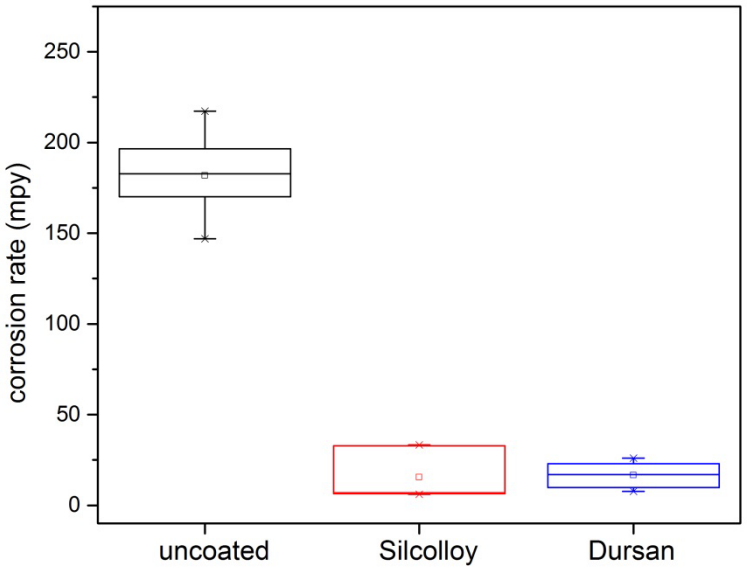
Hydrochloric acid

- ASTM G31 guidelines
- 20% (6M) HCl acid exposure
- One week (168 hours) at room temperature

uncoated 316L

Silcolloy-coated 316L

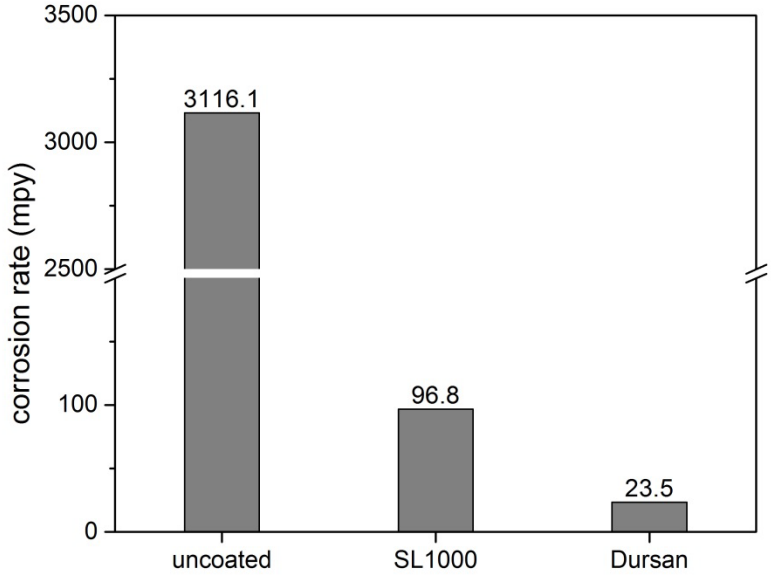
Dursan-coated 316L



Elevated temperature: 50°C

- ASTM G31 guidelines
- 20% (6M) HCl acid exposure
- 7 hours at 50°C

uncoated 316L | Silcolloy-coated 316L | Dursan-coated 316L



Offshore

- Analyzers
- Tube bundles
- Valves
- Fasteners
- Sample cylinders
- Stainless steel components

HCl, Salt Water, Bleach, & more

Salt Spray (ASTM G85)

- 8,736 hours of acidified salt spray per ASTM G85-A2
  - 5% NaCl, pH 2.9 (acetic acid) fog

uncoated 316L

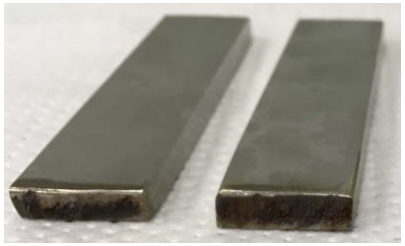
Silcolloy-coated 316L

Dursan-coated 316L

Salt Spray (ASTM G85)

(continued from previous slide)

- Dursan-coated 316L SS is completely unaffected by over 8,700 hours of acidified salt spray
  - Even corrosion resistant duplex alloy 2205 showed moderate corrosion on the edges

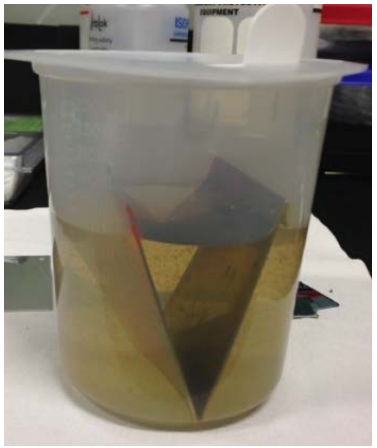


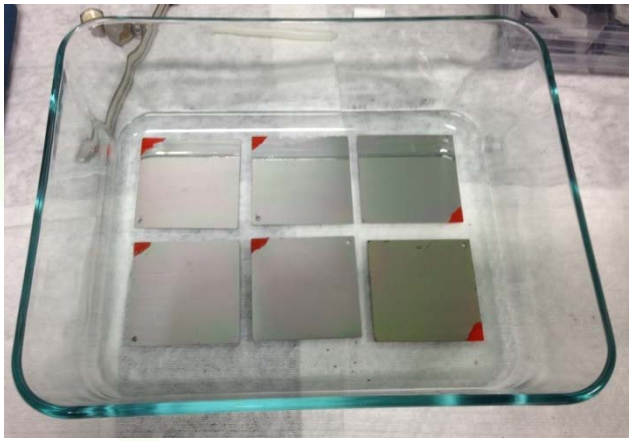
Uncoated duplex alloy 2205

Dursan-coated 316L

Salt water immersion (5% NaCl)

- Dursan coating (right) shows no degradation in salt water after 8 months of exposure
  - An inferior coating (left) rusted after 20 days of exposure in salt water

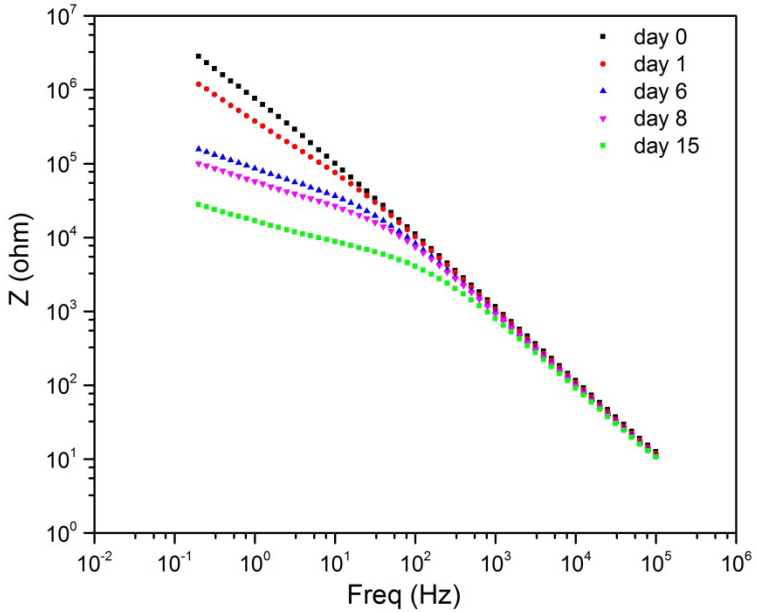


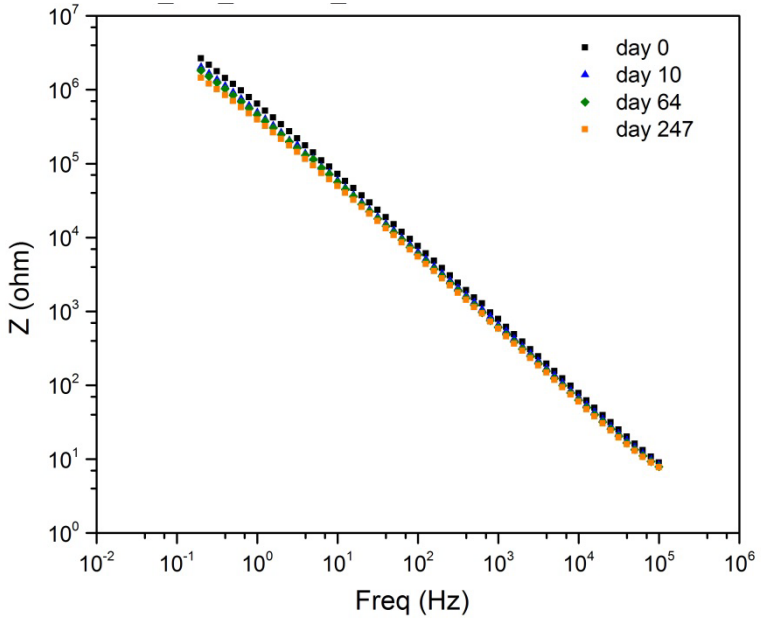


After 8 months in 5% NaCl

EIS monitoring (5% NaCl)

- Dursan coating (right graph) shows excellent EIS stability in salt water after 8 months, providing excellent corrosion protection to the 304 stainless steel substrate





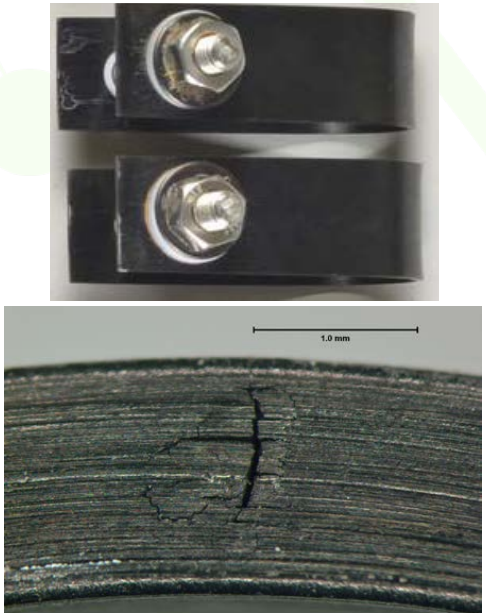
Oil and Gas Exploration

- Downhole sampling equipment
- Cylinders
- Probes

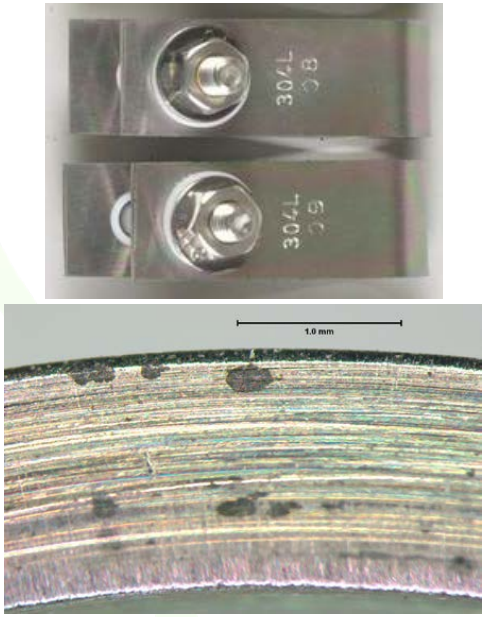
HCl, H_2S, Hg, LNG, and more

H_2S testing

- NACE TM0177
- H_2S saturated acidic brine solution for 30 days
- Dursan coating provides protection



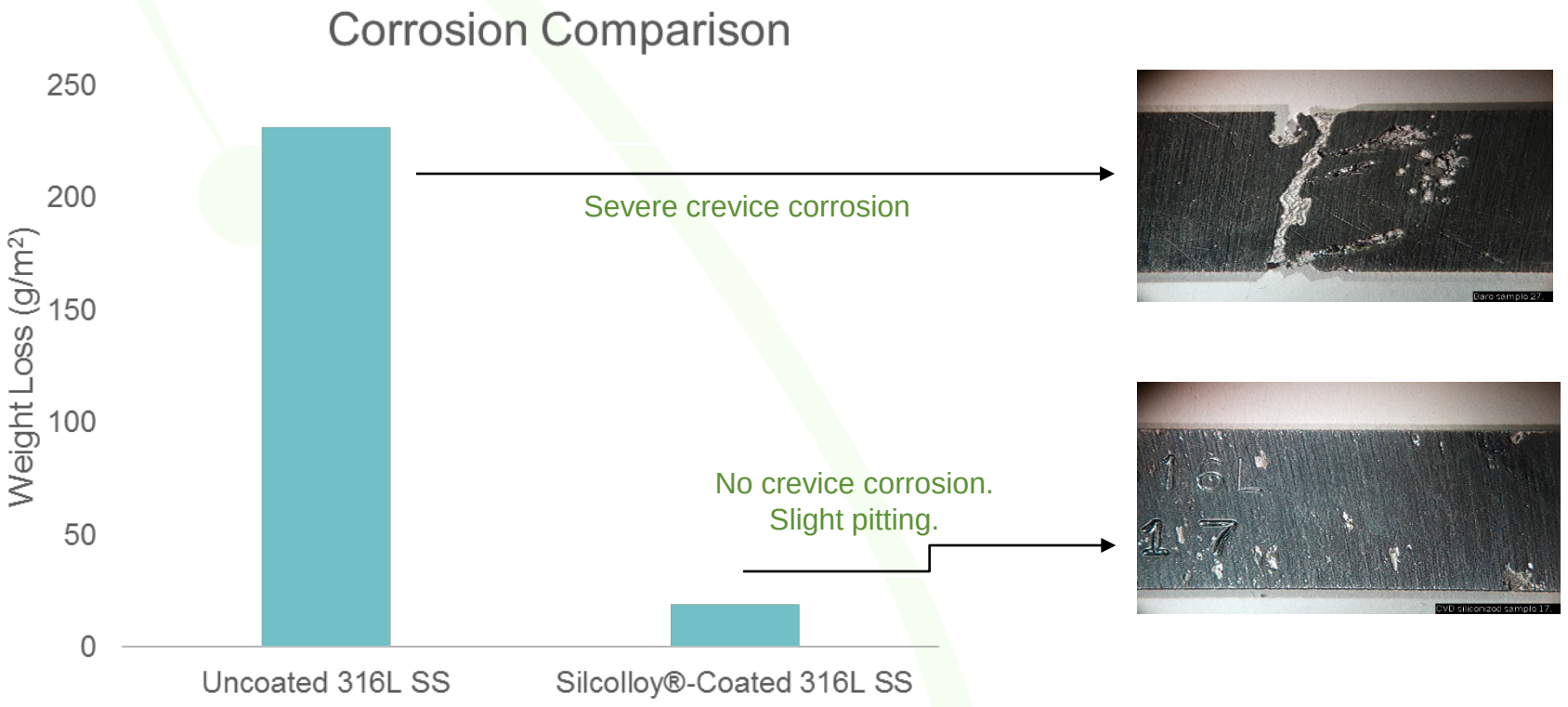
uncoated 304L



Dursan-coated 304L

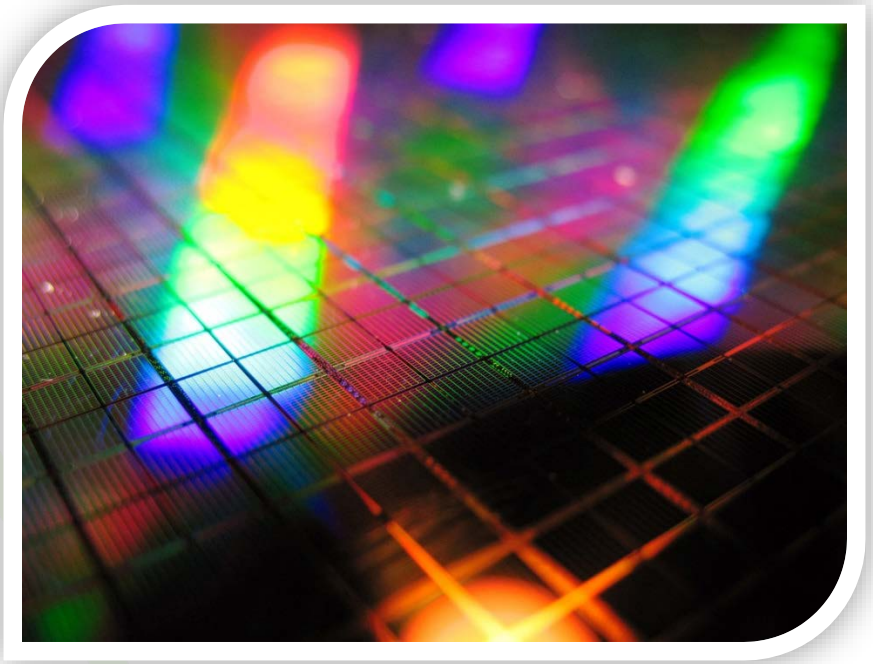
Pitting and crevice corrosion

- ASTM G48 B
- 6% ferric chloride solution: 72 hours, 20°C



Semiconductor

- Gas delivery equipment
- Flow control
- Etch systems
- Deposition systems
- Showerheads



HCl, HBr, Cl_2, more

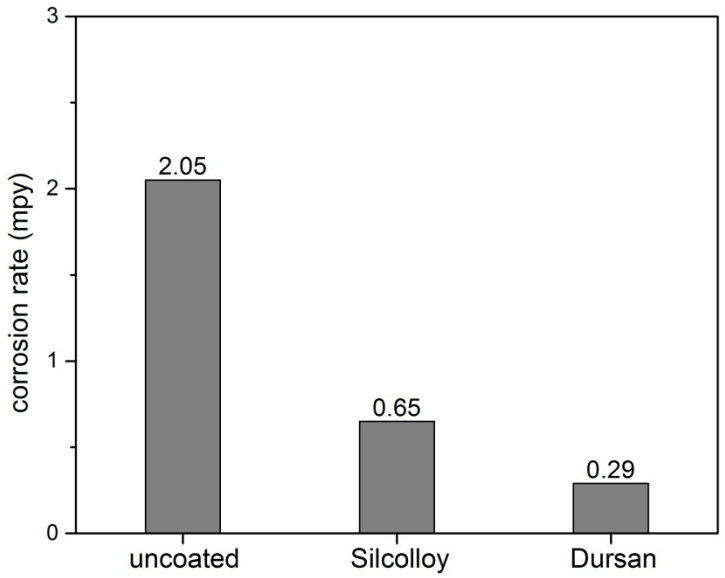
Hydrobromic Acid

- ASTM G31 guidelines
- 48% (wt) HBr exposure
- 264 hours at room temperature

uncoated 316L

Silcolloy-coated 316L

Dursan-coated 316L



Other Test Data

	5% HF		70% Nitric		85% Phosphoric		25% Sulfuric	
	MPY rate	factor	MPY rate	factor	MPY rate	factor	MPY rate	factor
316L SS	120.00	-	0.78	-	0.62	-	91.8	-
Dursan	80.38	1.49	0.10	7.50	0.08	8.00	1.8	51
Silcolloy	44.26	2.71	0.36	2.14	0.28	2.18	15.7	5.85

Gas exposure corrosion date collection is currently underway with instrument assistance from Penn State

Aerospace

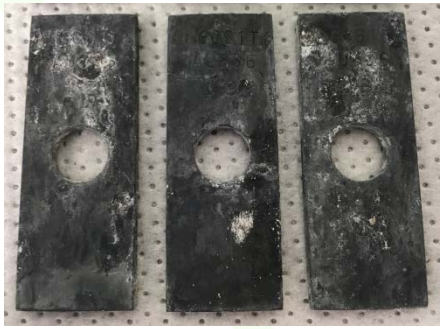
- Aluminum substrates
- Nozzles
- Fuel lines
- Injectors
- Probes
- Pistons

Salt exposure, galvanic corrosion, etc.

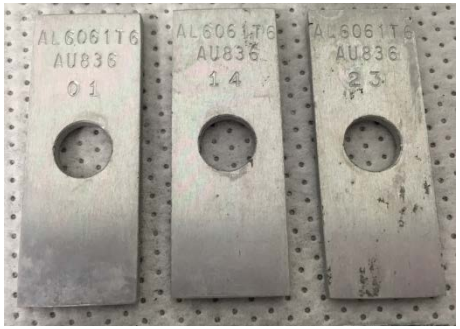
Salt Spray (ASTM G85-A2)

- 6061 Aluminum: 840 hours of exposure
- The bare Al coupons exhibited a weight gain after exposure, which was reported in literature as a result of Al corrosion due to water uptake and oxide formation[1,2]

uncoated



Silcolloy-coated



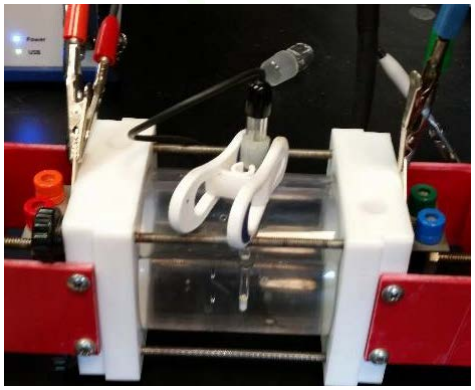
Dursan-coated

corrosion rate **0.189 mpy** **0.058 mpy**

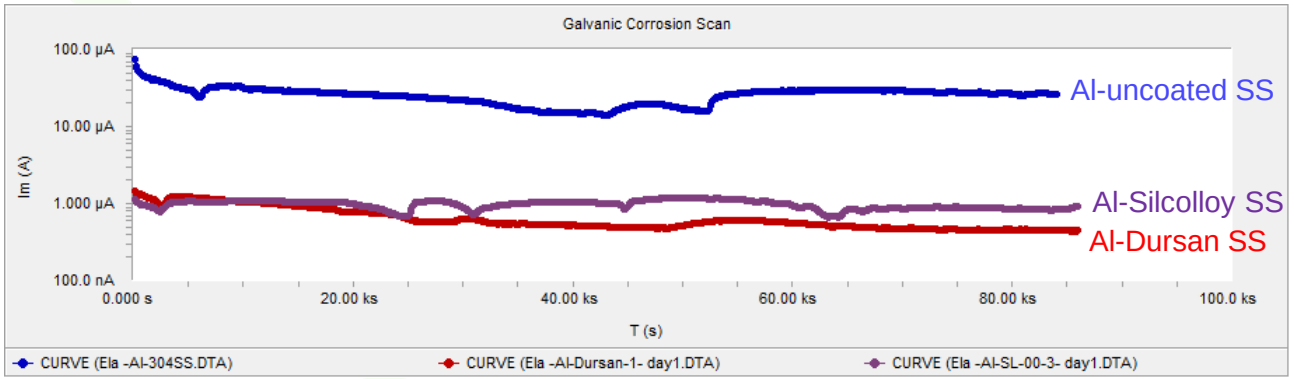
1) Neumann, P. D., The corrosion of aluminum alloys in the Oak Ridge research reactor, ORNL-3151, 1961
2) Peacock, H. B., Sindelar, R. L. and Lam, P. S., Temperature and humidity effects on the corrosion of aluminum-base reactor fuel cladding materials during dry storage, XA04C0098, 2004

Galvanic corrosion

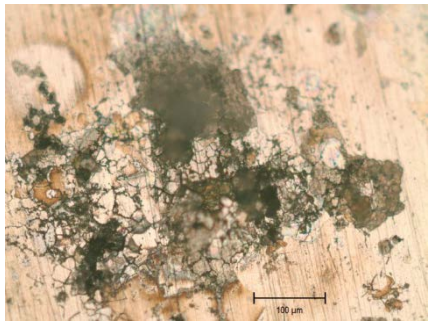
- An artificial seawater (conforming to ASTM D1141) electrolyte was used for the 6061 Aluminum and 304 SS (coated vs. uncoated) couples
- Coatings substantially reduced the galvanic current by two orders of magnitude
- Coatings reduced the number and size of pits observed on Al surface



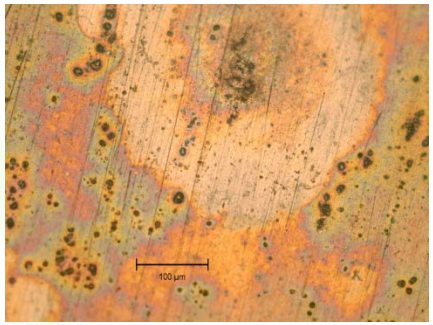
experimental set up



galvanic current as a function of immersion time



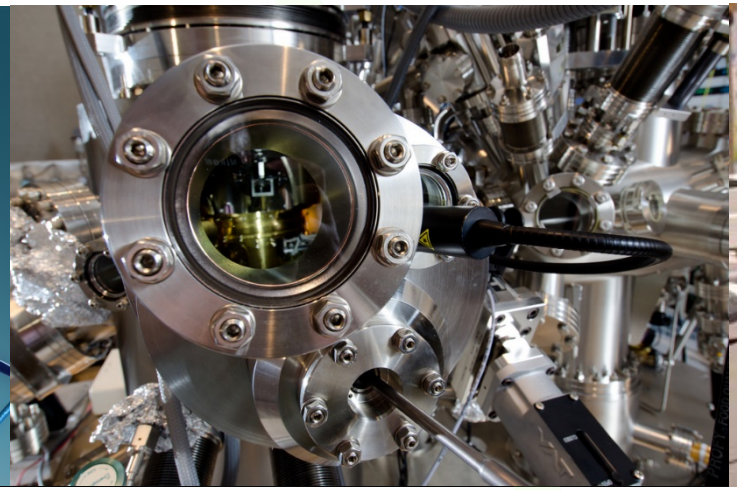
coated SS



Test performed by Dr. Elizabeth Sikora and Dr. Barbara Shaw at Penn State University



And many more…


SilcoTek®

Success Stories

SilcoTek®

Case Study: Oil in Water Monitors

"We use every opportunity to offer SilcoTek products where exotic metals are specified. The cost difference is enormous and our customers receive the benefit from cost savings and equal or better performance."

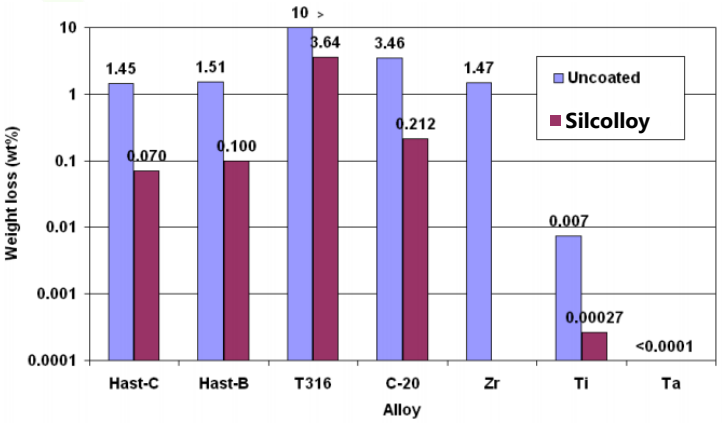
-Gary Bartman, President

Turner Designs Hydrocarbon Instruments Inc.

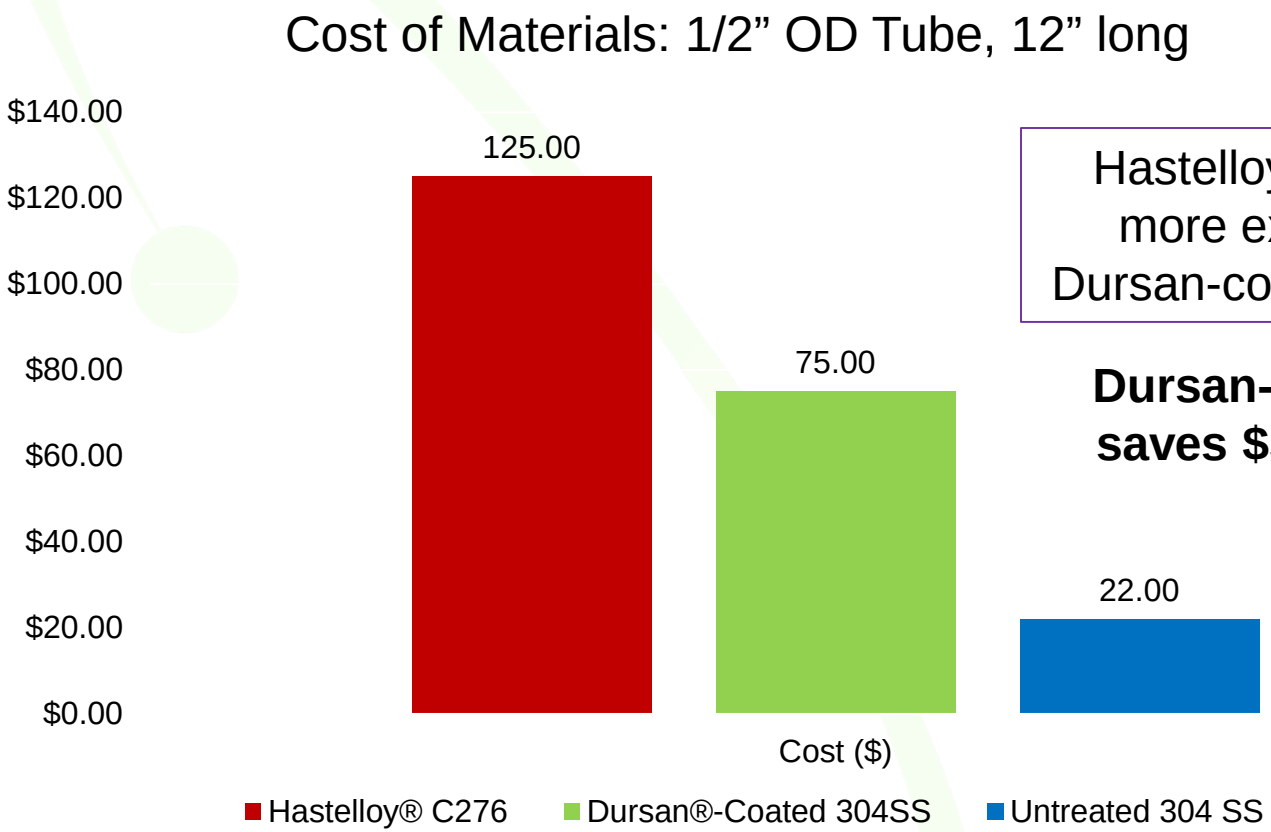
Case Study: Autoclave Corrosion

"Silcolloy reduced corrosion 20-fold for each alloy in our testing."

-Shawn M. Allan, Ceralink Inc.
-Dr. Lawrence Shore, BASF Catalysts



Cost Savings vs. Super Alloys



Hastelloy® tube is 66% more expensive than Dursan-coated 304SS tube

Dursan-coated tubing saves $5000 per 100’!

Protecting more than just Stainless Steel

SilcoTek®

SilcoTek can also coat:

- Titanium
- Inconel
- Ceramics
- Glass
- High nickel alloys
- Aluminum
- Many other substrates requiring corrosion resistance

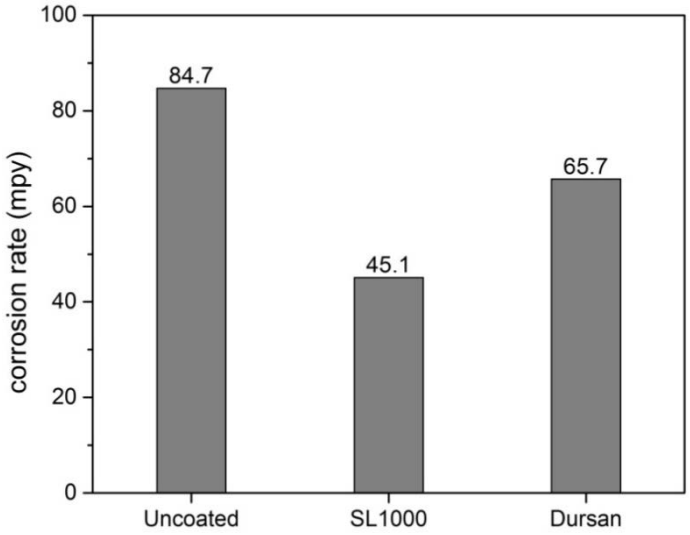
Carbon steel

- Only see limited corrosion protection from coating
- 264 hours of acidified salt spray per ASTM G85-A2

uncoated

Silcolloy-coated

Dursan-coated



“How long will it last?”

SilcoTek®

“How long will it last?”

- Every application is different

1. SilcoTek data helps determine feasibility and proper coating selection

2. Work with SilcoTek for samples, testing, validation, and scale-up

Putting it all Together

- ✓ SilcoTek's coatings on stainless steel and other materials can offer the corrosion resistance properties of exotic metals like Hastelloy® but at a fraction of the price.

- ✓ SilcoTek's coatings are very unique compared to other corrosion resistant treatments. Complex part geometries can be thoroughly treated and design tolerances are unaffected by the thin CVD coatings.

- ✓ Coating stainless steel not only saves significant amounts of money, but also allows engineers and integrators to maintain optimal design and installation flexibility.

Use SilcoTek® When…

- You need more corrosion resistant stainless steel, aluminum, titanium, high nickel alloys, etc.

- You need already-corrosion resistant alloys to have better surface properties
  - Improve chemical compatibility/inertness
  - Increase hydrophobicity or “anti-stick” properties
  - Improve process purity and eliminate contamination from metals

Consider Alternatives When…

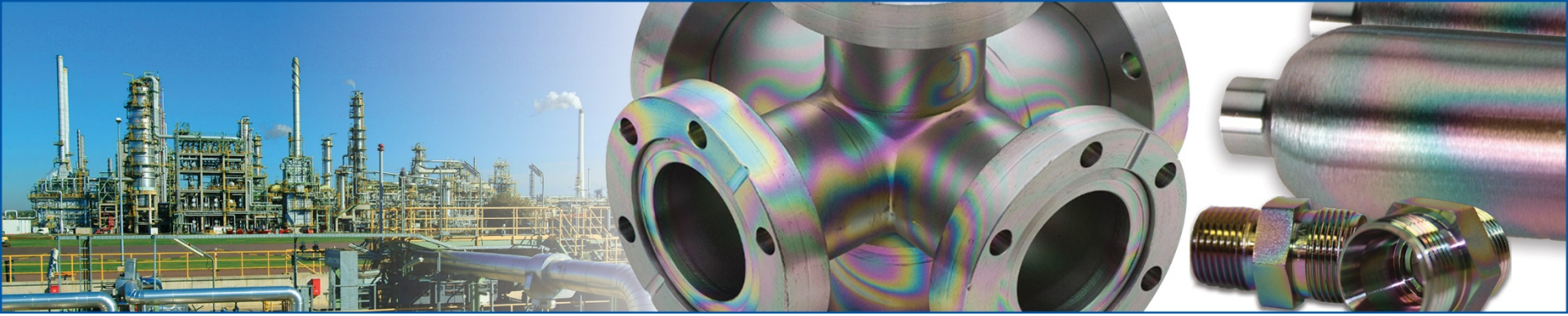
- You need more corrosion resistant carbon/tool steels
- The parts you need to coat are very large (in general, >6’ length and >3’ in width)
- You need to re-coat in the field

Questions?

Submit via the Webinar app.,

#AskSilcoTek on Twitter, or by

emailing **SilcoD@SilcoTek.com**



Thank you!

E: SilcoD@SilcoTek.com | P: +1 (814) 353-1778

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