SilcoTek® Corrosion Resistant CVD Coatings

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- The challenge of corrosion
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- Corrosive immersions (HCl, H₂SO₄, bleach, HBr, H₃PO₄, etc.)
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- Galvanic corrosion
- Case study
The Challenge of Corrosion

• Aggressive process and sample media
• Harsh external environments
• Expensive maintenance and replacement
• Little room for failure
SilcoTek’s Solutions

**Dursan®**

Amorphous silicon oxide coating with full pH range resistance and increased mechanical durability.

**Silcolloy®**

Amorphous silicon coating ideal for improving service life in acidic and oxidative environments.

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Salt Spray (ASTM G85)

- 8,064 hours of acidified salt spray per ASTM G85-A2
  - Dursan coating is unaffected and provides excellent protection on stainless steel in a salt spray environment. Silcolloy shows minor rust.
Salt Spray (ASTM G85)

(continued from previous slide)

• Dursan-coated 316L SS is completely unaffected by 168 days of acidified salt spray
  • Even corrosion resistant duplex alloy 2205 showed moderate corrosion under these conditions

Uncoated Duplex Alloy 2205

Dursan-coated 316L
Salt Spray (ASTM G85)

- 4 weeks of pH-neutral salt spray (NaCl), then 4,032 hours of acidified salt spray per ASTM G85-A2
  - Total exposure time: 8,736 hours
Salt Spray (ASTM G85)

(continued from previous slide)

- Dursan coating provides complete protection even after 8,736 hours of cyclic salt spray exposure

- Silcolloy shows minimal corrosion at coupon edges
Hydrochloric Acid (HCl)

- ASTM G31 Guidelines
- 6M HCl Acid Exposure
- 24 hrs at Room Temperature

Both Dursan and Silcolloy coatings provide an excellent barrier to corrosion from HCl.

The coatings add considerable lifetime to parts in refinery and chemical manufacturing service, amongst others.
Hydrochloric Acid (HCl)

The solution containing Dursan-coated 316L SS shows no discoloration (corrosion) after the 24hr immersion test.
Bleach (NaClO)

- ASTM G31 Guidelines
- 15% NaClO Exposure
- 72 hrs at Room Temperature

Bleach is very aggressive to stainless steel and other surface treatment, but Dursan provides stable protection.

This is especially useful in biomedical and pharma applications where bleach is commonly used.
Bleach (NaClO)

Bleach Corrosion

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Sulfuric Acid (H₂SO₄)

- ASTM G31 Guidelines
- Sulfuric Acid Exposure
- 24 hrs at Room Temperature

SilcoTek coatings can even withstand aggressive concentrations of sulfuric acid.

Even in the harshest conditions of a refinery or other chemical process, SilcoTek-coated stainless steel will improve the performance of your products.
Hydrobromic Acid (HBr)

- ASTM G31 Guidelines
- 48% HBr Exposure
- 11 days (264 hours) at Room Temperature

HBr is a critical chemical of concern in semiconductor processes.

In addition to protecting stainless steel from HBr, Silcolloy and Dursan both can increase tool uptime in challenging chloride and acidic chemistries.
Nitric Acid (HNO₃)

- ASTM G31 Guidelines
- 68% HNO₃ Exposure
- 11 days (264 hours) at Room Temperature

Though nitric acid isn’t overly aggressive to uncoated stainless steel at room temperature, our testing confirms that SilcoTek coatings are compatible with nitric acid even after several days of exposure.

No samples were affected in this test, and all corrosion rates are within measurement error.
Phosphoric Acid ($H_3PO_4$)

- ASTM G31 Guidelines
- 85% $H_3PO_4$ Exposure
- 13 days (311 hours) at Room Temperature

Though phosphoric acid isn’t overly aggressive to uncoated stainless steel at room temperature, our testing confirms that SilcoTek coatings are compatible even after several days of exposure.

No samples were affected in this test, and all corrosion rates are within measurement error.
Phosphoric Acid ($\text{H}_3\text{PO}_4$)

- ASTM G31 Guidelines
- 85% $\text{H}_3\text{PO}_4$ Exposure
- 7 hours at elevated temp. (80°C)

Increasing temperature often increases the aggressiveness of corrosive effects.

SilcoTek’s Silcolloy and Dursan coatings outperform uncoated 316L SS by more than 2x in the presence of 85% phosphoric acid at 80°C (176°F)
Salt Water Immersion

Dursan® Coating (right) shows no degradation in salt water after 60 days of exposure
Salt Water

Dursan® Coating (right) shows excellent dielectric stability in salt water after 60 days, providing an effective corrosion barrier on the substrate.
ASTM G48 B: Pitting and Crevice Corrosion

Corrosion Comparison

- **Uncoated 316L SS**
  - Slight pitting.

- **Silcolloy®-Coated 316L SS**
  - No crevice corrosion.

- **Severe crevice corrosion**

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Corrosion Resistance on Carbon Steel
Carbon Steel

- SilcoTek’s coating processes are optimized for stainless steel, titanium, and other performance alloys

- Carbon steel can still be coated successfully

- Coatings perform well on carbon steel for barrier/general chemical resistance applications. They do not provide corrosion resistance comparable to SilcoTek coatings on stainless steel substrates
Material

- Three types of carbon steel corrosion coupons were tested, with increasing amount of carbon content
  - C1018 is the most commonly available of the cold-rolled steels
  - A36 is the most commonly available of the hot-rolled steels
  - C1045 is generally supplied in the hot-rolled condition

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>C1018</th>
<th>A36</th>
<th>C1045</th>
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<tr>
<td>Carbon content</td>
<td>0.18%</td>
<td>0.26%</td>
<td>0.45%</td>
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</table>

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Carbon Steel – Salt Spray
Salt spray: ASTM G85-A2

- Carbon steel type: C1018
Salt spray: ASTM G85-A2

- Carbon steel type: A36

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Salt spray: ASTM G85-A2

- Carbon steel type: C1045

- Uncoated
- SL1000-coated
- Dursan-coated

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Carbon Steel – Salt Spray Testing

- Both coated and uncoated carbon steel coupons were severely rusted after 264 hours of exposure

- Still, SilcoTek coatings helped to reduce the corrosion rate

- Consult SilcoTek tech. service to select both the best coating and substrate for your application
Carbon Steel - Hydrochloric Acid
Carbon Steel – HCl Corrosion Resistance

• SilcoTek coatings on stainless steel provide excellent protection to HCl exposure (see previous slides)

• However, the coating did not provide much benefit on carbon steel in the same tests

• Optimizing coating and substrate selection to deliver best performance for the right cost is key
Galvanic Corrosion
304 SS coupled to 6061 Al
Both Dursan and Silcolloy noticeably minimize the effect of galvanic corrosion when coated 304 SS is coupled to 6061 aluminum.

Dursan offers drastically improved protection from galvanic corrosion over uncoated 304 SS (up to 2 orders of magnitude).
SilcoTek Coatings as a Solution

• Cost-effective alternative to exotic metals

• Upgrade current components or easily install new, coated parts

• Advantages of CVD process: easily coats complex geometries; doesn’t affect tolerances; environmentally benign
Case Study: Turner Designs Hydrocarbon Instruments

See how Turner Designs Hydrocarbon Instruments cut costs and increased performance of their oil in water monitors by using stainless steel coated by SilcoTek’s corrosion resistant surface technology instead of exotic metals.

Download the case study
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