



To > CHROMTECH
Silco Website .HTM

UPDATE
June 2016



Applications Note

Keep Sulfur in Sight with SilcoNert® 2000 for Subpart-Ja Compliance

- Improved system stability
- Reduced troubleshooting
- Accurate, reliable results
- Fast equilibration
- Proven performance

Sulfur regulation compliance requires a sampling system that's inert, reliable and robust. SilcoNert® offers all three.

Ensure Tier 3 Sulfur Regulation Compliance with SilcoTek® Coatings

Tier 3 Compliance Guide



By 2017, the EPA's Tier 3 gasoline sulfur regulations require that oil refineries reduce the average sulfur level in gasoline by more than 60 percent, to just 10 parts per million (ppm) in 2017, from the current 30 ppm.

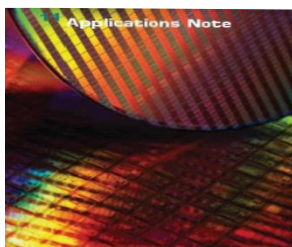


13 Applications Note

Upgrade Produced Water Processes with SilcoTek® Coating Solutions

- Increase component life
- Enhance analytical performance
- Save money and reduce downtime

Apply the Dursan® and Silcolloy® coatings to stainless steel, titanium, super alloys and ceramics to increase corrosion resistance and chemical inertness.



Applications Note

Next Generation Coating Solutions for the Semiconductor Industry

- Enhance yield
- Ease factory integration
- Optimize process efficiency

Ideal surface treatments for semiconductor applications

Silcolloy

- Resistant to HBr, NF₃, HCl and more
- Ultra-high purity amorphous silicon
- Etch and deposition compatible

Dursox

- Silica-like surface
- Provides erosion and corrosion barrier
- Minimizes metal ion contamination

U.S. EPA Method 325

Ensure Fenceline Monitoring Compliance with SilcoTek® Coatings

Rule 325 Compliance Guide

In an effort to improve air quality near the fenceline of refineries, the EPA has implemented Method 325 to comply with US Federal regulations. Accurate analysis of airborne VOCs is now a nationwide requirement.

7 SilcoTek® Coatings Improve Reliability, Lower Costs, and Ensure Compliance at your Refinery



Petrochemical Coating Solution Guide

When ideal materials for engineering and construction of petrochemical processing and analyzer systems fail to provide proper surface properties, SilcoTek® coatings offer the best solution for optimizing performance and cost.

- Versatile - bring robust chemical inertness, stability and corrosion resistance to a variety of substrates and applications
- Effective - fully coat complex geometries and tortuous pathways with a thin, flexible, and durable coating
- Valuable - save money with equipment that lasts longer, performs better, and assures compliance to regulatory standards

Bio-Inert Coatings from SilcoTek®



The medical and pharma industries rely on stainless steel or polymer coatings for bio-inertness, but these materials are often susceptible to corrosion, sticking, and wear that threatens purity and performance.

SilcoTek's coatings help OEMs create flexible, high performance products with low maintenance costs.

Chromatography Applications

Applications Note



A Chromatographic View at a SilcoNert®-treated Sample Flow Path

An inert sample flow path is imperative for accurately quantifying sample profiles that are now more complex than ever before. Regulatory requirements coupled with increasingly difficult sampling environments require solutions that cannot be achieved with any selection of raw material alone; metal components provide adequate robustness but quickly adsorb important molecules that must be analyzed at trace levels. In order to accurately quantify these critical compounds, the entire sample flow path throughout the analyzer must be inert to ensure that the whole sample reaches the detection point.

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Rule 325 Compliance Guide

In an effort to improve air quality near the fenceline of refineries, the EPA has implemented Method 325 to comply with US Federal regulations. Accurate analysis of airborne VOCs is now a nationwide requirement.



EPA Method 325 requires low-level monitoring of benzene via passive sorbent tubes over 2-week intervals. Other VOCs are also targeted in the rule.

Without inert-coated sampling tubes and analytical instrumentation, refiners cannot achieve accurate results; more importantly, they put neighboring communities at risk while potentially facing fines.

SilcoTek's SilcoNert® coating is recognized industry-wide as the leading inert surface that enables refiners to sample their processes reliably with high accuracy and reproducibility. If left uncoated, even low surface area parts will adsorb compounds of interest and lead to invalid results, causing expensive retesting.

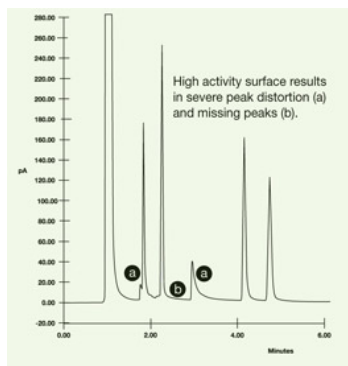


Figure 1: Uncoated surfaces within the GC flow path adsorb benzene, toluene, xylenes and other target analytes, leading to severe peak distortion and missing peaks.

Benzene, organosulfur compounds, and other hazardous air pollutants (HAPs) that can be measured with Method 325 protocol are known to be highly reactive with bare, untreated stainless steel. SilcoNert provides a uniform barrier between substrate and sample while preventing analytes of interest from adsorbing onto the surface, ensuring they reach the analyzer and can be accurately assessed at low levels (ppb or lower).

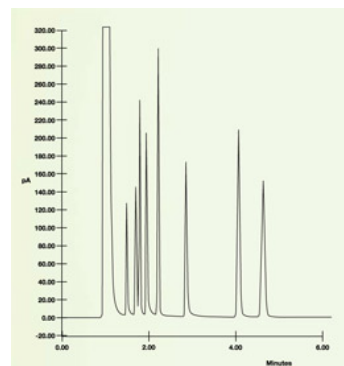


Figure 2: SilcoNert-coated GC flow paths produce sharp peaks with high resolution, giving refineries superior analytical accuracy and full compliance with EPA regulations.

SilcoNert-coated sampling tubes and analytical instrumentation allow refineries to obtain accurate benzene and VOC readings the first time, every time without delays, sample errors, or false results. Now charged with meeting stringent air monitoring regulations from the EPA, refineries can comply with the law and save money while keeping local communities safe.

How to Buy

Ask your manufacturer to add SilcoTek's SilcoNert® coating to your tubes and other stainless steel sampling equipment.

For a full listing of partners who stock coated products, visit www.SilcoTek.com/buy-coated-products.

Or, visit www.SilcoTek.com to send your parts in for coating.

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Lit. Cat. #ST-015

SilcoTek

Coatings that Expand Material Limits

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Applications Note



A Chromatographic View at a SilcoNert®-treated Sample Flow Path

An inert sample flow path is imperative for accurately quantifying sample profiles that are now more complex than ever before. Regulatory requirements coupled with increasingly difficult samples and sampling environments require solutions that cannot be achieved with any selection of raw material alone; metal components provide adequate robustness but quickly adsorb important molecules that must be analyzed at trace levels. In order to accurately quantify these critical compounds, the entire sample flow path throughout the analyzer must be inert to ensure that the whole sample reaches the detection point.

SilcoNert® 2000 Coating

SilcoNert® 2000, previously named Sulfinert®, is an amorphous silicon (a-Si) based coating that is applied via chemical vapor deposition (CVD). The deposition is performed under vacuum as a proprietary blend of precursor gases react to molecularly bond the coating to the substrate. This process allows for a completely non-line-of-sight coating which penetrates small orifices and easily coats complex geometries. The result is a robust, fully adhered coating that can move with components that must be configured to meet the physical demands of the analytical system.

Although naturally inert, silicon alone is not adequately resistant to some of the more reactive compounds such as hydrogen sulfide (H_2S), mercury (Hg), or ammonia (NH_3), especially when these analytes must be quantified at very low - even parts-per-trillion - levels. To address this, SilcoTek functionalizes the silicon surface with hydrocarbon molecules in a secondary deposition process to increase inertness and reduce the effects of porosity in the layer. This, the final SilcoNert® 2000 surface, is the most inert coating available to the chromatography market.

When to use SilcoNert®

A SilcoNert-treated flow path is especially important for highly reactive species, e.g. sulfurs, NO_x , SO_x , stack gas, alcohols, pharmaceuticals, explosives, chemical weapons, volatile organic compounds (VOCs), OP pesticides, chlorinated pesticides, herbicides, and more. SilcoTek® is dedicated only to providing coating services and can make any stainless steel, glass, ceramic, titanium or exotic alloy inert, even outside of a standard GC configuration. Any surface that contacts your sample should be coated to ensure reliable results.

Ideal Applications

- ✓ Trace sulfurs, mercury, and ammonia
- ✓ Moisture
- ✓ Natural gas testing
- ✓ NO_x and SO_x
- ✓ Stack gas monitoring
- ✓ Acidic streams
- ✓ Environmental sampling/compliance
- ✓ Refinery and petrochemical monitoring
- ✓ Down-hole oil and gas sampling
- ✓ Any time complete inertness is required



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Material Limits

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3 Experimental - Organosulfur Compounds

Certain species e.g. H_2S tend to readily adsorb to steel surfaces much more drastically than others, causing false and unstable analytical readings [1]. Prior to inert coating technology, passivation was a frequently chosen technique for stabilizing the analytical system. Studies have shown that, for gas phase transport at low temperature, flowing sulfur compounds through the sample pathway will cause them to adsorb onto active sites of the steel, creating a passive surface for the actual sample to flow through afterward (a.k.a. "priming") [2]. However, this is an extremely limited, time-consuming solution that is not feasible for meeting the now rigorous analytical demands in applications dealing with odorants, beverage grade CO_2 , and the production of ethylene and propylene, amongst others. In conjunction with Restek® Corporation, we have examined the adsorption effects of sulfur species on stainless steel sample storage and transfer components in simulated applications via GC.



Got used liners? SilcoTek offers redeactivation services!

[Click here to learn more](#)

Figure 1: Block diagram of analytical system

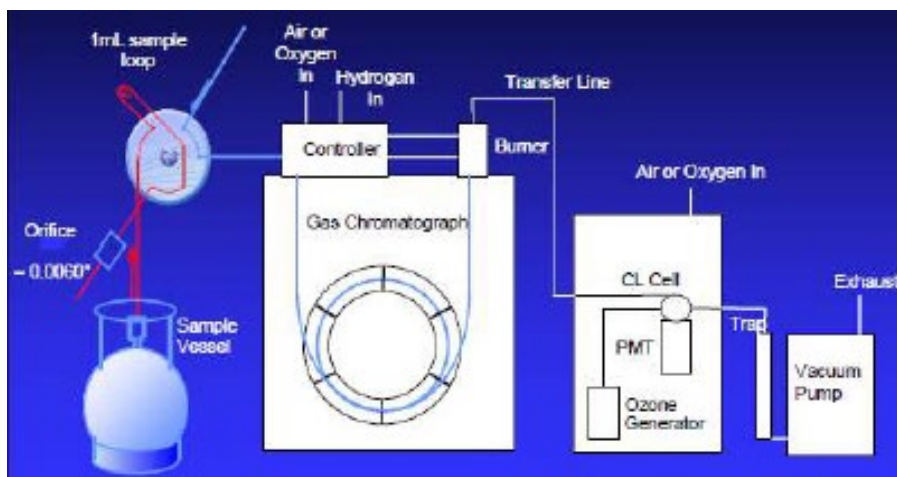


Figure 2: List of sulfur compounds and concentrations

Compound Name	Formula	Conc (ppmv)	Conc (ppbv)	Conc as S (ppbv)
hydrogen sulfide	H_2S	105	11.51	10.83
carbonyl sulfide	COS	98	10.74	5.73
methyl mercaptan	CH_3SH	101	11.07	7.38
ethyl mercaptan	$\text{CH}_3\text{CH}_2\text{SH}$	101	11.07	5.71
dimethylsulfide	CH_3SCH_3	99	10.85	6.81
dimethyl disulfide	CH_3SSCH_3	100	10.96	7.46



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Results

As shown in the data below, SilcoNert® 2000 treated sample holding vessels show virtually no loss of H₂S compounds after 6 days. Additionally, 11 ppbv methyl mercaptan did not adsorb or degrade after 14 days.

Figure 3: H₂S at 11.51 ppbv 6-day storage

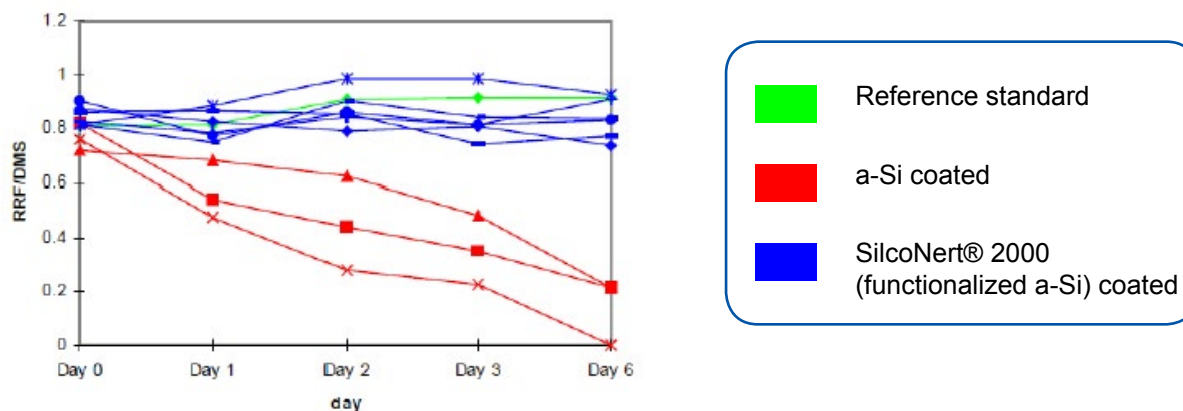
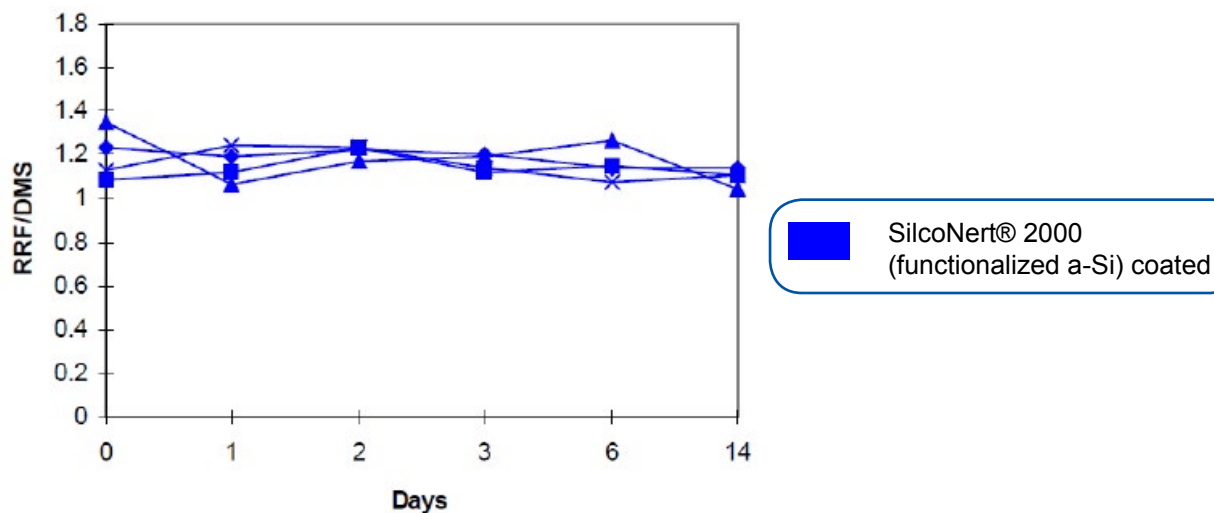


Figure 4: Methyl mercaptan at 11.51 ppbv 14-day storage



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5 SilcoNert® 2000-treated components are especially optimal when single digit ppb or even ppt levels of impurities must be tested; other surface treatments simply are not suited for analysis at these trace concentrations. A GC outfitted with a SilcoNert-coated flow path produced chromatographic results of sulfur testing in beverage-grade CO₂, beer, and refinery gas which are illustrated in figures 5, 6, and 7 below, respectively.

Figure 5: Beverage-grade CO₂ at 20 ppbv, sulfur standard added

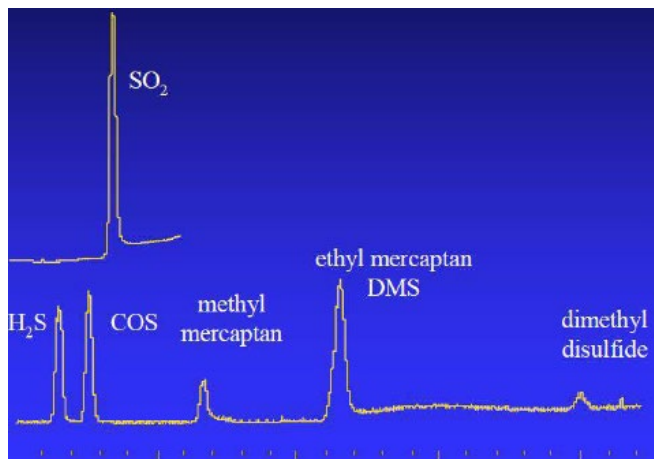


Figure 6: Typical run to determine beer's sulfur content

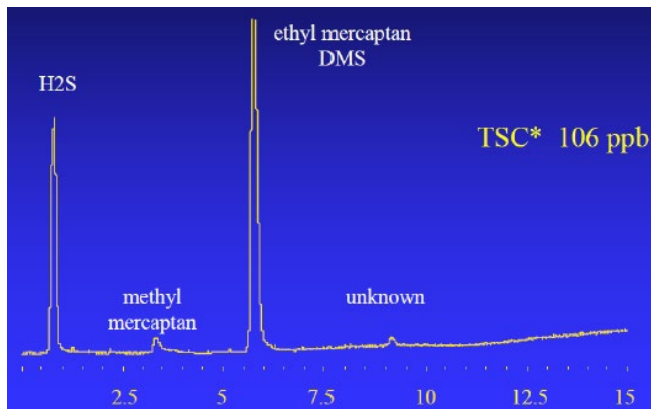
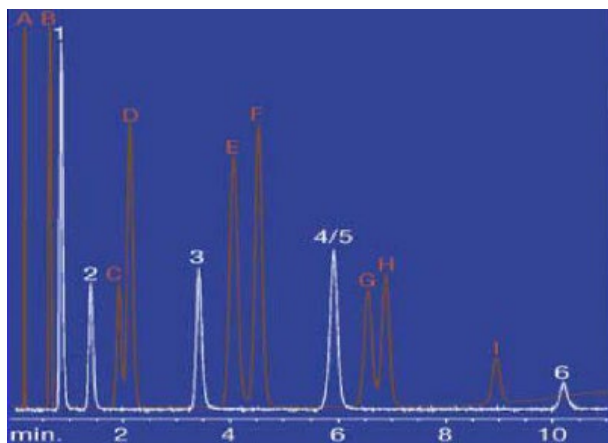


Figure 7: Sulfur and hydrocarbon analysis of refinery gas



Rt-XL Sulfur Micropacked 50 ppb each

1. Hydrogen sulfide
2. Carbonyl sulfide
3. Methyl mercaptan
4. Ethyl mercaptan
5. Dimethyl sulfide
6. Dimethyl disulfide

- A. Methane
- B. Ethane
- C. Propylene
- D. Propane
- E. Isobutane
- F. Butane
- G. Isopentane
- H. Pentane
- I. Hexane

SilcoNert® 2000 provides any compatible surface with industry-leading inertness with drastically improved durability compared to glass and PTFE linings. Coat any surface that touches the sample to ensure the best results.



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The SilcoTek® Difference

SilcoTek is a company solely dedicated to improving the performance of customer-supplied products. Our unwavering focus to coatings has expanded our reach to a variety of industries outside of gas and liquid chromatography, including semiconductor manufacturing, petrochemical, refining, oil and gas exploration, automotive, aerospace, and more. This drives an endless commitment to our customers to provide them with a service that is fast, effective, and mistake-free. Our ZIP code (**Z**ero disappointments, **I**ntegrity in all we do and **P**lus 1 customer service) embodies these everyday beliefs and is the reason why customers love to work with us.

SilcoTek's coating process is unlike any other available on the market. Aside from the actual deposition of the coating, our workflow is designed to treat your parts quickly and with quality, documenting every step of the way. Once received, we perform a thorough inspection to confirm that your parts arrived at our facility just the way they left your's. Then, the parts' surfaces are prepared using our proprietary aqueous cleaning method that thoroughly removes contaminants even as simple as fingerprints. Parts are then re-inspected, coated, cleaned, and rigorously inspected once more, all to ensure you say "wow" when you open the box and experience the new upgraded performance of your SilcoTek-treated components.

Coating your parts is easy!

1. Request a quote on SilcoTek.com or by emailing SilcoD@SilcoTek.com. Simply list the parts requiring treatment and include drawings or photographs.
2. After helping you choose the best coating, a SilcoTek representative will send you a quote with a customized shipping label to include on your box.
3. Send us your parts. In 10 business days or fewer, you will get them back; this time, they will be ready to perform better than ever.

That's it!

Visit www.SilcoTek.com to learn more

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SilcoTek's line of coating solutions:

SilcoNert®

The world's most inert coating

Dursan®

Durable, corrosion resistant, and inert, all in one

Silcolloy®

High purity, acidic corrosion resistance

SilcoKlean®

Resists carbon build up

SilcoGuard®

Low outgassing, ideal for ultra high vacuum

REFERENCES

- [1] Barone, G., Smith, D., and Higgins, M. "Improving the reliability of analytical and sampling systems in challenging and corrosive environments. Presented at the 57th Analysis Division Symposium in Anaheim (2011).
- [2] Biela, B., Moore, R., Benesch, R., Talbert, B., Jacksier, T. "The Do's and Don'ts in the Analysis of sulfur for Polyolefin Producers", Presented as paper 081 at the Gulf Coast Conference, Galveston Island, TX, October 22, 2003.

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6 (of 18) for 2017
Lit. Cat. # GC-001

7 SilcoTek® Coatings Improve Reliability, Lower Costs, and Ensure Compliance at your Refinery

Petrochemical Coating Solution Guide



When ideal materials for engineering and construction of petrochemical processing and analyzer systems fail to provide proper surface properties, SilcoTek® coatings offer the best solution for optimizing performance and cost.

- **Versatile** - bring robust chemical inertness, stability and corrosion resistance to a variety of substrates and applications
- **Effective** - fully coat complex geometries and tortuous pathways with a thin, flexible, and durable coating
- **Valuable** - save money with equipment that lasts longer, performs better, and assures compliance to regulatory standards

Introduction

The petrochemical industry fuels the modern world. In addition to transportation, petrochemicals contribute to a majority of basic human necessities, including housing, hygiene, health and food.

Converting crude oil into useful products involves complicated, multistage chemistry and processing. Engineers are charged with quickly and accurately measuring the chemical contents of process streams without delay in order to maintain productivity and meet legal requirements.

SilcoTek® provides coatings that protect sampling, analyzer and production components from the negative yet inevitable consequences of processing highly reactive chemicals like sulfur and mercury while helping to assure compliance with environmental regulatory standards. This solution guide covers the materials challenges those working in the petrochemical industry face and how SilcoTek's coatings solve them.

Materials Challenges in the Petrochemical Industry

• **Lost time and performance:** regulated chemical compounds such as H_2S must be measured at ultra-sensitive levels, but instrumentation constructed of bare stainless steel alone fails to provide adequate results

• **Frequent maintenance:** oil and gas processing streams are corrosive to untreated stainless steel, yet exotic materials like Hastelloy® are expensive and greatly hinder profitability

• **Poor reliability:** commonly chosen solutions like PTFE fail at high temperatures, lack durability, and easily delaminate in demanding applications common to petrochemical processing

Problem	Solution	Result
Poor analytical accuracy with H_2S , Hg, NOx, etc.	SilcoNert.	Improved sampling reliability and throughput
Corrosion	Dur-san.	Longer lifetimes and lower costs
Slow instrument response	SilcoNert.	Drastically faster signals and higher efficiency
Regulations e.g. Tier 3, EPA 325	SilcoNert.	Assured compliance with accurate results
Oxidation	Silcolloy.	Sustained appearance and performance in extreme conditions
Moisture	Dur-san.	Reduced contamination, corrosion, and sample loss

Applications where SilcoTek Coatings Boost Performance

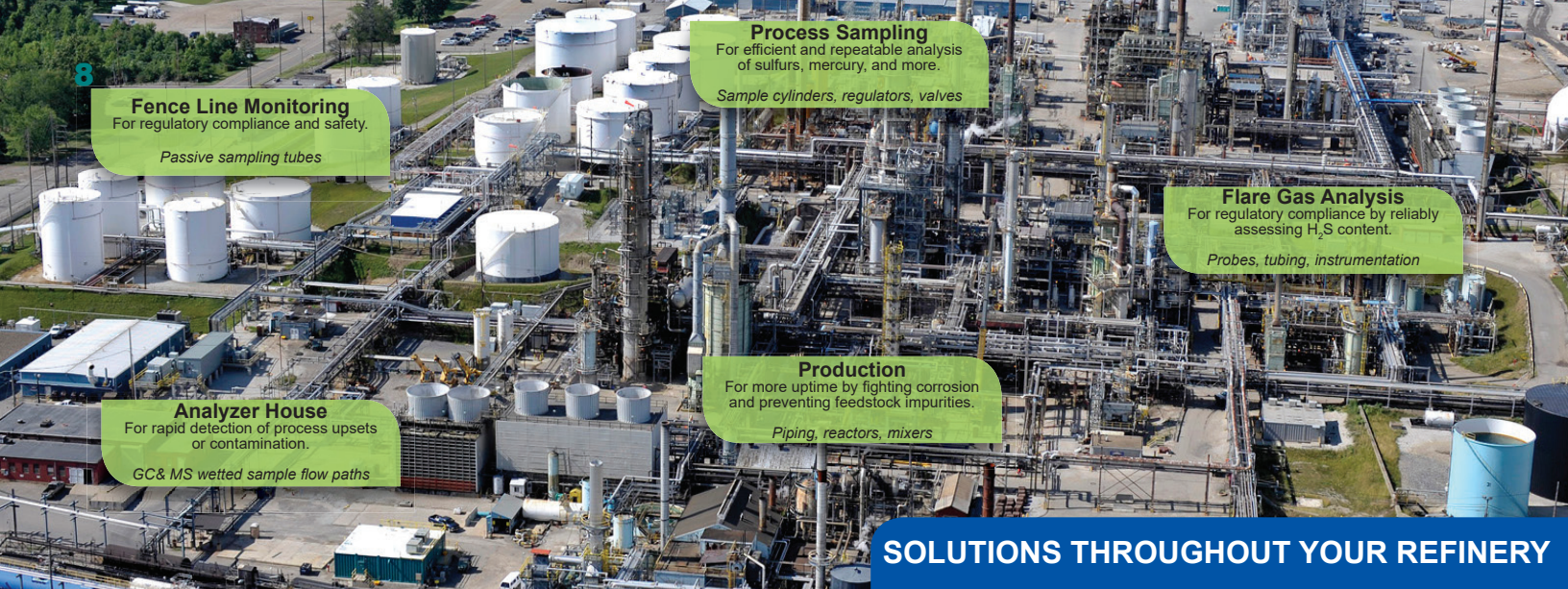
- Downhole crude sampling and testing
- Olefin and aromatic production
- General process monitoring
- Flare gas sampling (40 CFR Part 60 Subpart -Ja)
- ULSD / ULSG (Tier 3)
- Fence line monitoring (EPA 325)
- Ammonia slip monitoring
- Odorant sampling
- Offshore / splash zone
- Ethylene and propylene purity

Common Parts that Benefit from SilcoTek Coatings

GC & MS components	Fittings	Filters
Valves	Pressure regulators	Injectors
Sample cylinders	Reactors	Downhole/wireline tools
Tubing	Probes	Custom parts

Visit SilcoTek.com/blog and subscribe for weekly coating resources dedicated to petro applications.





8

Fence Line Monitoring
For regulatory compliance and safety.

Passive sampling tubes

Process Sampling
For efficient and repeatable analysis of sulfurs, mercury, and more.

Sample cylinders, regulators, valves

Flare Gas Analysis
For regulatory compliance by reliably assessing H₂S content.

Probes, tubing, instrumentation

Analyzer House
For rapid detection of process upsets or contamination.

GC & MS wetted sample flow paths

Production
For more uptime by fighting corrosion and preventing feedstock impurities.

Piping, reactors, mixers

SOLUTIONS THROUGHOUT YOUR REFINERY

Advanced Surfaces for Advanced Performance

SilcoTek's patented chemical vapor deposition (CVD) coatings provide numerous advantages over alternatives, giving petrochemical customers ultimate performance along with flexibility in system design, fabrication, and installation.

1. Innovative Deposition Process Makes Integration Easy

The CVD process binds the coating to the molecular structure of the base metal, leading to a flexible layer that can bend with tubing and doesn't flake like PTFE. Plus, the gas-phase process thoroughly coats complex geometries and narrow internal passageways.

2. Maximum Chemical Inertness for Reliable Analysis

Analyzing trace levels of sulfur, mercury, and ammonia is necessary for quality control and regulation compliance in the refinery. Uncoated instrumentation calibrates slowly and fails to provide the accuracy and resolution of inert-coated systems.

3. Super Alloy Corrosion Resistance at a Fraction of the Price

SilcoTek coatings on stainless steel are cost-effective replacements for expensive materials like Hastelloy®. They provide a dense barrier to attack while simultaneously preventing iron, nickel and other metal ions from leaching out of equipment and into the process stream.

SilcoTek coatings drastically outperform uncoated 316L SS in ASTM G85-A2 acidified salt spray testing.



Upgrading stainless steel with Dursan® or Silcolloy® is an effective alternative to costly super alloys.

Making the Impossible Possible

SilcoTek coatings were born in the lab but grew up in the refinery. Whether you need better sulfur analysis to comply with the law or want to extend the life of your parts in corrosive environments, our coatings provide solutions that don't require system redesign and won't bog down your supply chain.

Working with SilcoTek is a unique service experience that puts customers and the quality of their parts first. This drives an endless commitment to providing fast, high-quality, mistake-free coatings every day. Our ZIP Code - **Z**ero Disappointments, **I**ntegrity in all we do, and **P**lus 1 customer service - embodies these beliefs and drives our mission.



Resources

Visit www.SilcoTek.com/coating-resources for literature, data, and more.

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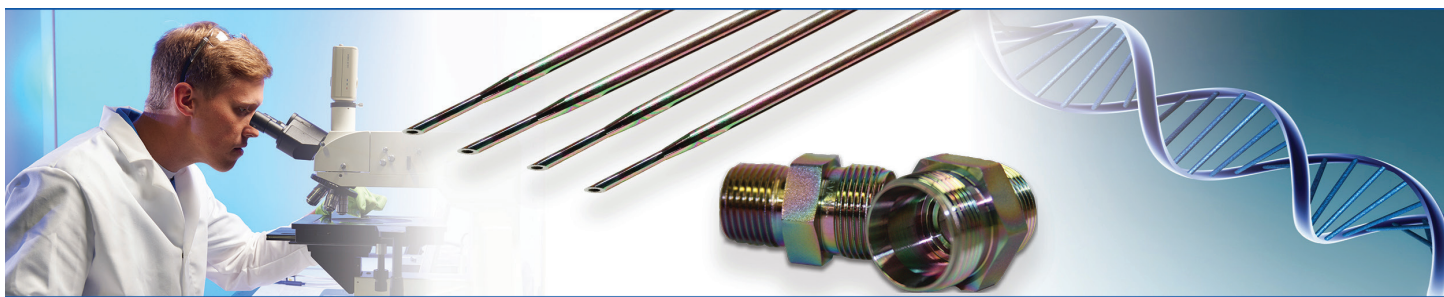
Coatings that Expand Material Limits

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Bio-Inert Coatings from SilcoTek®



The medical and pharma industries rely on stainless steel or polymer coatings for bio-inertness, but these materials are often susceptible to corrosion, sticking, and wear that threatens purity and performance.

SilcoTek's coatings help OEMs create flexible, high performance products with low maintenance costs.

Introduction

Medical device and biopharmaceutical manufacturers face the most strict regulations for purity and sanitation in industry. Matched with constantly growing demand, these companies need to maximize productivity while keeping costs low.

Popular materials of construction in production and diagnostic applications fail to provide the lifetime and performance required for the end user's ideal workflow. Corrosion from bleach, frequent cleaning, and worn or damaged componentry threaten both output and profitability.

SilcoTek® provides advanced coatings that make products last longer, work faster, and perform better.

The chemical vapor deposition (CVD) process creates a nano-scale coating of elemental silicon, oxygen, and carbon that resists chemical attack better than stainless steel with functionality and durability that significantly outlasts fluoropolymers.

Material Challenges in Medical and Biopharma Industries

- **High costs from corrosion:** even super-austenitic grades of stainless steel corrode and threaten the purity of products, especially when bleach is commonly used in cleaning cycles
- **Frequent maintenance:** proteins and other biomolecules readily adsorb onto stainless steel surfaces, requiring manual maintenance, component replacement, and long delays
- **Poor reliability:** metal ions from stainless steel leach into process streams while polymer coatings can easily delaminate during routine maintenance, causing upsets or false results

Problems Solved by SilcoTek® Coatings

- Poor performance caused by sticking of proteins
- High costs due to corrosion, especially from bleach
- Contamination from leaching of metal ions out of equipment
- Unreliable analytical results caused by chemical reactivity
- Recurring replacement because of material wear

Applications where SilcoTek Coatings Boost Performance

- Immunoassay analysis
- Liquid chromatography
- Medical devices
- Mass spectroscopy
- Consumable disposal
- Reaction and mixing

Common Parts that Benefit from SilcoTek® Coatings

Needles	Probes	Sensors
Tubing	Filters	Valves
Consumables	Vessels/Reactors	Fittings

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Coatings that Expand Material Limits

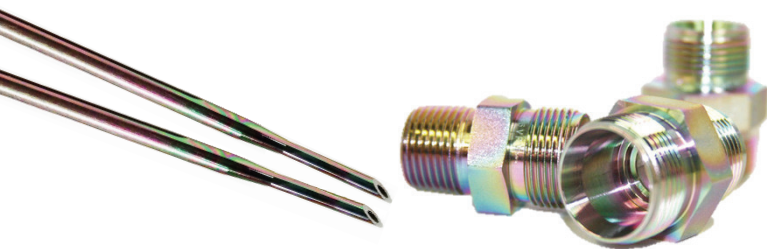
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SilcoTek's patented coatings provide numerous advantages over alternatives, giving biopharma and medical device manufacturers ultimate performance along with flexibility in system design, fabrication, and installation.

1. Innovative Deposition Process Makes Integration Easy

The gas-phase CVD process binds the coating to the molecular structure of the base substrate, leading to a flexible layer that can bend without flaking like PTFE or other polymers. Plus, challenging geometries and narrow internal passageways can be thoroughly coated with ease.

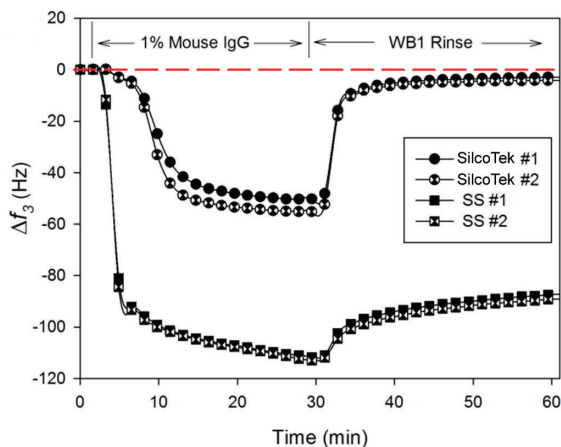


SilcoTek improves parts made of stainless steel, ceramics, glass, and more, even those with complex geometries or high aspect ratios.

2. Low Surface Energy Prevents Protein Sticking

Prevention of non-specific protein adsorption to surfaces is highly desirable in the medical industry. SilcoTek's coatings provide a robust, low energy surface that prevents proteins, moisture, and more from being retained. This improves analytical results and leads to significantly higher throughput.

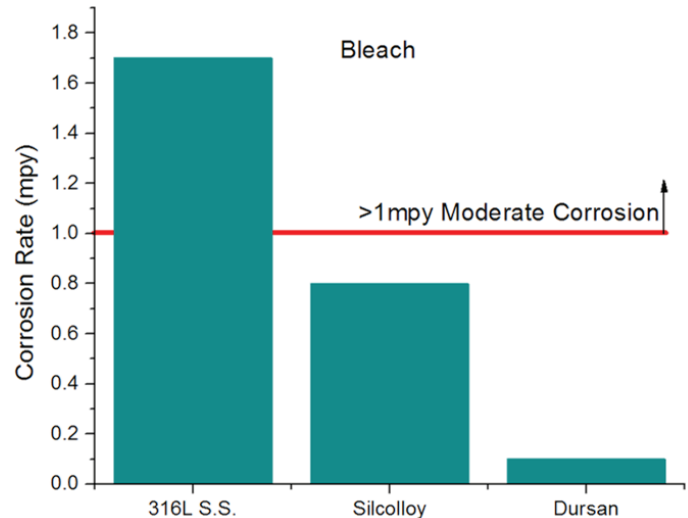
When compared to common solutions like fluoropolymers, SilcoTek-coated stainless steel offers both better protein resistance as well as durability to withstand common cleaning and maintenance procedures.



¹SilcoTek coatings enable better diagnostic results and decrease maintenance by greatly reducing protein sticking

3. Superior Corrosion Protection for Longer Usable Life

SilcoTek coatings substantially improve the corrosion resistance of stainless steel and other alloys, ensuring purity and sanitation.



SilcoTek coatings (right) allow the use of concentrated bleach without any of the corrosion issues that are common with bare stainless steel

Making the Impossible Possible

Working with SilcoTek is a unique service experience that puts customers and the quality of their parts first. This drives an endless commitment to providing fast, high-quality, mistake-free coatings every day. Let SilcoTek's coating services be the greatest asset to your supply chain.



Resources

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¹ Vaidya, S., Yuan, M., Narváez, Daghfal, D., Mattzela, J., Smith, D. "Protein-resistant properties of a chemical vapor deposited alkyl-functional carboxysilane coating characterized using quartz crystal microbalance." Published in Applied Surface Science. December 2015.

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Next Generation Coating Solutions for the Semiconductor Industry

- Enhance yield
- Ease factory integration
- Optimize process efficiency

The semiconductor industry is now driven as much by cost, productivity and speed as it has traditionally been by performance. As output continues to increase, manufacturers are faced with a new wave of challenges to deliver higher volumes at faster rates, stabilize processes with large amounts of data, and maintain exceptional standards of purity. Process reliability, equipment reuse, and rapid technology deployment have never been more crucial.

SilcoTek's patented 3D, non-line-of-sight chemical vapor deposition (CVD) processes produce high purity, flexible layers with excellent adhesion to typical semiconductor fab materials like aluminum, stainless steel and ceramics. The layer will conform to the most intricate component geometries. The SilcoTek® surface will deform with tubing surfaces, allowing radius bends and leak-free seals.

Figure 1a 316L stainless steel shows significant crevice corrosion; a Silcolloy®1000 treated coupon shows only minor pitting (ASTM G 48, Method B).

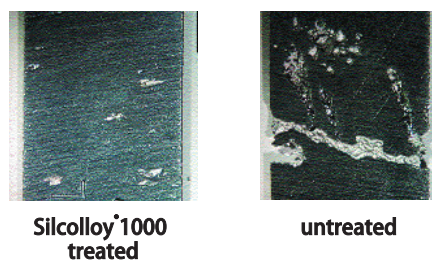
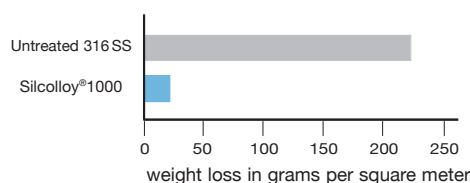


Figure 1b Silcolloy1000 treated stainless steel outperforms uncoated metal by an order of magnitude in chloride environments.



Silcolloy®1000 treatment improves corrosion resistance

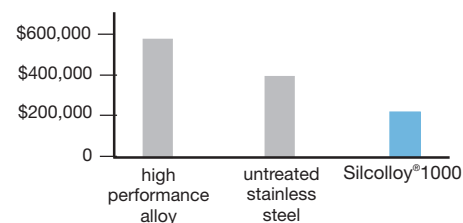
Independent laboratory testing shows Silcolloy®1000 treatment improves corrosion resistance by up to 10x over untreated 316L stainless steel (Figure 1a & 1b).¹ Silcolloy1000 treatment is compatible with many chemicals used in the semiconductor industry. Visit us online at www.SilcoTek.com for a complete list of common semiconductor chemicals and their coating compatibility.

Improve reliability while reducing costs

316L gas delivery systems exposed to corrosive environments are replaced 5 years or less from the time of installation. Substituting a high performance alloy for 316L stainless steel can increase the cost of the system by as much as five-fold.² The high-performance alloy may still be susceptible to metal ion contamination.

Improving the corrosion resistance of 316L stainless steel by up to 10x, the Silcolloy1000 treatment reduces costly maintenance and field failures due to steel corrosion. Figure 2 compares the cost of Silcolloy1000 treatment versus Hastelloy™ C22 construction in a typical gas delivery system. Silcolloy1000 treatment demonstrates significant lifecycle cost savings compared to unprotected stainless steel or stainless steel alloys.

Figure 2 Silcolloy1000 significantly lowers the life cycle cost of stainless steel or alloys (US dollars).



Ideal surface treatments for semiconductor applications

Silcolloy.

- Resistant to HBr, NF₃, HCl and more
- Ultra-high purity amorphous silicon
- Etch and deposition compatible

Dursox™

- Silica-like surface
- Provides erosion and corrosion barrier
- Minimizes metal ion contamination



12 Meet increasing industry requirements

Product performance is no longer the sole factor of success for semiconductor manufacturers. Products must be made efficiently at demanded volumes, on schedule and able to meet cost targets. According to the International Technology Roadmap for Semiconductors, Moore's Law will only be realized with consistently near-100% yield improvement, wafer size increases, and other productivity upgrades.³

SilcoTek's semiconductor coating solutions help prevent costly maintenance and downtime by protecting critical deposition and etch parts like:

- Showerheads
- In-chamber components
- Gas delivery systems
- And more

Enhance yield, reduce waste, and have more process control with Silcolloy® and semicon-modified Dursan®

SilcoTek's patented coating solutions designed for the semiconductor manufacturing industry offer a chemically inert, high-purity amorphous silicon surface that resists corrosion and particle contamination.

Silcolloy® and modified Dursan® are a reliable barrier for manufacturing equipment that makes defect detection easier, stabilizes processes, and increases output.

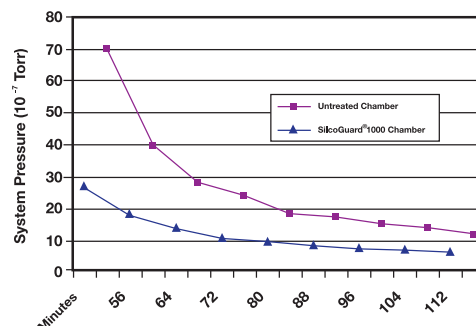
Greatly reduce the variability in data and output caused by corrosion from:

- HBr
- HCl
- NF₃
- And others

SilcoTek® treatments cut pump-down time Semiconductor processes requiring frequent pump-downs can realize dramatic productivity improvements by treating vacuum chambers with SilcoGuard®1000.

The slow outgassing of water vapor and other contaminants in process vacuum chambers can greatly hinder evacuation rates, process throughput, and ultimate base pressures. The application of SilcoGuard®1000 throughout exposed surfaces of vacuum systems can dramatically reduce outgassing rates and provide a productivity advantage to process chambers that require more rapid and efficient evacuations.

Figure 5 compares pump-down rates for a SilcoGuard1000 treated vs. an untreated chamber. SilcoGuard1000 will reduce pump down times by 2.5x or more, compared to untreated chambers.⁴



Conclusion

SilcoTek can help semiconductor manufacturers meet cost and productivity challenges by improving the surface performance of stainless steel:

- Eliminate process variables caused by corrosion
- Save money via reduced downtime and maintenance
- Enhance yield and throughput

SilcoTek treatments can be applied to existing process components. Custom treatment is available for process-specific components and applications. To learn more about how SilcoTek can improve the performance of your system, go to www.SilcoTek.com or call us at 814-353-1778.

References

1. M. Zamanzadeh; G. Bayer; G. Rhodes; D. Smith; M. Higgins; Laboratory Corrosion Testing of a Chemical Vapor Deposited Amorphous Silicon Coating; Matco Associates, Inc. Pittsburgh, PA; Restek Corporation, Bellefonte, PA. 2005
2. Vininski, Joseph; Lawrence, David; Torres, Robert; Diede, Ehrich; Daniels, Mia; "Corrosion Resistance of Cost Effective Alternative Materials for Semiconductor Gas Distribution Systems"; Matheson Tri-Gas, Longmont, CO; Diede Precision Welding, Longmont, CO; Sherwood, Harsco Corporation, Washington, PA. 2002
3. International Technology RoadMap for Semiconductors, 2013 Edition, Factor Integration Summary (http://www.itrs.net/Links/2013ITRS/2013Chapters/2013Factory_Summary.pdf)
4. D. Smith; M. Higgins; B. Kendall; Low Outgassing of Silicon-Based Coatings on Stainless Steel Surfaces for Vacuum Applications; Presented at annual SVC meeting, Restek Corporation/Elvac Laboratories (2005).

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SilcoTek treatments are available worldwide!

SilcoTek offers treatments on a custom basis direct from our facility. Just follow 2 easy steps to maximize the performance of your product!

Step 1 - Get a quote!

We make it easy with quote options to fit your needs visit our website at www.SilcoTek.com and complete our on-line quote request form or fax your quote request to Quotes at 814.353.1697 or e-mail it to Silcod@SilcoTek.com. We'll get a quote out to you within 24 hours!

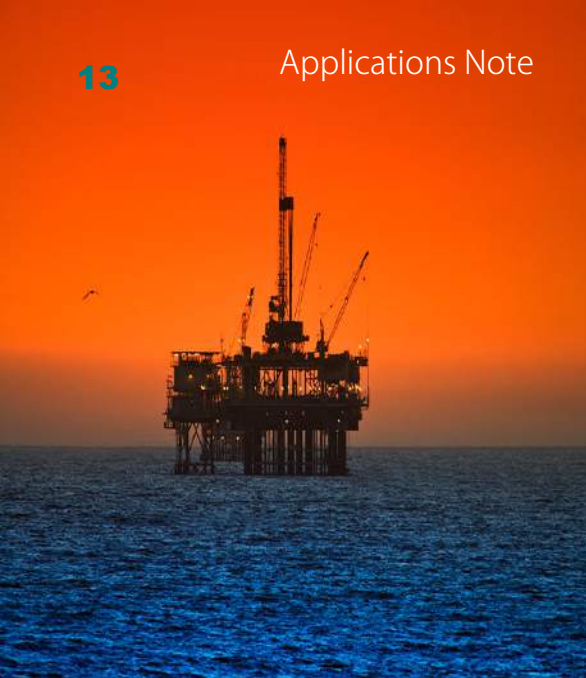
Step 2 - Send in your parts!

Mailing instructions, shipping labels and service number will be forwarded to you along with your quotation. Box up your parts and send them to us. Your order will be processed in 10 working days or less.

Our 2 touch system means zero disappointments. We'll notify you when we receive your parts and when your order is ready to ship.



SilcoTek treatments are available worldwide through representatives in analytical instrumentation, tubing specialists, fitting manufacturers, and other technology industries. For a complete listing of where you can purchase SilcoTek treated products, go to our website www.SilcoTek.com



Durable, inert, and corrosion resistant

2x the wear resistance of 316 SS

Suitable for pH 0-14

Inert for parts-per-billion analysis



High temperature and acid resistant

Stays intact up to 1400° C

Effective in salt environments

Comprised only of silicon



Upgrade Produced Water Processes with SilcoTek® Coating Solutions

- Increase component life
- Enhance analytical performance
- Save money and reduce downtime

Apply the Dursan® and Silcolloy® coatings to stainless steel, titanium, super alloys and ceramics to increase corrosion resistance and chemical inertness.

Offshore, marine and produced water processes are highly corrosive to untreated equipment. Although stainless steel and even exotic alloys provide corrosion resistance to some extent, the protection they offer rarely measures up to the demands of offshore and marine environments.

Both Silcolloy® and Dursan® are ultra-thin chemical vapor-deposited (CVD) coatings that are applied to a wide variety of componentry and custom fabrications to make them more durable, corrosion resistant and chemically inert. While certain applications call strictly for chemical inertness (e.g. analytical chemistry in the lab), most require a surface that is as robust as it is deactivated for precise trace level analysis.

Improve corrosion resistance
by 8x or more

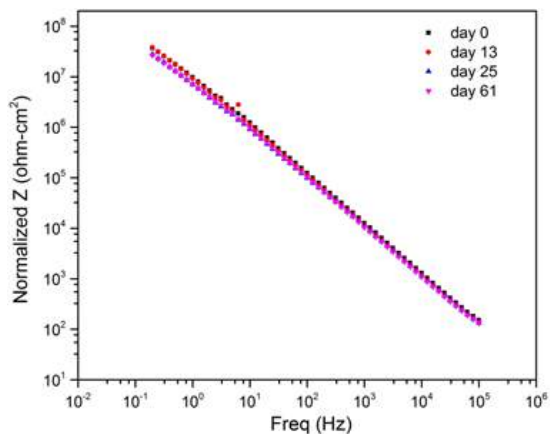
- 2x wear resistance vs. 316 SS
- <1.5µm thick: maintains tolerances
- Parts can be bent after coating
- Industry-leading inertness



SilcoTek's coatings offer a complete solution for precise process monitoring and measuring hydrocarbons in water. Outfit your new system with Silcolloy® or Dursan® to achieve super alloy performance at a fraction of the cost, or simply upgrade your existing equipment. The Silco'D process takes 10 business days or less (15 or less for Silcolloy). Every order is monitored and inspected by trained technicians, engineers, and R&D staff with state-of-the-art techniques to ensure the end product meets the performance standards required by the application.

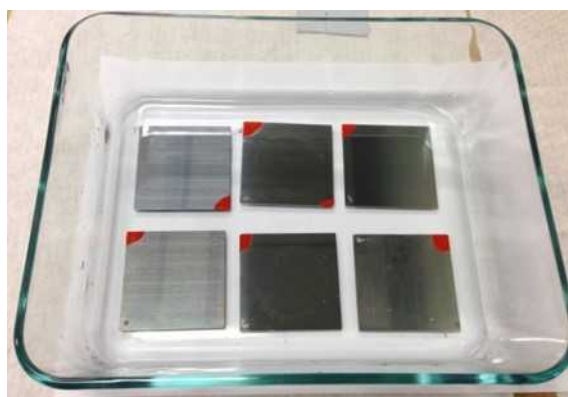
14 Data Appendix

Dursan® shows great stability after 60 days in salt water.



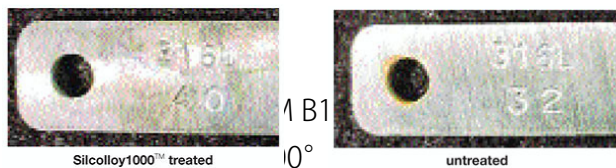
Dursan® in 5% NaCl monitored with EIS

Dursan® coated 304 SS coupons show no degradation after the test

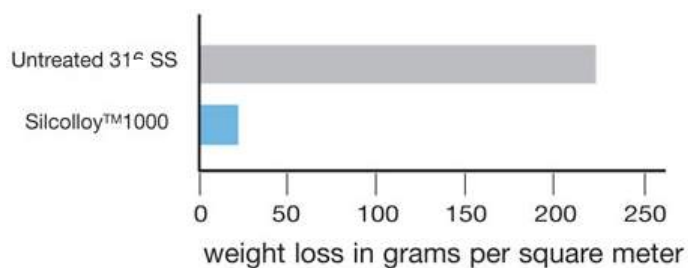
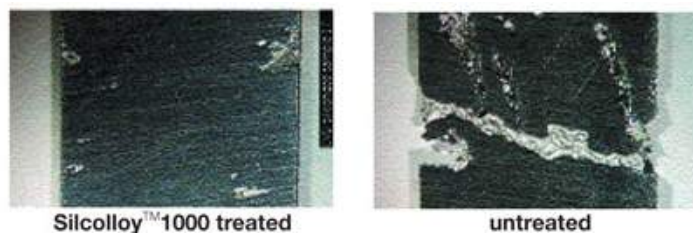


Dursan®, 60 days in salt water

Silcolloy® coupons are virtually unaffected by a 4000 hour salt spray



Greatly reduce pitting and crevice corrosion.



Silcolloy®: ASTM G 48, Method B2
72 hour ferric chloride pitting and crevice corrosion

Silcolloy®: ASTM D4585, Condensing Humidity
Water resistance of coatings using controlled condensation

1000 hours; 100° F; Distilled Water



Silcolloy® coupon is completely unaffected

Dursan®: ASTM G31 HCl Immersion
24 hours; room temp.; 18% HCl

	Un-treated	Treated
24hr; 6M HCl; 22°C	304 SS	Dursan
Mils Per Year	389.36	1.86
Improvement Factor	---	209.8

Dursan®: 1/2 the wear rate of 316 SS

Pin on Disc; 2.0N	316 SS	Dursan
Wear rate (x10 ⁻⁵ mm ³ /Nm)	13.810	6.129
Improvement Factor	---	2 times



Applications Note

Keep Sulfur in Sight with SilcoNert® 2000 for Subpart-Ja Compliance

- Improved system stability
- Reduced troubleshooting
- Accurate, reliable results
- Fast equilibration
- Proven performance

Sulfur regulation compliance requires a sampling system that's inert, reliable and robust. SilcoNert® offers all three.

SilcoNert.2000

The coating solution for sulfur

Trust your results below parts-per-billion levels

Eliminate adsorption and contamination

Meet US EPA requirements

- Subpart -Ja
- Tier 3 Emissions Standards
- Rule 1118



By November of 2015, most refinery flares will require emission monitoring systems to ensure compliance with new Subpart -Ja regulations from the United States EPA. But, with all process media in a refinery now going through the flare, can analyzers deliver reliable analytical results?

Since the advent of ULSD (ultra low sulfur diesel) and ULSG (ultra low sulfur gasoline) regulations in the 90's, the need to accurately measure stream sulfur content in the refinery has significantly grown. SilcoNert® 2000 was developed to meet and exceed the requirements of the industry by creating the most inert surface on components and tubing used to build sample pathways. After the ULSD/ULSG initial entry point, SilcoNert (Sulfinert®) coating use has spread throughout all aspects of refining/petrochemicals for on-line, process, lab and grab samples.

SilcoNert 2000's use in refinery sampling applications involving sulfur, ammonia and mercury streams is well documented in many publications. SilcoNert coatings can be found in use all the way up stream in well exploration and many down stream processes where part-per-billion levels of sulfur are important, such as in ethylene and propylene production.

See the whole sample
every time.

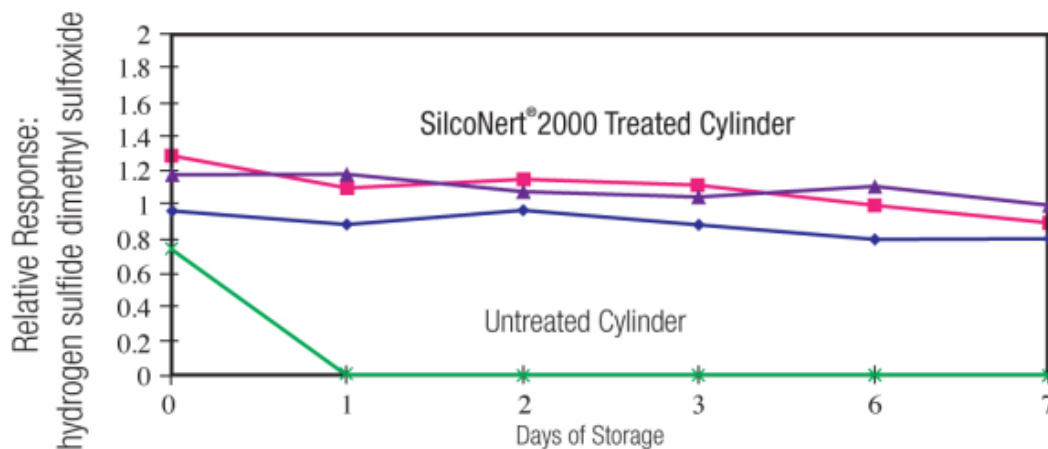


Figure 1: Sulfur compounds remain stable in SilcoNert-treated stainless steel sampling systems for long periods. Sulfur composition of samples in untreated cylinders is totally adsorbed within 24 hours.

The California Environmental Protection Agency led the way into flare gas emission sampling with Rule 1118 approval in 2007. A study and paper by Davidson, et al.¹ demonstrates the importance of system design and coating considerations in creating a durable and reliable system that is stable over many months and shows good calibration consistency. This real life application of the coatings in the field and on-the-flare supports the fact that an inert sample pathway is required to assure compliance.

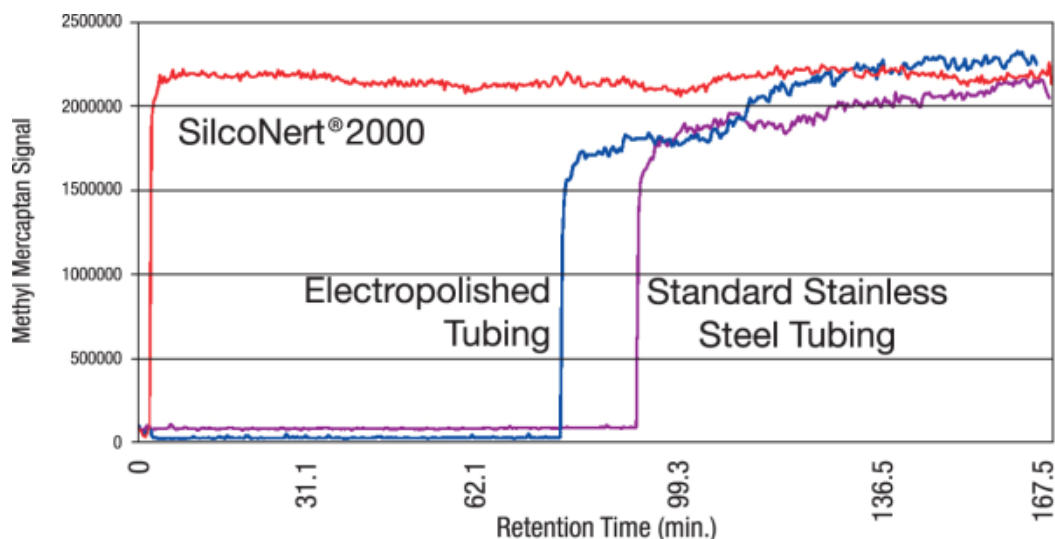


Figure 2: SilcoNert-treated tubing responds instantly and doesn't absorb methyl mercaptan (500ppbv) compared to electropolished and standard stainless steel tubing.²

Now, the challenge is monitoring a flare cocktail that is prone to upsets and can even contain hydrofluoric acid (HF). The SilcoNert coating is very stable, but the harsh nature of HF can have an impact on the lifetime of the treatment. It is important in these processes to ensure that calibration checks are monitored regularly, especially during upsets with wet HF which can etch the SilcoNert layer. Additionally, the substrate material of tubing and sampling lines in contact with an HF stream must be considered.

Traditional sampling systems for alkylation units use Monel® sampling cylinders which are stable for HF but terrible for sulfur sampling. Work by Hashem, Elshahaw et. al³ has demonstrated that Monel® acts as a "scrubber;" any reduced sulfurs are completely lost when contacted by this particular substrate.



Coating Monel® with SilcoNert® 2000 is not possible. This uniqueness of copper also causes inhomogeneous growth of the SilcoNert layer. In a scenario with harsh process media like HF, a paper published by Phil Harris⁴ at Haritec supports the conclusion that SilcoNert-treated alloy C-276 should be used for sampling equipment.

Conclusion

SilcoNert 2000 is a required treatment for analyzing sulfurs and other trace compounds due to its ultimate chemical inertness, reliability and robustness. For today's sampling challenges presented specifically by sulfur monitoring regulations like the EPA's Subpart -Ja, SilcoTek leads the industry by working with all component manufacturers, analyzer OEMs and integrators to deliver coated sampling systems and other products that will yield superior analytical consistency and reliability right out of the box.

¹Davidson, T.; Limfueco, R.; et. al. "Performance of Environmental Monitor For Total Sulfur and High Heating Value of Refinery Flare Vent Systems" ISA 56th Analysis Division Symposium, League City, TX, pages 1 – 11 (2011)

²Application of TrueTube(tm) in Analytical Measurement Cardinal UHP, August 2004. The authors thank the staff at Shell Research and Technology Centre, Amsterdam.

³Hashem, M.; Elshahaw, H.; et. al. "Low-Level Hydrogen Sulphide Detection using Wireline Formation Testers" International Petroleum Technology Conference, Dubai, U.A.E. December 2007

⁴Harris, P.; Mankin, K. "How to Improve Sulfur Sampling & HF Corrosion Resistance in Flares" SilcoTek Blog, February 2014: <http://cdn2.hubspot.net/hub/22765/file-523283917-pdf/docs/hf_in_flare_gas_pharris.pdf>



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Ensure Tier 3 Sulfur Regulation Compliance with SilcoTek® Coatings

Tier 3 Compliance Guide

By 2017, the EPA's Tier 3 gasoline sulfur regulations require that oil refineries reduce the average sulfur level in gasoline by more than 60 percent, to just 10 parts per million (ppm) in 2017, from the current 30 ppm.

i Sampling system flow paths constructed of bare stainless steel quickly adsorb sulfur molecules and prevent them from reaching the analyzer.

Therefore, process instruments without inert-treated tubing, fittings, valves, and other wetted parts are not suitable to comply with Tier 3 regulations for trace sulfur measurement.

SilcoTek's inert coatings implemented throughout the sample flow path ensure accuracy and reliability by preventing sulfur and other reactive compounds from adsorbing onto transfer equipment. Without these coatings, refineries will not obtain sulfur signals at the 10ppm level required by the EPA.

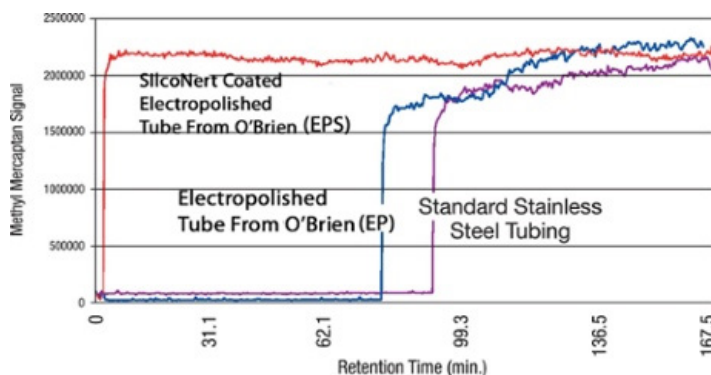


Figure 1: SilcoNert-coated tubing provides nearly instant methyl mercaptan signal whereas untreated tubing adsorbs the compounds and takes over an hour to calibrate.

(Data courtesy of O'Brien Corp./Cardinal UHP and Shell)

Since the advent of ULSD (ultra-low sulfur diesel) and ULSG (ultra-low sulfur gasoline) in the 1990s when the need for accurate sulfur measurements became widespread, use of inert coatings like SilcoNert® expanded throughout the petrochemical industry for on-line, process, lab and grab sampling applications.

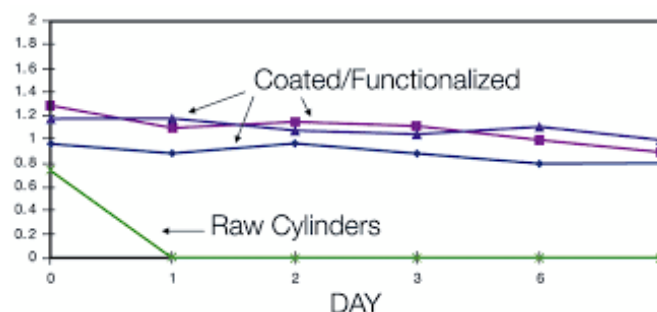


Figure 2: Hydrogen sulfide (H₂S) samples are retained in SilcoNert-coated sample cylinders for over a week with minimal loss, making labs more efficient and flexible. Uncoated cylinders adsorb the entire sample within one day.

SilcoNert-coated sampling and transfer systems allow refineries to obtain accurate sulfur data the first time, every time without delays, sample errors, or false readings. Now charged with meeting stringent Tier 3 sulfur regulations from the EPA, analysts and engineers can comply with the law while saving thousands in improved yields, test cycle times, and system reliability.

How to Buy

Ask your manufacturer to add SilcoTek's SilcoNert® coating to your sampling and transfer equipment.

For a full listing of partners who stock coated products, visit www.SilcoTek.com/buy-coated-products.

Or, visit www.SilcoTek.com to send your parts in for coating.

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