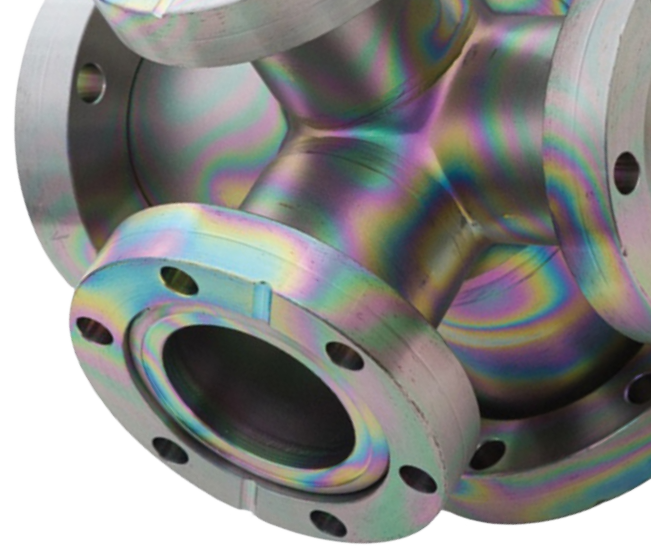
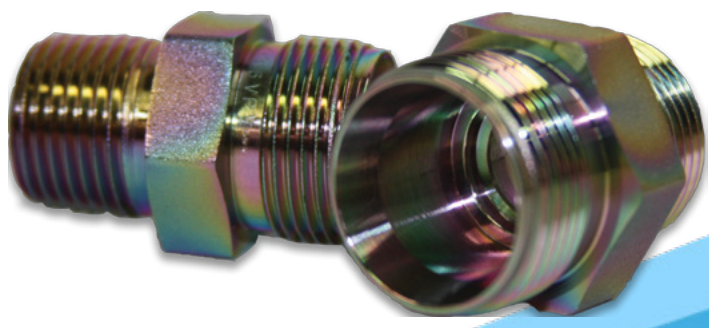


An Introduction to Inert Coatings



How to Ensure your Sampling System Always Delivers Maximum Reliability

SilcoTek®

E-book #2 of 4 in

The Ultimate Guide to Reliable Sampling with SilcoTek® Inert Coatings

Table of Contents

1. Introduction

SilcoTek® became a coatings company because we have a passion for helping people and businesses conquer their most difficult material challenges. We help our customers improve analytical results, improve yield and efficiency, and to develop innovations that push the scientific and industrial world forward.

Why Should I Read This E-book?

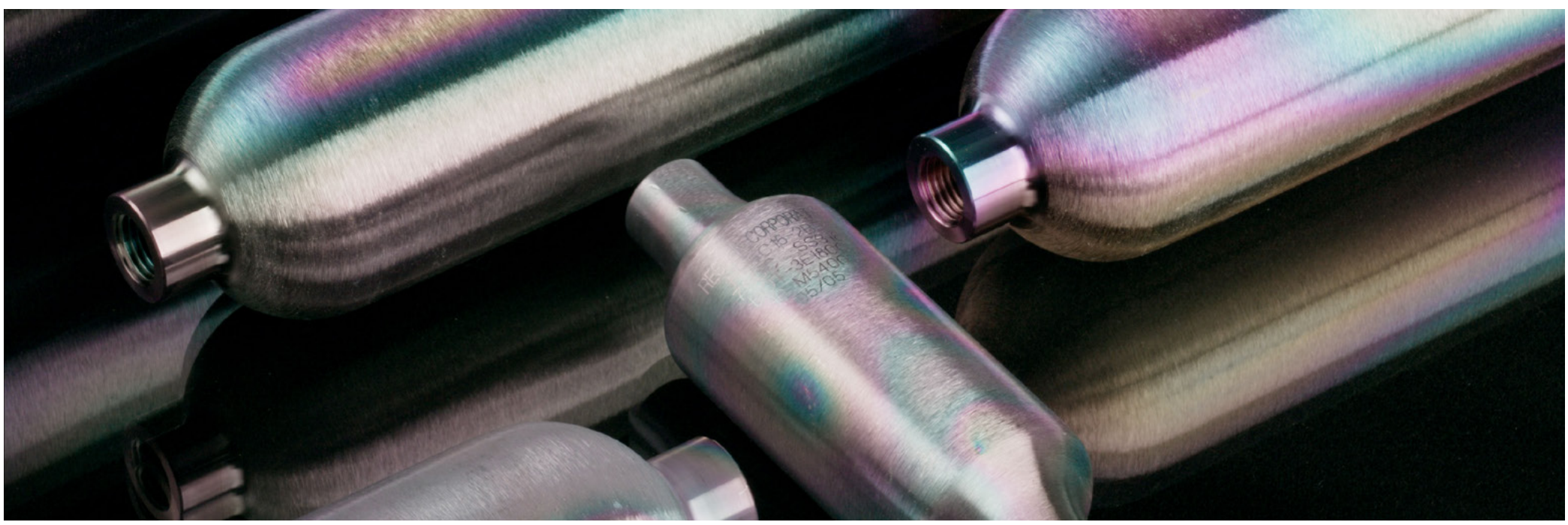
Because you'll learn how to prevent common sampling and analytical problems and learn ways to save time and money. You will learn how to:

- Improve sample system reliability
- Improve system response and process control
- Reduce troubleshooting
- Get the results you need the first time, every time

Our scientists and engineers are dedicated to teaching the customer how to improve the material performance of their products and processes. Read on and benefit from our over 250 years of analytical experience.

Paul Silvis, Head Coach

2. What are Inert Coatings and How can they Improve my Product?



What are inert coatings?

Inert coatings are non-reactive barrier materials that are bonded to a flow path container (be it tubing, sample cylinder, instrument components or other structure). Inert coatings offer known benefits to applications ranging from process analytical, chemical process, & refinery, to semiconductor manufacturing. Benefits include:

- Preventing sample loss
- Preventing contamination
- Improving process monitor response
- Improving corrosion resistance and durability
- Preserving sample integrity by preventing sticking to the surface
- Reducing maintenance and burn-in

Typical inert surface materials include:

- Silicon
- PTFE
- PEEK
- Gold

Conversely, materials that are not inert include:

- Stainless steel and other alloys
- Glass
- Quartz and other ceramics
- Viton (some may be inert)
- Monel
- Brass
- Rubber and neoprene
- Paint

Application method can be a determining factor in the performance of an inert coating. An amorphous silicon coating applied by chemical vapor deposition (CVD) to interior and exterior stainless steel instrument or process surfaces will provide a tough bond to the surface and assure complete flow path coverage. A coating that is thin, tough, and will conform to complex sealing surfaces while maintaining high dimensional tolerances is ideal.

Chemical vapor deposition coating process

SilcoTek's CVD coating process starts with a thorough assessment of the parts and customer requirements. Understanding the customer performance need, specifications, and end use help to assure that the best coating for the application is applied.

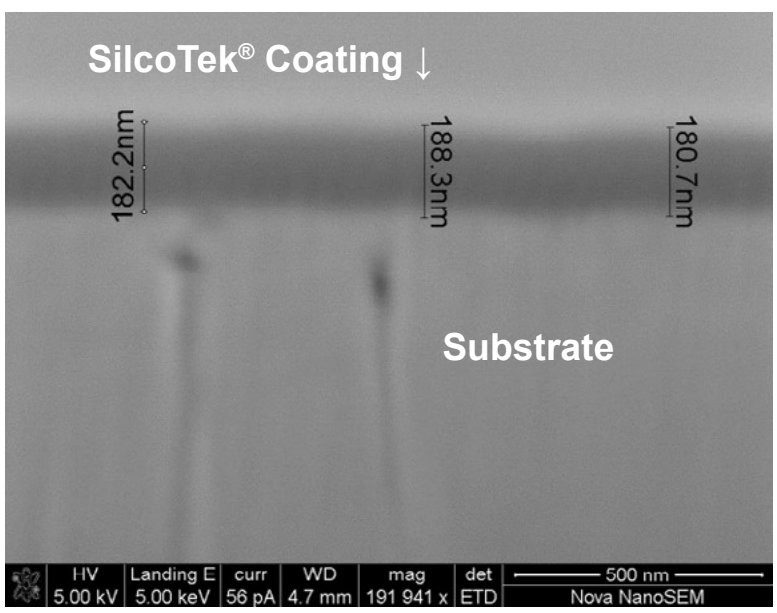
Watch our process demonstration video to learn more.

After receiving a part for coating, surface preparation technicians clean the surface and prepare parts for the CVD process. It is critical that any parts that will be coated are free of contamination, even as minor as a fingerprint.

After a thorough surface preparation, our technicians load customer parts into corresponding holding fixtures and then place them into a vacuum vessel corresponding to the size of the parts.

The coating vessel is placed into the CVD process oven where it is heated to 400-450 °C. A proprietary blend of gas enters the vessel and starts a reaction with the base substrate, causing the coating to diffuse into the molecular lattice of the surface. The result is the ultra-thin, high performance SilcoTek coating that so many have come to recognize and trust.

Want more details about our coating process? Watch our process overview webinar.



After heating, the part is exposed to high purity silicon precursor gases. The gases coat internal and external surfaces and bond securely to the surface. Highly inert compounds can then be bonded to the silicon to create a super inert barrier. This is known as surface functionalization. Even sub-micron-sized surfaces can be uniformly coated to assure inertness.

After coating, the part is cleaned and inspected per both customer and SilcoTek specifications. The finished product is packaged and shipped using best practices to ensure safety in transit, or per specific customer requests. The total lead time for most SilcoTek coating processes is fewer than 10 working days.

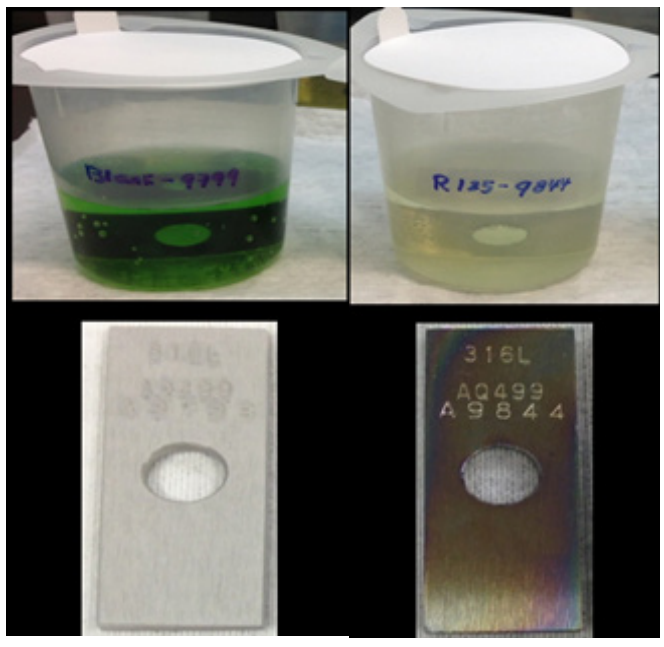
You may also purchase pre-coated products directly from the part manufacturer to reduce lead times. We team up with industry leaders to offer a more direct solution for your supply chain.

How does an inert coating improve my process or product?

Inert coatings offer three distinct properties that improve process analytical systems:

1. Corrosion resistance

SilcoTek® coatings resist corrosive attack by acids commonly used in chemical process, refinery and analytical applications. SilcoTek coatings can extend the life of tools by 10x or more. Comparative results show inert coatings like Dursan can significantly improve corrosion resistance over stainless steel and other steel alloys. Dursan performance compares favorably to super alloys. HCl immersion tests show uncoated stainless steel severely corrodes, turning the acid green. The Dursan coated coupon shows minimal corrosion and uncontaminated acid.

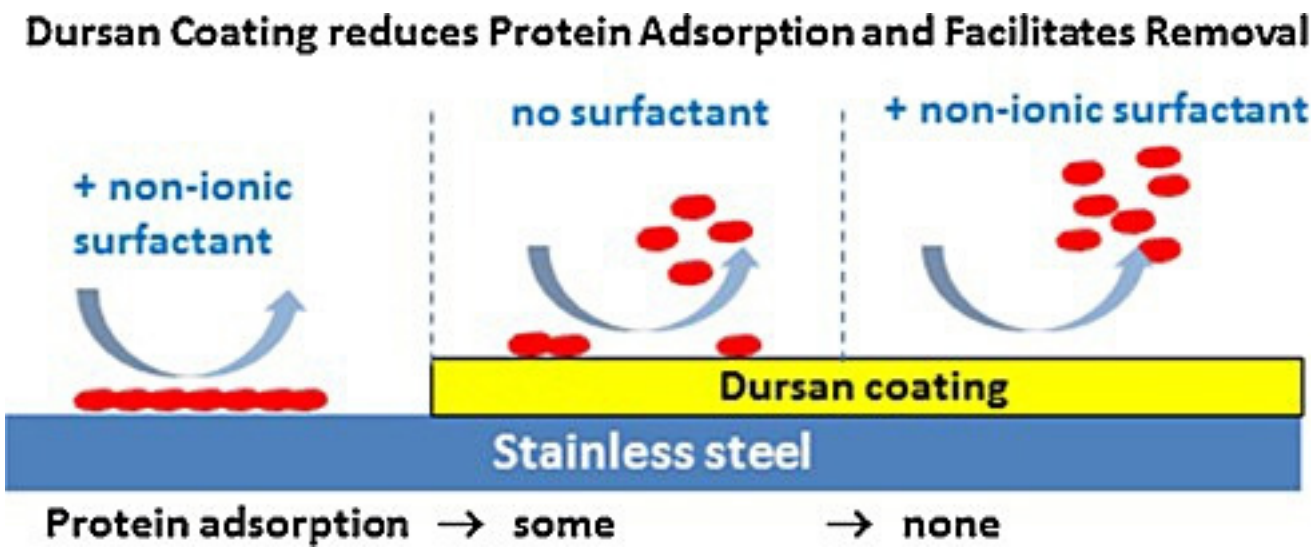


Uncoated 316L SS **Dursan-Coated 316L SS**

2. Purity

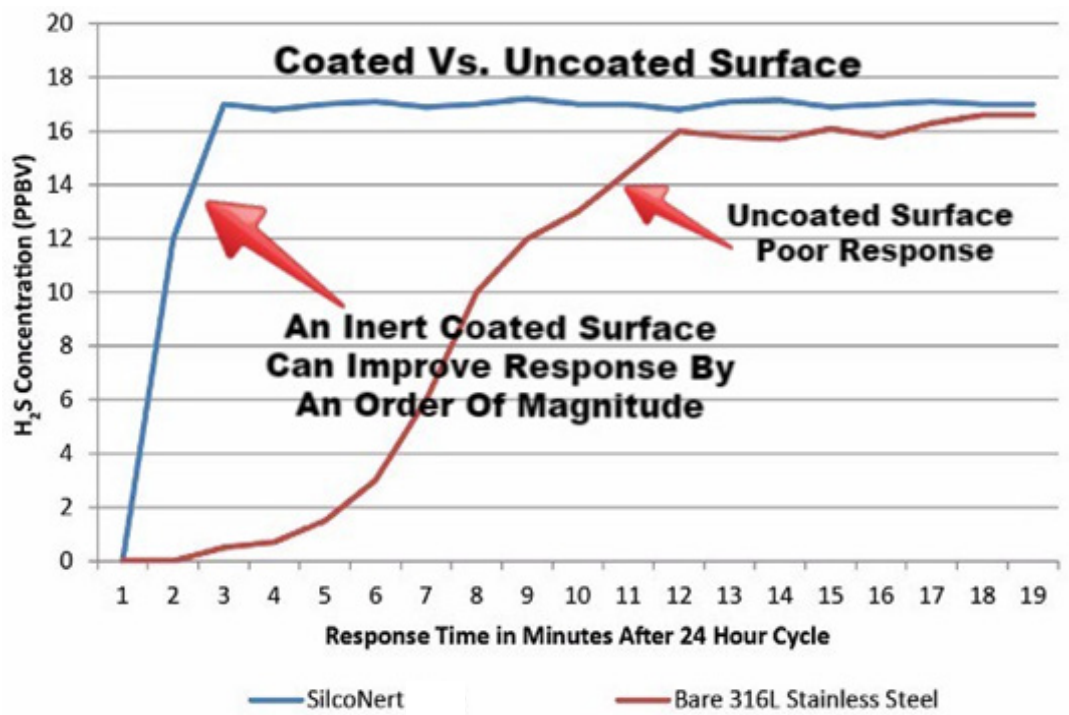
SilcoTek coatings act as a barrier, preventing contact of the test analyte with reactive stainless steel or glass substrate. A high purity surface prevents contamination of the process fluid and prevents bonding of “sticky” media to the surface. The high purity silicon surface won’t allow corrosive gases from leaching metals from the surface, improving process yield and analytical test accuracy.

The illustration below highlights the benefit of a high purity non-reactive & non-stick surface. Uncoated stainless steel can allow contaminants and “sticky” materials like proteins to bond to the surface. Dursan prevents materials from interacting with the substrate and allows even the most reactive compounds to be removed from the surface, preventing cross contamination and false positive results.



3. Inertness

Inert coatings do not adsorb or react with product or sample flow, preventing test failures, inaccurate results and contamination. An inert surface will improve system response because there is no interaction with the test sample.*



Silicon also does not require burn-in or seasoning of the stainless steel surface. This means that instruments perform at their peak right from the start. Because there is no adsorption, test compounds flow through the system easily, making calibration fast and easy. The built-in inertness of silicon can cut hours off tool burn-in or calibration, adding to plant productivity.

That’s the short version of the why and how or coatings can improve the performance of your products and process. Want the long version? Go to our Solutions Page and read on.

*Image & Data courtesy of CONCOA

3. Inert Coatings, not Passivation, the Answer for Accurate Sulfur Test

Inert coatings offer significant benefits over traditional surface passivation or priming techniques used in analytical & sample transfer systems. Industry whitepapers and articles have proven that surface interaction and corruption of sample results can be avoided through the use of inert barrier coatings. Reactive or active compounds found in hydrocarbon processing and environmental sampling can be especially difficult to accurately test at low part-per-million or parts-per-billion sensitivity. That's why a non-reactive flow path has become the industry standard for a high performance sampling system. Benefits include:

- Accurate & reliable H2S & sulfur test data
- No delay in analyzer response
- Reduced sample error & false readings
- Improved product yield and test productivity
- Faster cycle times

Passivation Not the Answer

Passivation or priming is a technique that is based on the assumption that – if all active sites of a transport system or storage vessel are taken up by a reactive analyte, like sulfur compounds, those active sites are “filled” and can no longer take up sulfur compounds or other reactive compounds. Early studies supported this idea for low temperature gas phase transport of relatively high concentration sulfur compounds through low surface area components.

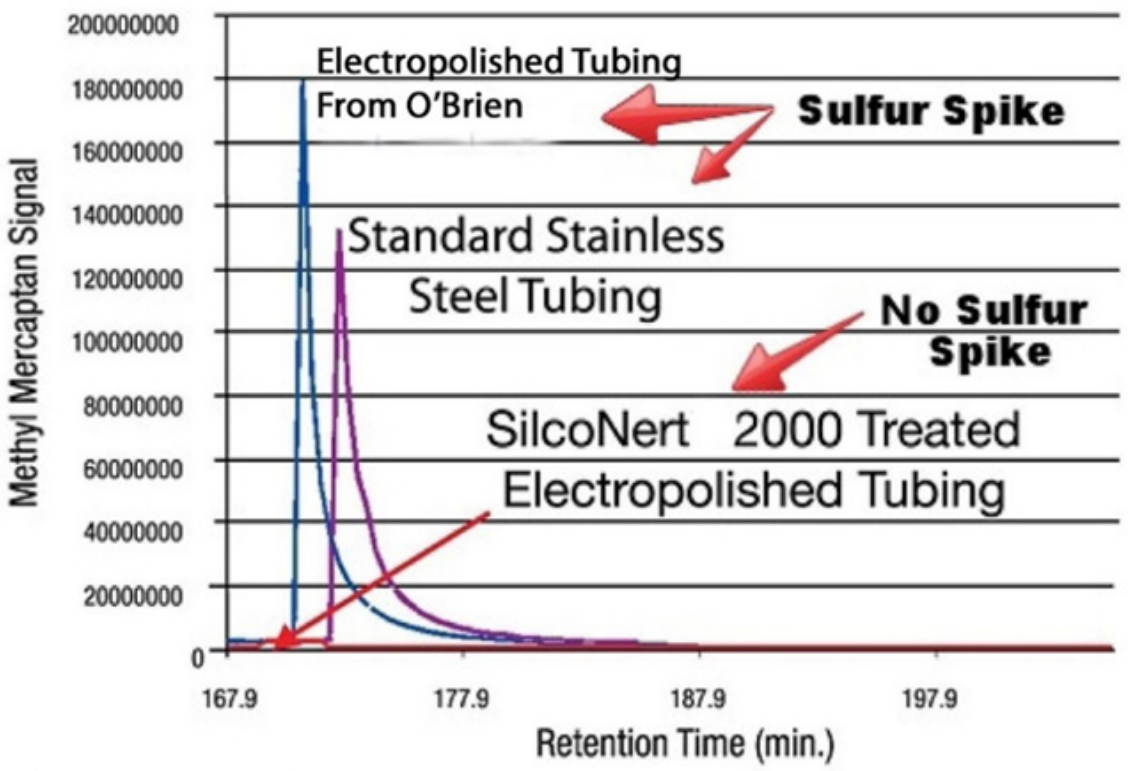
The results were encouraging to operators looking for the lowest possible component cost. Why pay for an inert coating when I can make the surface resistant to adsorption by taking up all the active sites with the very chemical I’m testing? All that’s needed is time for the sites to “season”. That logic held up somewhat when desired or regulated sulfur content in product was measured in the percent to high part-per-million range. That’s because loss of a few ppm of sulfur to adsorption from remaining active sites was no big deal.

Today, however, fuel standards, environmental standards, and refinery catalysts require sulfur measurement capability ranging from single digit parts-per-million (ppm) down to parts-per-billion sensitivity. A once acceptable loss of a few ppm when calibrating to 50 or 100 ppm (amounting to a 1 or 2% loss to adsorption) is now a major problem when calibrating a system to 5 ppm (now a 20 or 40% loss)!

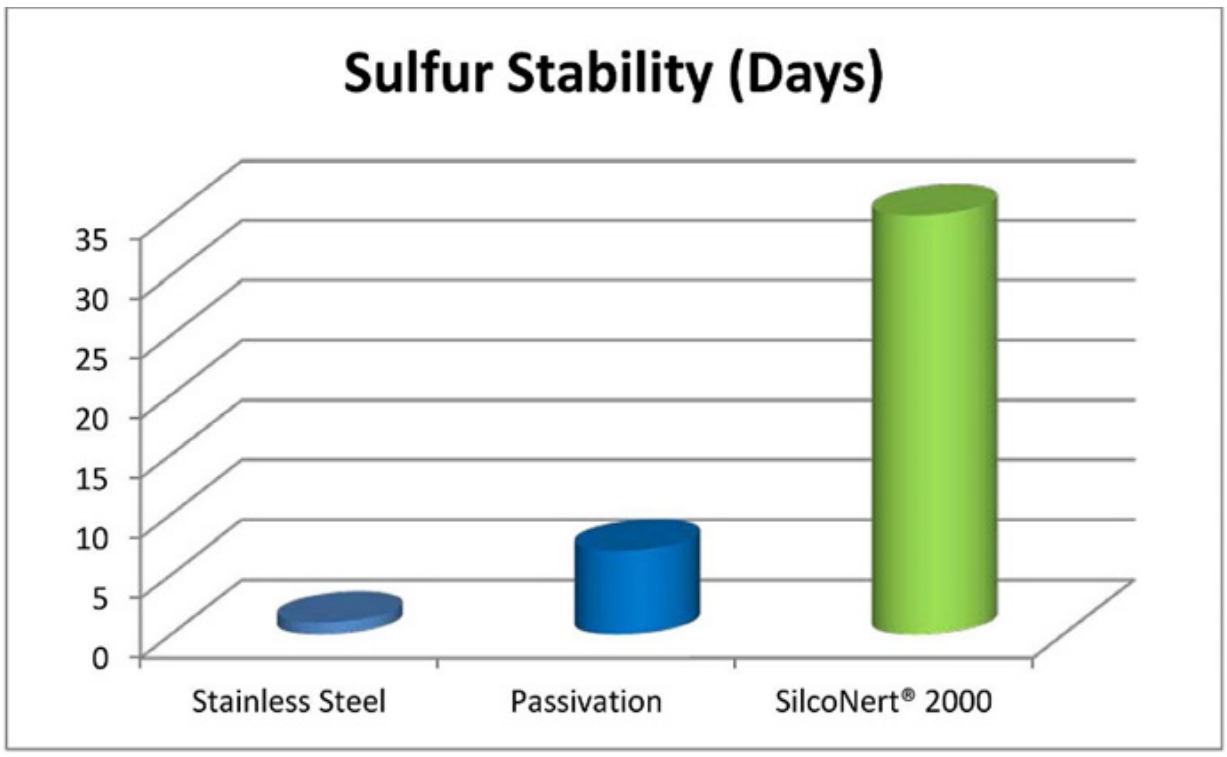
Most common surface passivation techniques, priming, oxidation, or electropolishing either lack the inertness needed to achieve meaningful analytical results or are not durable enough to withstand corrosive attack, heat, wear, and general abuse commonly found in process sampling. Some drawbacks to passivation include, amongst others:

- Reduced inertness to active compounds
- Total loss of passivation within short duration
- Heated stainless steel does not passivate
- Potential of complete adsorption of sulfurs or other reactive compounds

The growing consensus is that passivation or priming may be a short-term solution to high sulfur content analysis, but long-term reliability and test precision suffers, especially in applications where concentrations are below 200 ppm.
Recent testing by Shell and O’Brien Corp found purging a component with clean gas can reduce the inertness of the passivation and create a spike of contamination in the system, causing a false positive result.**



Further studies have shown that low concentration exposure to passivated surfaces resulted in rapid loss due to adsorption, with measurable impact occurring within hours and complete loss within days.



Additionally, heated stainless does not improve passivation, complete adsorption of sulfur will occur no matter the conditions and previous exposure to sulfur compounds within a day of exposure.

Read the complete article.

**Data courtesy of O'Brien Corporation and Shell Corporation.

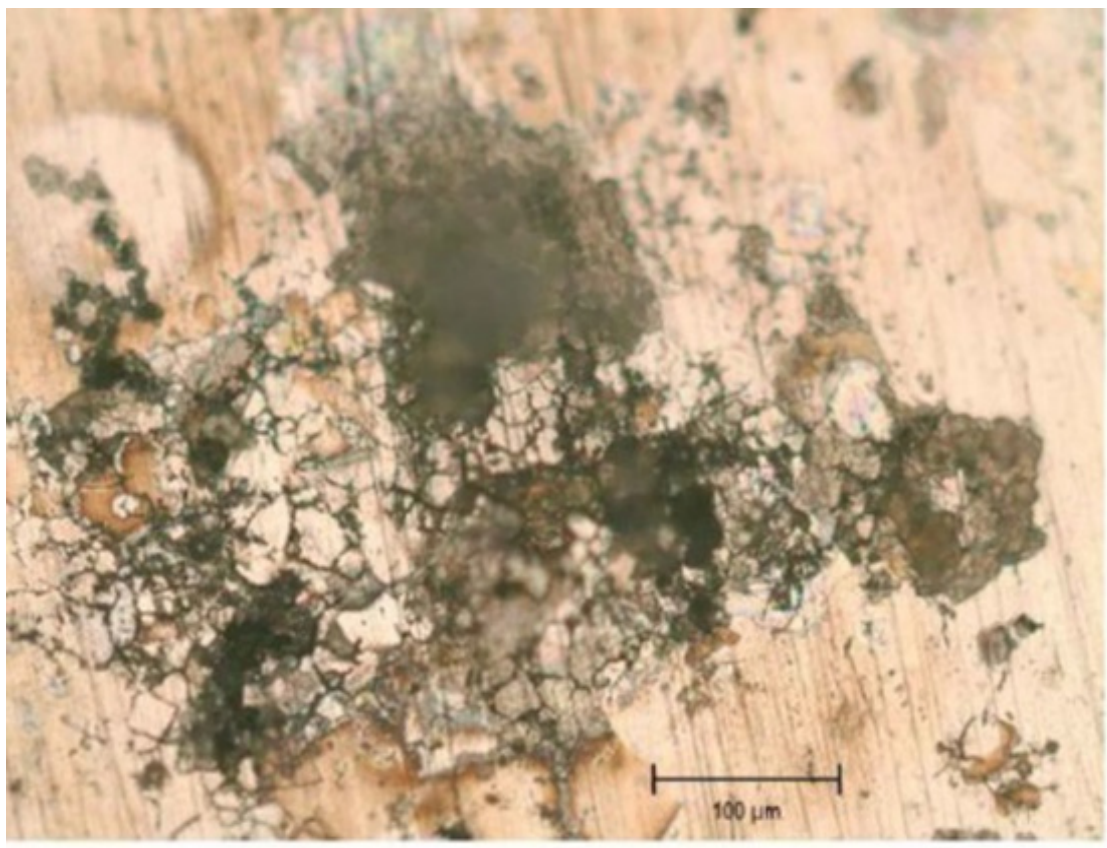
Avoid risking plant performance or environmental compliance to an unreliable passivation technique. Coat the entire sample flow path with an inert coating like SilcoNert®. Sulfurs ammonia, mercury and H_2S sampling and transport must have a completely inert flow path in order to prevent adsorption and loss of the sample, especially when testing trace amounts ranging from 200 parts-per-million down to low parts-per-billion.

SilcoNert can be applied to all components commonly used in process sampling:

- **Tubing and heat trace tubing**
- **Fittings**
- **Regulators**
- **Filters**
- **Probes**
- **Sample cylinders**

Components can be purchased from the manufacturer with an inert coating already applied, making high performance sample and transfer reliable and easy.

4. An Alternative for Corrosion Resistance and Inertness



Corrosion can not only compromise analytical system integrity and increase maintenance cost; it can also generate particulates that can result in obstruction and fouling of the system and cause adsorption of reactive compounds, ultimately compromising test results. Pitting can also create excellent hiding places for “sticky” molecules, resulting in carryover and false positive results. Passivation and polymeric coatings have been utilized to reduce corrosive attack, but there’s a higher performing alternative that improves both inertness and corrosion resistance of the surface.

About Passivation

Nitric acid passivation is commonly used in an effort to remove exogenous iron from surfaces and to prevent staining in the hope that the stainless steel flow path will become more corrosion resistant or inert.

Traditional passivation techniques involve the following steps:

- Thorough cleaning of surfaces
- Immersion in nitric or citric acid bath for 30 minutes. (acid concentration and additives are dependent on the grade of stainless steel)
- Rinse parts thoroughly in water
- Test part for passivation by placing in a humidity cabinet.

Unfortunately, when applications require the use of aggressive agents like bleach, sulfuric, or hydrochloric acid, no amount of passivation or electropolishing will prevent corrosive attack.

An Alternative to Passivation

There is an alternative to passivation that produces better results: change the surface properties of the material by bonding enhanced silicon compounds onto the steel surface via chemical vapor deposition (CVD). A coating like Dursan®, for example, will improve the corrosion resistance and inertness of the surface, offering a multitude of benefits. The chemical vapor deposition process used to passivate stainless steel flow paths will prevent disruption of grain boundaries and act as an inert barrier to aggressive and sticky compounds. Dursan-coated analytical flow paths will prevent HCl, sulfuric acid, bleach, and other corrosives from pitting and attacking stainless steel surfaces.

Click here to learn more about improving the corrosion resistance and durability of analytical systems.

The Dursan® Process

Watch our process video and see how we bond silicon compounds to stainless steel sufaces to improve their performance:

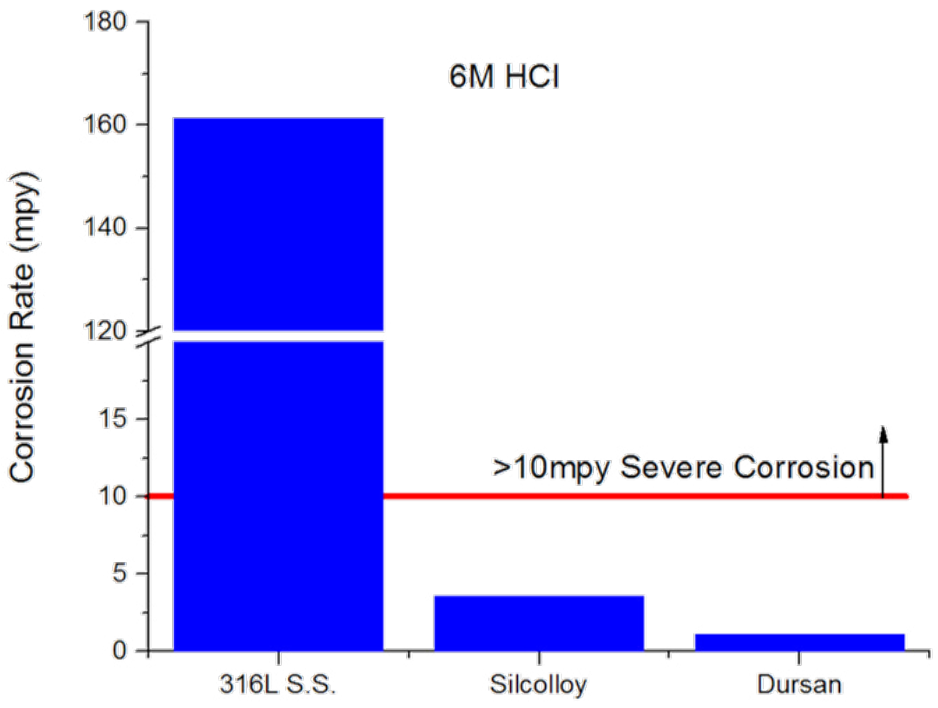
The Dursan CVD coating process is quite different than typical surface treatment or coating methods, even compared to other CVD methods. In addition to the coating deposition itself, the Dursan process also contains the following steps:

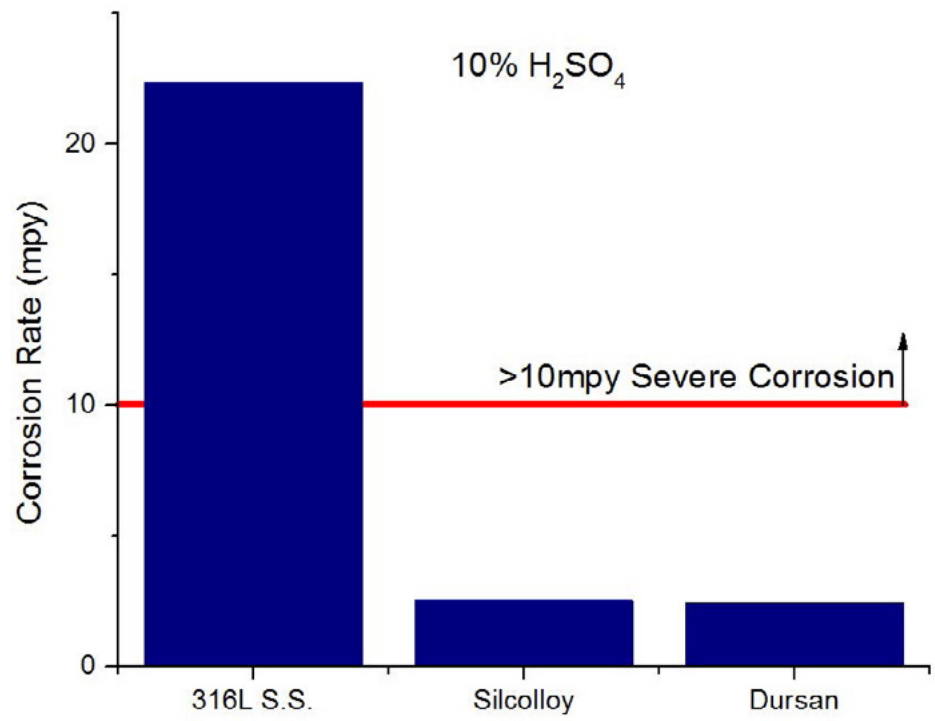
- Surface preparation (typically aqueous sonication)
- Multi-step deposition of silicon and other compounds to the surface
- Post-deposition cleaning
- Testing and inspection

Protecting Stainless Steel from Corrosive Attack in Continuous Emissions Monitoring (CEMS) Flow Paths

Dursan® can increase corrosion resistance by 10x or more through preventing interaction of the analyte or process fluid and the stainless steel surface. Dursan exceeds typical metal passivation capability and inertness by orders of magnitude while maintaining dimensional tolerance. Immersion testing in 6M hydrochloric acid (HCl) shows that Dursan coated surfaces prevent surface attack by orders of magnitude compared to passivated stainless steel.

Sulfuric acid can form in process analytical sampling systems and stack sampling systems that transport stack emissions or hydrocarbon flare samples. When exposed to water and heat, sulfur compounds commonly found in stack samples can form sulfuric acid and corrode and contaminate sample systems. Inert coatings like Dursan reduce the risk of corrosion, even when exposed to sulfuric acid.





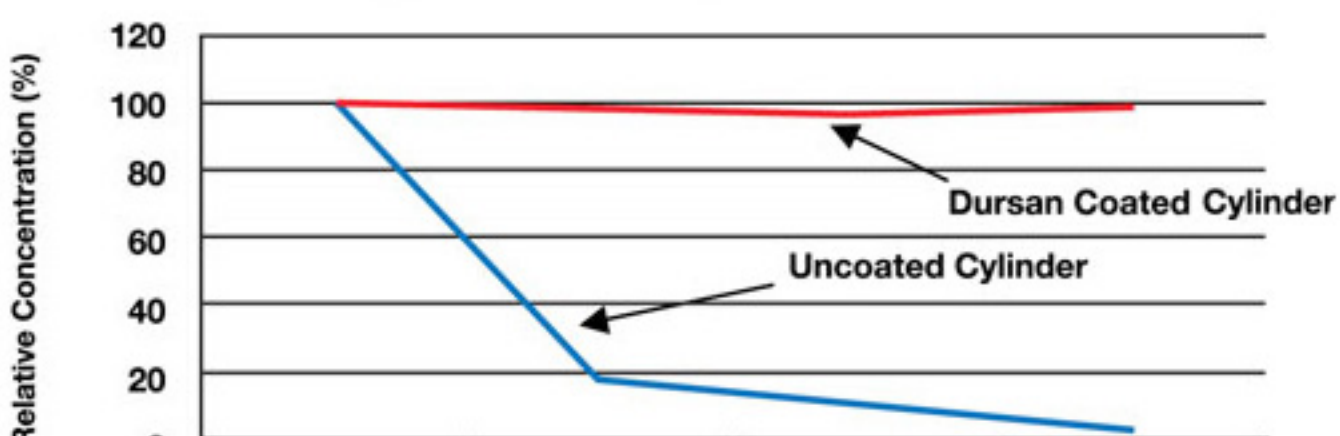
Stop Carryover and Contamination

Sticky compounds like COS and H_2S can be difficult to remove from CEMS sampling flow paths. Existing techniques for enhancing release such as priming do not assure complete inertness of the analytical flow path.

SilcoTek provides an alternative coating solution in Dursan that offers better stability in air and other oxidative environments, even under elevated (450° C+) temperatures. Dursan ensures near-zero adsorption compared to passivated stainless steel.

Assure your analytical system is performing at its peak. **Click here to read our inert coatings presentation.**

Sulfur compounds at 50 parts-per-million in Dursan-treated stainless steel sample cylinders versus non-treated cylinders



	0:00	25 hours	50 hours	75 hours
Stainless Steel	100	19	10	4
Dursan Coated	100	98	96.6	98.3

5. Choosing the Right Coating

SilcoTek's technical experts are here to help you select the best coating for your application. Some applications may require specialized treatment, but often one of our standard surface coatings will perform well for you.

SilcoTek's complete platform of coating solutions offers a multitude of surface properties for your most challenging applications:

- Low surface energy
- Oleophobicity
- Hydrophobicity
- Abrasion resistance
- Easy cleaning/anti-stick
- Chemical inertness/compatibility
- Corrosion resistance
- Anti-coking/anti-fouling
- High purity/low outgassing
- Contamination resistance

The recommendation process involves listening to the customer's application and need, providing coating samples, testing & evaluation at both customer and SilcoTek® sites, technical consultation regarding coating & process optimization, site visits, and more.

The time needed to select a coating can be as short as a few minutes or can involve months of evaluation, depending on customer requirements and the application. The SilcoTek service experience couples technical expertise with coating capability and performance to give customers a solution they (and their customers) can rely on.

Common Applications

SilcoTek offers a range of coatings developed to solve difficult material problems in a wide variety of industry, analytical, process, and research applications. SilcoTek's technical staff can also modify an existing coating or develop a new coating technology to meet your needs.

Common coating applications include:

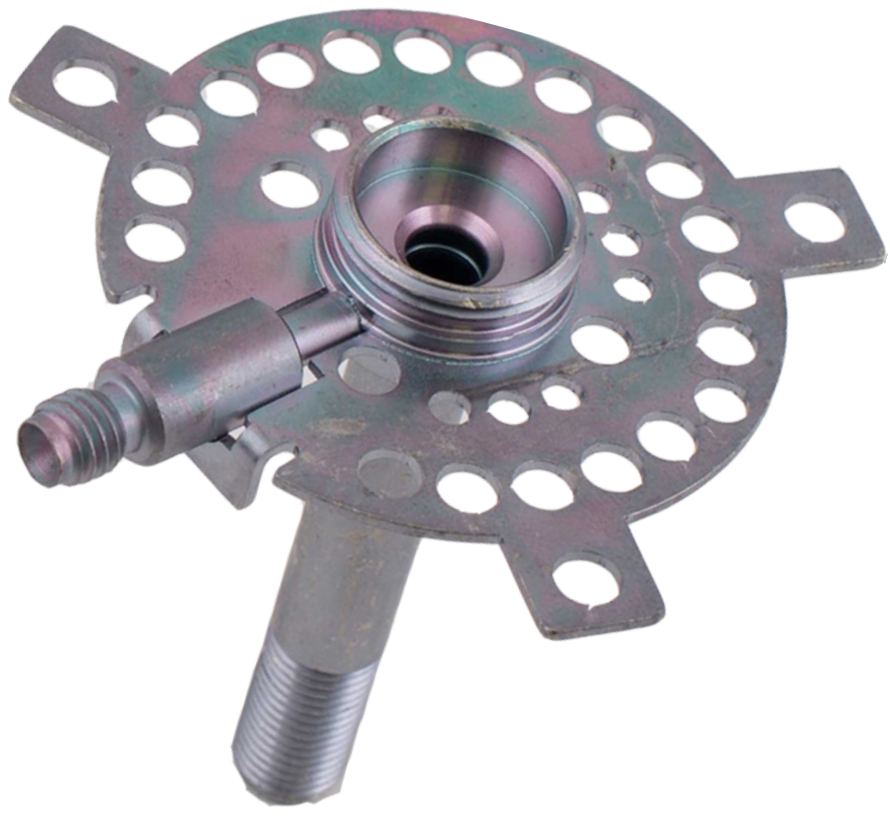
- LNG/CNG sampling and testing
- Process monitoring
- Air emissions analysis
- Chemical manufacturing
- Power generation (coal-fired)
- Odorant sampling
- Moisture analyzers
- Liquid and gas chromatography
- Refinery, flare, and flue gas
- HCl streams
- NO_X and SO_X
- Mercury
- Ammonia
- Low sulfur regulation compliance
- Research (reactors, vacuum, etc.)
- Hydrocarbon analysis

Tips for Selecting the Right Coating

A successful coating solution involves matching the performance environment of both the application and the coating. Here are questions to consider and review with SilcoTek's technical experts before making a coating selection.

Chemical exposure and environment

- Is the application exposed to acids or bases?
- What target chemicals are you sampling?
- Duration of exposure
- Operating temperature
- Cleaning solvents and methods used
- Abrasives or other durability concerns
- Previous chemical exposure of the part



Form factor of the part

- What areas of the part are sensitive to damage?
- Surface finish of the part
- Wear points of the part
- Metallurgy of the part
- Where can the part be held with a handling fixture?
- Are there seals or o-rings in the part?
- Is the part disassembled?

Performance requirement of the part's surface

- How do you need the surface to behave? Corrosion resistant, inert, hydrophobic, etc.
- Are there welded or brazed/soldered joints in the component?
- Are there blind holes or small cavities in the part?
- Overall dimensions and quantity

That's a lot to consider! If you don't know something about a part, our technical staff and production technicians will address any questions or potential issues. If you know lots about your part, you may feel comfortable selecting a coating and completing our online quote request form.

Go to our coating applications page to learn more about where SilcoTek coatings solve material problems.

6. Conclusion

So, what have we learned about inert coatings? Silicon coatings applied by chemical vapor deposition have several advantages over polymer coatings and even super alloys:

- Chemically compatible, inert, non-reactive
- Boost analytical performance by preventing adsorption. Excellent in several applications, including:
  - Sulfur analysis/sampling
  - Environmental analysis
  - Chromatography
  - Stack and flare sampling
  - Downhole oil and gas sampling
- Improve corrosion resistance
- Increase purity
- Increase durability

Inert coatings can be a cost effective solution in many industries and applications including analytical/laboratory instrumentation and sampling, oil and gas upstream and downstream sampling, refinery/petrochemical, semiconductor and research, amongst many more.

Go to our coating selection guide to get the right coating solution for your application. Or contact our technical service staff, we'll be happy to discuss your application in detail.

Read book 3 in our series "Managing the Sample Environment" to learn how to improve sampling and test results for difficult to test compounds.

Received this e-book from a colleague but want to make sure you get the rest of the series? Click here to subscribe.

Start Improving Process Sampling Now

You've read the e-book, now it's time to take action! Contact our technical service team so we can help you select the best coating and evaluation methods for your application. We'll even send you free coated samples for you to put to the test. Click the link below to get started!

Contact our Technical Service Team