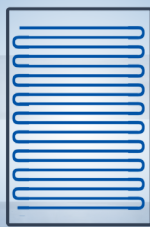


Coatings for Enhanced Heat Exchanger and Filtration Performance



Filtration



Heat Exchanger





This e-book is dedicated to our customers, their drive for continual improvement and making the advancement of coating material science possible.



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1.0: Introduction, About SilcoTek



SilcoTek® is the world's leading provider of high-performance coatings applied by [chemical vapor deposition](#), or CVD. We became a coatings company because we have a passion for helping people and businesses conquer their most difficult material challenges.

By improving the surface properties of the materials they use, our customers can run their machines longer, manufacture complex products more efficiently, and continue to develop innovations that push the scientific and industrial world forward.

In this e-book we take a deep dive into how SilcoTek coatings, like [Dursan®](#) and [Silcolloy®](#), can improve the performance of heat exchanger and filtration systems. We'll discuss how manufacturers benefit from improved fouling resistance and corrosion resistance by using our coatings. We'll present data and resources to further support how our coatings help customers save money and enhance the performance of their products and processes. Finally, we'll examine coating applications and components that can be coated as well as how to purchase our coatings.

We don't sell coated products because we're solely focused on offering coating services that make your product better. Coating options range from sending parts to our facility for coating service to buying coated products directly from the manufacturer. To learn more about our coating process [Watch our video](#) and see how SilcoTek can improve your products.



Our Mission and ZIP Code

SilcoTek's mission is to provide game-changing coatings for our customers.

What does this mean for you? It means you are doing business with a company where “employees enjoy coming to work as much as going home” and where employees are passionate, enjoy working with each other, and work in an atmosphere based on mutual respect and trust. You'll see the SilcoTek® difference in every order you place.

Our ZIP Code guides the conduct we follow each-and-every day. It creates a culture of success for SilcoTek® and our customers.

What does Z.I.P. mean?

Zero disappointments

We strive for a perfect coating process from quote to shipping, every time.

Integrity in all we do:

We are open, honest, and admit mistakes.

Plus 1 customer service:

We aim to go above and beyond every time you interact with us.

You'll find working with SilcoTek staff easy, helpful, and informative. It's our goal to delight our customers with game changing service and coatings!

Now that you've gotten to know us, let's give you a quick overview of our products.



SilcoTek Coatings

SilcoTek® coatings are uniquely tailored to solve tough material problems in a variety of industries and applications. We offer over 20 custom coatings for challenging flow path problems. [Read about some of our coatings here](#). Our patented process eliminates interactions between materials and a variety of chemicals, liquids, gases, and more to enhance surface performance in a broad variety of applications. Since 1987, SilcoTek has provided surface coating technology solutions to process, analytical, gas & oil, semiconductor, and corrosion applications worldwide. From prototype to production, SilcoTek offers patented and custom surface coating technologies that allow the user to improve the performance of their process and products.

Our current offering of coatings:

- [SilcoNert®](#)
- [Silcolloy®](#)
- [Dursan®](#)
- [SilcoGuard®](#)
- [SilcoKlean®](#)
- [Notak®](#)
- [Dursox®](#)

We also offer specialized coating processes for specific materials or applications. [Contact us to learn more.](#)



2.0 The Benefit of Using Coatings in Heat Exchanger and Filtration Applications

Filtration and heat transfer systems benefit from coated surfaces in applications ranging from midstream oil and gas processing, power generation, energy management, downstream refining and petrochemical, gasification systems, semiconductor fab systems, water, and wastewater management, and analytical or process monitoring systems.

Coatings like Dursan and Silcolloy act as an inert barrier that protect stainless steel flow path surfaces from reacting with the process fluid, be it corrosive process chemicals, high purity deionized water, wastewater, produced water or samples from chemical processes. Our coatings protect metal filtration, heat exchanger systems, and sensitive processes from common process problems like corrosion, fouling, wetting, metal contamination, and surface oxidation.

Processes that use our coatings benefit in many ways.

- Improve yield by preventing process fluid contamination
- Reduce process and maintenance cost due to fewer repairs due to fouling or corrosion
- Optimize process flow by reducing fouling in filtration
- Reduce energy use due to fouling and corrosion in heat exchangers.
- Prevent rouging in water systems.

→ All without impacting thermal transfer properties of the base material.

2.1 Corrosion resistance (Benefit: longer life, less maintenance)

SilcoTek corrosion resistant barrier coatings prevent flow path surface interaction with corrosives, extending component life while preventing product contamination. Our corrosion resistant coatings, Silcolloy[®] and Dursan[®], are particularly useful for fighting corrosion in high purity or otherwise sensitive processes in semiconductor, pharmaceutical, research, and complex chemistry applications. In addition to extending the usable life of precision stainless steel



parts, SilcoTek coatings prevent nano-scale corrosive reactions that can cause metal ion leaching and contamination, ultimately increasing process yield and reducing failure rates.

SilcoTek coatings perform in a variety of corrosive environments including sulfuric acid and bleach.

Corrosive	Stainless Steel Corrosion Rate (mpy)	Dursan Coated Stainless Steel (mpy)
6M Hydrochloric Acid, 24 hr exposure	160	1
25% Sulfuric Acid, 24 hr exposure	55	5
52 Week Salt Spray	<0.01	<0.01
Bleach	1.7	0.1

2.2 Prevent Rouging in Water Systems (Benefit: reduce contamination, increase service life)



Rouging can be found in a variety of water systems or water containing systems including pure water, ultra-pure water, steam, treated potable water or untreated process water systems.

Preventing rouging and corrosion in high purity water, and process systems is preferred to costly component replacement or the associated maintenance and risk of product contamination. Options for preventing rouging range from:

- Selecting materials that are resistant to oxidation and chloride attack.
- Adjusting the pH of the water system to reduce the rouging potential.
- Adding a strong surfactant to the rinse solution to remove chlorides.

- Coating the stainless steel surface with a corrosion resistant and inert barrier coating like Dursan.

Rouging Prevention

Of the prevention options listed, coating the surface with a high purity, non-line-of-sight, precision, corrosion resistant coating like Dursan[®], is a simple and cost effective way to reduce or eliminate rouging.

To test the effectiveness of Dursan as a rouging prevention option we compared coated and uncoated 316L stainless steel coupons. When exposed to 6M guanidine hydrochloride, 316L stainless steel showed rouging while Dursan coated coupons were unaffected.

Since there was no loss of mass for the coupons after the 1-week trial (scale accuracy is 0.1 mg), they were returned to the 6M guanidine hydrochloride solution to soak for 3.5 more weeks (1 month total exposure). Again, there was no change in the mass of the coupons, but the minor rusting and rouging effects were much more dramatic as seen in figure 1 below.



Figure 1: A bare stainless steel coupon (left) and a Dursan coated stainless steel coupon (right) were exposed to guanidine hydrochloride for one month. The rusting on the bare coupon is more severe than the 1 week exposure. As seen previously, the Dursan coated coupon is unaffected by the exposure.

In addition to the increased rouging, there was also a discoloration in the guanidine hydrochloride solution with the uncoated coupon immersed in it for one month. This color change, seen in Figure 2, was not seen at the one-week point of the experiment. The yellow tint to the liquid indicates that iron has leached out of the coupon and into the solution. This is a potential issue for many high purity applications, as iron ions can interact with product and cause impurities and/or low product yield.

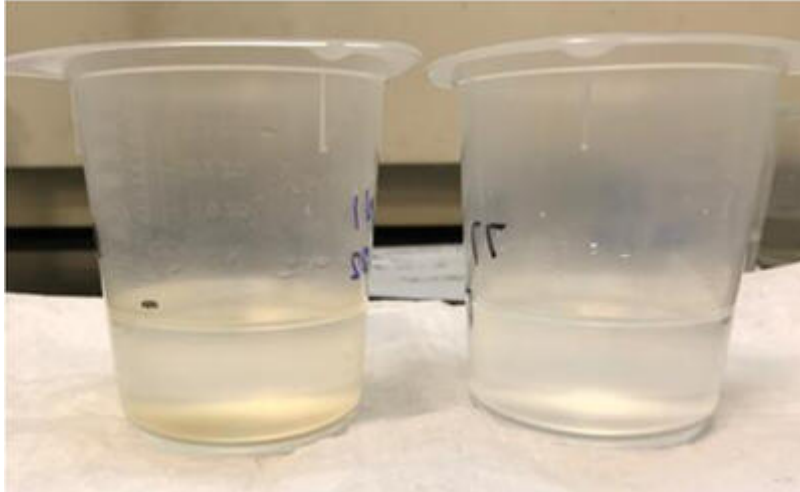


Figure 2: Guanidine hydrochloride solutions after a bare (left) and a Dursan coated (right) coupons were immersed for one month. The yellow tint in the solution that contained the bare coupon is a sign of corrosion, whereas the solution that contained the Dursan coated coupon showed no color change over the immersion period.

2.3 Fouling resistance (Benefit: reduce maintenance, ease cleaning)

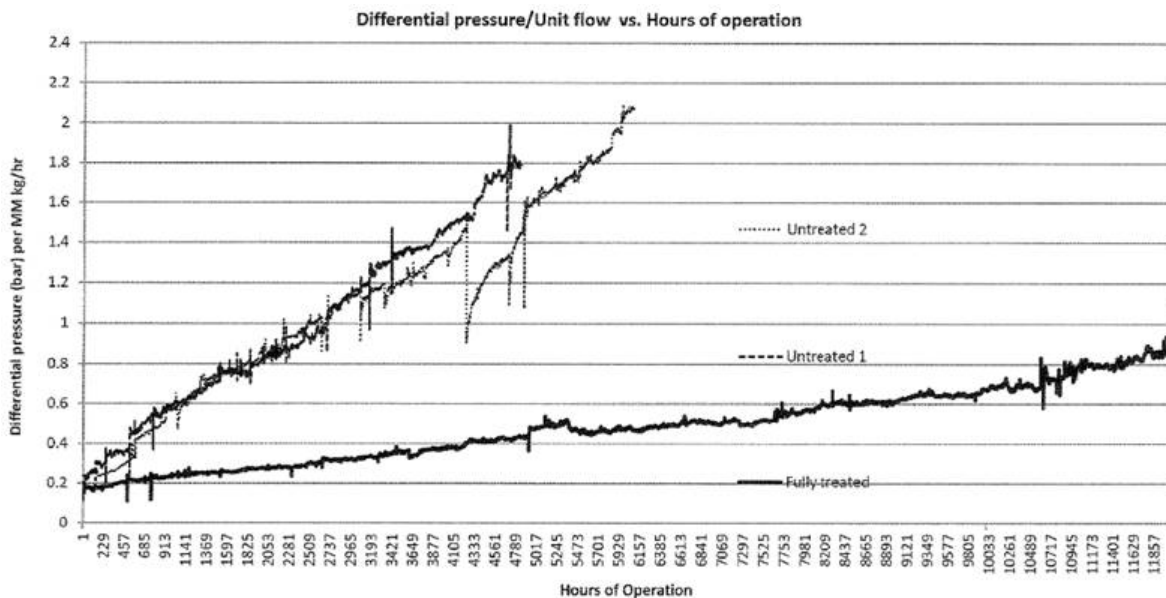


Heat exchanger fouling and filter fouling can severely impact the performance of processes and instrumentation in just about every industry. The effects of the accumulation of substances, be it binding of proteins in medical diagnostics or carbon particulates in aerospace, can have a range of impacts:

- Flow path contamination
- Flow problems: high differential pressure or low flow
- Higher energy use
- Corrosion
- Higher emissions
- More maintenance and expense

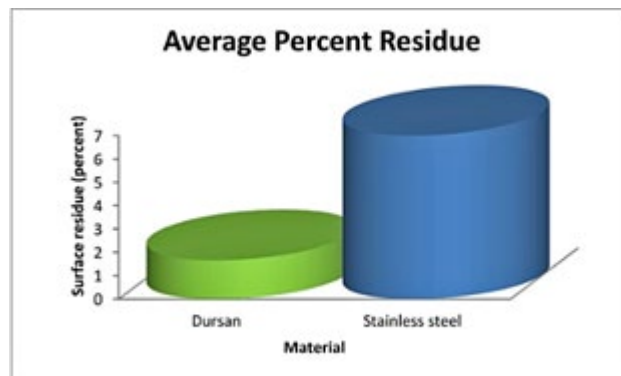
Improve Flow Reduce Differential Pressure with Dursan in Filtration Systems

The graph below (figure 3) compares the differential pressure over time of uncoated stainless steel filters and Dursan coated stainless steel filters. The Dursan coated filters more than double the service life of the filters and reduce the differential pressure by more than 50%.



Bio fouling Reduction

Bio fouling in food applications and water systems can take hours to mitigate. For example, spores from sour milk suspension can stick to processing equipment, filters, tubing and heat exchangers. Dursan coated tubes help to prevent binding of bio films to stainless steel surfaces. Bio film accumulation can be reduced by up to 76% compared to uncoated stainless steel.



Prevent bio formation and fouling

304 stainless steel is a widely used material for cooling water, chemical process, industrial process systems, and food processing equipment. Stainless is used because it is corrosion resistant, durable, and low cost compared specialty steel alloys. Previous studies investigated coatings on stainless steel for bio film formation prevention, showing positive results. A recent paper extensively tested 5 coatings for listeria bio fouling resistance. The researchers also investigated and compared several surface morphologies including:

- A relatively smooth, machine finished surface.
- A slightly rougher, brushed surface.
- A micropatterned, pillar surface.

The study measured listeria cell formation on coated and uncoated surfaces. Results of the viable cell count from each surface showed that, regardless of the surface topography, Dursan was the only coating that decreased active cells on the surface, see figure 4 below. Results showed up to a roughly 4 order of magnitude reduction in viable cell count, significantly reducing bio fouling formation.*

Viable Cell Count Results of Dursan on 304 Stainless Steel

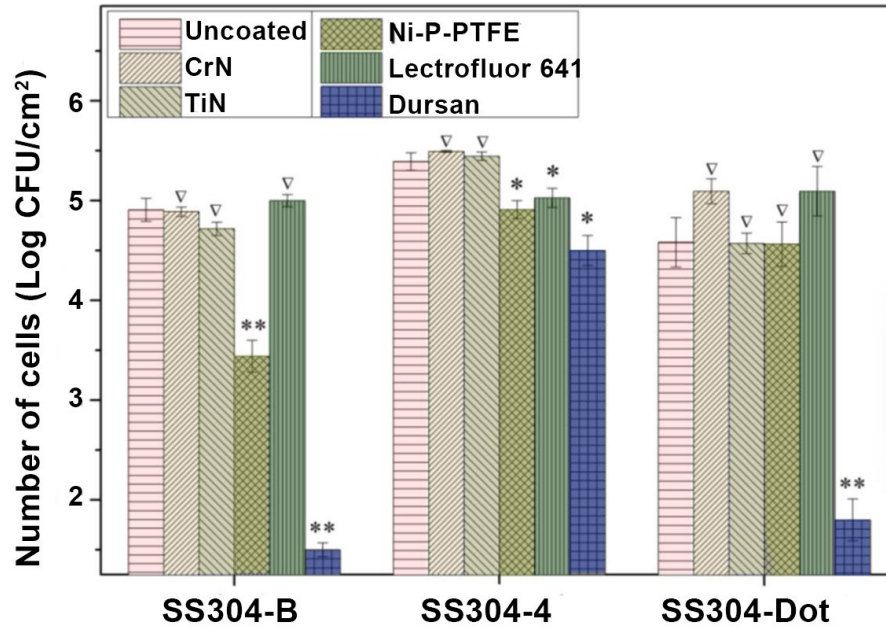


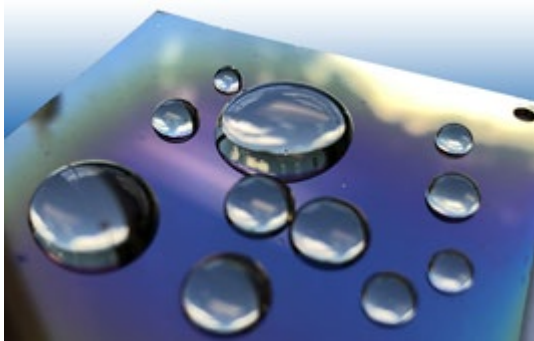
Figure 4: Measurement of active listeria cells on the surface of various coupons. ** shows a significant statistical difference from the control, * shows statistical difference, and ∇ shows essentially no statistical difference.

According to the paper, all 5 of the tested coatings, including Dursan, are FDA compliant. This means a Dursan coated part can pass FDA approval if required to bring a product to market. However, it is important to remember that coated components and/or systems must go through the FDA approval process, i.e., the coating alone is not submitted for approval, the coated component would be submitted.

* "[Listeria monocytogenes biofilm formation as affected by stainless steel surface topography and coating composition](#)"; TingtingGua; ApisakMeesrisoma; YaquangLuob; Quynh N.Dinha; SophiaLina; ManyunYang; ArnavSharma; RuoguTang; JindeZhang; ZhenJia; Patricia D.Millner; Arne J.Pearlstein; BoceZhang; Food Control, Volume 130, December 2021, 108275

2.4 Non-wetting/hydrophobic, (Benefit: for applications where low adhesion, low moisture adsorption and contamination, or complete draining is desired)

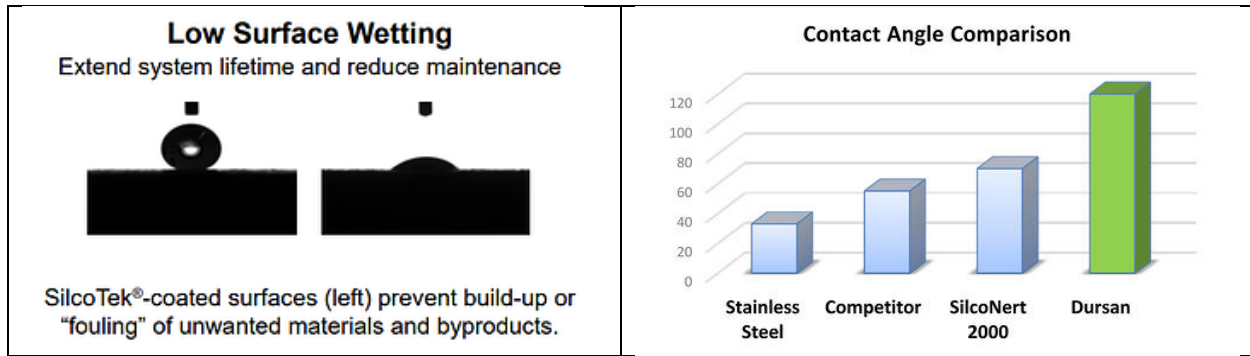
SilcoTek's inert high-temperature barrier coatings enhance hydrophobic interaction between critical flow path surfaces and your product. Dursan[®] coating improves moisture repelling properties of stainless steel, glass, and ceramic surfaces, minimizing wetted surface effects. Coating critical flow path surfaces help process engineers and analysts manage moisture and improve results.



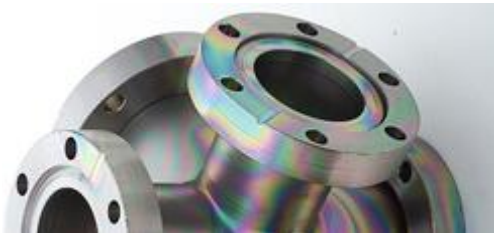
Hydrophobic Coating benefits include:

- Prevent product contamination
- Reduce moisture adsorption
- Improve system corrosion resistance
- Improve purge and flush efficiency

Our low surface energy (high contact angle) surface repels water, preventing system contamination and improving analytical test reliability. Comparative testing shows the Dursan[®] coated surfaces significantly improve hydrophobicity by reducing surface energy by 60% or more. Surface energy water droplet testing below compares various coated surfaces. Stainless steel, a high surface energy material, exhibits significant wetting and a very low water droplet contact angle of 36 degrees (flat droplet) (see comparative images below). High surface energy can lead to moisture adsorption and cross contamination, causing moisture control problems. The Dursan low energy surface shows minimal wetting and a high contact angle (round droplet), improving hydrophobicity and preventing adsorption, contamination, and surface outgassing.



2.5 Metal contamination. (Reduce process contamination, improve product quality and yield.)



Metal contamination is of interest to a variety of industries. Chemical exposure to solutions, such as, organic solvents, deionized water, acids, or bleach, can cause a significant amount of metal ions to dissolve into the liquid, causing product contamination, system corrosion, and test problems in analytical and high purity processes including:

- Semiconductor Manufacturing
- Biopharmaceutical Production
- Medical Diagnostics
- Precision Cleaning
- Food and Beverage Processing
- HPLC Analytical Flow Paths

SilcoTek® offers CVD coating solutions to make your process, analytical, and sampling systems perform better. Our chemically inert coatings improve test accuracy and reliability by preventing contamination from metal ion leaching caused by chemical reactions between the sample and flow path surface.

The summary below demonstrates how metal ions can be readily leached into flow path solutions and how coated surfaces (right column, green) prevent contamination under all conditions tested. Even deionized water can leach up to



1000 ppb of iron and nickel from stainless steel surfaces. This can result in product contamination in processes that demand high purity.

Metal Ions leached into solution after a 1-month soak

	316 Stainless steel	Titanium	MP35N	C-22 Hastelloy	Any coated alloy
UHPLC Grade DI water	Fe (red), Cr (yellow), Ni (red), Mo (yellow)	Ti (green)	Ni (black), Cr (black), Mo (black), Co (black)	Fe (yellow), Cr (yellow), Ni (black), Mo (black)	All Metals (green)
UHPLC grade Methanol	Fe (black), Cr (red), Ni (red), Mo (yellow)	Ti (red)	Ni (black), Cr (black), Mo (black), Co (black)	Fe (yellow), Cr (black), Ni (black), Mo (yellow)	All Metals (green)
UHPLC grade Acetonitrile	Fe (yellow), Cr (yellow), Ni (green), Mo (green)	Ti (green)	Ni (black), Cr (red), Mo (red), Co (black)	Fe (yellow), Cr (green), Ni (black), Mo (green)	All Metals (green)

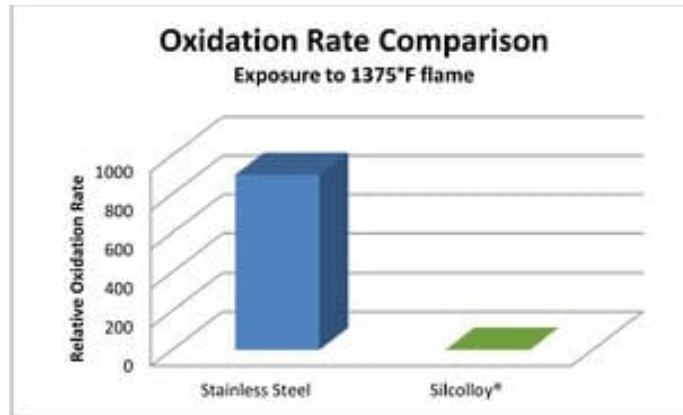
■ <1 ppb/m²
 ■ <100 ppb/m²
 ■ <1000 ppb/m²
 ■ >1000 ppb/m²

SilcoTek has conducted several studies relating to effectiveness of our CVD coatings in preventing metal ion leaching from various surfaces when exposed to organic solvents and deionized water. [Read our Technical Insights](#) to understand how SilcoTek coatings improve product and test quality.

2.6 Oxidation resistance for high temperature applications

Surfaces exposed to high temperature can oxidize and degrade over time. Oxidation can damage process systems, exhaust system ducts and filters and can shorten the life of heat exchangers. Over time, severe oxidation can lead to excessive maintenance and process failures.

Silcolloy[®] is a high temperature-capable silicon barrier coating that protects stainless steel and alloy surfaces from interaction with hot air or process fluids, making Silcolloy an ideal oxidation resistant coating for high temperature applications. Comparative flame exposure data (below) show minimal surface oxidation for the Silcolloy coated surface.



Silcolloy will maintain a lustrous surface finish even under the most demanding conditions. The benefits of an oxidation resistant surface include:

- Extend the life of heat exchanger tubing and filtration components exposed to high temperatures
- Eliminate contamination from corrosion/oxide formation
- Maintain critical tolerances under high heat conditions
- High temperature coating maintains surface finish, even when exposed to 1000°C in air
- Eliminate time consuming cleaning/oxide removal

[Go to our Coating Properties Handbook](#) to learn more about how our coatings perform under high temperature conditions.



3.0: Applications, use, and process capability

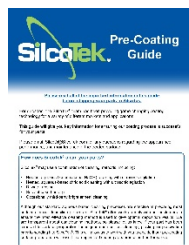
SilcoTek offers coatings for a variety of markets including:

- Manufacturing process, refining, petrochemical, and chemical process (small scale)
- Semiconductor and PV manufacturing, cooling water, filtration, high purity applications
- Analytical
- Extrusion and plastic forming processes

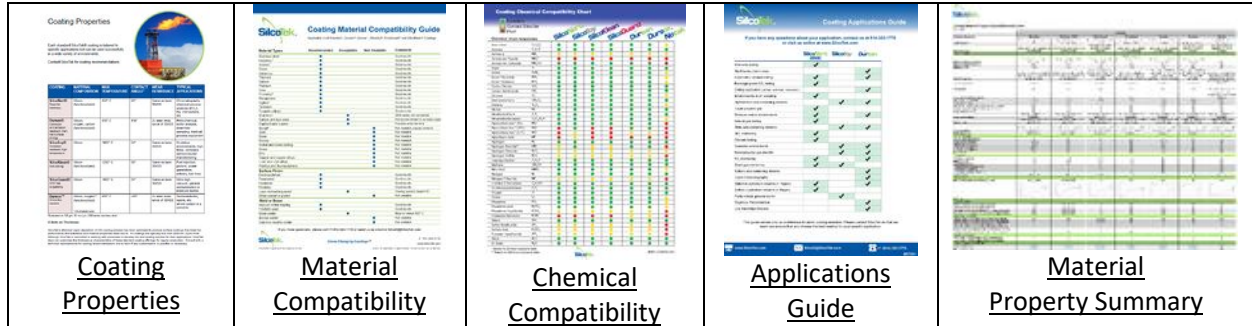
In this chapter we'll review some common coating applications for heat exchanger and filtration. We'll also review our coating process capability and provide additional reference material for those who want more detailed information about properties and material compatibility.

3.1 Process Capability

SilcoTek can coat a variety of form factors, but we do have part size limitations. Often, we're able to accommodate our customers by coating at the component level rather than a completed assembly. We apply our silicon coatings by a patented chemical vapor deposition process. Coatings are applied at our 70,000 square foot facility in Bellefonte, Pennsylvania. Part size limitation and logistics limit our coating application to relatively smaller heat exchangers, metal filters, and related components, but SilcoTek is actively expanding our capabilities to better serve customer needs. [Go to our Frequently Asked Questions page](#) to get the latest in process capability. Learn more about our process by reading our pre-coating guide. Just click on the image below to read the guide.



We're able to coat a wide range of metals, metal alloys, ceramics, and glass. For an overview of our coating properties, compatibility, and applications, just click on the thumbnails below to learn more.



3.2 Applications for Heat Exchangers



Without coating, heat exchangers can rust and foul, as seen in the photo to the left. SilcoTek coatings act as a fouling resistant and corrosion resistant barrier, reducing fouling and corrosion. Because SilcoTek applies silicon coatings by chemical vapor deposition, the gas used in the application process

flows to both exposed and unexposed areas of the heat exchanger, making our process non-line-of-sight. This allows for complete coverage of intricate parts, tubes, and plates for use in a wide variety of heat exchanger applications including:

- Manufacturing processes
- Small scale refinery and petrochemical processes.
- Semiconductor processes
- Plastic and extrusion operations
- Cooling water systems
- Analytical sampling and environmental sample prep
- Any challenging heat transfer application



Our process does have process size limitations, please contact our Technical Service Team to discuss coating options for heat exchangers.

Options for coating heat exchangers range from coating the entire assembly (for smaller shell and tube systems) to coating individual tubes and plates. Components must be free of seals or other components that are not able to withstand process temperatures of approximately 400°C. [Go to our material compatibility chart](#) to review acceptable materials that offer optimum coating benefit. Coat the entire flow path to maximize system performance.

Here are some of the components relating to heat exchanger systems that can be coated.

- Shell and tube heat exchangers, end plates, and tubes
- Plate heat exchangers and individual plates
- Immersion heaters and heat exchangers
- Flanges and connectors
- Tube and pipe
- Valve, fittings (disassembled)
- Metal filters and filter housings
- Eductors and other mixing and blending systems
- Pump bodies and impellers
- Probes
- Mass flow controllers

3.3 Applications for Filtration



Process fluids can cause metal filter corrosion and can prematurely foul filters, pipe, and tubing. Fouling and corrosion can result in higher energy use, poor system flow, and increased maintenance or system downtime. SilcoTek coatings offer superior corrosion and fouling resistance at a low cost, eliminating the need for super alloys or fluid treatments.



The SilcoTek process can be applied to metal filters, including fritted filters, as well as ceramic and glass filters. The CVD coating process penetrates filter media and builds a layer of protective silicon on the filter surface without obstructing flow or requiring system redesign to accommodate pressure changes. Our process applies a precision coating designed to have minimal impact on filtration back pressure and performance. Our coatings are used in a wide range of filtration systems including:

- Analytical sampling and environmental sampling
- Stack particulate filtration systems
- Water filtration systems
- Produced water systems in oil and gas production
- Process fluid filters
- Ship ballast filtration
- Precision cleaning systems
- High temperature filtration systems employing ceramics
- Manufacturing process, refining, petrochemical, and chemical process systems
- Semiconductor and PV manufacturing
- Cooling water filtration
- High purity water and DI water filtration

Protecting the filtration system from corrosion can apply to the entire process system including pumps, filter housings, valves, fittings, pipe, mass flow control devices, regulators, and tubing. Instrumentation probes and instrument flow paths can also be coated to improve the reliability of in-plant analytical or monitoring systems.



4.0: Conclusion, Where to Buy



Protecting heat exchanger and filtration systems has never been easier. Silicon coatings like [Dursan®](#) and [Silcolloy®](#) are proven to reduce fouling and improve corrosion resistance. The data presented in this e-book is just a fraction of the coating performance information available to manufacturers. [Go to our Learning Center](#) to read studies, whitepapers, presentations, and technical insights about our coatings and learn more about how our coatings perform in your application.

Buying and using our coatings is easy! You can learn more about how to send parts to our coating facility in Bellefonte, PA, USA by going to our [Ordering Options web page](#). We've also teamed up with leading manufacturers to offer SilcoTek coated products, so you don't have to take the time to send parts to our facility for coating service. You can learn more about how to buy coated products directly from the manufacturer by going to our [Buy Coated Products web page](#). There you'll get a listing of approved partners. Just click on the partner's name to learn more about how to purchase coated products from that supplier.

Thanks for taking the time to read our e-book and learn about how our coatings improve heat exchangers and filtration systems. If you'd like to read more of our insightful e-books you can [go to our Coating E-book web page](#). There you can access informative e-books for applications ranging from analytical, biotech, process sampling, and general coating properties. As applications grow and new coatings are developed, we'll be adding to our e-book library, technical insights and other information in our coating resource library so check back to our website frequently!

Finally, the SilcoTek Team would like to thank all our dedicated customers for making the advancement of coating material science possible.

End