

Silcosteel®-CR Surface Treatment

Improve Corrosion Resistance by Tenfold or More in Semiconductor Processes

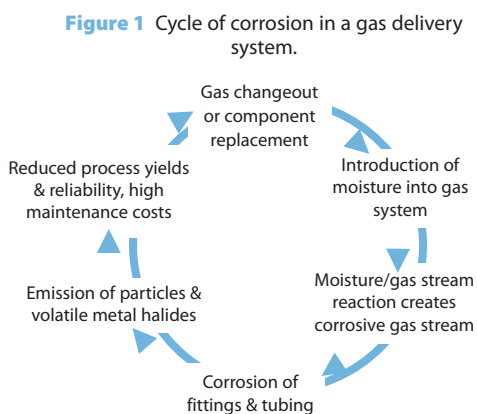
Semiconductor manufacturers face unique challenges in today's manufacturing environment. Market pressures for increased productivity, increased reliability, and improved production yields are greater than ever, while material and operating cost pressures continue to rise.

Key challenges to improved reliability in future chip designs are:¹

- ion contamination/process purity
- poor gas purity
- equipment reliability
- rising operating costs
- process corrosion/contamination

Process corrosion costs the US semiconductor industry over \$1.2B per year through manufacturing losses and increased maintenance costs.^{2,3} One contributor to poor reliability and high cost is the corrosion of gas distribution systems. Studies have shown that 68% of contamination issues in CMOS processes are traceable to the gas distribution system.⁴

Figure 1 outlines the cycle of corrosion in gas distribution systems:⁴



Adding to the challenge, facility material costs are increasing rapidly, due to higher commodity prices and reduced availability of stainless steel, nickel, and super alloys such as Hastelloy® C22™.

Corrosion resistant silicon coatings

Corrosion-resistant, high-purity silicon coatings from Restek Performance Coatings can improve the corrosion performance of stainless steels by an order of

magnitude, or more. Silcosteel®-CR is a proprietary (patent pending) multilayer silicon CVD coating delivering an order of magnitude improvement in corrosion resistance to a wide range of corrosive environments. Silcosteel®-CR maintains high system purity, demonstrates extreme heat capability, and exhibits leak-tight system performance when applied to steel, stainless steel, and alloy systems.

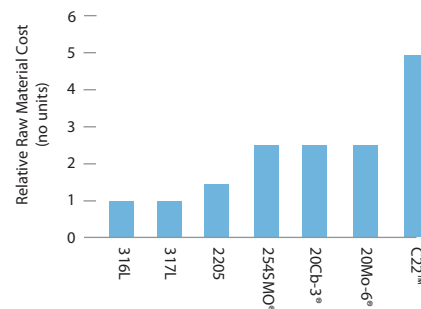
The unique non-line-of-sight CVD process produces a high purity, flexible amorphous silicon layer, diffused into the base metal lattice. The layer will conform to the most intricate surface while maintaining high dimensional tolerances. The Silcosteel®-CR layer will deform with tubing surfaces, allowing leak-free seals or radius bends.

Table I (reverse) shows compatibility of Silcosteel®-CR treatment with common chemicals used in the semiconductor industry.⁵

Improve reliability while reducing costs

316L gas delivery systems exposed to corrosive environments typically are replaced within 5 years of installation. Substituting a high performance alloy for 316L stainless steel can increase the cost of the system by as much as five-fold (Figure 2).⁴

Figure 2 High performance alloys substantially increase the cost of a gas delivery system.



By improving the corrosion resistance of 316L stainless steel by up to 10x, Silcosteel®-CR treatment reduces costly maintenance and yield failures due to system corrosion. Figure 3 compares the cost

Greatly improve purity & corrosion resistance

Silcosteel®-CR treatment is designed to:

- Improve process purity by reducing ion contamination in process tools.
- Eliminate moisture contamination in gas delivery systems.
- Improve corrosion resistance in process gas delivery systems, without the use of super alloys.



Restek Performance Coatings

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of Silcosteel®-CR treatment versus Hastelloy C22™ construction in a typical gas delivery system. Silcosteel®-CR treatment demonstrates significant life cycle cost savings, compared to unprotected stainless steel or stainless steel alloys.

Figure 3 Silcosteel®-CR significantly lowers the life cycle cost of stainless steel or alloys (US dollars).

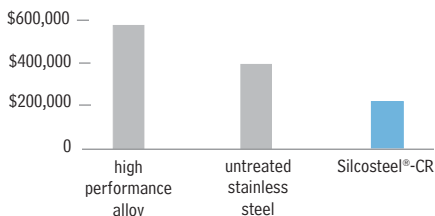


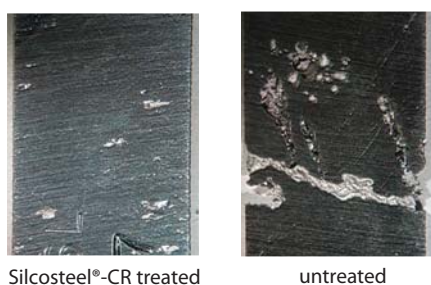
Table I Silcosteel®-CR treatment is compatible with many chemicals used in the semiconductor industry.

Chemical	Compatibility Rating		
	Excellent	Good	Poor
2-Propanol	C ₃ H ₈ O	●	
Acetic Acid	C ₂ H ₄ O ₂	●	
Acetone	C ₃ H ₆ O	●	
Ammonia	NH ₃		●
Ammonium Fluoride	NH ₄ F		●
Ammonium Hydroxide	NH ₄ OH	●	
Argon	Ar	●	
Arsine	AsH ₃	●	
Boron Tribromide	BBr ₃	●	
Boron Trichloride	BCl ₃	●	
Carbon Dioxide	CO ₂	●	
Carbon Tetrafluoride	CF ₄	●	
Chlorine	Cl ₂	●	
Dichloromethane (methylene chloride)	CH ₂ Cl ₂	●	
Disilane	Si ₂ H ₆	●	
Helium	He	●	
Hexafluoroethane	C ₂ F ₆	●	
Hexamethyldisilazane HMDS	C ₆ H ₁₉ Si ₂ N	●	
Hydrochloric Acid	HCl	●	
Hydrofluoric Acid	HF		●
Hydrogen	H ₂	●	
Hydrogen Bromide	HBr		●
Hydrogen Peroxide	H ₂ O ₂		●
Methanol	CH ₃ OH	●	
Nitric Acid	HNO ₃	●	
Nitrogen	N ₂	●	
Nitrogen Trifluoride	NF ₃		●
n-Methyl 2-Pyrrolidone	C ₅ H ₉ NO	●	
Octafluorocyclobutane	C ₄ F ₈	●	
Oxygen	O ₂	●	
Ozone	O ₃	●	
Phosphine	PH ₃	●	
Phosphoric Acid	H ₃ PO ₄	●	
Phosphorus Oxychloride	POCl ₃		●
Potassium Hydroxide	KOH		●
Silane	SiH ₄	●	
Sulfur Hexafluoride	SF ₆		●
Sulfuric Acid	H ₂ SO ₄		●
Tungsten Hexafluoride	WF ₆		●
Water	H ₂ O	●	
DI Water	H ₂ O		●

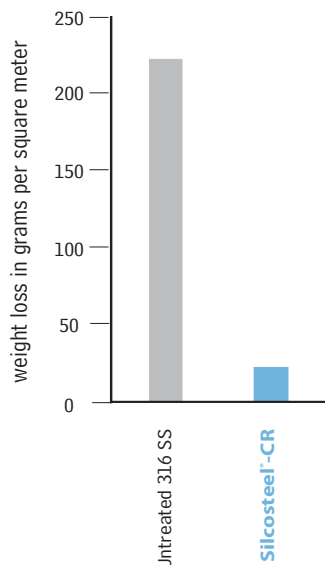
Independent laboratory testing: Silcosteel®-CR improves corrosion resistance by up to 10X over untreated 316 stainless steel

Corrosion testing of Silcosteel®-CR treated 316L stainless steel vs. uncoated 316L stainless steel, shows corrosion of the coated stainless steel is reduced by an order of magnitude, as measured by weight loss (per ASTM G 48, Method B, 72-hour ferric chloride pitting and crevice corrosion testing⁶) (Figure 4).

Figure 4 316L stainless steel shows significant crevice corrosion; a Silcosteel®-CR treated coupon shows only minor pitting (ASTM G 48, Method B).



Silcosteel®-CR treated stainless steel outperforms uncoated metal by an order of magnitude (ASTM G 48, Method B).



for more info

Learn more about our precisely applied, highly durable surface treatment, Silcosteel®-CR: request information packet 59048.

Independent laboratory testing: Cyclic polarization electrochemical tests per ASTM G61 show Silcosteel®-CR treated 316L stainless steel outperforms untreated 316L stainless steel by up to 50x⁶

Figure 5 compares pitting potentials and corrosion rates for Silcosteel®-CR treated and untreated 316L stainless steel in various chloride solutions. Results show Silcosteel®-CR treated coupons exhibit a 10x to 50x reduction in corrosion!

Figure 5 Silcosteel®-CR treated 316L stainless steel exhibits a 10–50x reduction in corrosion (per ASTM G61).

Breakdown or pitting potential, E_b, in millivolts.

Neutral Solution	Silcosteel®-CR	Bare Steel
100ppm chloride	>3000	674
3000ppm chloride	1460	370
5000ppm chloride	1590	285
Acidic Solution (1N H ₂ SO ₄)		
100ppm chloride	1128	580
3000ppm chloride	927	370
5000ppm chloride	983	563

Corrosion of Silcosteel®-CR treated 316L stainless steel versus bare stainless steel at 3000ppm Cl⁻ concentration.

Neutral Solution	Silcosteel®-CR	Bare Steel
Corrosion Rate, mpy	0.0009	0.04
Breakdown Potential, E _b	1460	370
	50X Improvement!	
Acidic Solution (1N H ₂ SO ₄)		
Corrosion Rate, mpy	0.05	0.83
Breakdown Potential, E _b	927	37
	10X Improvement!	

Summary

Test data show that Silcosteel®-CR delivers an order of magnitude improvement in corrosion resistance in semiconductor applications. Silcosteel®-CR improves purity and saves money by reducing corrosion related system maintenance and by reducing yield failures caused ion contamination and moisture in process streams.

Silcosteel®-CR treatment can be applied to existing process components, so process equipment life can be extended without significant re-engineering. We offer Silcosteel®-CR treated Swagelok® and Parker tubing and fittings from stock.

Custom treatment is available for process-specific components.

To learn more about how Silcosteel®-CR treatment can improve the corrosion performance of your process system, visit Restek Performance Coatings at www.restekcoatings.com/semicon or contact our technical service group at 814-353-1300 or 800-356-1688, ext. 4.

Restek Performance Coatings

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Silcosteel®-CR Treated Swagelok® Fittings

- Full line of treated 1/16", 1/8", and 1/4" fittings.
- Silcosteel®-CR treatment enhances corrosion resistance by 10X, or more.
- Custom treatment available for any Swagelok® fitting, or other system parts.

Fitting Type	Size	Swagelok® #	Silcosteel®-CR Treated	
			qty.	cat.#
 Union	1/16"	SS-100-6	ea.	22575
	1/8"	SS-200-6	ea.	22576
	1/4"	SS-400-6	ea.	22577
 Tee	1/16"	SS-100-3	ea.	22578
	1/8"	SS-200-3	ea.	22579
	1/4"	SS-400-3	ea.	22580
 Reducing Union	1/8" to 1/16"	SS-200-6-1	ea.	22581
	1/4" to 1/16"	SS-400-6-1	ea.	22582
	1/4" to 1/8"	SS-400-6-2	ea.	22583
 Elbow	1/8"	SS-200-9	ea.	22584
	1/4"	SS-400-9	ea.	22585
 Plug	1/16"	SS-100-P	ea.	22619
	1/8"	SS-200-P	ea.	22620
	1/4"	SS-400-P	ea.	22597
 Cross	1/8"	SS-200-4	ea.	22586
	1/4"	SS-400-4	ea.	22587
 Tube End Reducer	1/8" tube to 1/16"	SS-100-R-2	ea.	22588
	1/4" tube to 1/16"	SS-100-R-4	ea.	22589
	1/8" tube to 1/4"	SS-400-R-2	ea.	22590
	1/4" tube to 1/8"	SS-200-R-4	ea.	22591
 Port Connector	1/8"	SS-201-PC	ea.	22592
	1/4"	SS-401-PC	ea.	22593
	1/8" tube to 1/4"	SS-401-PC-2	ea.	22594
 Male Connector	1/8" to 1/8" NPT	SS-200-1-2	ea.	22595
	1/4" to 1/4" NPT	SS-400-1-4	ea.	22596
	1/16" to 1/8" NPT	SS-100-1-2	ea.	22610
	1/8" to 1/4" NPT	SS-200-1-4	ea.	22611
	1/4" to 1/8" NPT	SS-400-1-2	ea.	22612
 Female Connector	1/8" to 1/8" NPT	SS-200-7-2	ea.	22613
	1/4" to 1/4" NPT	SS-400-7-4	ea.	22614
	1/8" to 1/8" NPT	SS-400-7-2	ea.	22615
	1/8" to 1/4" NPT	SS-200-7-4	ea.	22616
 Bulkhead Union	1/8"	SS-200-61	ea.	22617
	1/4"	SS-400-61	ea.	22618

References

1. Factory Integration Committee; "International Technology Roadmap for Semiconductors 2005 Edition"; The International Technology Roadmap for Semiconductors (ITRS). 2005
2. Committee on Cost of Corrosion in Japan, "Survey of Corrosion Cost in Japan"; Japan Society of Corrosion Engineering, Tokyo, Japan; Japan Association of Corrosion Control, Tokyo, Japan; National Research Institute for Metals, 2001
3. Bureau of Industry and Security; "Semiconductor Materials 1997"; U.S. Department of Commerce. 1997
4. 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
5. North American Gases Committee; Semi F79-0703 "Guideline for Gas Compatibility with Silicon used in Gas Distribution Components"; Semi.org. 2003
6. Zamanzadeh, Mehrooz; Bayer, George; Rhodes Geoffrey; Smith, David; Higgins, Martin; "Laboratory Corrosion Testing of a Chemical Vapor Deposited Amorphous Silicon Coating"; Matco Associates, Inc. Pittsburgh, PA; Restek Corporation, Bellefonte, PA. 2005

Tubing

Restek sets the standard in tubing for analytical and process applications. Complete your system with treated fittings and valves for an inert, corrosion-resistant pathway.



Top: electropolished finish, surface roughness average number: 5-10.

Bottom: conventional finish, surface roughness average number: approx. 23-27.

Silcosteel®-CR Treated Coiled Electropolished 316L Grade Stainless Steel Tubing

- Exceptional inertness.
- Improved reliability and reproducibility; longer lifetime.
- Use with treated fittings for the most inert sample pathway available.

ID	OD	cat.#
0.085"	1/8"	22536
0.180"	3/4"	22537

Silcosteel®-CR Treated Coiled 316L Grade Stainless Steel Tubing

ID	OD	cat.#
0.055" (1.40mm)	1/8" (3.18mm)*	22896
0.180" (4.57mm)	1/4" (6.35mm)*	22897

Silcosteel®-CR Treated Straight Seamless 316L Grade Stainless Steel Tubing

6 foot Length

ID	OD	qty.	cat.#
0.055" (1.40mm)	1/8" (3.18mm)*	ea.	22898
0.180" (4.57mm)	1/4" (6.35mm)*	ea.	22899
0.277" (7.04mm)	3/8" (9.52mm)**	ea.	22900

*0.035" wall thickness

**0.049" wall thickness



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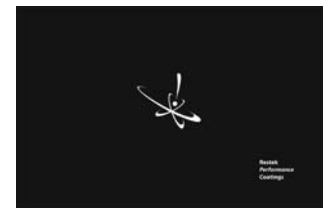
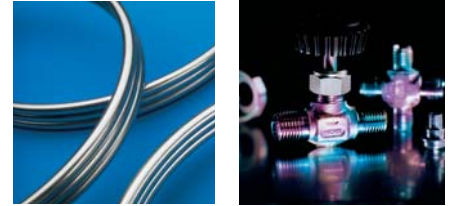
Silcosteel®-CR Treated Parker Fittings

If you do not see everything you need, contact us for information on custom coating services.

Fitting Type	Similar to Parker #	Size	Silcosteel®-CR Treated qty.	cat.#
 Union	1SC1	1/16" $\frac{1}{16}$ "	ea.	22863
	1SC1	1/8" $\frac{1}{8}$ "	ea.	22864
	4SC4	1/4" $\frac{1}{4}$ "	ea.	22865
 Tee	1ET1	1/16" $\frac{1}{16}$ "	ea.	22866
	2ET2	1/8" $\frac{1}{8}$ "	ea.	22867
	4ET4	1/4" $\frac{1}{4}$ "	ea.	22868
 Reducing Union	2RU1	1/8" to 1/16" $\frac{1}{8}$ " to $\frac{1}{16}$ "	ea.	22869
	4RU1	1/4" to 1/16" $\frac{1}{4}$ " to $\frac{1}{16}$ "	ea.	22870
	4RU2	1/4" to 1/8" $\frac{1}{4}$ " to $\frac{1}{8}$ "	ea.	22871
 Elbow	1EE1	1/16" $\frac{1}{16}$ "	ea.	22874
	2EE2	1/8" $\frac{1}{8}$ "	ea.	22875
	4EE4	1/4" $\frac{1}{4}$ "	ea.	22876
 Plug	1BLP1	1/16" $\frac{1}{16}$ "	ea.	22877
	2BLP2	1/8" $\frac{1}{8}$ "	ea.	22878
	4BLP4	1/4" $\frac{1}{4}$ "	ea.	22879
 Cross	2ECR2	1/8" $\frac{1}{8}$ "	ea.	22872
	4ECR4	1/4" $\frac{1}{4}$ "	ea.	22873
 Tube End Reducer	2TUR1	1/8" tube to 1/16" $\frac{1}{8}$ " tube to $\frac{1}{16}$ "	ea.	22880
	4TUR1	1/4" tube to 1/16" $\frac{1}{4}$ " tube to $\frac{1}{16}$ "	ea.	22881
	2TUR4	1/8" tube to 1/4" $\frac{1}{8}$ " tube to $\frac{1}{4}$ "	ea.	22882
	4TUR2	1/4" tube to 1/8" $\frac{1}{4}$ " tube to $\frac{1}{8}$ "	ea.	22883
 Port Connector	2PC2	1/8" $\frac{1}{8}$ "	ea.	22884
	4PC4	1/4" $\frac{1}{4}$ "	ea.	22885
	2PC4	1/8" tube to 1/4" $\frac{1}{8}$ " tube to $\frac{1}{4}$ "	ea.	22886
 Compression to NPT Male Connector	2MSC2N	1/8" to 1/8" NPT $\frac{1}{8}$ " to $\frac{1}{8}$ " NPT	ea.	22887
	4MSC4N	1/4" to 1/4" NPT $\frac{1}{4}$ " to $\frac{1}{4}$ " NPT	ea.	22888
	1MSC2N	1/16" to 1/8" NPT $\frac{1}{16}$ " to $\frac{1}{8}$ " NPT	ea.	22889
	2MSC4N	1/8" to 1/4" NPT $\frac{1}{8}$ " to $\frac{1}{4}$ " NPT	ea.	22890
	4MSC2N	1/4" to 1/8" NPT $\frac{1}{4}$ " to $\frac{1}{8}$ " NPT	ea.	22891
 Compression to NPT Female Connector	2FSC2N	1/8" to 1/8" NPT $\frac{1}{8}$ " to $\frac{1}{8}$ " NPT	ea.	22892
	4FSC4N	1/4" to 1/4" NPT $\frac{1}{4}$ " to $\frac{1}{4}$ " NPT	ea.	22893
	4FSC2N	1/4" to 1/8" NPT $\frac{1}{4}$ " to $\frac{1}{8}$ " NPT	ea.	22894
	2FSC4N	1/8" to 1/4" NPT $\frac{1}{8}$ " to $\frac{1}{4}$ " NPT	ea.	22895

Please note: Nuts and ferrules are not treated unless requested (custom parts). Nuts and ferrules normally are not in contact with samples, and thus do not require coating.

Contact us!
Restek will treat your
tubing, fittings, & custom
process components
with Silcosteel®-CR.



free literature

Learn more about our precisely applied, highly durable surface treatments: request our brochure lit. cat.# 59493.

Questions?

Our Coatings Experts are here to help. For a free technical consultation, call: Marty Higgins at 800-356-1688, ext 2307 Gary Barone at 800-356-1688, ext 2135 David Smith at 800-356-1688, ext 2154

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Restek Surface Treatments

We offer many surface treatments that enhance performance in many applications:

- Silcosteel®** A general-purpose passivation layer for steel and stainless steel. U.S. patent 6,511,760.
- Silcosteel®-AC** Dramatically reduces carbon buildup on stainless steel components. U.S. patent 6,444,326.
- Silcosteel®-CR** A corrosion resistant layer that increases the lifetime of system components in acidic environments containing hydrochloric acid, nitric acid, sulfuric acid, or seawater. Patent pending.
- Silcosteel®-UHV** Greatly reduces outgassing from components of ultra-high vacuum systems. Recognized as one of the 100 most technologically significant products by R&D magazine. Patent pending.
- Siltek™** The ultimate passivation for treated components, from glass to high nickel alloys of steel. U.S. patent 6,444,326.
- Sulfinit®** A required treatment for metal components when analyzing for parts-per-billion levels of organo-sulfur compounds. U.S. patent 6,444,326.