
SilcoTek®
Driving Innovation

SilcoTek Coating Solutions

from science to performance

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Presentation Outline

- Problem Statement for Semiconductor industry
- Coating Composition and Physical Properties
- Sample Testing & Inertness
- Corrosion Control
- Vacuum Environments
- Conclusions

Addressing material problems in Semiconductor industry

- **Etch:**
  - Coatings to eliminate ion contamination given corrosive etch gas streams
- **ALD:**
  - Enhances purity by coating of all chambers and equipment. Reduces carryover and potential corrosion
- **EPI:**
  - Addressing corrosion
- **Ozone:**
  - Stabilize flow path to assure ozone ….
- **Overall Gas Transfer**
  - Ability to work in all layers of supply chain to provide valves/regulators/MFC's/tubing/fittings and custom weldments coated

Why use coatings?

- High Purity
  - Reduce system contamination
  - Eliminate ion contamination
  - Reduce moisture effects
  - Reduce vacuum pump down time

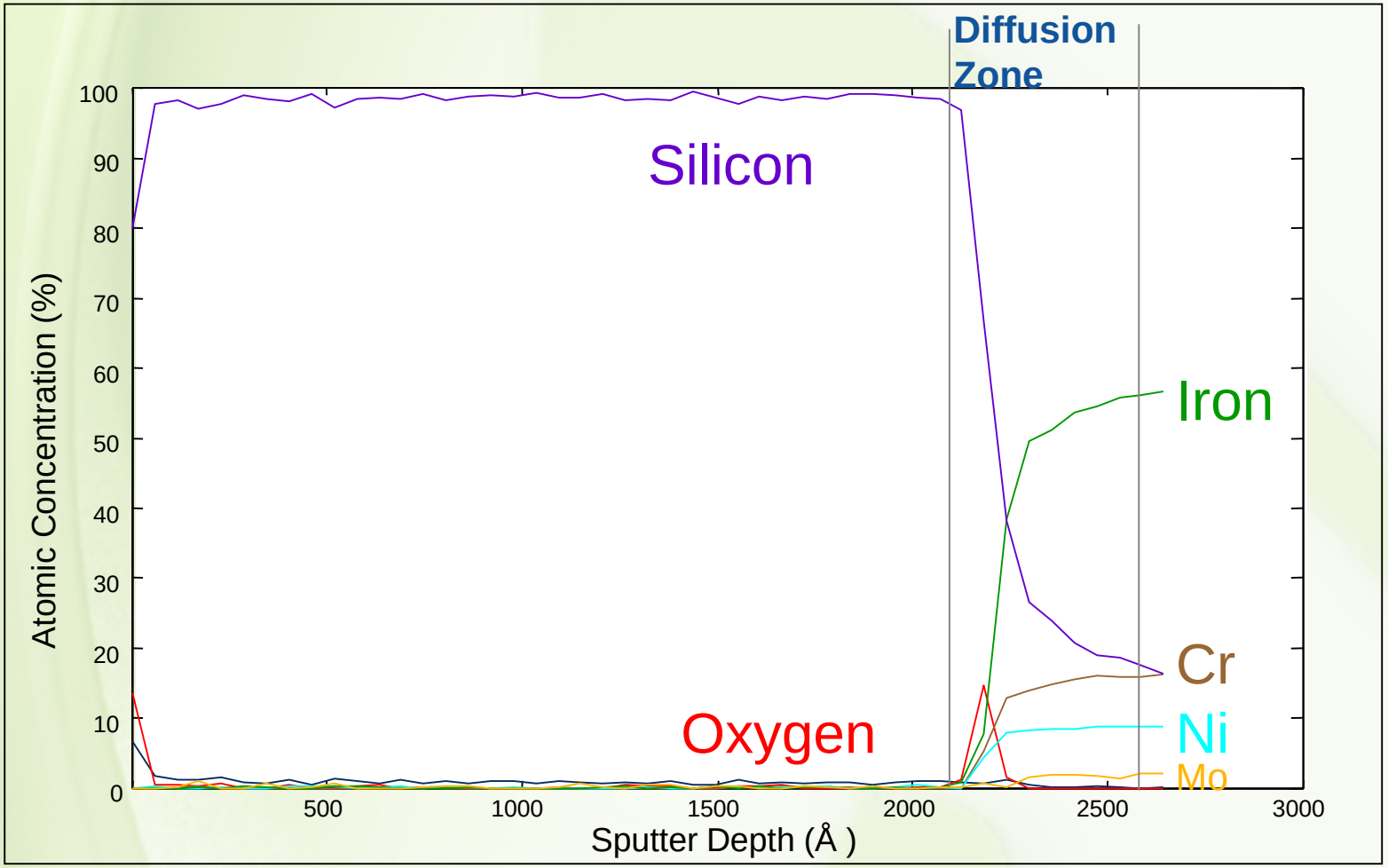
SilcoTek Solutions

- **Silicon-based**
  - Silcolloy
    - US Patent #7,070,833
    - Amorphous, hydrogenated silicon (a:Si-H)
    - 400-800 nm typical thickness
- **Silicon oxide-based**
  - Dursan
    - US Patent Pending
    - Silicon oxide from organic source gas
    - 300-1500 nm typical thickness
    - Functionalized and non-functionalized available

Process Outline

- **Coatings applied to stainless steel and chrome/moly/nickel alloys**
- **Chemical Vapor Deposition process**
- **Customer supplied parts**
  - Either direct from OEM (mass flow controllers/regulators)
  - End user (custom components)
  - Fabricators (weldments/assemblies)
- **Surface Preparation**
- **Vacuum deposition process**
  - Non-line of site
  - Batch process
- **100% inspection**
- **Return**

Silicon-based Coatings

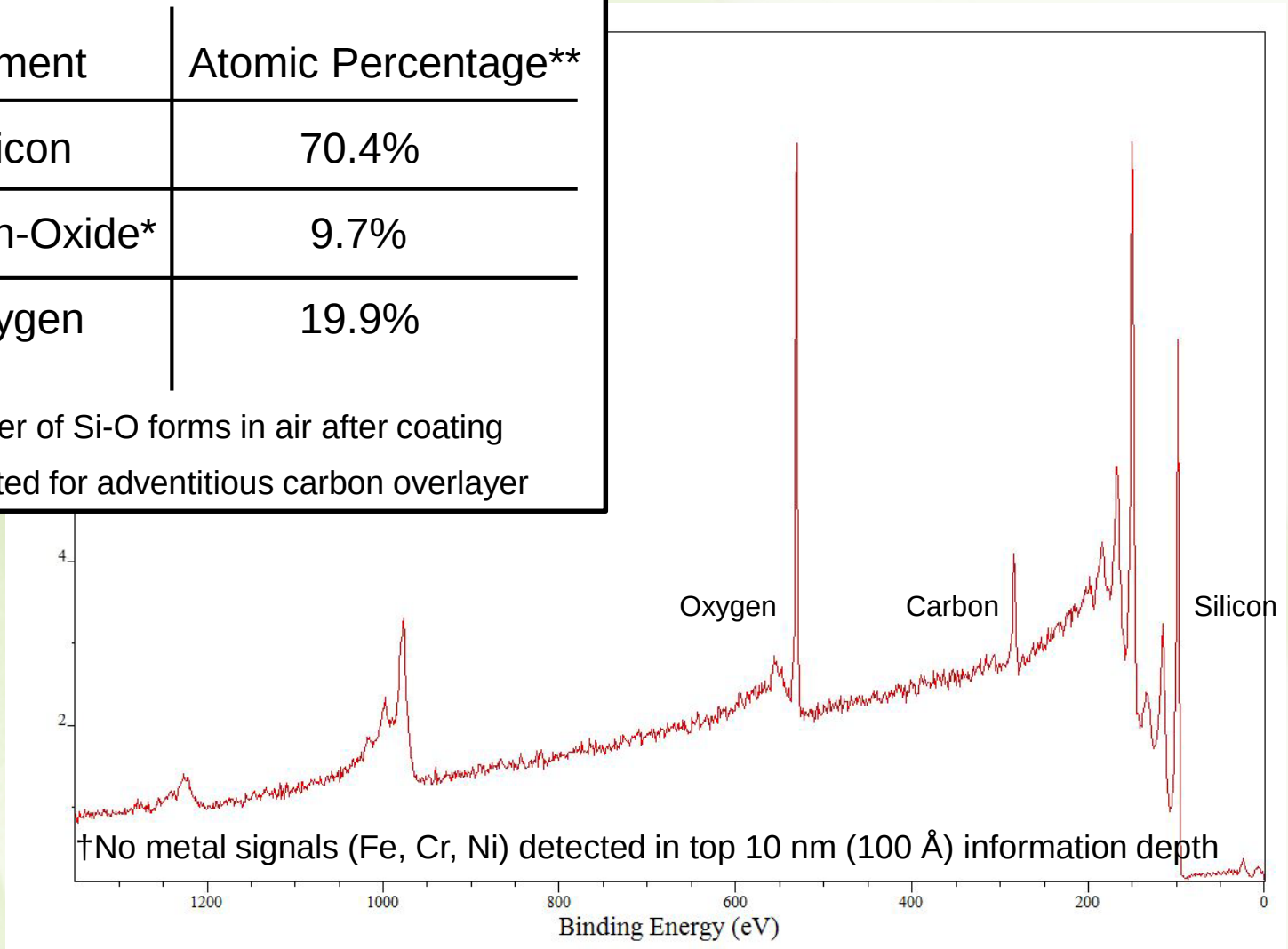


Silicon-Oxide Dursan

Element	Atomic Percentage**
Silicon	70.4%
Silicon-Oxide*	9.7%
Oxygen	19.9%

*Thin layer of Si-O forms in air after coating

**Corrected for adventitious carbon overlayer



†No metal signals (Fe, Cr, Ni) detected in top 10 nm (100 Å) information depth

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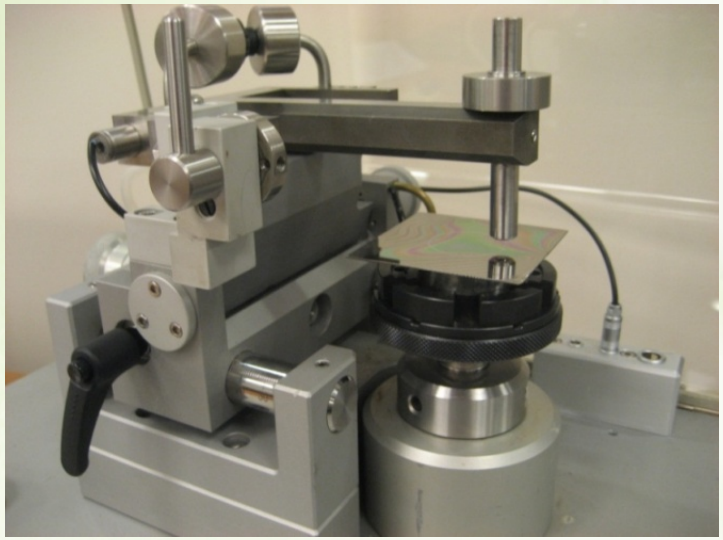
Technique:
X-Ray Photoelectron Spectroscopy (XPS)

Physical Properties of CVD coated surfaces

Wear and Friction

	Avg. Coeff. Friction	Wear Rate ($x10^{-5} mm^3/Nm$)
Uncoated SS	0.589	13.810
Si_xO_y-base (functionalized)	0.378	6.129
Si-base (corrosion)	0.7	14.00

- ASTM G133 (Pin-on-Disc)
- Mirror Finish 316L SS



Experimental Parameters	
Load	2.0 N
Duration	20 min
Speed	80 rpm
Radius	3mm
Revolutions	1,554
Ball Diameter	6mm
Ball Material	SS 440

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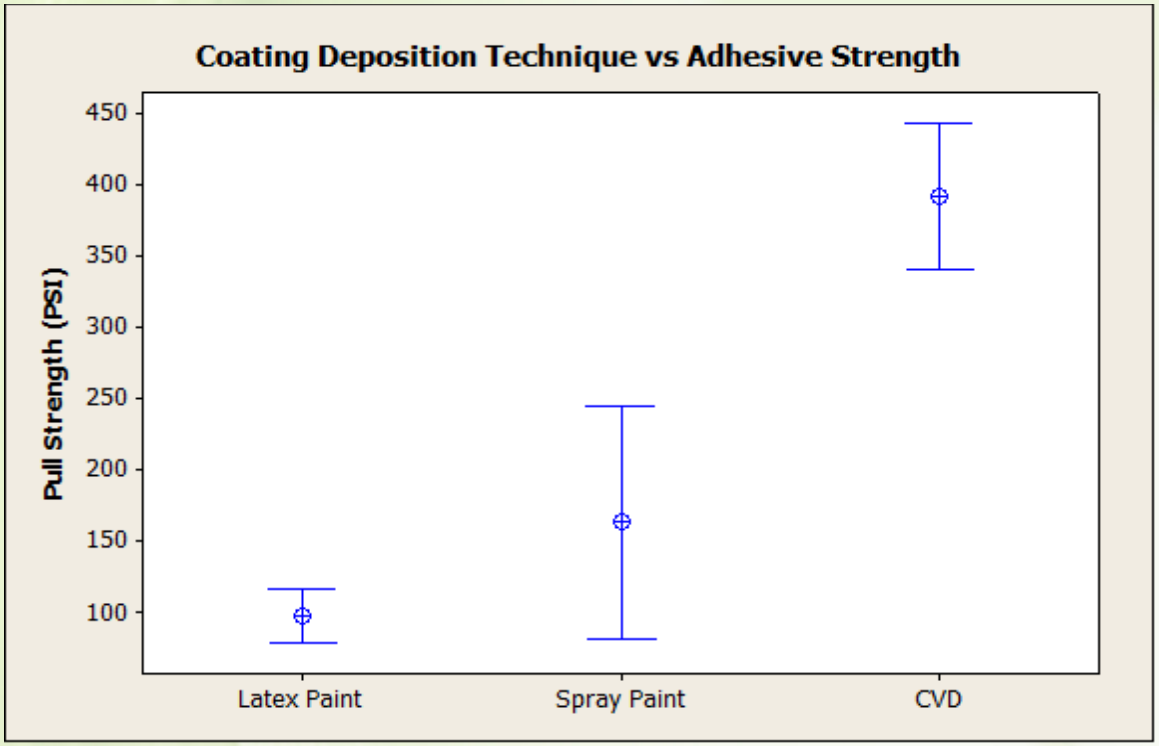
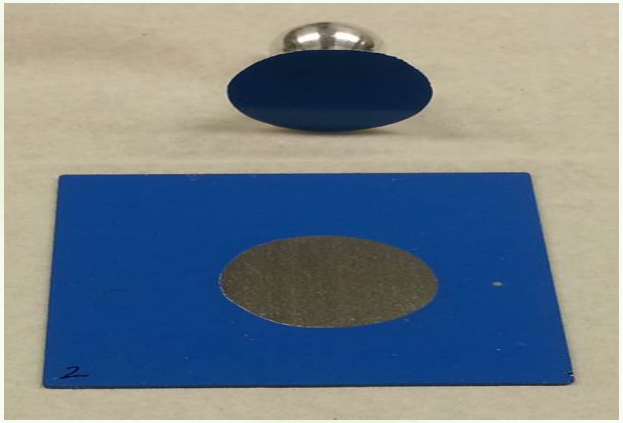
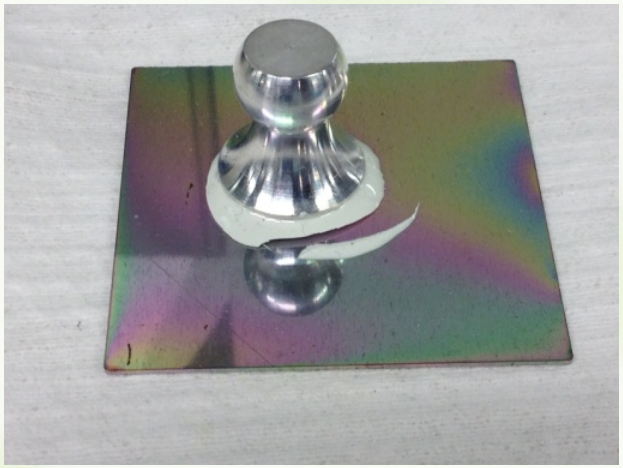
CVD Coating Solutions







Material Properties Sheet

Property	Si-Based	Si_xO_y-Based	PTFE, PFA
Max Temperature	900ºC	450ºC	260ºC
Min Temperature	-196ºC	-100ºC	-240ºC
Low pH limit	0	0	0
High pH limit	7	14	14
Thickness	0.12um to 0.8um	0.3um to 1.5um	25um
Adhesion	Very Good	Very Good	Poor
Wear resistance	~90% of SS	2x SS	~10% of SS
Moisture contact	72-90˚	104-140˚	125˚
Inertness vs. SS	Excellent	Good	Excellent

Corrosion Resistance

Corrosion Resistance

- **Challenges**
  - Physical Losses
    - Maintenance & Replacement Cycles
  - Increased Activity
  - Metal Contamination
- **Solutions**
  - Extended Lifetimes
  - Lower Reactivity
  - Substrate Barrier

Corrosion in semiconductor applications

- Gases attacking flow path or reactor components made of steel
- Creates metal ion contamination
- Reduces component lifetime
- Reduces tool efficiency and throughput

Corrosion Testing Results (ASTM G31)

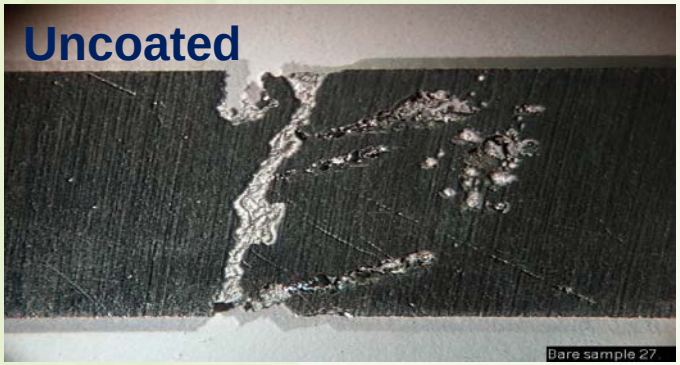
	6M HCl		3M HCl		1M KOH		10% Sulfuric	
	MPY rate	factor	MPY rate	factor	MPY rate	factor	MPY rate	factor
316L SS	161.4	-	67.93	-	0.00	-	22.35	-
Dursan	2.2	75	5.14	13.2	0.01	261	2.42	9.9
Silcolloy	3.6	45	14.85	4.6	0.01	Dissolved	2.52	8.9

Corrosion Testing Results (ASTM G31)

	5% HF		70% Nitric		85% Phosphoric		25% Sulfuric	
	MPY rate	factor	MPY rate	factor	MPY rate	factor	MPY rate	factor
316L SS	120.00	-	0.78	-	0.62	-	54.64	-
Dursan	80.38	1.49	0.10	7.50	0.08	8.00	5.36	10.19
Silcolloy	44.26	2.71	0.36	2.14	0.28	2.18	23.62	2.31

Corrosion Testing Results (ASTM G48B)

Sample	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Weight Loss (g/m^2)
Silcolloy Sample 17	10.4105	10.3710	0.0395	19
Silcolloy Sample 28	10.1256	10.0743	0.0513	25
Silcolloy Sample 47	10.1263	10.0742	0.0521	25
Bare Sample 27	10.0444	9.5655	0.4789	231
Bare Sample 34	10.1265	9.6923	0.4342	209
Bare Sample 37	10.1007	9.6276	0.4731	228



Pitting & Crevice Corrosion

- 6% Ferric Chloride
- 72 hrs @ 20C
- Gasket Wrapped

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Corrosion Testing Results (ASTM B117)

Salt Spray

- **4000 hour exposure**
  - 100 F
  - 3.5% by weight sodium chloride
- **No Effect on Silcolloy Coating**
- **Reproduction of Exposure to Marine Environments**

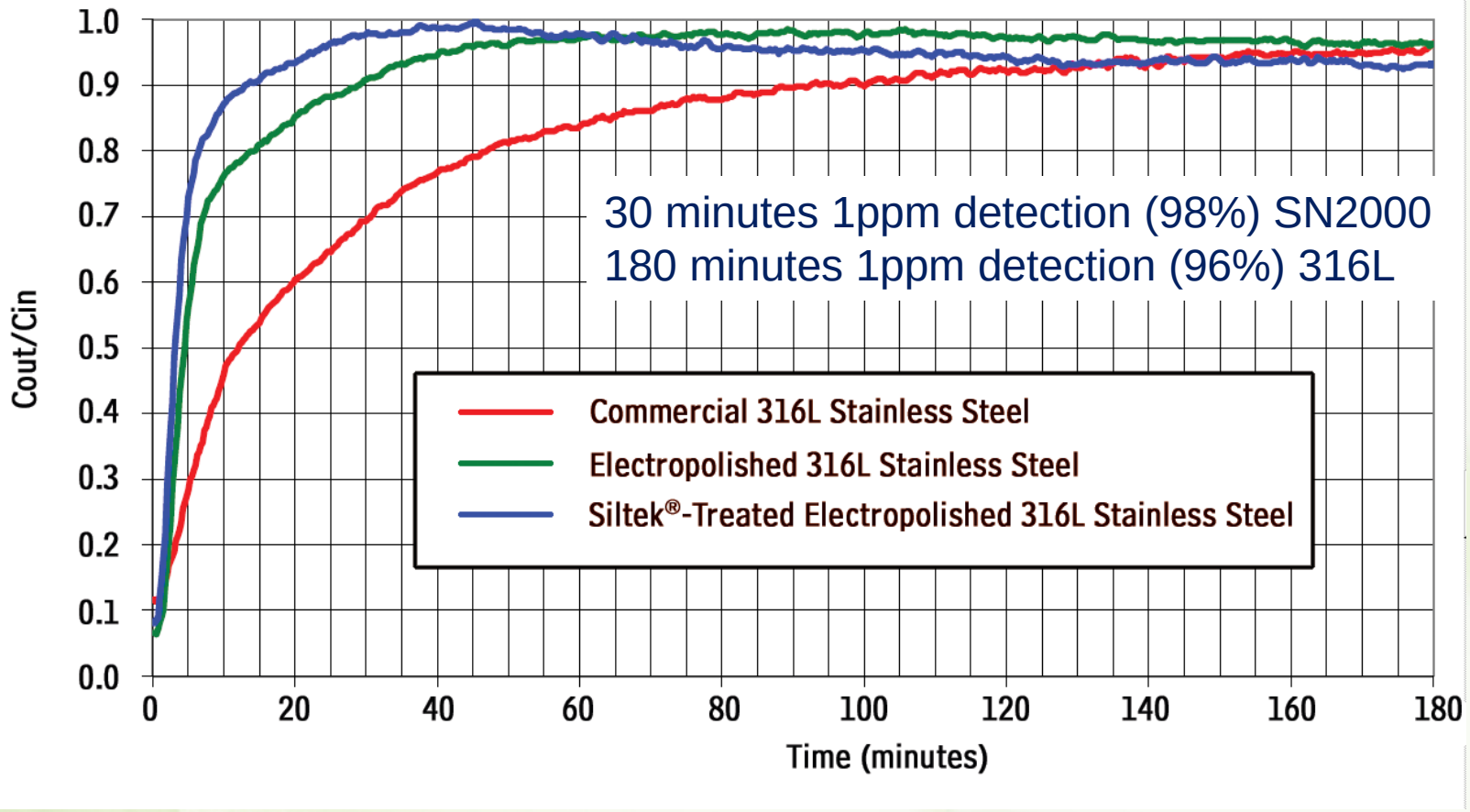
Reduce cross contamination, carryover and adsorption

Chemical Inertness

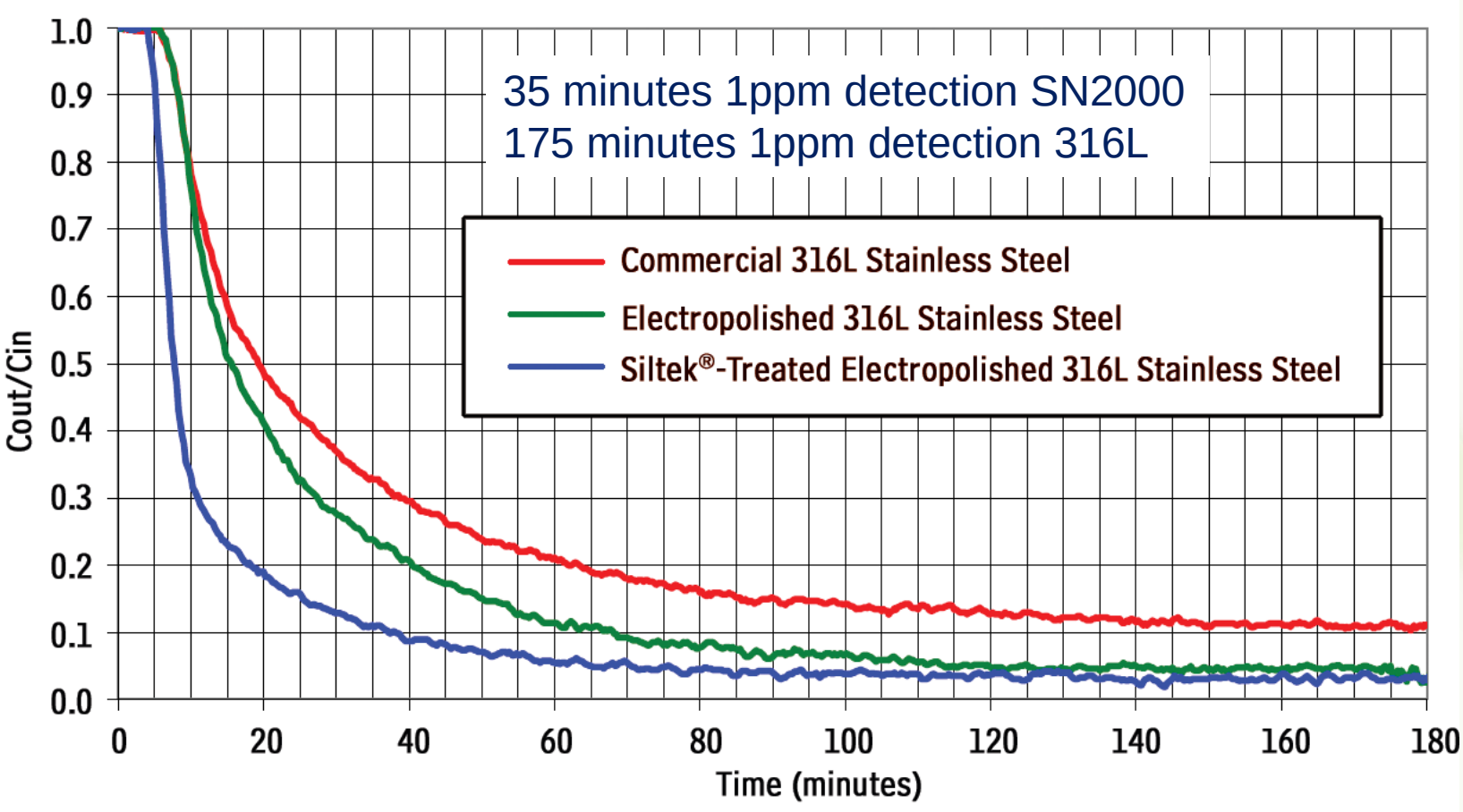
- **Low reactivity with wide range of chemicals**
  - Sulfurs, Ammonia, Mercury
- **Allows low level (ppm-to-ppb) contamination monitoring**
  - Petrochemical refining, Oil & Gas, LNG production/transfer, Emissions & Air monitoring
- **Quick recovery after process upsets**

Functionalized silicon (SN2000) good to single-digit ppb detection levels!

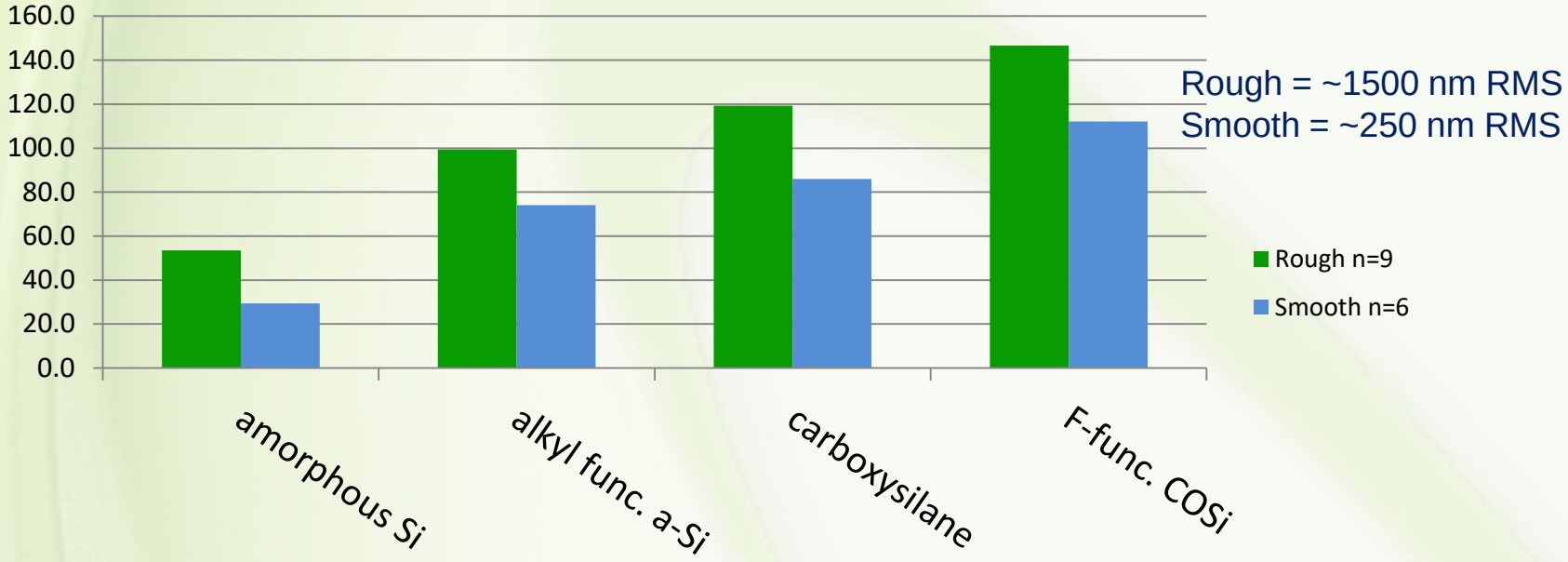
“Wet-Up” Moisture Detection



“Dry-Down” Moisture Removal



Hydrophobicity Measurement



amorphous Si
Silcolloy
49°

alkyl func. a-Si
SilcoNert
101°

Carboxysilane
Dursan
121°

F- func. COSi
FluoroDursan
163°

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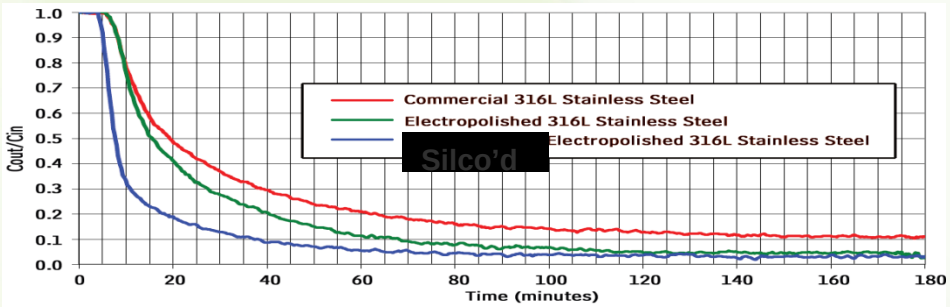
Decrease system pump down time

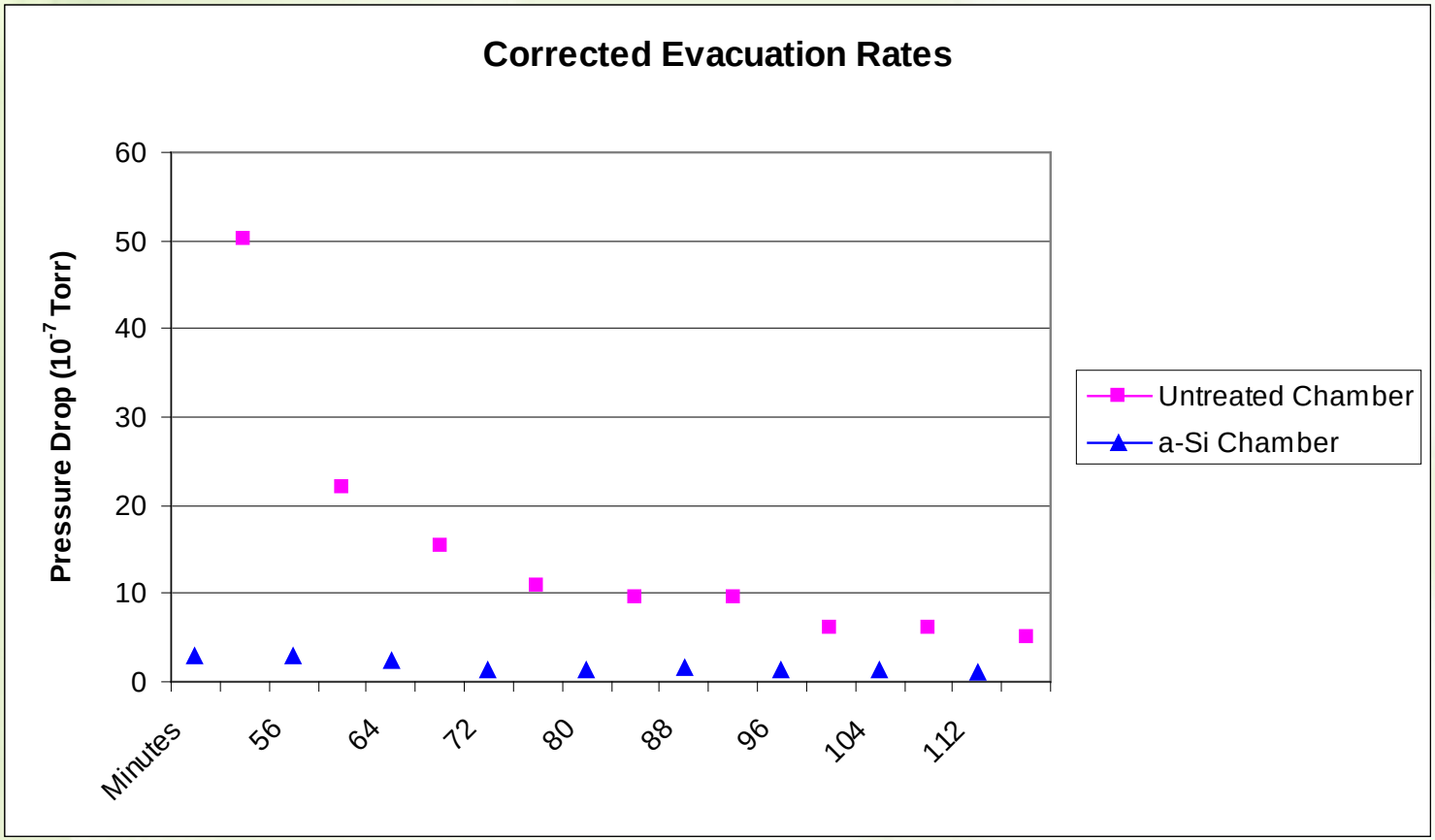
SilcoGuard:

- Ultra-High-Vacuum (UHV) environments (1x10^{-7} Torr or better)



  - Materials outgas into the vacuum environment.
  - Outgassing increases pressure in the chamber (directly related to dry down data)
  - Requires large pumps and long "pump down" times
- SilcoGuard blocks materials from outgassing into the vacuum environment.

Comparative Evacuation Rates



SilcoGuard Advantages

- Consistently outperforms cleaned parts for ability to pump down faster: No need to clean
- Eliminates bake out of components as received from manufacturer
- Ability to achieve lower base pressure with smaller pumps
- Faster process cycle time vs. uncoated systems
- Superior high temperature stability up to 600°C

SilcoGuard Applications

- University/Research
  - Coating of accelerator chambers to create higher vacuum environment
- Semiconductor
  - Use in coating of semi-conductor manufacturing equipment to decrease defect rate
- Analytical
  - Reduce time needed to achieve high vacuum environments in analytical equipment (SEM, XPS, etc.,.)
- Manufacturing
  - Reduce cycle time of vacuum pass-through chambers

Conclusion

- Coatings are available for a wide range of applications
- Optimize based on desired property
  - Inertness
  - Corrosion Resistance
  - Anti-Coking
  - Purity
- Ultimate benefit is superior performance
  - Analytical results
  - Extend life
  - Reduce labor and capital cost
  - Improve efficiency
  - Optimize material selection and cost performance