

# Solving Surface Fouling with New Non-Stick CVD Coatings

Your  
Presenter:

**Dr. David  
Smith**

SilcoTek R&D  
Manager



David's team is responsible for developing and improving coating solutions for SilcoTek customers. A founding member of the original Restek Performance Coatings division and pioneer of SilcoTek's coating technology, he has been helping companies improve material performance of their products since 1992.

Today, David will introduce you to a new line of coating solutions aimed to help you solve surface fouling problems.

**We will begin 2 minutes past the hour**



# Welcome!



Webinar will be recorded and emailed to you

- You can find it any time on [SilcoTek.com](http://SilcoTek.com)



#AskSilcoTek on Twitter (@SilcoTek)



Send questions via message bar

# Today's Webinar will Cover:

- What is surface fouling and why is it a problem?
- Existing technology and strategies for mitigation
- A new solution: non-stick CVD coatings from SilcoTek®
- Applications and data
- Future work, conclusions, and Q&A



# What is Surface Fouling?





# The Challenge of Surface Fouling

- Fouling is the deposition of byproducts or otherwise unwanted material on a surface
- Occurs everywhere
  - Petrochemical / refining
  - Automotive and aerospace
  - Medical and biopharma
  - Power generation
  - Molding and plastic applications
  - Your car, home, and much more



# The Bane of Fouling in Industry

- Increases weight
- Causes contamination
- Reduces flow
- Increases drag
- Encourages corrosion
- Increases emissions
- Increases maintenance requirements
- Creates false results



**...COSTS MONEY \$**

# The High Price of Fouling

- Medical / bioanalytical
  - Annual costs of false results in USA >\$3 billion annually
- Automotive
  - 10%+ increase in fuel consumption due to fouling
- Refining
  - \$0.5 billion spent to overcome fouling issues (2002)
- Heat exchangers
  - 50% of maintenance costs are caused by fouling → billions of dollars



# Potential Solutions

- Increase energy / power / fuel consumption
  - Expensive and does not solve the problem
- Control the incoming media that's causing fouling
  - Rarely an option in industrial applications



# Potential Solutions

- Material selection
  - Several options, difficult to optimize performance & cost
- “Surface engineering” through advanced coating technology
  - Flexible and cost effective
  - Modify the existing part’s surface to make it behave how you need it to

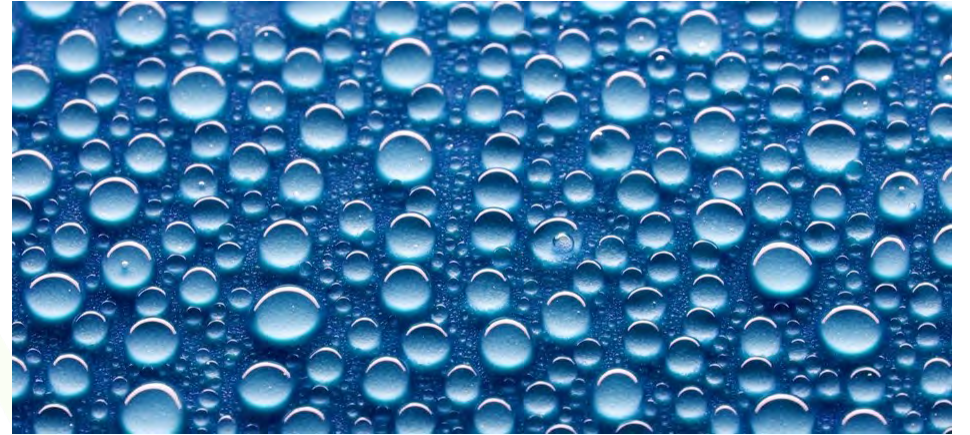


# Coatings and Surface Treatments

- Most cost-effective solution
  - Enhance the performance of existing components
- Several variables to consider for coating selection
  - Do I have to re-engineer to account for tolerance changes?
  - Is there environmental impact?
  - Can the coating withstand temperature, abrasion, corrosion, etc. in the application?
  - How long will it last?

# Coatings and Surface Treatments

- Fouling applications require versatility
  - Anti-stick
  - High temperature
  - Oxidation protection
  - Corrosion resistance
  - Hydrophobicity
  - Oleophobicity
  - Abrasion resistance
  - Often all required in these challenging situations





# SilcoTek® CVD Coatings





# Brief History – Our Start in Chromatography

**RESTEK**<sup>®</sup> invents SilcoSteel<sup>®</sup> in 1987 to make stainless steel capillary columns act like glass



Paul Silvis – Founder of Restek<sup>®</sup> and SilcoTek<sup>®</sup>. Current President of SilcoTek.



# SilcoTek History

- Throughout the 1990s, a team dedicated to the SilcoSteel® technology began to experiment with custom coating for various uses.
- Demand grew for coatings outside of chromatography applications.
- **2009:** Restek coatings group splits off and forms SilcoTek®, an independent company

**2013:** 3,400 m<sup>2</sup> state-of-the-art coating facility opens, tripling previous coating capacity



# Industries Served

- Chromatography
- Process analytical
- Medical device and diagnostic
- Semiconductor
- Oil and gas upstream
- Petrochemical refining
- Automotive and aerospace
- Much more





# What Does SilcoTek Provide?

- Vapor phase modification of parts through:
  - Barrier coatings - preventing interactions with the surface of a part
  - Surface functionalization – enhance existing surface performance
- Why?
  - High expectations of plain materials is not realistic
  - Gain control of surface properties
  - Take performance to a higher level

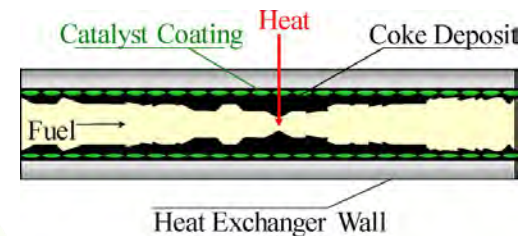


# How SilcoTek Addresses Fouling

- Barrier approach

- Preventing catalytic or chemical interaction with a surface
- Nickel-containing substrates catalytically form carbon deposits (coke) from petrochemical media

**SilcoKlean®**



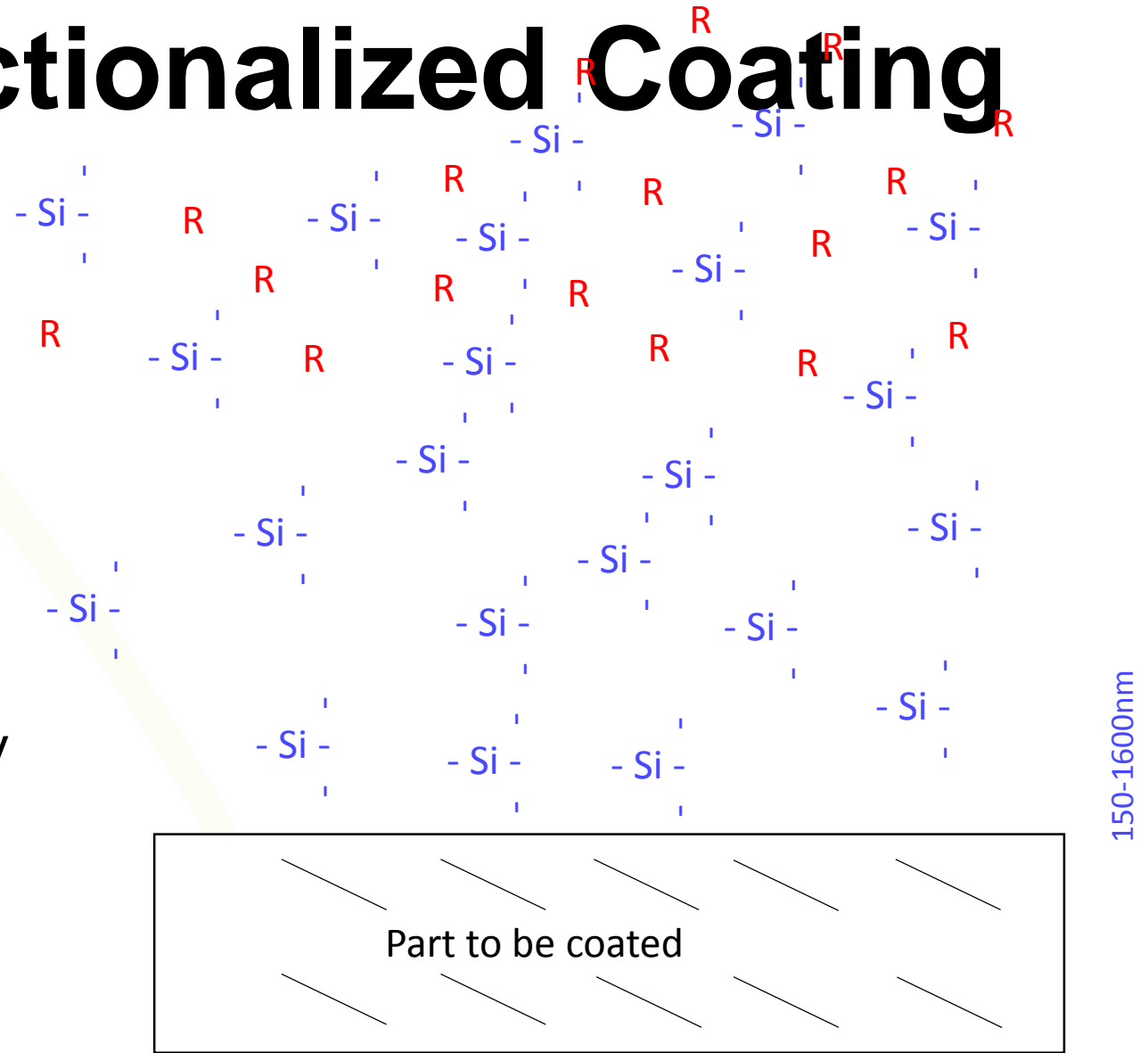
- Chemistry approach

- Preventing chemical adhesion / adsorption to substrate
- Using an inert, low energy surface to block unwanted media

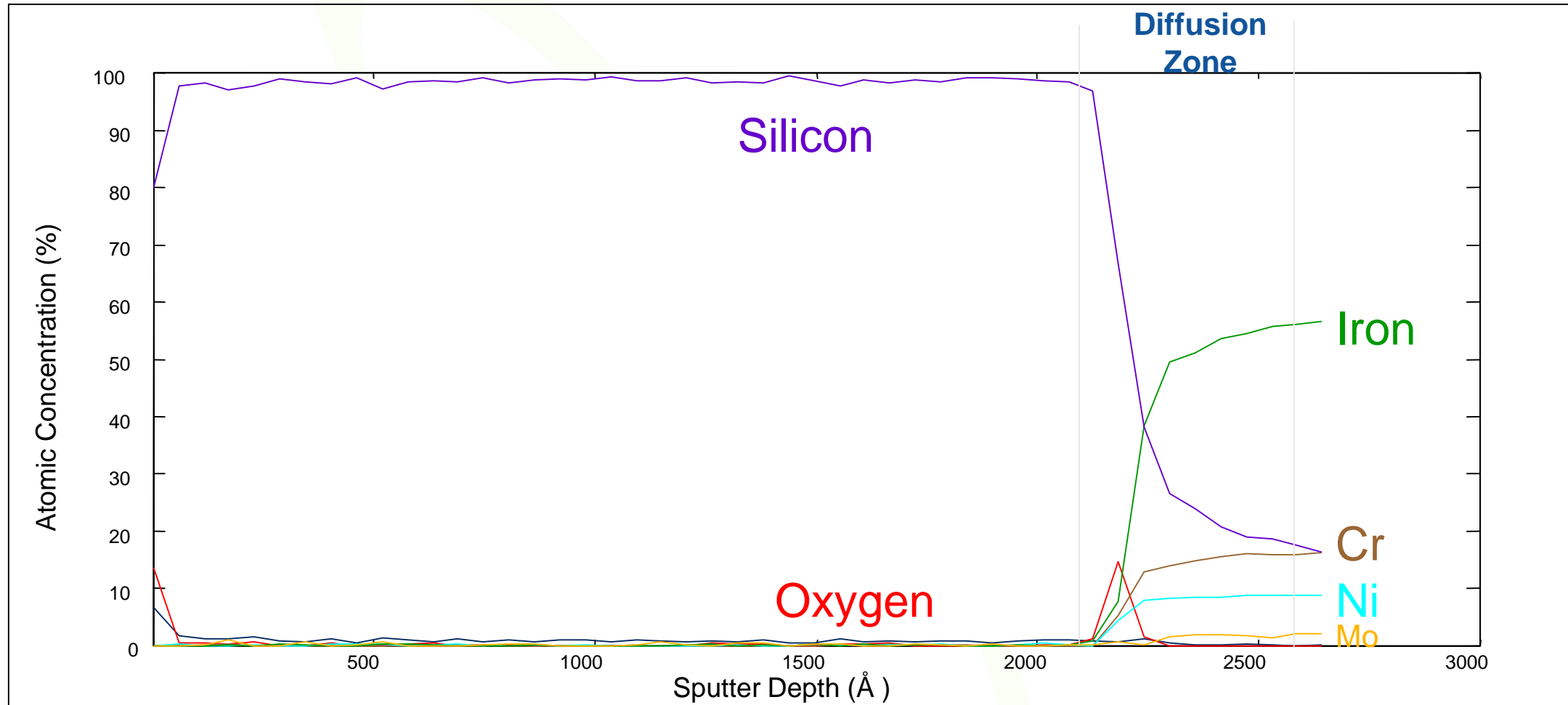
**Dursan®** and **NEW Fluoro Surface Functionalization Technology**

# The Barrier / Functionalized Coating

- Coatings consist of a and a **Surface Layer**
  - Base is 150-1600nm of:
    - Si (SilcoKlean) or
    - Si – O – C (Dursan)
  - Functionalized surface – Chemistry is key to performance

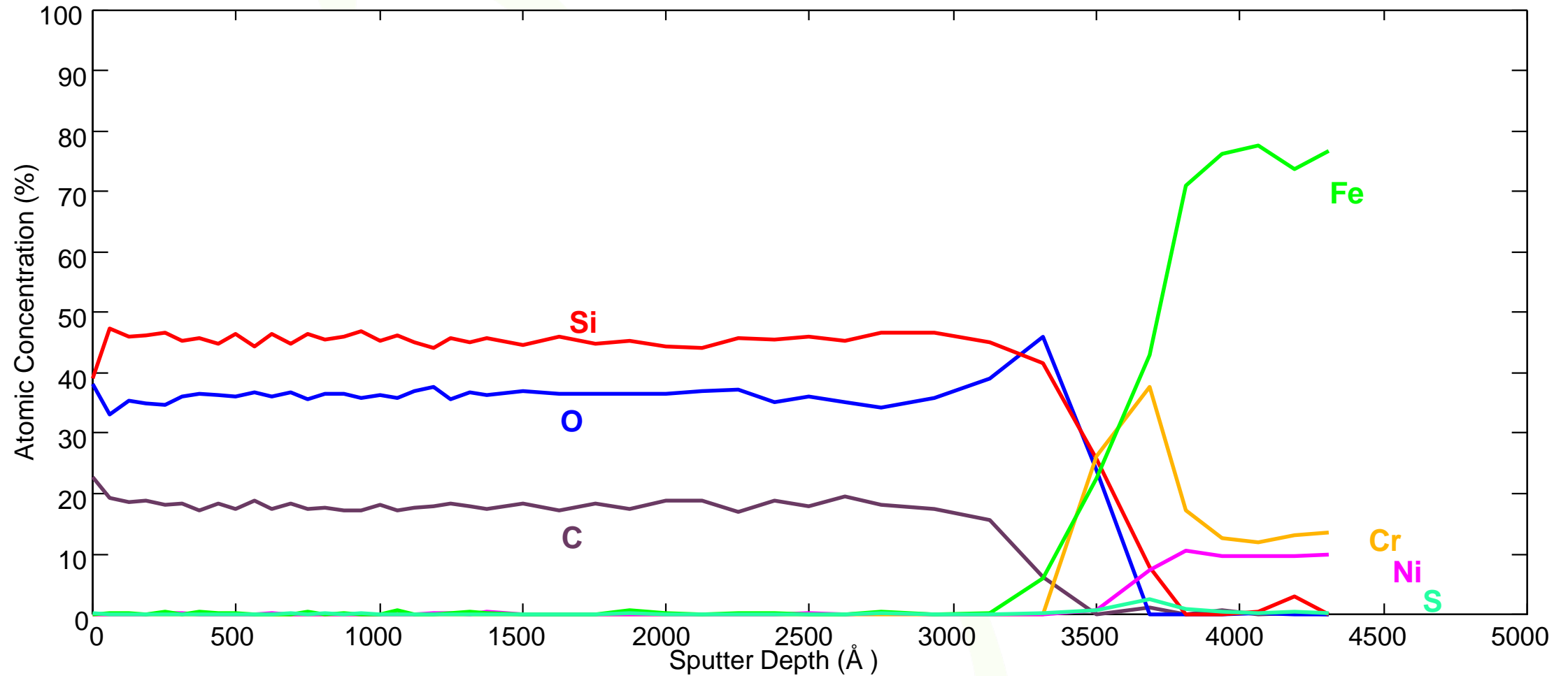


# SilcoKlean Composition





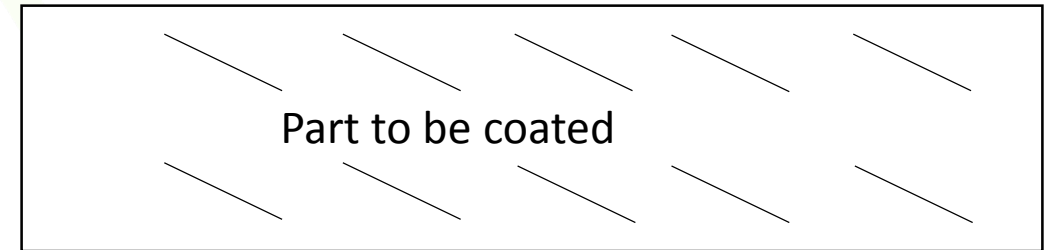
# Dursan Composition



# The Functionalized Surface<sup>R</sup>

- Direct functionalization of the substrate surface

- Stainless steels
- Aluminum
- Brass
- Glass
- DLC
- Copper
- Zinc?



# Process Chambers & Tubing



# Benefits of SilcoTek Thermal CVD vs. Plasma-Enhanced CVD

- Deposition on all part surfaces, regardless of geometry
    - Inside/outside, blind holes, tubing
    - Frits, filtration media
    - Narrow bore, needles
  - Wide variety of deposition substrates
  - Ability to process large batches of 100's -1000's of parts, simultaneously
  - Ability to process wide variety of part sizes
    - Current largest chamber 30" ID x 64" OD
    - Internal tubing depositions: ID's 0.1mm-1/2"; up to 2500' long
-



# Optimizing Performance, Easing Application, Lowering Costs

- SilcoTek's CVD coatings provide a low energy surface that resists fouling and other unwanted surface behavior
  - The thermal chemical vapor deposition process lends itself to scalable, cost effective coating of very small, narrow, or otherwise complex parts
- Treating existing components with SilcoTek's CVD coatings to reduce fouling problems **increases uptime and profitability.**

# Problems, Solutions, and Data

Applications for SilcoTek® Non-Stick CVD Coatings



# Problem: Catalytic Carbon Coking

- Carbon deposits (coke) form on injection / combustion components from incomplete burning of fuel
- **Solution:** SilcoKlean<sup>®</sup> functionalized barrier coating



**SilcoKlean<sup>®</sup>**

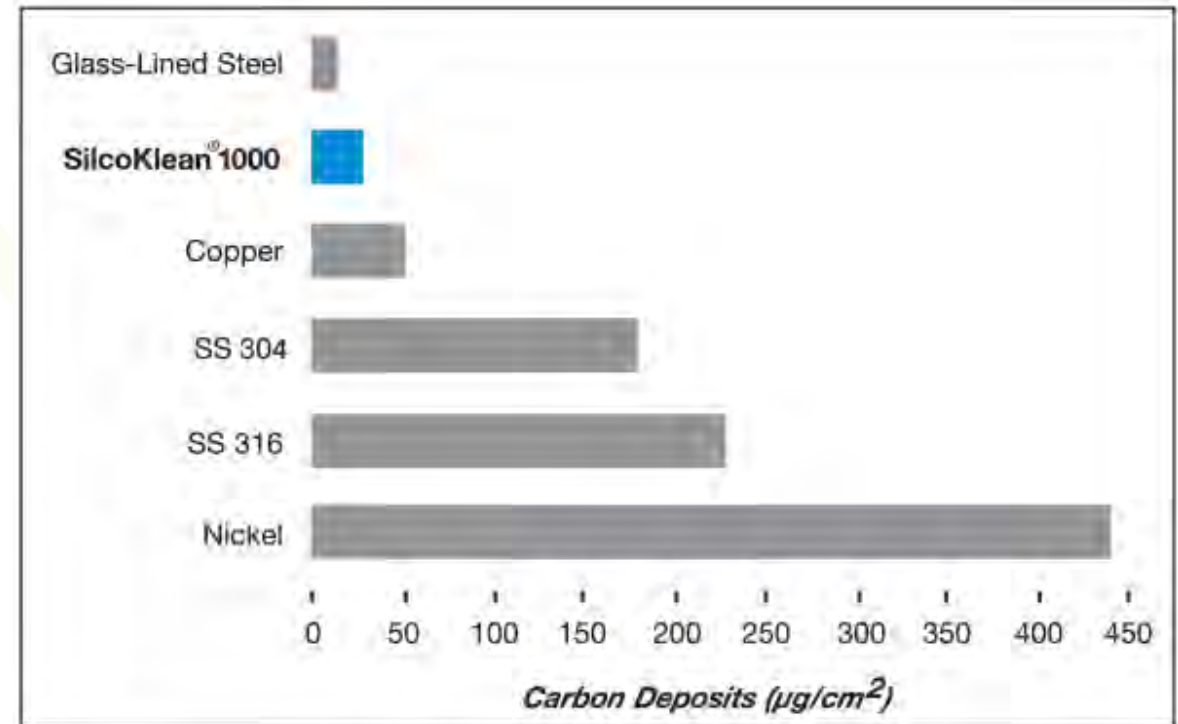


# SilcoKlean<sup>®</sup> drastically reduces carbon coking, boosting efficiency

- Tests by Semih Eser – Penn State Professor of Energy and Geo-Environmental Engineering

- JP-8 fuel
- 500° C
- 500psig
- 1 ml/min flow
- 5 hours

Altin, O.; Eser, S. *Ind. Eng. Chem. Res.* 2001, 40, 596-603



# Problem: Biofouling in Food Applications

- Spores from sour milk suspensions stick to testing equipment, skewing results and adding maintenance
- **Solution:** Dursan<sup>®</sup> functionalized barrier coating



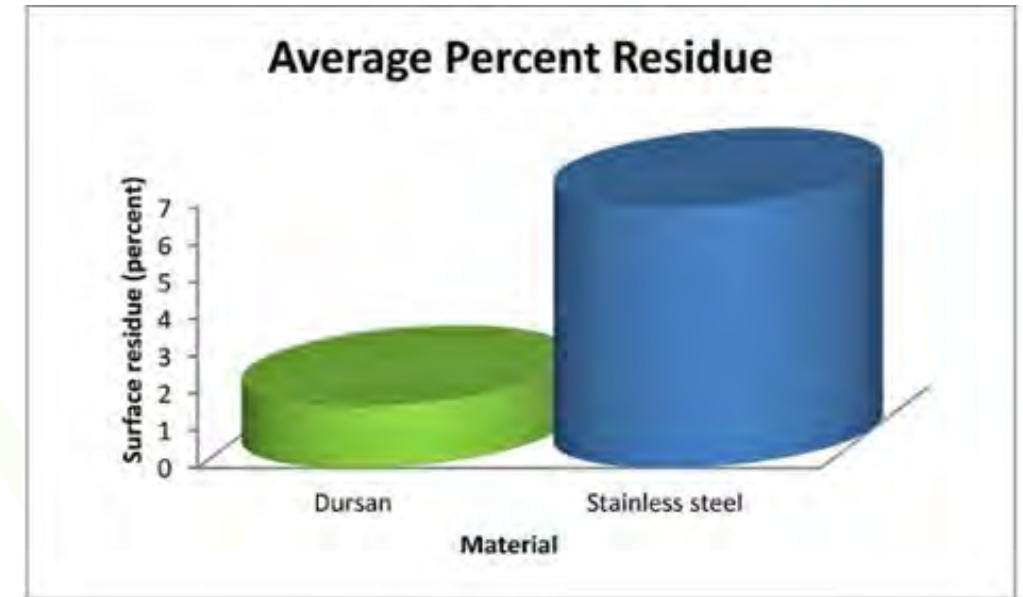
**Dursan**<sup>®</sup>





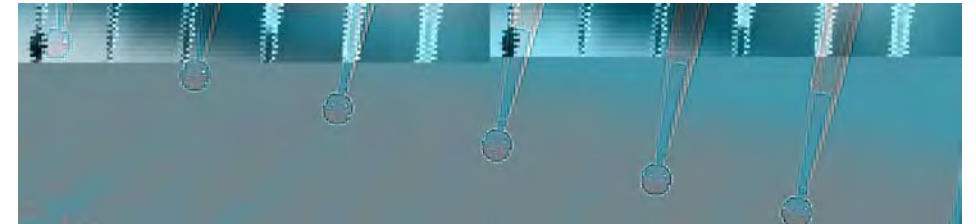
# Dursan® lowers maintenance costs by reducing unwanted sticking and biofouling

- Weihenstephan Research Center for Brewing and Food Quality
- Quantified sticking of spores from sour milk suspensions
- Rinsed tubes coated with Dursan vs. Uncoated
- Dursan: 76% improvement



# Problem: Protein Binding in Medical Diagnostics

- Protein molecules stick to the surfaces of diagnostic instrument probes, leading to false results for serious tests
- **Solution:** Dursan<sup>®</sup> functionalized barrier coating

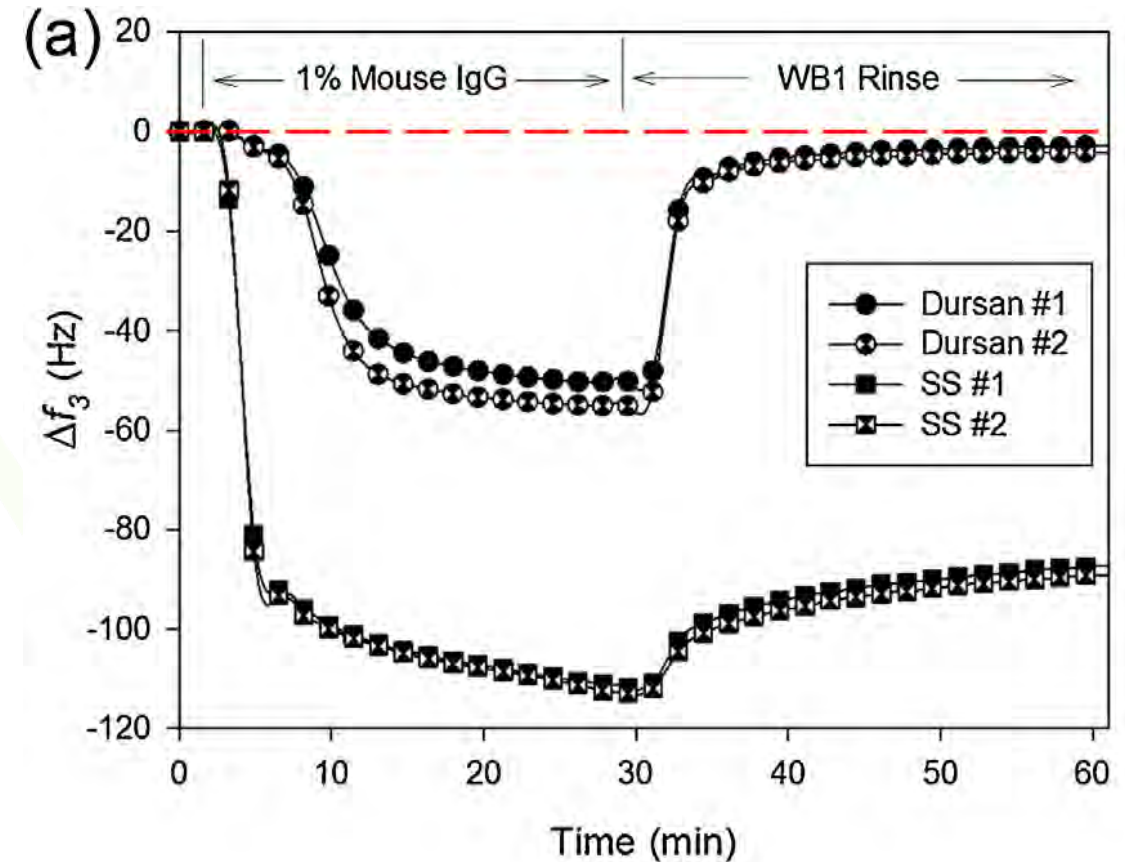


**Dursan**<sup>®</sup>



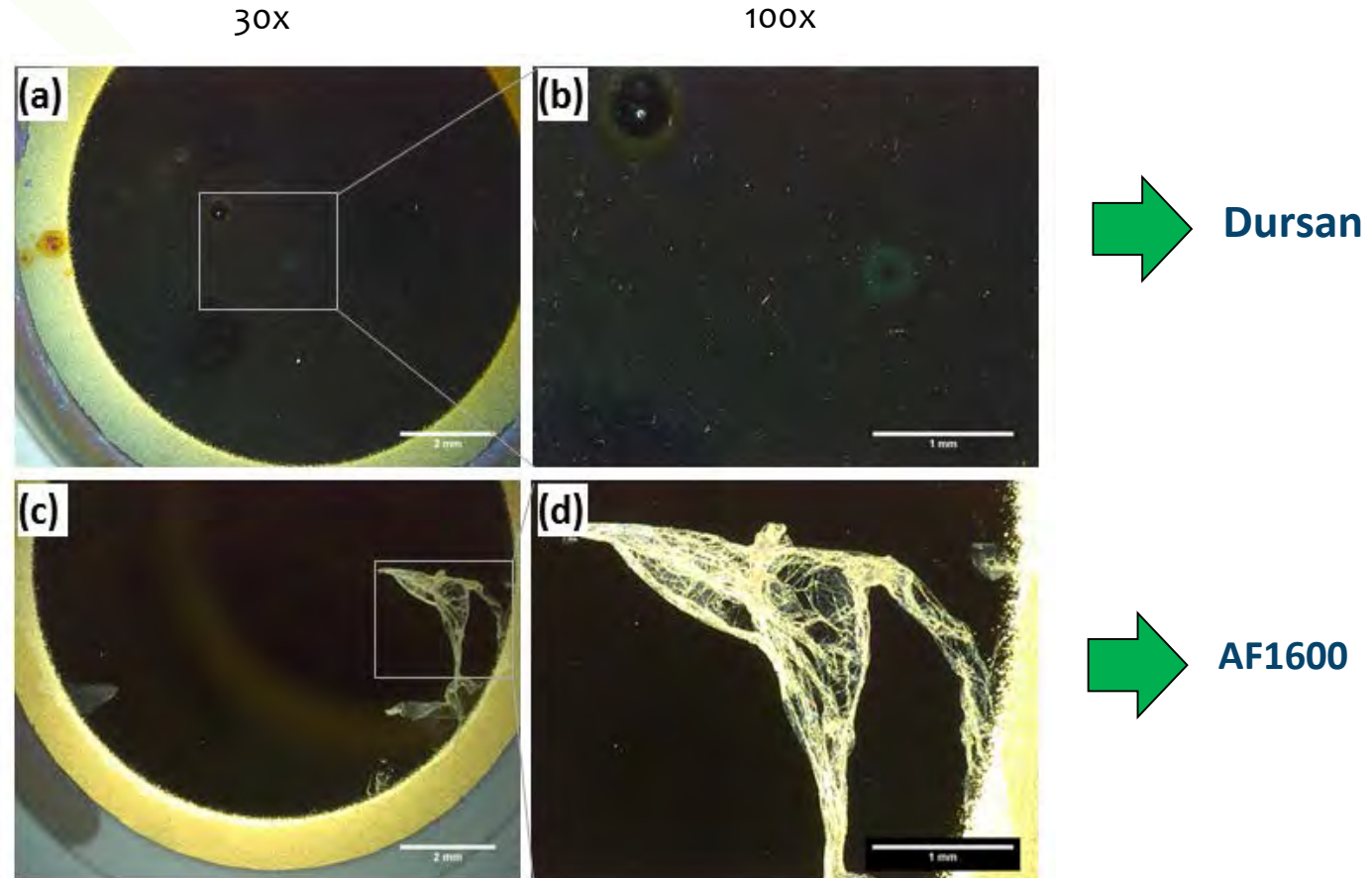
# Dursan<sup>®</sup> improves analytical accuracy by preventing surface interaction

- Collaborative paper with Abbott Laboratories
- Quartz crystal microbalance with dissipation (QCMD)
- Mouse immunoglobulin G
- WB1: Wash buffer with non-ionic surfactant (PBS with Brij 35)
- Dursan-coated vs. Bare Stainless Steel sensor



# Dursan<sup>®</sup> substantially outperforms fluoropolymers in real-world applications

- Dursan-coated vs. fluoropolymer-coated sensors
- Before and after sonication for 10 minutes in EtOH

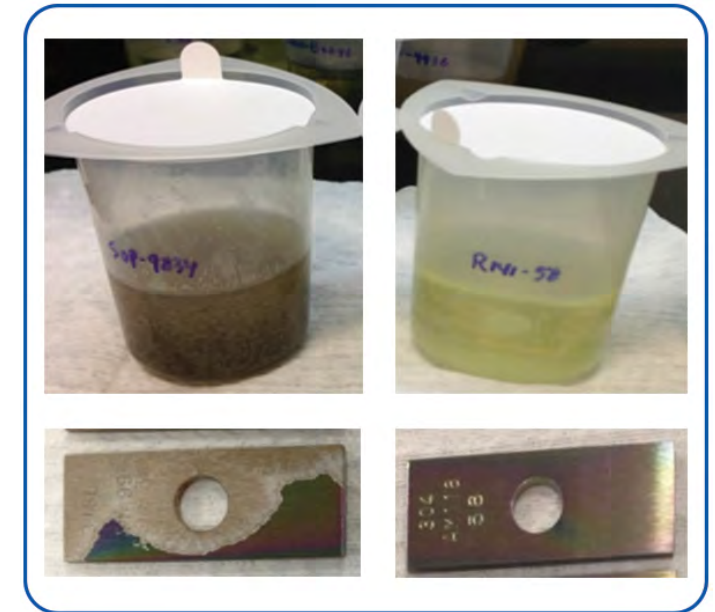
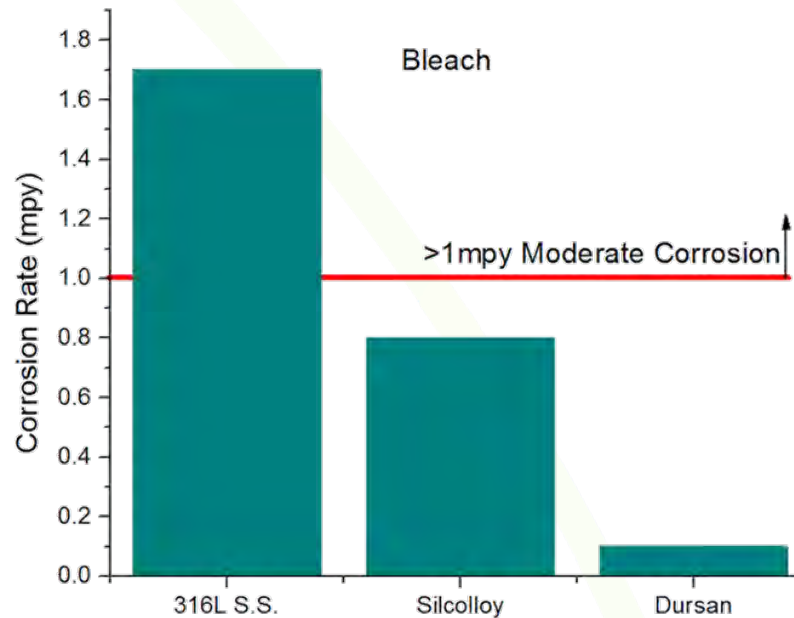


Vaidya, S.V.; Yuan, M.; Narvaez, A.R.; Daghfal, D.; Mattzela, J.; Smith, D. *Appl. Surf. Sci.* **2016**, 364, 896-908

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# Dursan® increases useable lifetime by fighting corrosion in harsh environments

- Dursan is virtually unaffected by bleach and other common cleaning agents



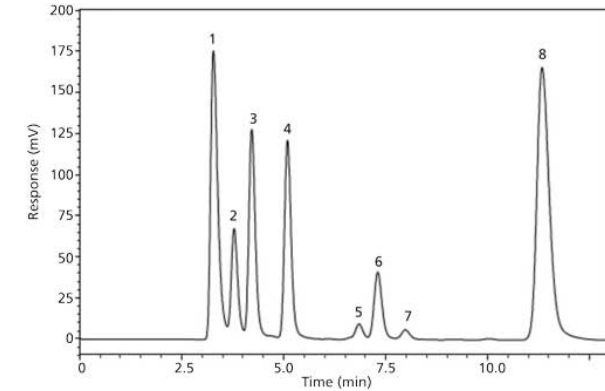
Inferior  
Coating

Dursan®

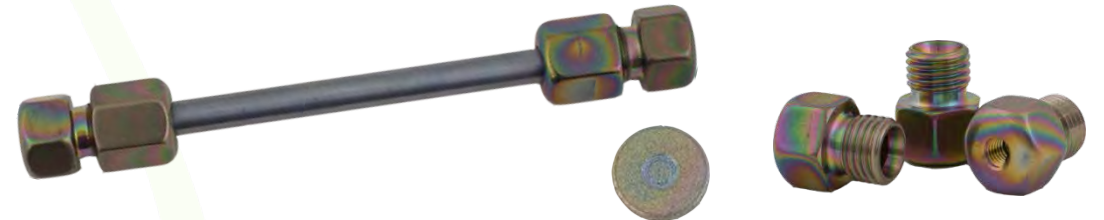


# Problem: Carryover in chromatography applications

- Inaccurate chromatograms due to interference with previously injected samples
- **Solution:** Dursan<sup>®</sup> functionalized barrier coating



**Dursan<sup>®</sup>**



# Dursan® significantly improves analytical reliability, speed, and accuracy

- HPLC is a fast-growing application area
  - Stainless Steel and PEEK issues
    - Stainless Steel
      - Acid Corrosion (Halogenated Solvents - HCl, HBr)
      - Ion Chromatography
      - Anionic Compounds (phosphates may chelate)
    - Peek
      - Temperature (Tg 148°C)
      - Halogenated solvents
      - Tetrahydrofuran
  - Dursan Solutions
    - Chemical inertness/compatibility, anti-corrosion (0-14 pH range), anti-biofouling, physically robust
    - Lots of test data to come soon
-

# An Array of Solutions

- SilcoTek's functionalized barrier coatings solve problems in several more applications not listed here, like:
  - Heat exchanger scaling and fouling
  - Fouling and oxidation on aviation component surfaces
  - Sticking that occurs during polymer production and extrusion processes
  - Mold release applications across numerous industries

# Still, the toughest applications require even greater anti-fouling performance...

- Coke and other surface byproducts can thermally form and remain looming...now what?
- The ultimate anti-fouling surface is needed:
  - Very high hydrophobicity, sometimes superhydrophobicity
  - High oleophobicity
  - Thermal stability
  - Physical durability



# Introducing SilcoTek's new Fluoro-Surface Technology

A preview of what's to come in 2018

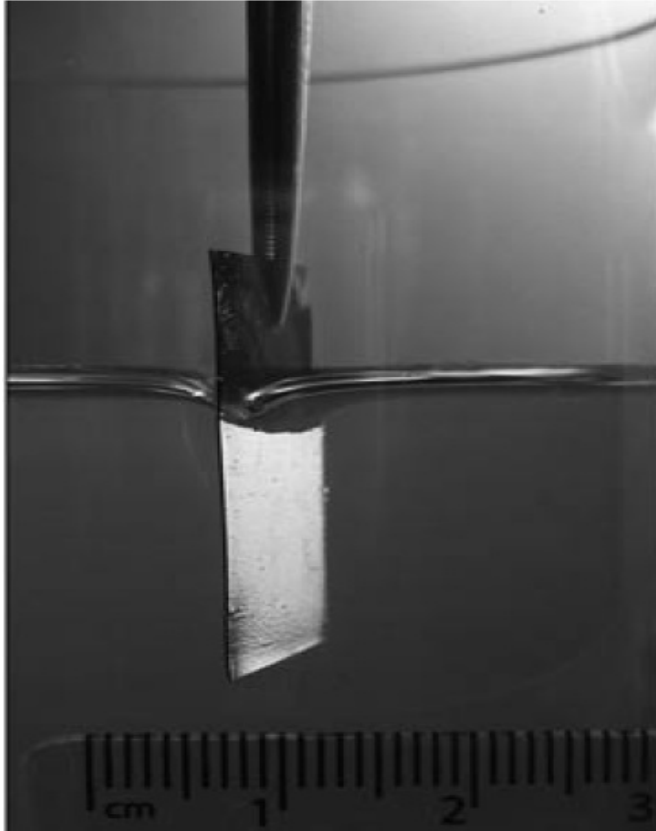




# Fluoro-Functionalized Surfaces

- Platform technology giving customers ultimate control of surface properties on their products
- Can be applied to some existing coatings or bare substrates
- New material capabilities outside of previous limitations

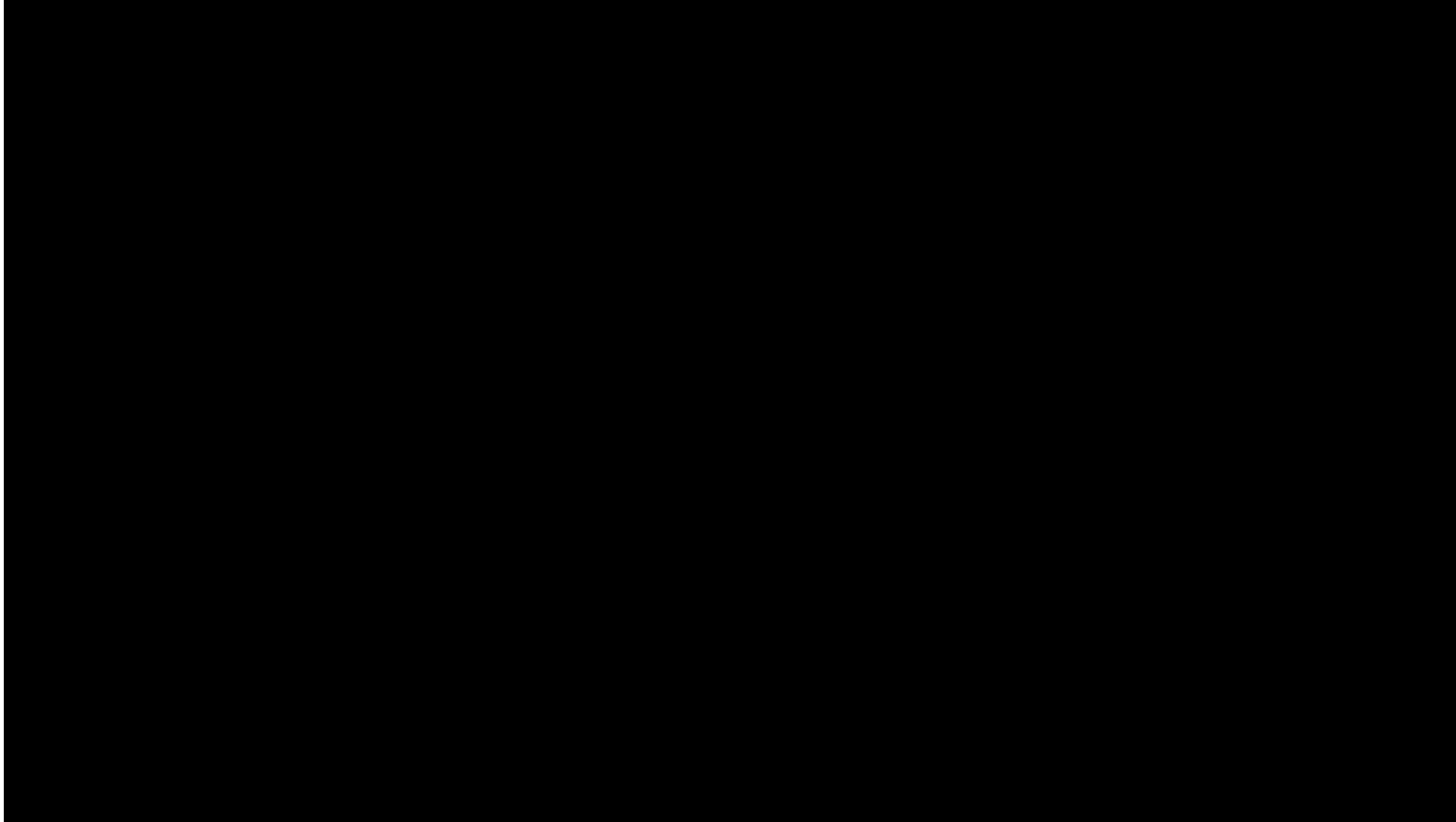
# Low Surface Energy: Powerful Potential



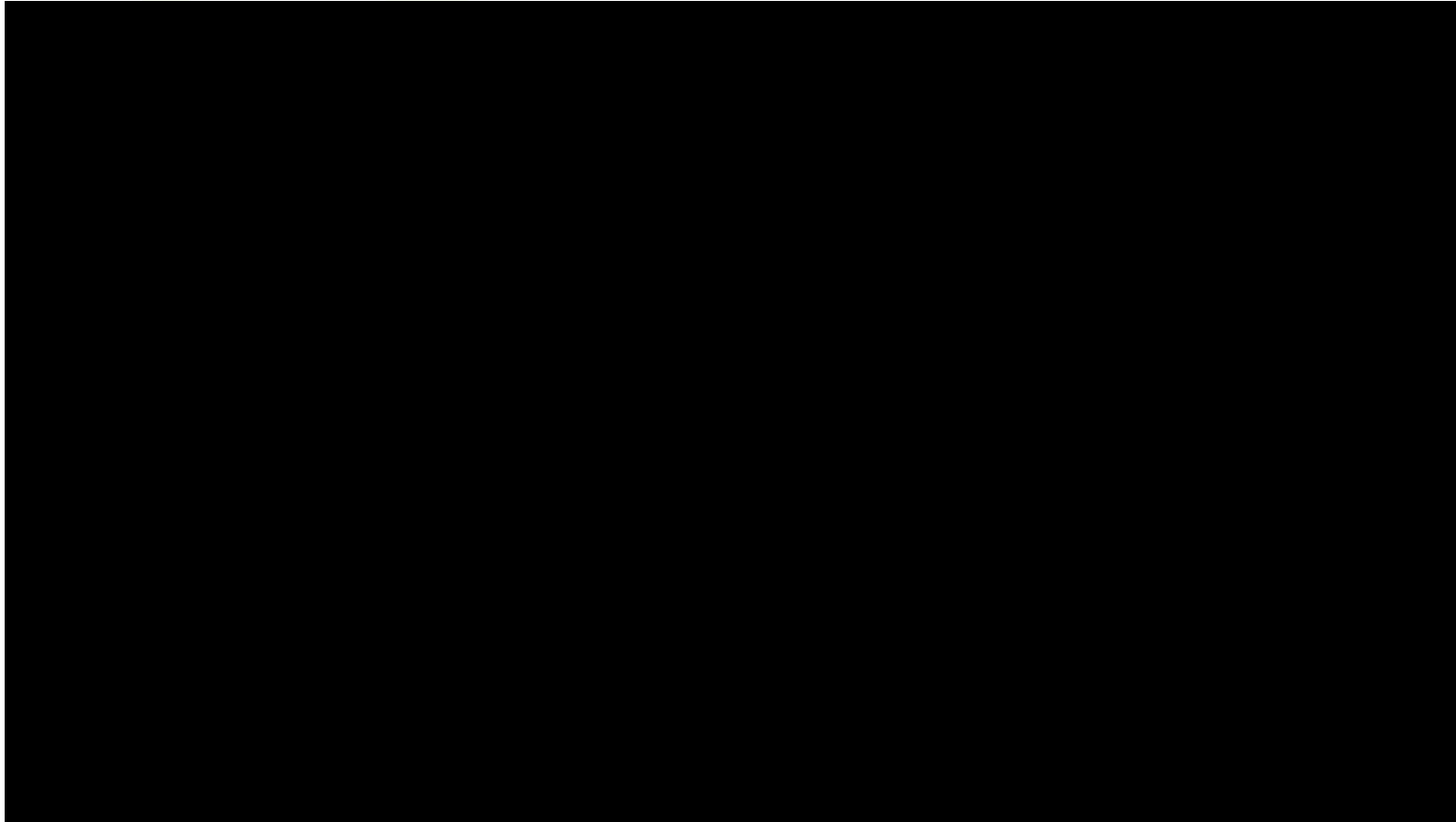
- Silver texture on copper with heptadecafluoro -1-decanethiol coating
- Air layer between water and metal coupon
- Critical viewing angle =  $48.6^\circ$  (same as water/air reflection boundary);  $<1\%$  water in contact with surface (CA =  $173^\circ$ )

Larmour, I.A.; Bell, S.E.J; Saunders, G.C. *Angew. Chem. Int. Ed.* **2007**, 46, 1710-1712.

# Water on untreated cast aluminum

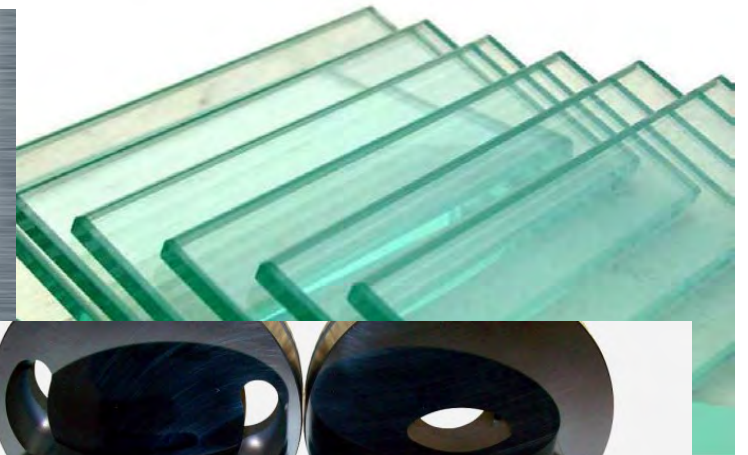
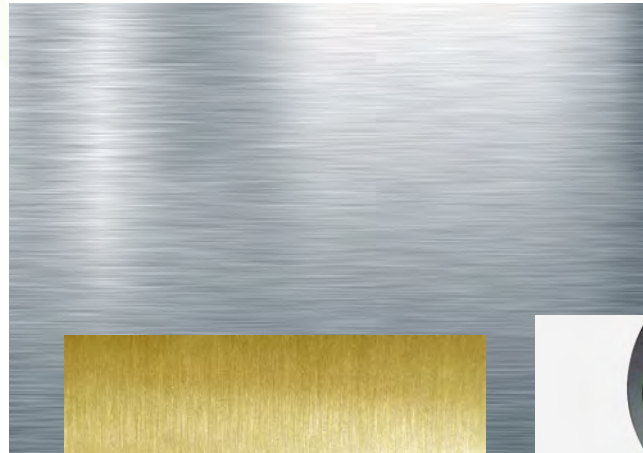


# Water on Fluoro-treated cast Aluminum



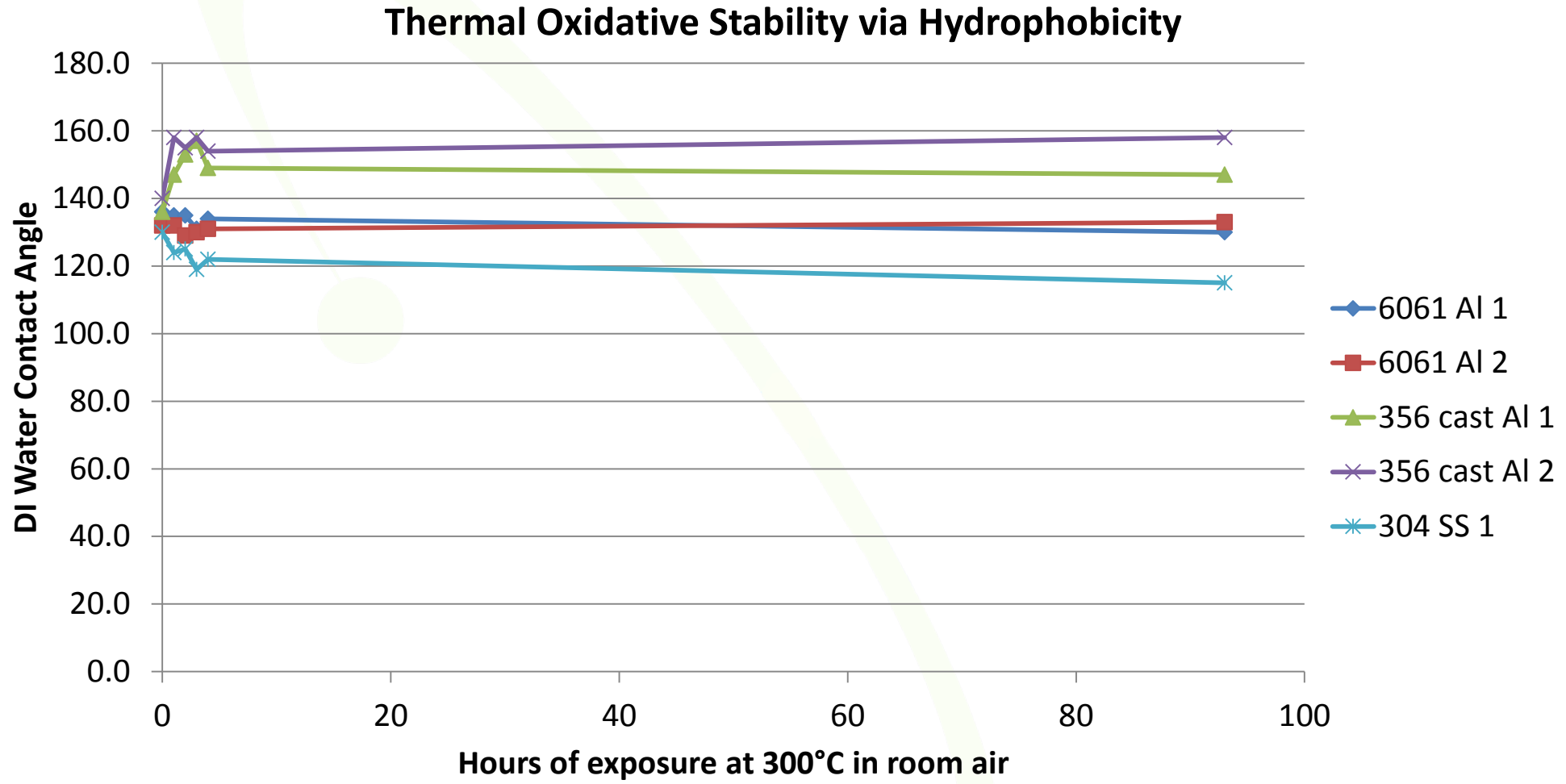
# Fluoro-Surface Substrate Compatibility

- Stainless steel
- Aluminum
- Glass
- Ceramic
- Brass
- DLC
- Copper?
- Zinc?

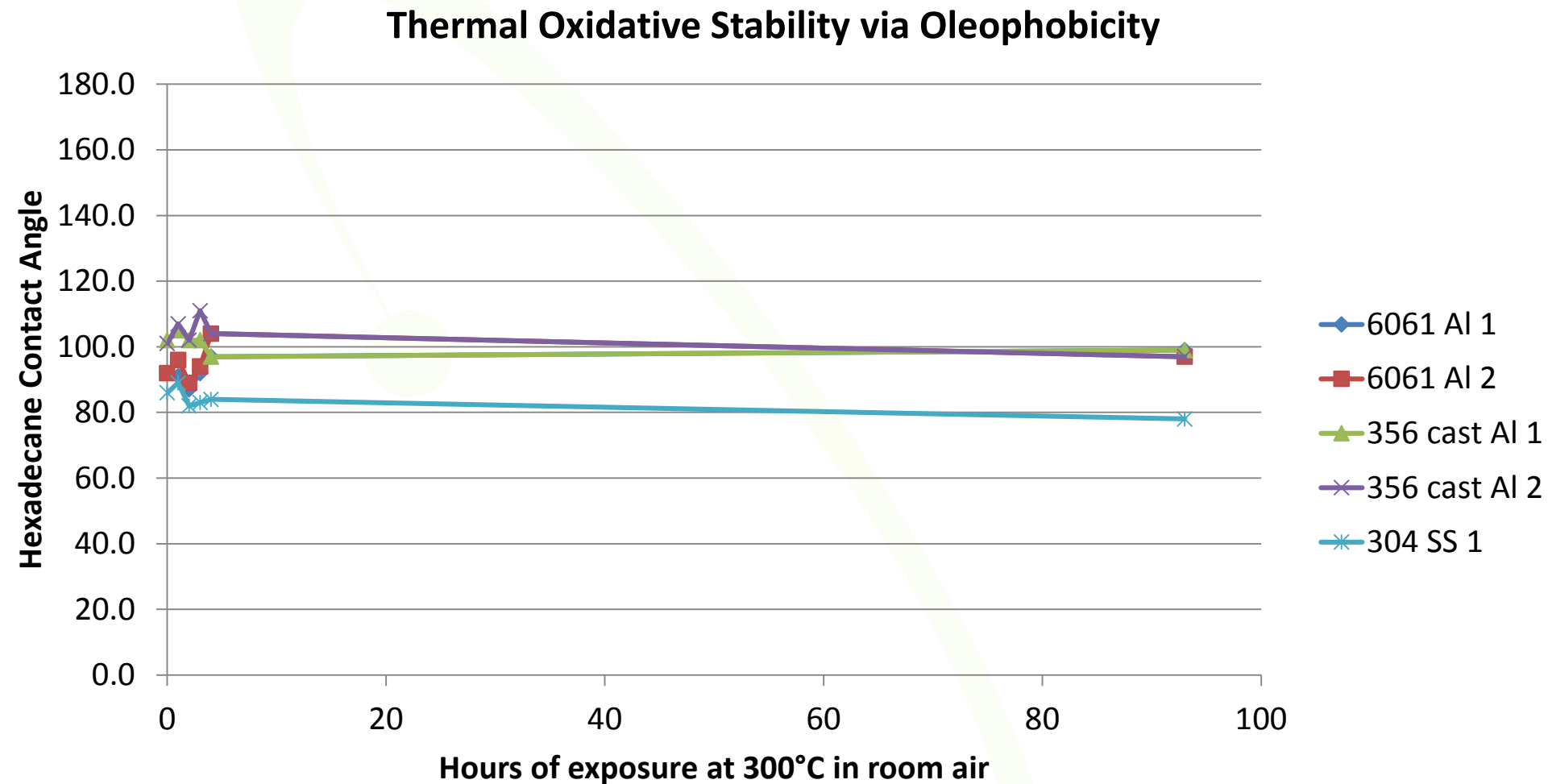




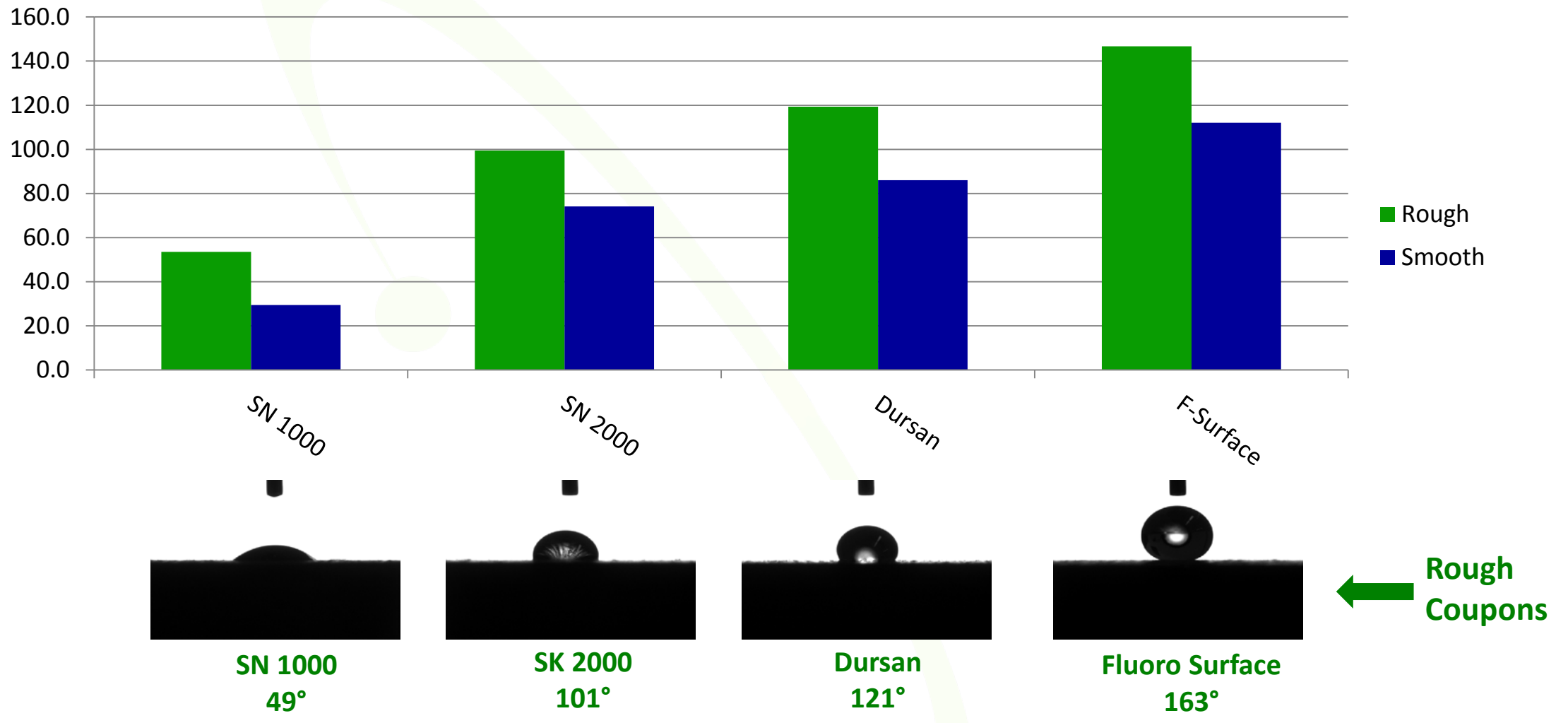
# Optimal Hydrophobicity Stability: Fluoro-Surface



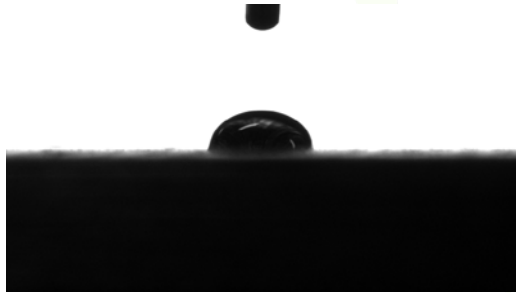
# Optimal Oleophobicity Stability: Fluoro-Surface



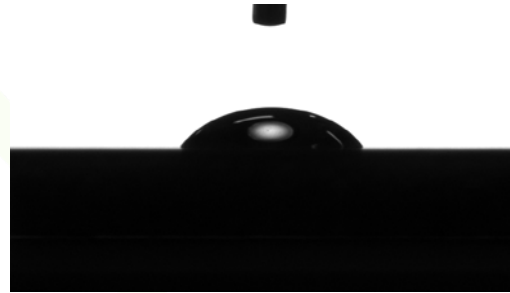
# Properties and Performance: Hydrophobicity



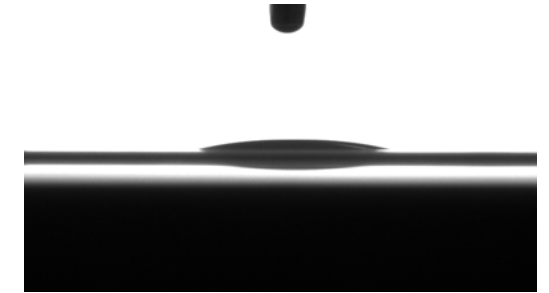
# Oleophobicity studies on 316 SS Fluoro-Treated Surface



Hexadecane on rough  
92.6°



Hexadecane on smooth  
66.0°



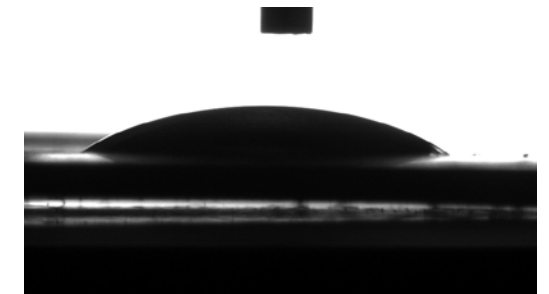
Hexadecane on Teflon  
29.7°



10W40 oil on rough  
95.5°



10W40 oil on smooth  
70.2°

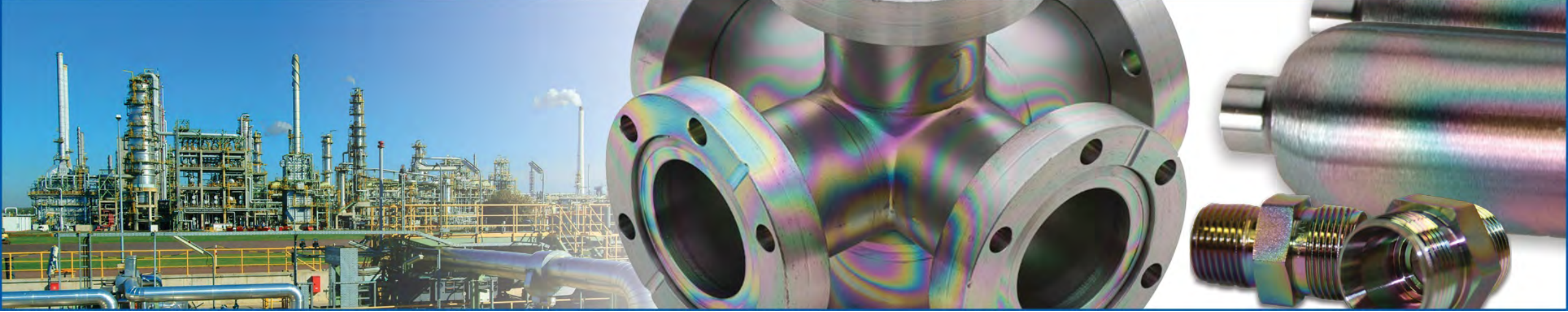


10W40 oil on Teflon  
48.5°

# What's on the horizon?

- Continued optimization of surface functionalization
  - Minimize surface energy
  - Maximize stability
  - Optimize on a variety of substrates
- Partnering with customers
  - Application exploration and testing (SilcoTek resources)
- **Official release of Fluoro technology platform in 2018**





# Thank you for attending!

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