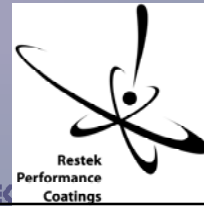


Low Outgassing of Silicon-Based Coatings on Stainless Steel Surfaces for Vacuum Applications

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Objective

Evaluate comparative outgassing properties of vacuum components with and without amorphous silicon coatings



Theoretical Basis – Heat Induced Outgassing

- Outgassing rate (F) in monolayers per sec:

$$F = [\exp (-E/RT)] / t'$$

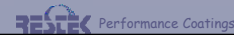
t' = period of oscillation of molecule perp. to surface, ca. 10^{-13} sec

E = energy of desorption (Kcal/g mol)

R = gas constant

source: Roth, A. Vacuum Technology, Elsevier Science Publishers, Amsterdam, 2nd ed., p. 177.

- Slight elevation of sample temperature accelerates outgassing rate exponentially



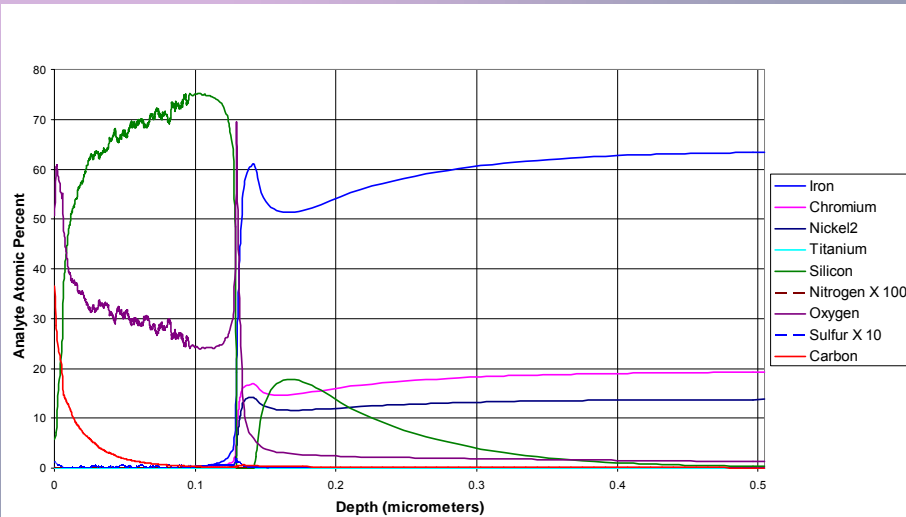
Experimental Design – Heated Samples



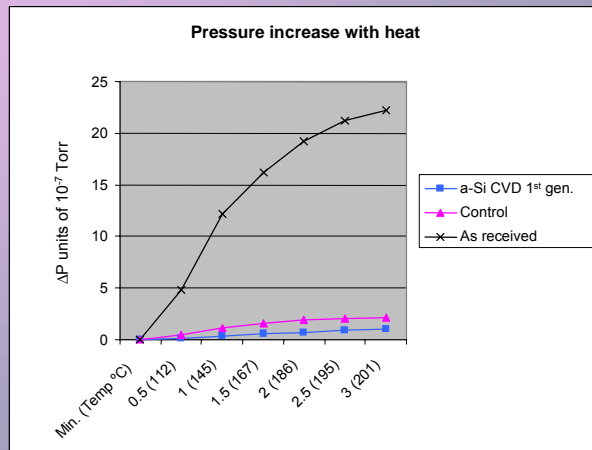
- Turbo pump for base pressures to 10^{-8} Torr
 - pumping rate between gauge and pump: 12.5 l/sec (pump alone: 360 l/sec)
 - system vent with dry N_2 between thermal cycles
- Comparative evaluation parts
 - a-silicon coated via CVD (Silcosteel[®]-UHV); 3D deposition
 - equally treated controls without deposition



Glow Discharge Surface Analysis of Coating – Bulk Depth Profile

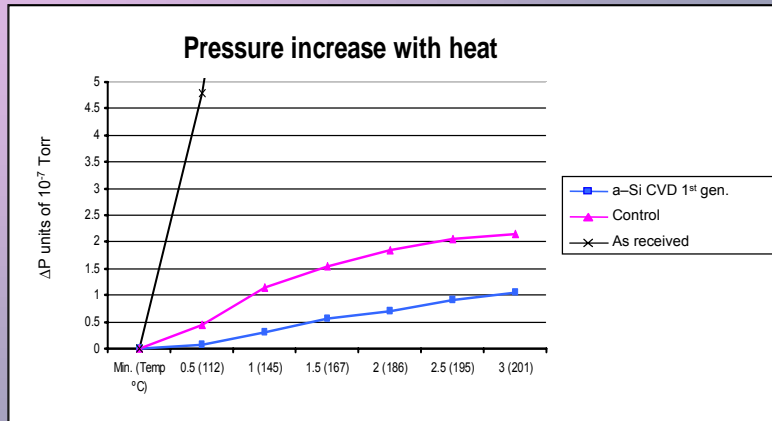


Outgassing Data – Heated Samples



- Turbopump, 1×10^{-7} Torr base pressure
- 10hr under vacuum

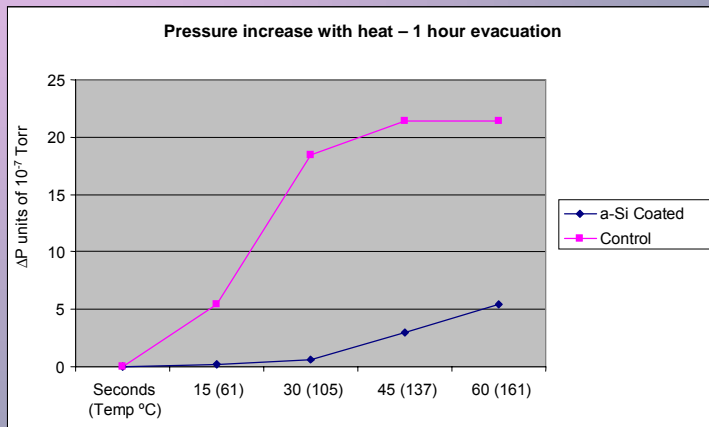
Outgassing Data – Heated Samples



- 7.5 fold improvement at 112°C
- Subsequent experiments down to 1.2×10^{-10} Torr base pressure (ion pump)
 - 6.4 fold improvement at 61°C (7.0×10^{-12} Torr ΔP)

RESISTEK Performance Coatings

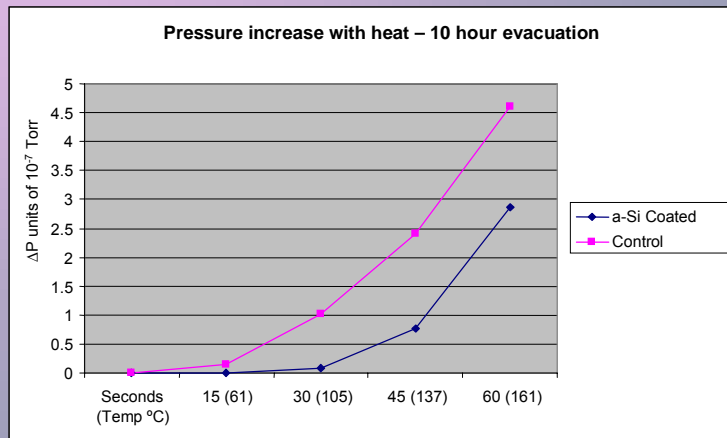
Outgassing Data – Approaching “Real World” Evacuation



- Turbopump, 4.6×10^{-7} Torr base pressure
- 1hr under vacuum (ΔP_1)

RESISTEK Performance Coatings

Outgassing Data – Approaching “Real World” Evacuation



- Turbopump, 7.5×10^{-8} Torr base pressure
- 10hr under vacuum (ΔP_2)

RESTEK Performance Coatings

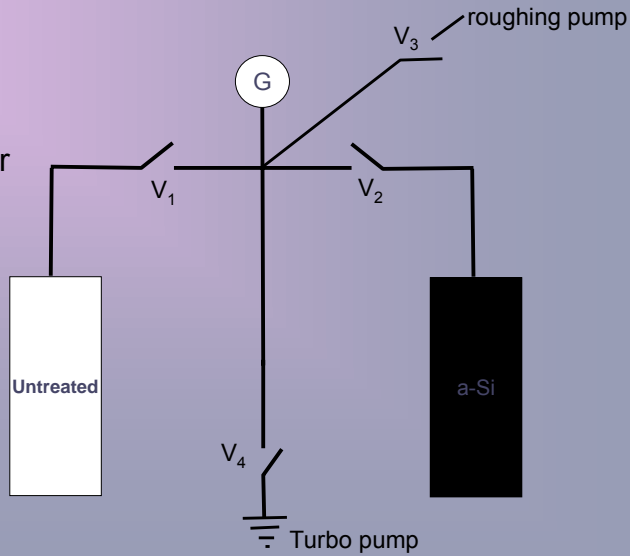
Outgassing Calculations

- For the system (P_A), sample area = 125cm^2 ,
conductance = 12.5 l/sec ;
therefore, $\Delta Q = \Delta P(12.5/125) = \Delta P/10$
- At 1 hour, 61°C :
 ΔQ_1 (control) = $5.4 \times 10^{-8}\text{ Torr l sec}^{-1}\text{ cm}^{-2}$;
 ΔQ_1 (a-silicon) = $0.2 \times 10^{-8}\text{ Torr l sec}^{-1}\text{ cm}^{-2}$
27x improvement
- At 10 hours, 61°C :
 ΔQ_{10} (control) = $0.14 \times 10^{-8}\text{ Torr l sec}^{-1}\text{ cm}^{-2}$;
 ΔQ_{10} (a-silicon) = $0.01 \times 10^{-8}\text{ Torr l sec}^{-1}\text{ cm}^{-2}$
14x improvement

RESTEK Performance Coatings

Chamber Comparison; No Heat

- Common pumping line
- Valve isolation
- Alternating chamber measurements
- Roughing pump for first 44 min.



RESTEK Performance Coatings

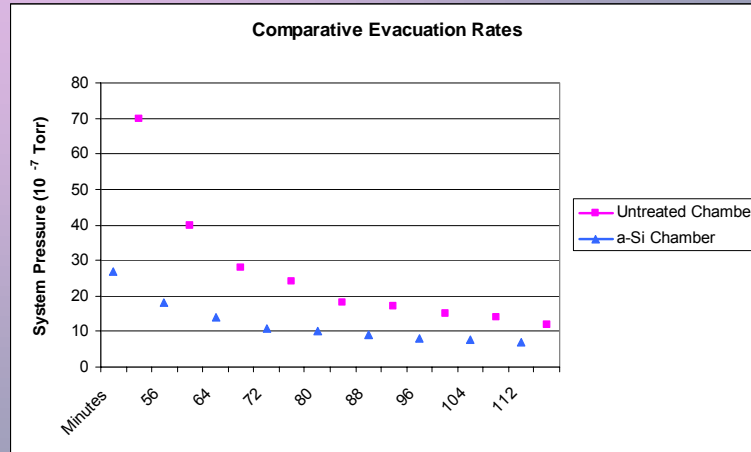
Chamber Comparisons; No Heat



- System conductance: 7.4 l/sec
- 360 l/sec turbomolecular pump
- Cold cathode gauge

RESTEK Performance Coatings

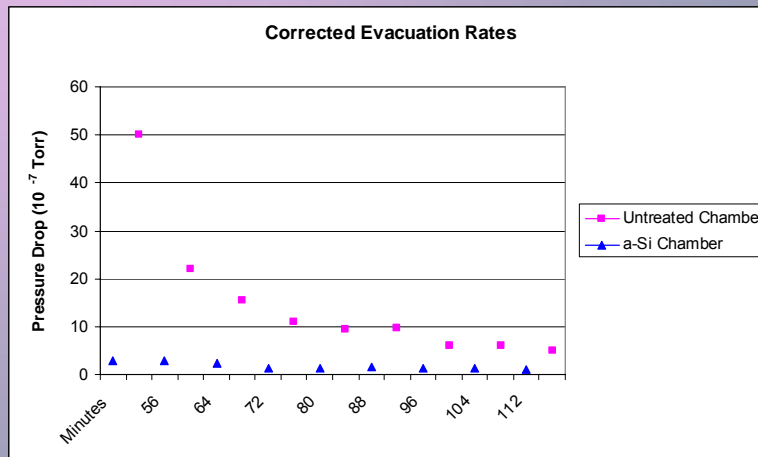
Chamber Comparisons; No Heat



- Alternate-pumpdown system pressures
- 80-84 minute range: 2.4-fold improvement

RESTEK Performance Coatings

Corrected Comparison



- Alternate pressure drop system measurements (true outgassing of isolated chambers)
- 80-84 minute range: 9.1-fold improvement

RESTEK Performance Coatings

Conclusions / Future

- Outgassing rates of vacuum system components can be dramatically reduced with CVD amorphous silicon coating
- Allows for a more rapid evacuation rate to lower base pressures

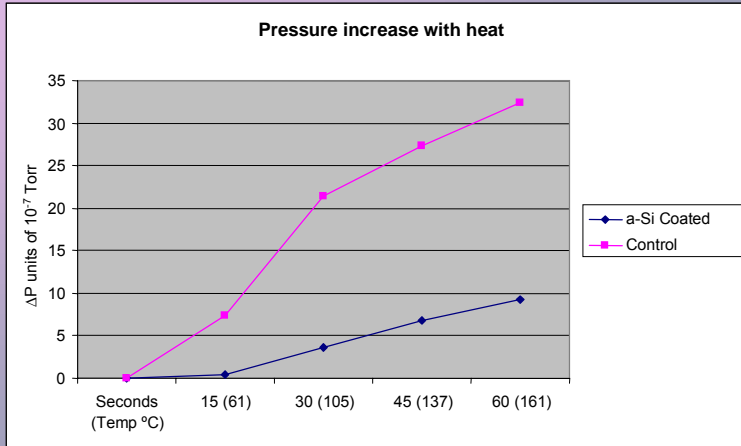


Acknowledgements

- Swagelok®
- Televac



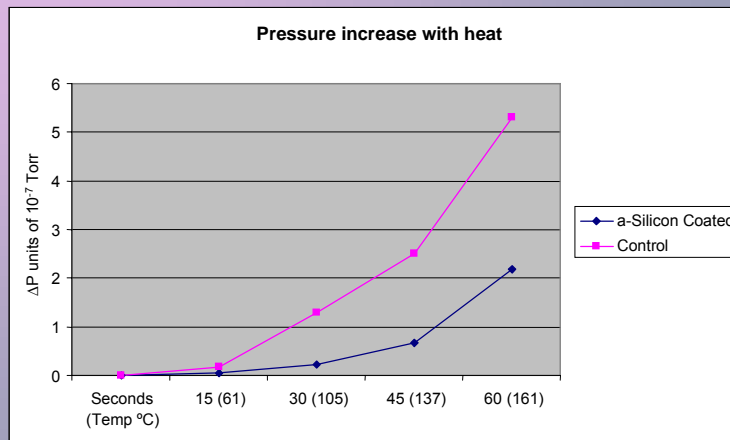
After air/humidity exposure



- Exposure: 70°F, 58% relative humidity, 114 days
- Turbopump, 2×10^{-7} Torr base pressure
- 1hr under vacuum (ΔP_1); 18.5 fold improvement

RESTEK Performance Coatings

After air/humidity exposure



- Turbopump, 8×10^{-8} Torr base pressure
- 10hr under vacuum (ΔP_2); 4.5 fold improvement

RESTEK Performance Coatings

Preliminary Electronic Performance Data

- Resistivity perpendicular to film range 12-60 Ω/cm^2
- Pinholes allow conductivity through film to substrate
- Practical applications
 - Comparison of coated vs. uncoated miniature cold cathode gauge housings showed no difference in performance
 - Current density (est.) = 10^{-6} amp/ cm^2
resulting from secondary electron emission from ion impact in gauge
 - Comparison of vacuum tubes with alternative anodes of uncoated vs. coated steel showed no detectable performance difference
 - Internal filament produced 1ma electron current
 - Anode voltage = 200 V
 - Anode area = 23.5 cm^2
 - Anode current density approx. 4×10^{-5} amp/ cm^2