Amorphous Silicon Coatings for Control of Corrosion and Metal Ion Contamination

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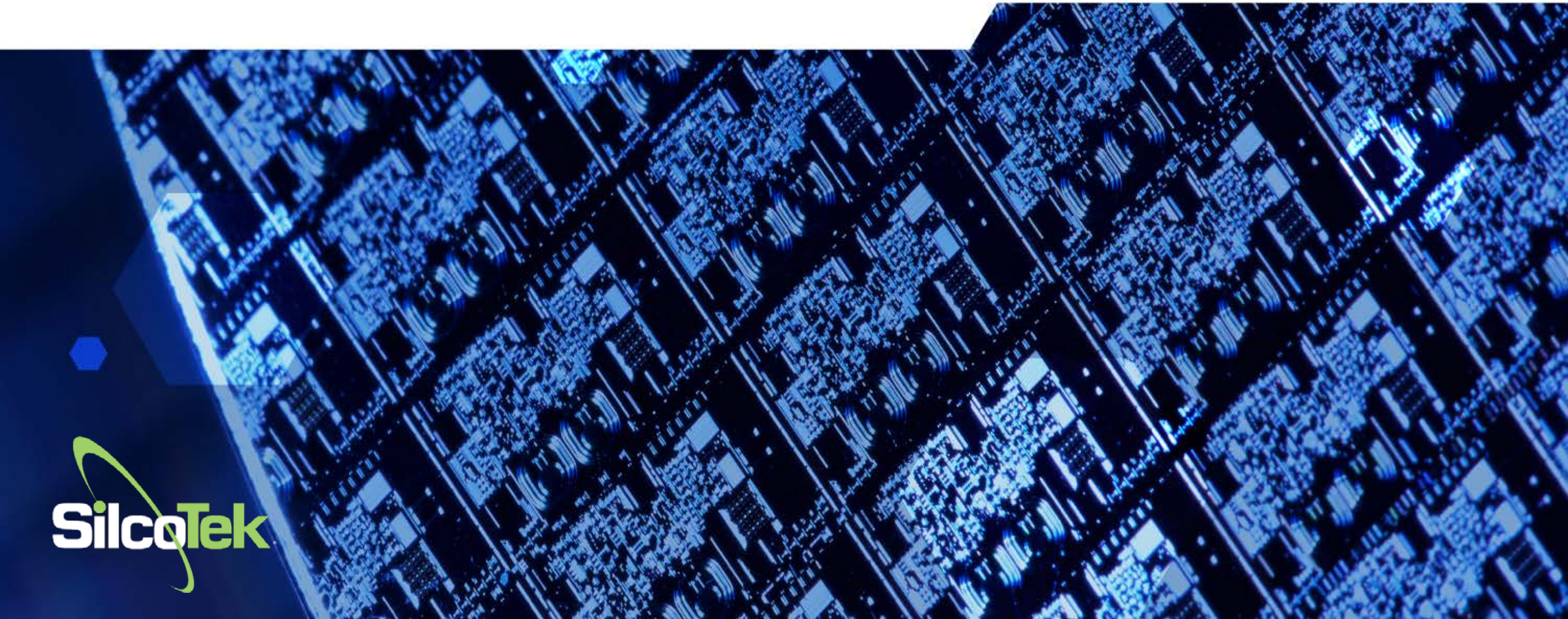


Motivation

- Purity increasing in importance
- Pushing physical limits
  - Devices become smaller
  - Metal ion contamination more important
- Etch (and cleaning) chemistries
  - Number of removal steps increasing
  - Gas chemistries more aggressive
- Corrosion limits productivity

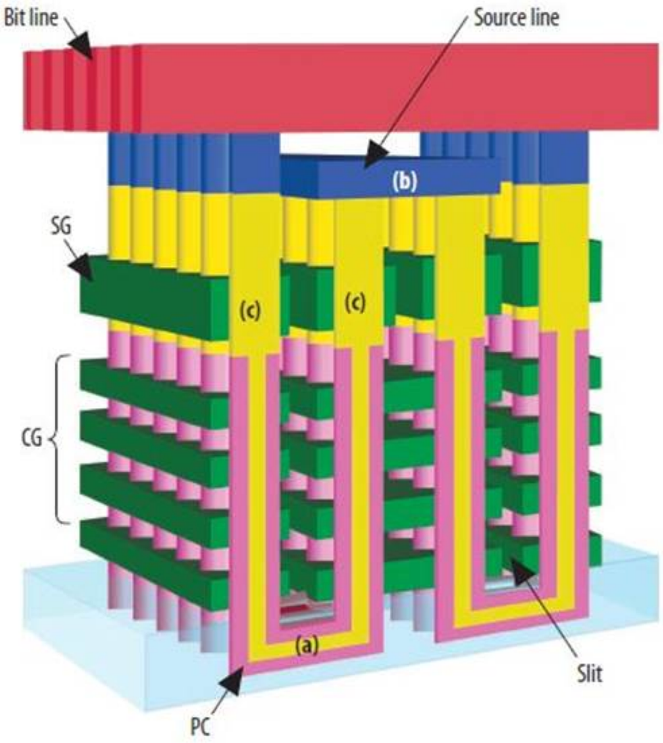


Image from Li, Y. and Quader, K.N. NAND Flash Memory: Challenges and Opportunities. *Computer* 2013, 46 (8), 23-29.

Silicon Coatings Technology

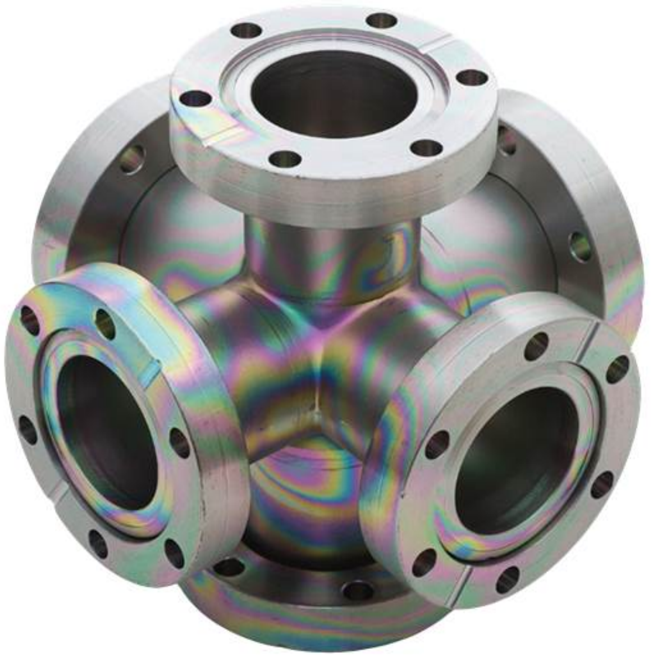
- Gas Chromatography
  - Robust alternative to glass columns
- Oil and Gas
  - Accurate ppm-to-ppb detection
- Environmental Sampling
  - Accurate ppm-to-ppb detection
- Corrosion Resistance
  - Affordable alternative to superalloys

Industrial CVD

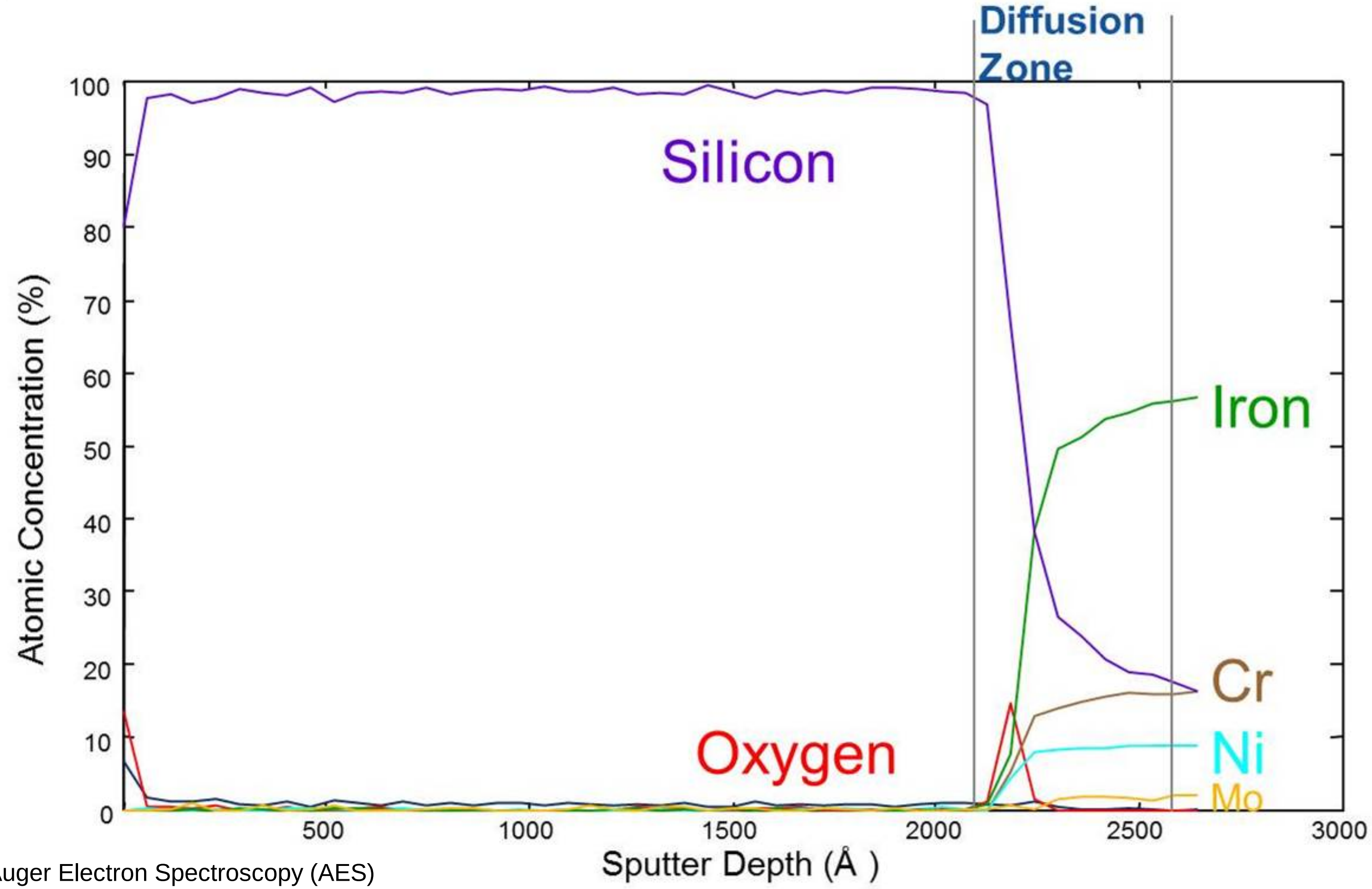
- Commercialized process
- 3-D deposition allows coating of all surfaces
  - High aspect ratio
  - Complex geometries
- Bonded to substrate material
- Wide range of substrate materials
  - Stainless steel, glass, ceramics, aluminum, superalloys
- Scalable process
  - Fittings to chambers
- Thin coating: ~100 nm up to nearly 2 µm
  - Does not impact drawing dimensions or tolerances

Advantages

- Thermally stable
  - Wide operating temperature range
- Reasonable cost
  - Superalloys are much more expensive
- Environmentally known
  - Silicon is a primary material
- Amorphous
  - Conformal over edges
  - Allows for mechanical flexing
- Low outgassing
  - Vacuum compatible
  - Barrier to substrate effects (moisture or outgassing)

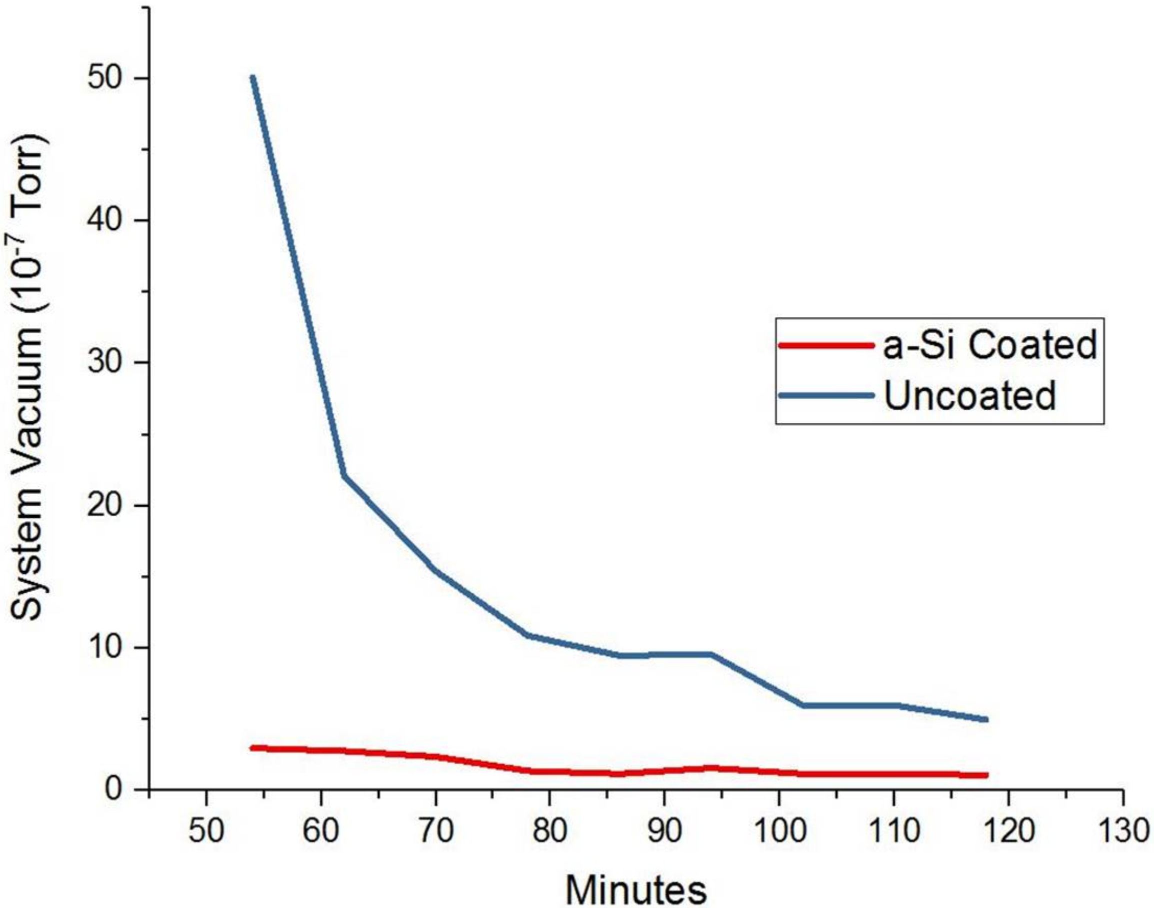


Coatings Composition



Auger Electron Spectroscopy (AES)

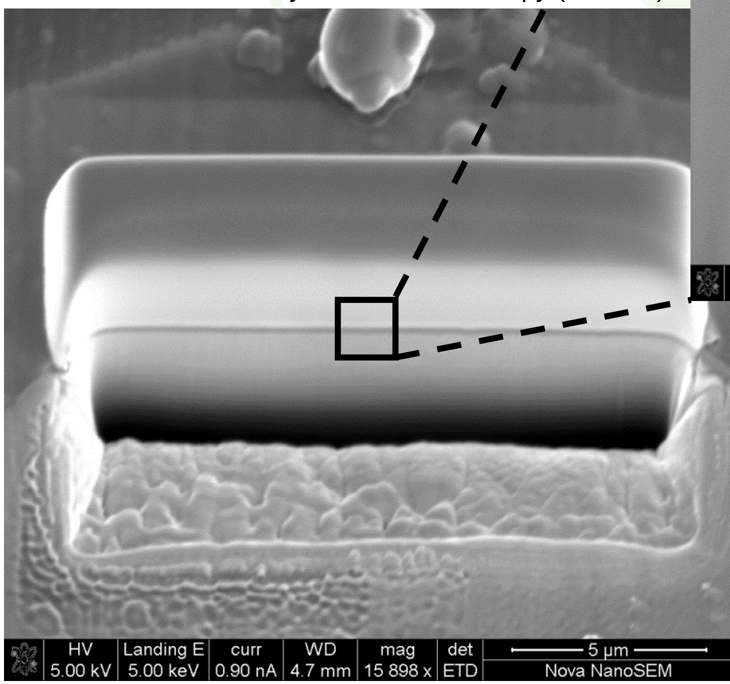
Improved Vacuum Pumpdown

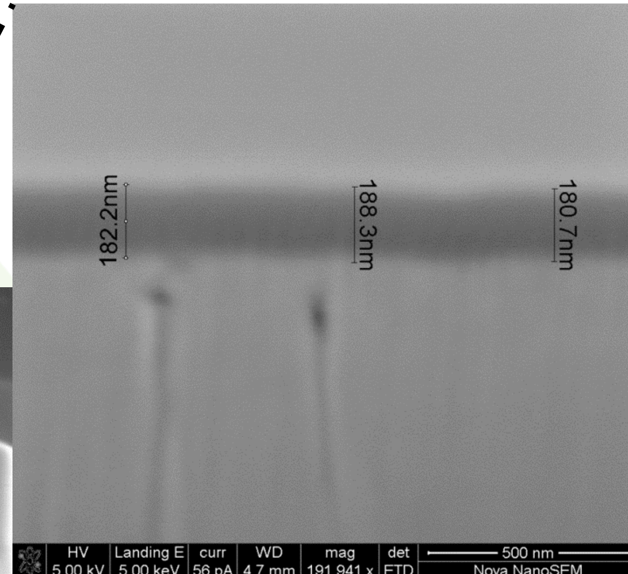


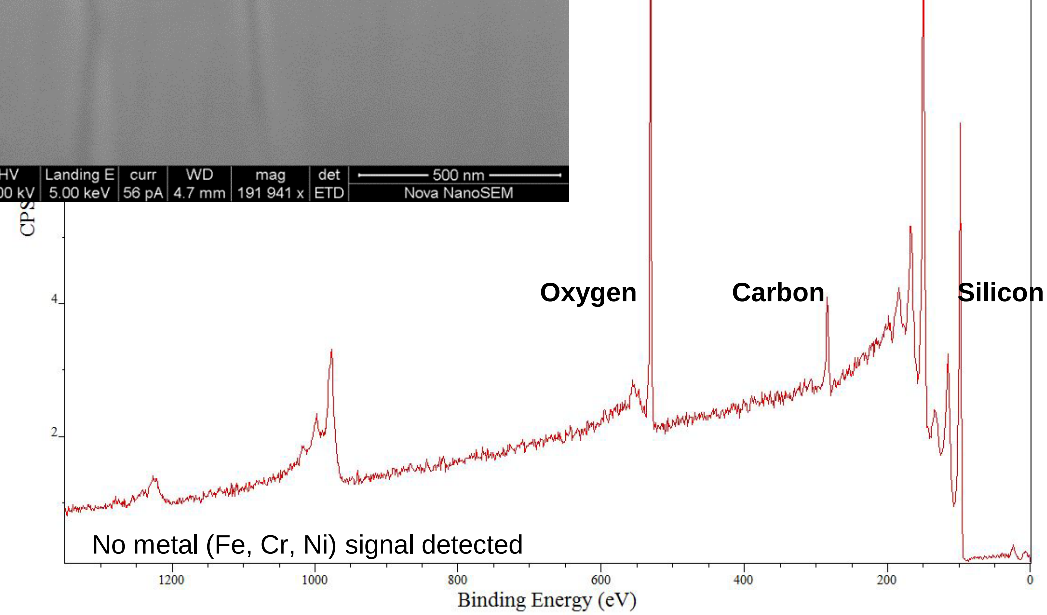
- Evacuation test on fixed volume chamber
- Corrected for background outgassing

Coatings Composition

Focused Ion Beam (FIB)
Field-Emission Secondary Electron Microscopy (FESEM)



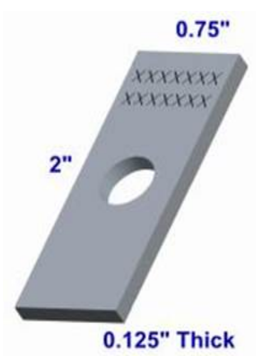


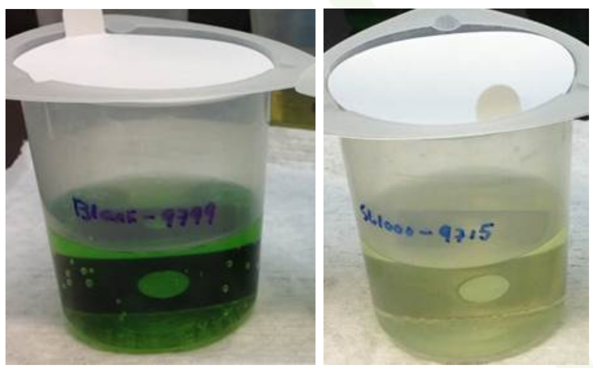


X-Ray Photoelectron Spectroscopy (XPS)

Corrosion Testing

- Follow ASTM G31-72(2004) “Standard Practice for Laboratory Immersion Corrosion Testing of Metals”
- Measure Mass Loss During Immersion
- Calculate Corrosion Rate in mils per year (mpy)





$$\text{Corrosion Rate} = \frac{\text{Weight loss (g)} \bullet \text{K-factor}}{\text{Density (g/cm}^3\text{)} \bullet \text{Area (A)} \bullet \text{Time (hr)}}$$

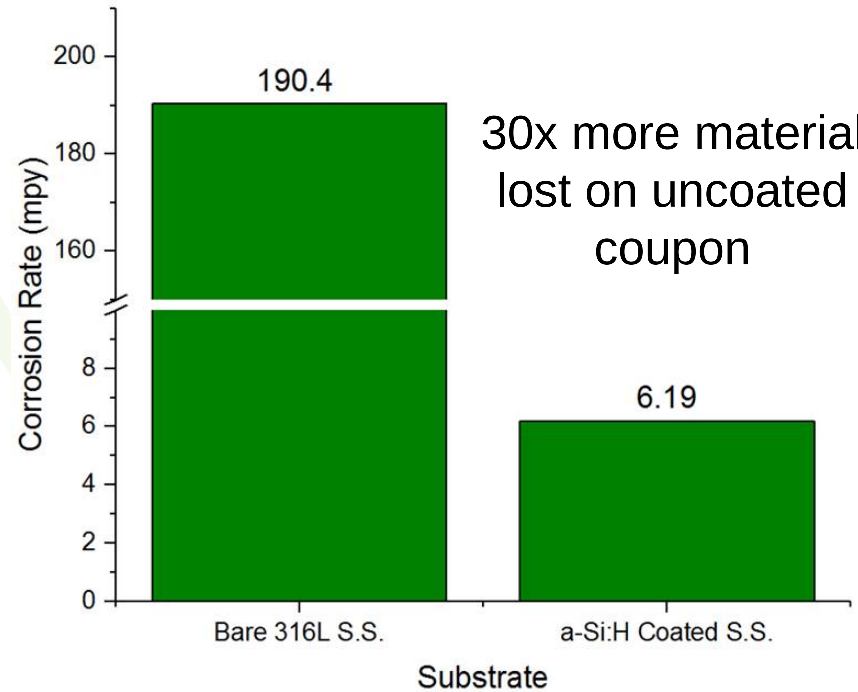
Standard Coupon → Corrosive Immersion → Calculate

HCl Corrosion Testing

- Test Conditions
  - 6 M HCl
  - Room temperature solution
  - 24 hrs of exposure

Uncoated 316L S.S.

a-Si:H coated 316L S.S.



30x more material lost on uncoated coupon

Elevated Temperature HCl Corrosion Testing

- Test Conditions
  - 6 M HCl
  - 50° C solution
  - 7 hrs of exposure

Uncoated 316L S.S.

a-Si:H coated 316L S.S.

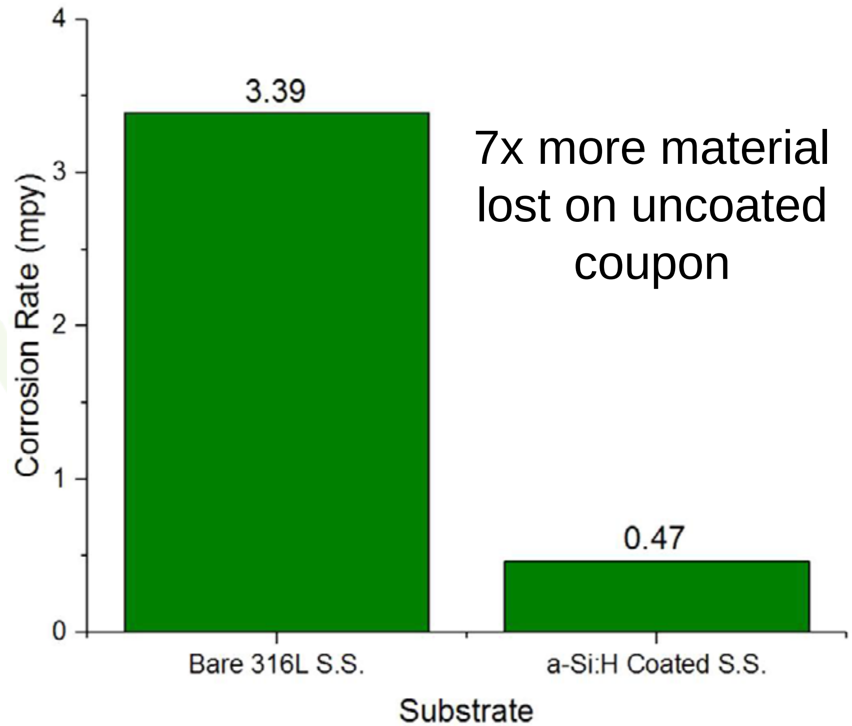
30x more material lost on uncoated coupon

HBr Corrosion Testing

- Test Conditions
  - 6 M HBr (gas dissolved in DI Water)
  - Room temperature solution
  - 72 hrs of exposure

Uncoated 316L S.S.

a-Si:H coated 316L S.S.



Data Extrapolation

- How long will the coating last in service?

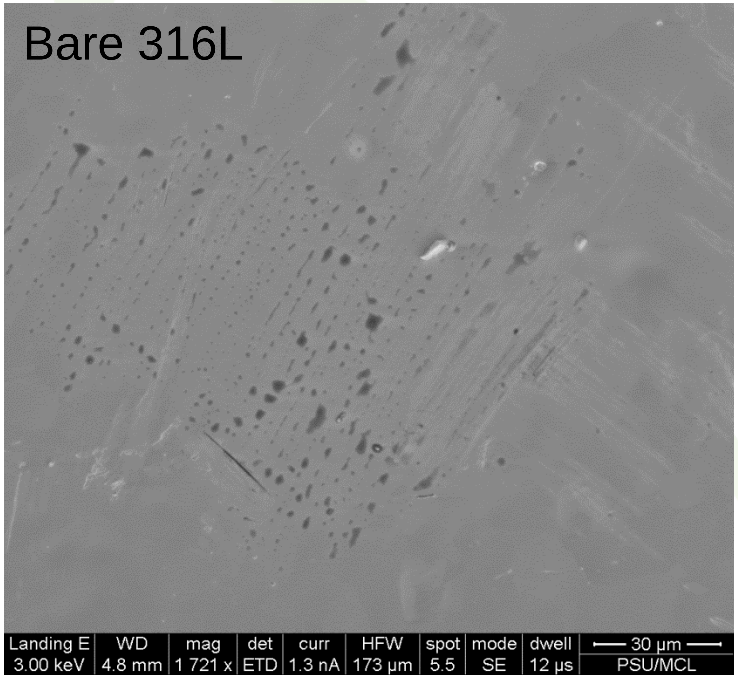
Typical Maintenance Cycle – 3,000 RF Hours

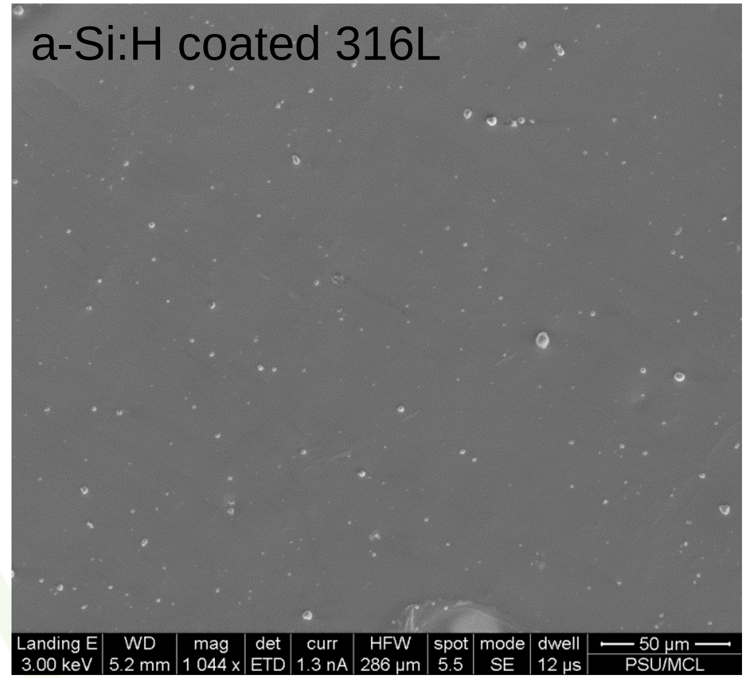
Improvement of coated vs uncoated is ~7.21x

(using exposure to 6 M HBr for 72 hrs at r.t.)

Possible Lifetime Extension – **23,000+ RF Hours**

Plasma Exposure





- 50 W SF_6 remote plasma exposure (3 min exposure)
- Stainless steel appears to begin to pit
- Some etching of silicon

Conclusions

- Amorphous, hydrogenated silicon can be used as a barrier coating for gas delivery in both etch and deposition environments.
- CVD deposition of a-Si:H offers unique benefits including non-line-of-sight deposition on existing components and good adhesion to a wide variety of commonly used materials.
- Additional benefits from a-Si:H deposition may be seen in low outgassing of surfaces in vacuum and low particulate creation from gas-surface interactions.

Future Directions

- Develop method for characterizing gas corrosion
- Develop method for characterizing coating lifetime in direct plasma environment