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Millenium Science Complex

New clean room: 10,000 sq. ft. class 100/1000

Support space : 6,500 sq. ft

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Savannah_200

- Al_2O_3(1.1Å GPC @200°C)
- HfO_2 (1Å GPC @110 °C)
- Ta_2O_5
- TiO_2 (0.457ÅGPC @150ºC)
  Titanium isopropoxide Ti(OiPr)4
  Tetrakis(dimethylamino)titanium (TDMAT)
- ZrO_2
- ZnO_2 (stopped due to cross contamination)

Usage:08-present

- ~2,000 hrs per year ~23% based on 24/7
- $50 per use for academic $100 for industry before 3/1/12
  $75 per use for academic $150 for industry after 3/1/12
- $1 per 1nm
- $20,000 per year

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High conformity of ALD coating

Cross-sectional FESEM view of 20 nm HfO_2

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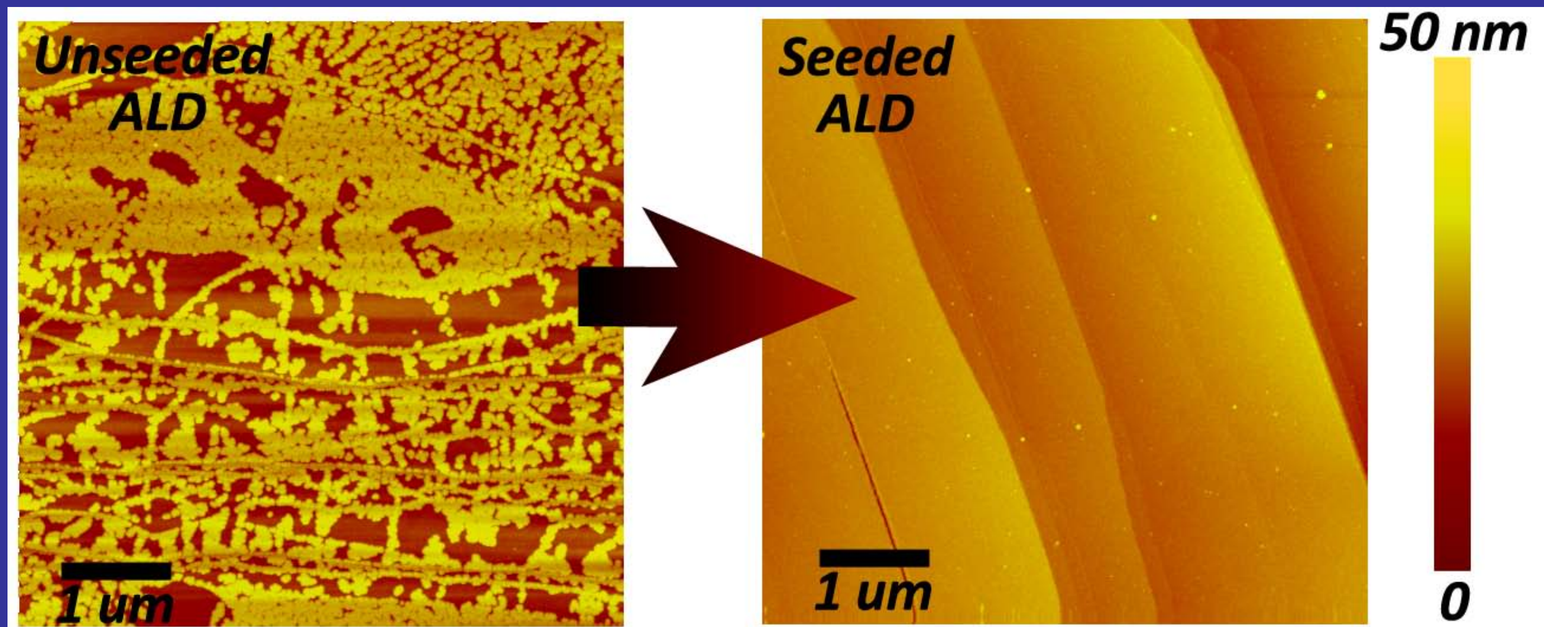
Comparison between seeded and unseeded ALD deposition on graphene by AFM



J. Robinson The Electro-Optics Center, Department of Materials Science and Engineering, Materials Research Institute, The Pennsylvania State University

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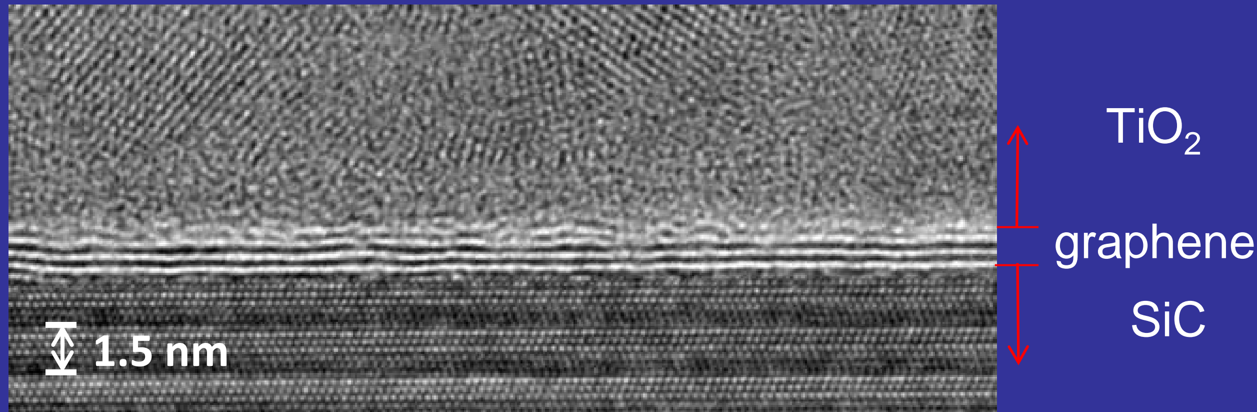
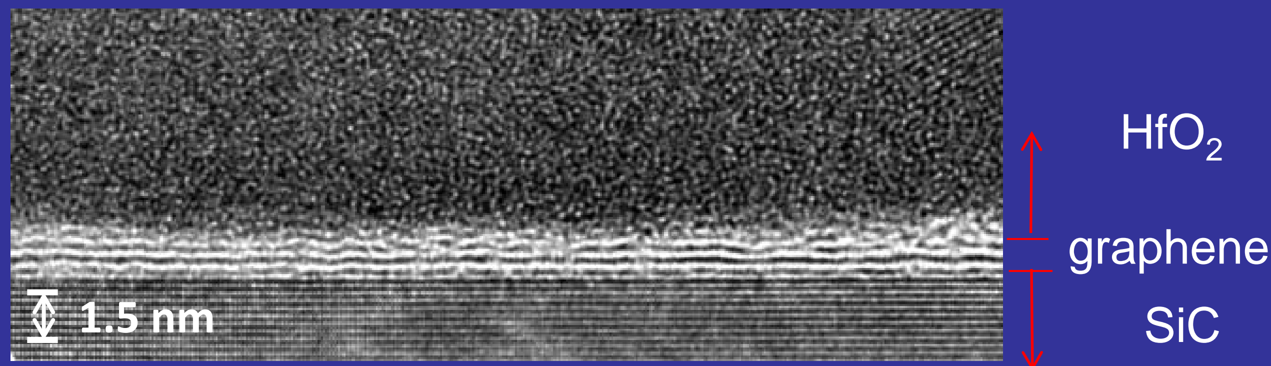
Cross-sectional TEM characterization



TiO_2 on Ti-seeded graphene @250°C



HfO_2 on graphene @110°C

X. Weng, J. Robinson The Electro-Optics Center, Department of Materials Science and Engineering, Materials Research Institute, The Pennsylvania State University

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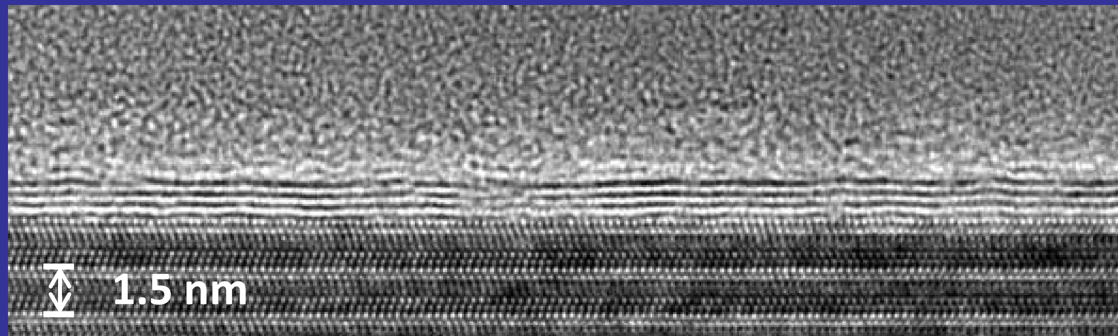
Cross-sectional TEM characterization

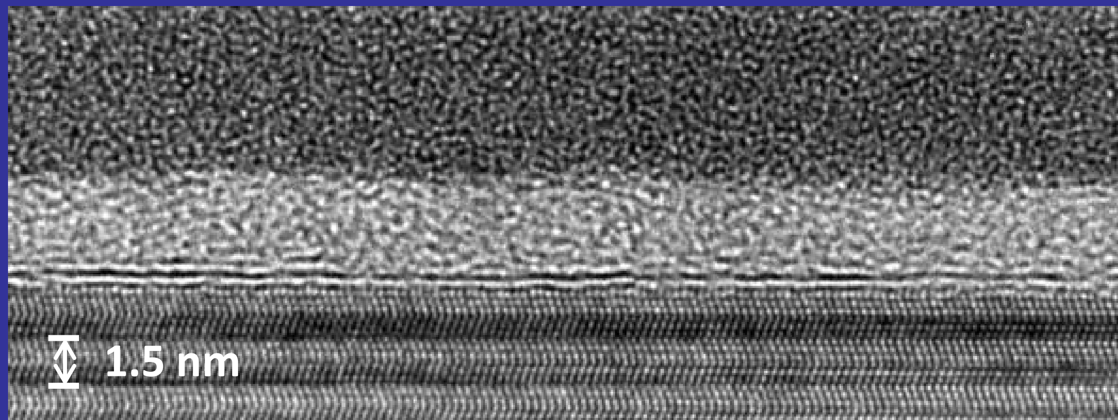


Al_2O_3

graphene

SiC

Al_2O_3 on Al-seeded graphene @300°C



Ta_2O_5

defective carbon region

graphene

SiC

Ta_2O_5 on Ta-seeded graphene @150°C

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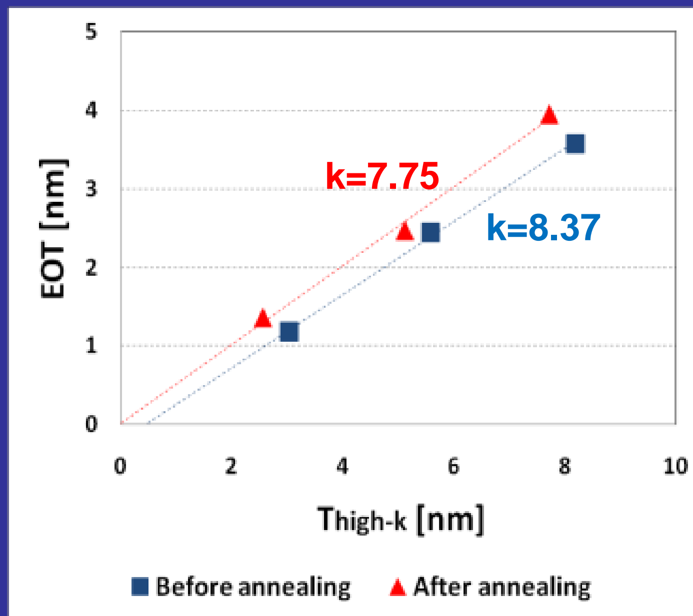
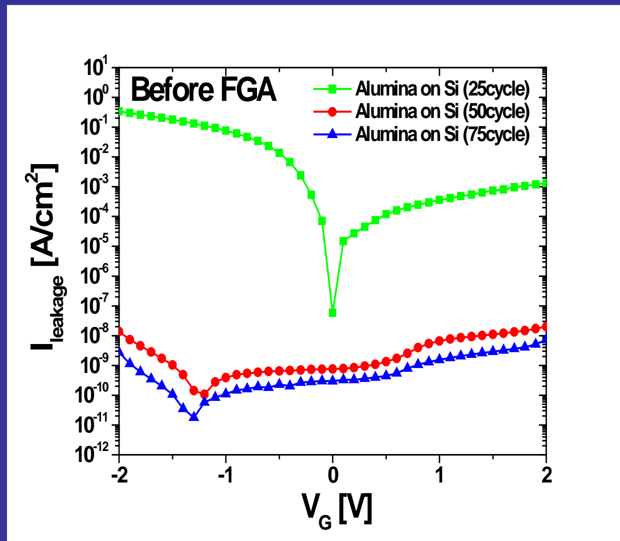
Electrical test of Al_2O_3 using MOSCAP

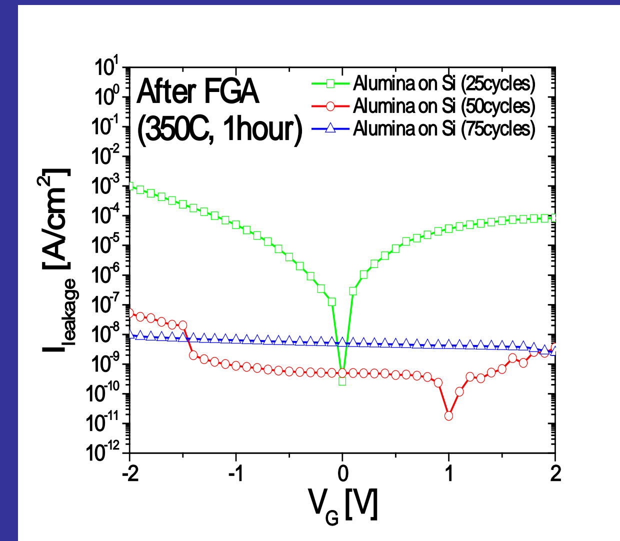


Dielectric constant : ~ 8

thinnest electrical oxide thickness (EOT) achieved till date is 12 A (1.2 nm)

Si MOSCAP with alumina - Leakage





Leakage improves significantly for the 1.2 nm EOT gate stack by forming gas anneal at 350C for 1 hour

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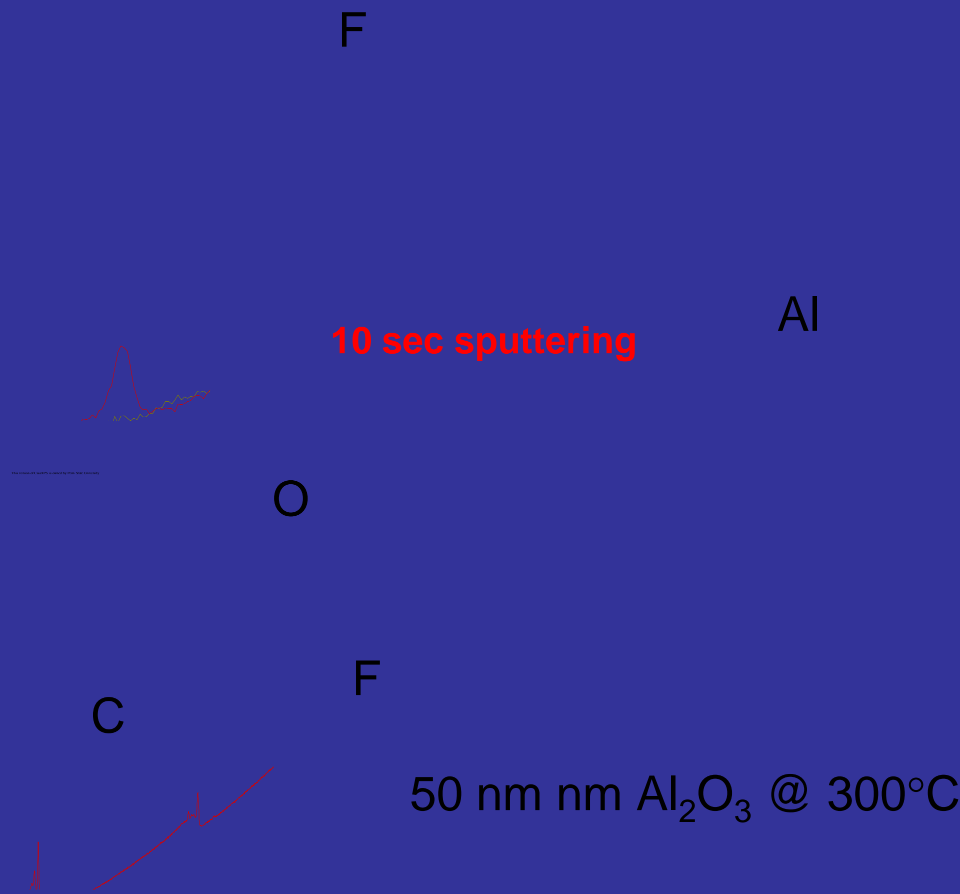
F outgassing characterization by Auger & XPS



F found in the top surface

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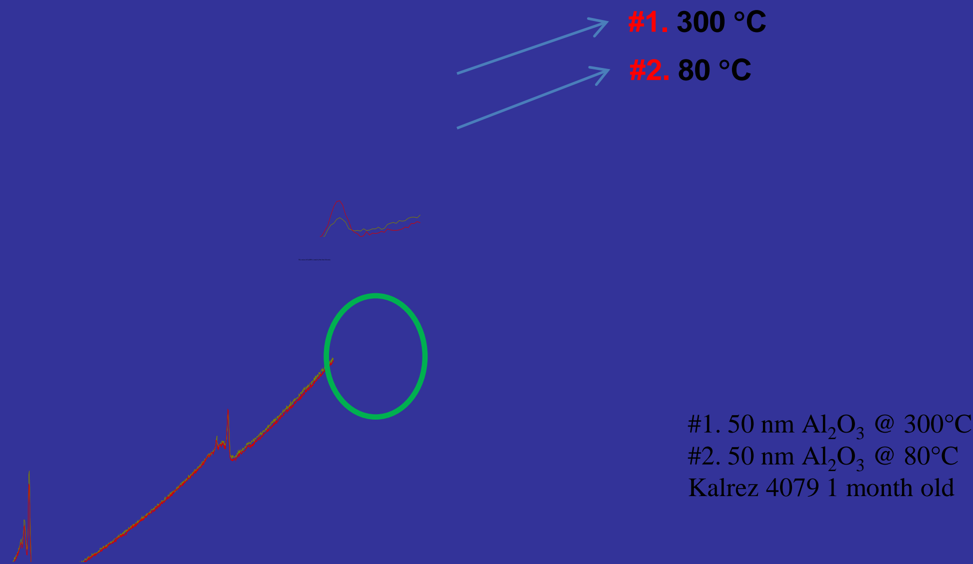
F contamination depends on process temperature



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F contamination depends on the age of O-ring

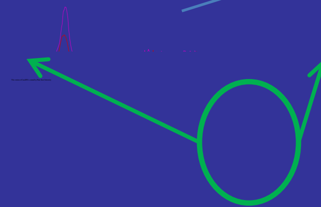
C

F

#1. 1 viton

#2. Kalrez 4079 1 month old

#3. Kalrez 4079 11 month old



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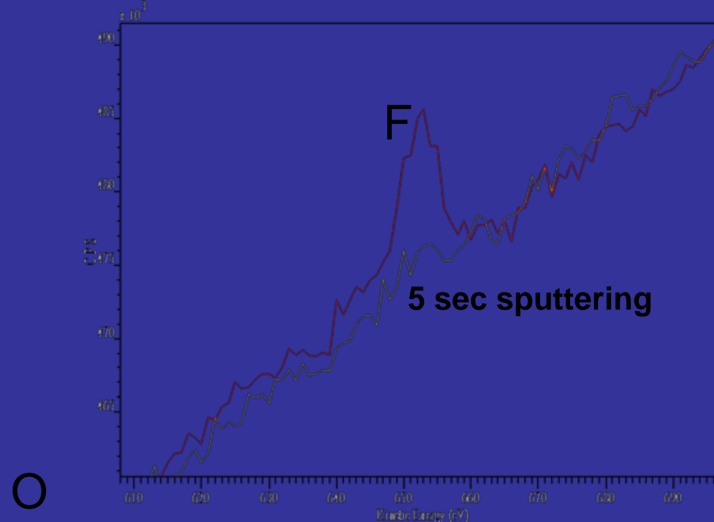
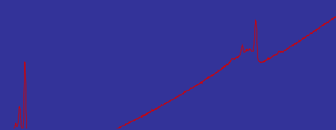
Auger analysis on Al_2O_3 sample prepared by Cambridge Nanotech



Al



40.9 nm Al_2O_3 , 250°C   Cambridge Nanotech

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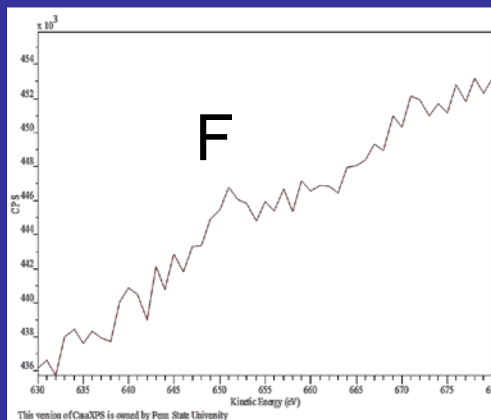
Auger analysis on SiO_2 sample prepared by Cambridge Nanotech

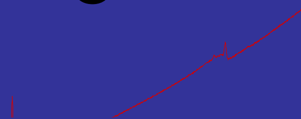


F

Al

O

C



34.7nm SiO_2 grown at 250°C
Cambridge Nanotech

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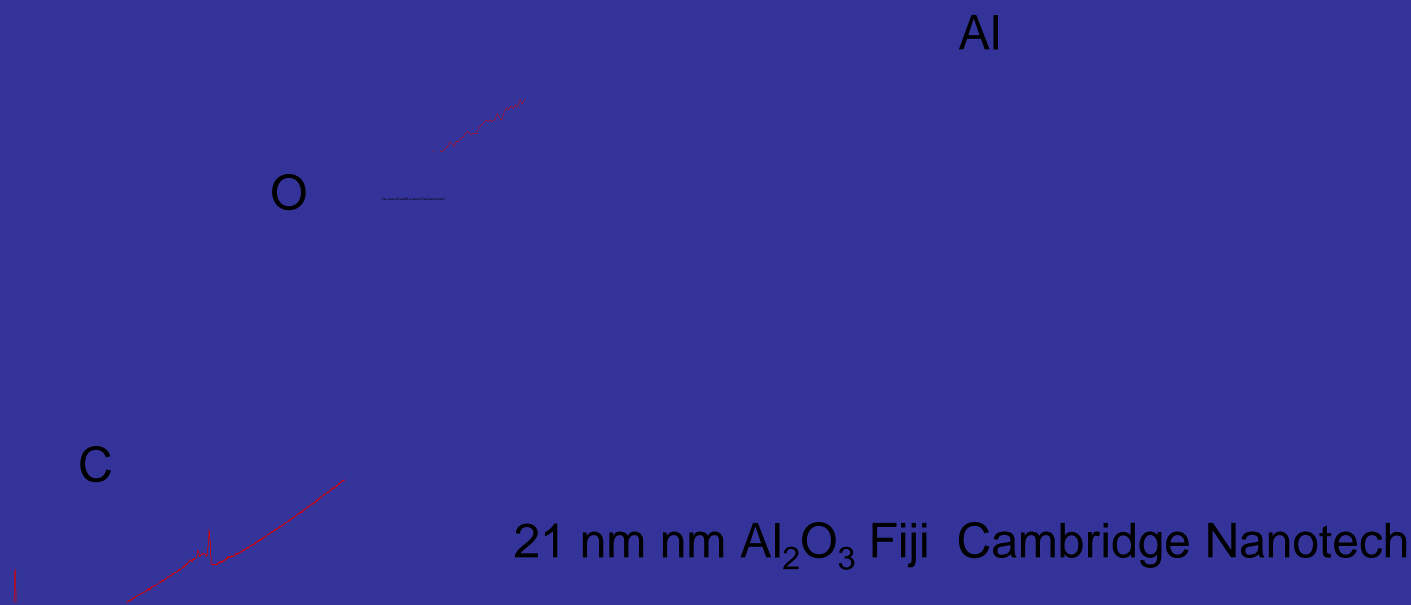
No F found in SiO_2 sample prepared by Fiji



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Conclusions:

- F contamination can be found on all films prepared on Savannah systems
- The source of F comes from O-ring outgassing
- All high temperature O-rings made of fluorocarbon or perfluorocarbon materials have this issue
- F contamination depends on process temperature and O-ring age

Question:

How F contamination relates to electrical leakage?

Fact:

All films contains F on the surface (possibly not at the interface?), but not all films leaks.

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F outgassing -> pitting on the lid -> vacuum leaking ->electrical leakage

pitting occurs outside o-ring

O-ring

Vacuum maintenance

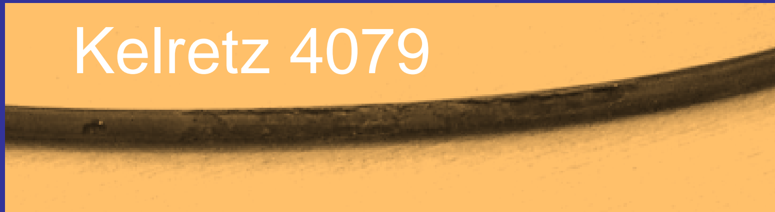
Leak checking regularly

- Rate of rise 20-50 mtorr/min
- He leak detector

Two Al lids to swap regularly (every 2 or 3 months)

Making another stainless steel lid

Change O-ring regularly



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O-rings:

Viton	204 °C	cheap
Kelretz 4079	316°C	$457.00
Kelretz 7075	327°C	$457.00
FFKM 75 Black Perlast	327°C	$325.24

(low outgassing, size G75TX,
Precision Polymer Engineering Ltd., UK)

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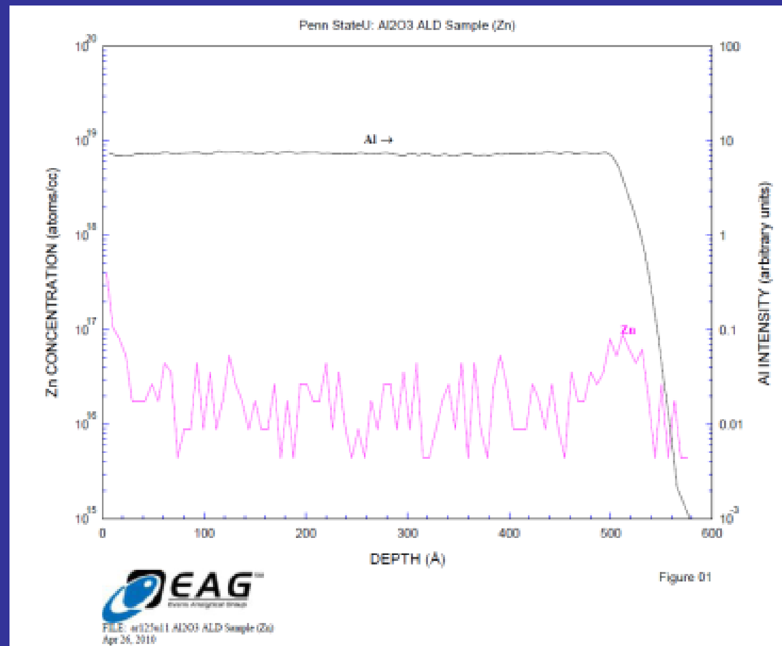
Cross contamination: ZnO



SIMS analysis of Al_2O_3

Facts:

User complained about degraded optical and electrical properties after ZnO deposition

Solutions:

Capping chamber by Al_2O_3

Complete chamber cleaning

Replacing manifold

Stopped doing ZnO

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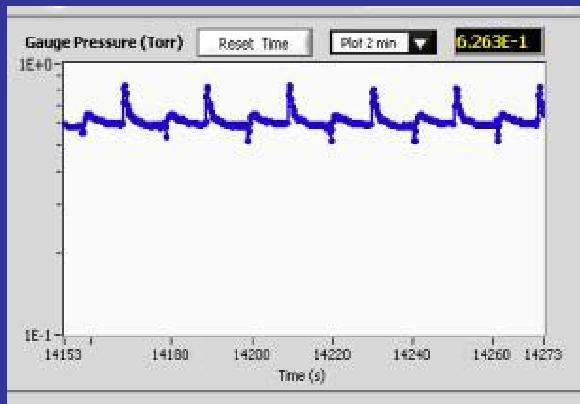
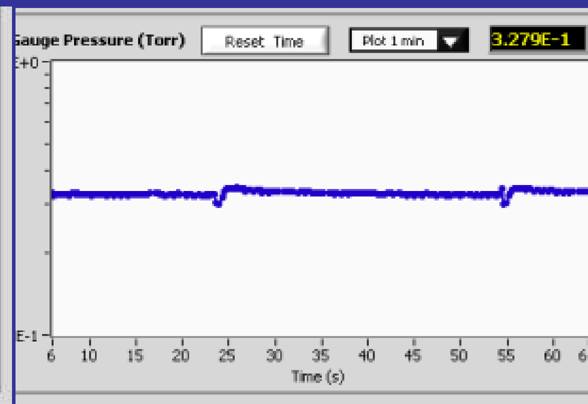
Major issues

- **Electrical leakage**
  1. Cross contamination: ZnO
  2. Chamber leak -- O-ring etches Al lid(F outgassing)
- **Software crashes frequently due to RF noise?**
- **Self contamination**
  1. ALD valve
  2. Stop valve
  3. Gauge- pulse dips





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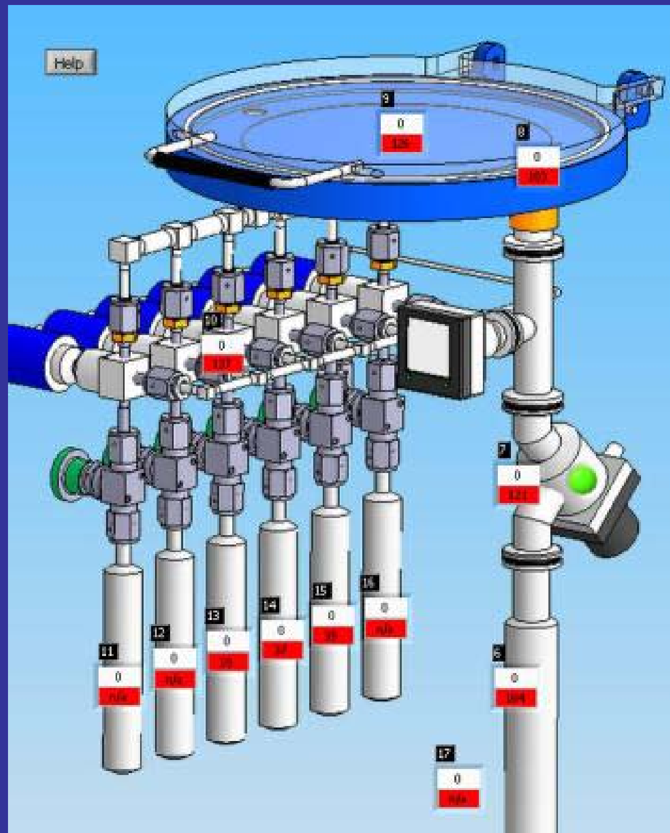

Major modifications

1. Expanded to 6-fold manifold
2. Made a second Al lid
2. To replace the Al lid w/ a stainless steel lid
3. To replace the existing black box w/ a silver box

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Proposed dual chamber ALD tool

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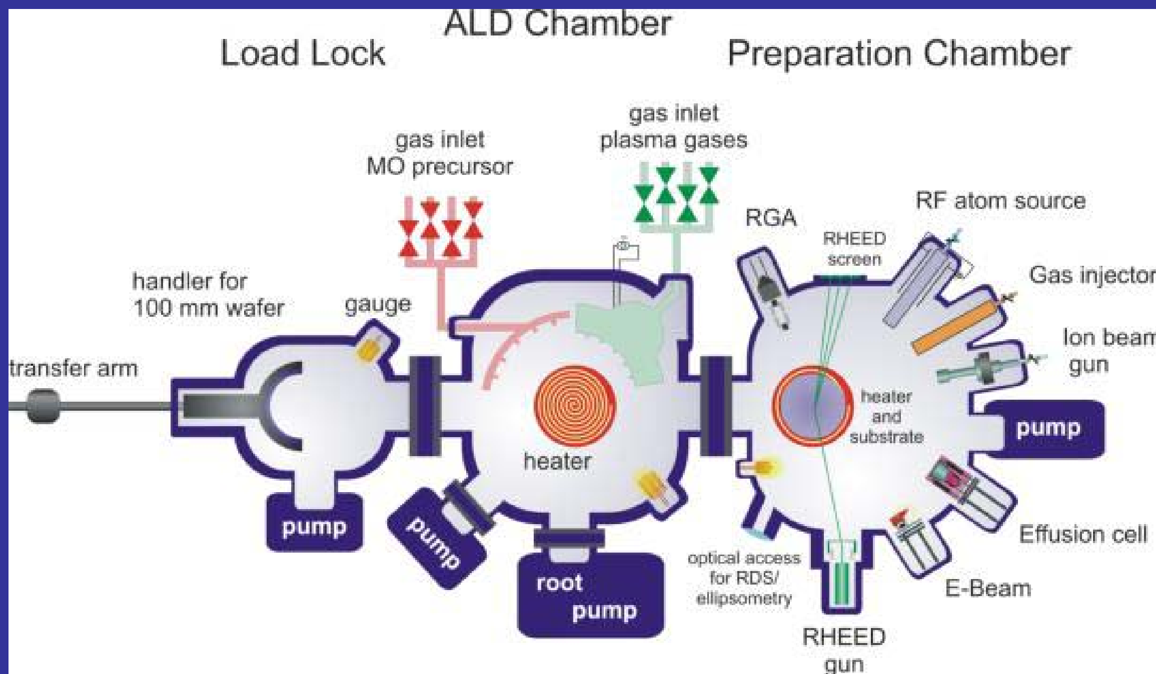

ALD growth chamber

- UHV compatible 10^{-8} torr
- Substrate heater up to 600°C
- thermal ALD & plasma enhanced ALD
- H2, N2 and O2 as plasma gas
- 6 precursor gas lines

Prep chamber:

- UHV compatible 10^{-8} torr
- Substrate heating to 600 °C
- O_2, H_2, N_2 and Ar
- Effusion cell
- Ion beam gun
- RF atom source
- e-beam evaporator
- Gas injector

In situ monitoring capability options

- Differentially pumped RHEED system
- Ellipsometry
- DS/RAS optical access (normal incidence)