RF Oxygen Discharge Cleaning of Carbon from EUV Optics

Sponsored by

International SEMATECH
Coordinator: Carmelo Romeo

Samuel Graham
Philip Grunow
Miles Clift
Lennie Klebanoff

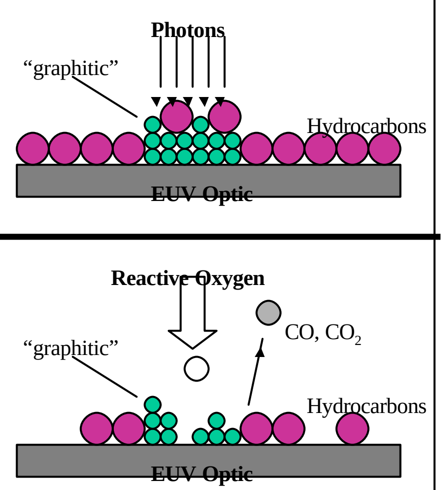
Sandia National Laboratories, Virtual National Laboratory (VNL)

INTRODUCTION

- Carbon deposition (due to hydrocarbon cracking) an issue for EUVL
- Develop in-situ cleaning methodology:
  - Remote O_2 / RF discharge

$$O_2 \xrightarrow{RF} O,\ O^+,\ O^*$$

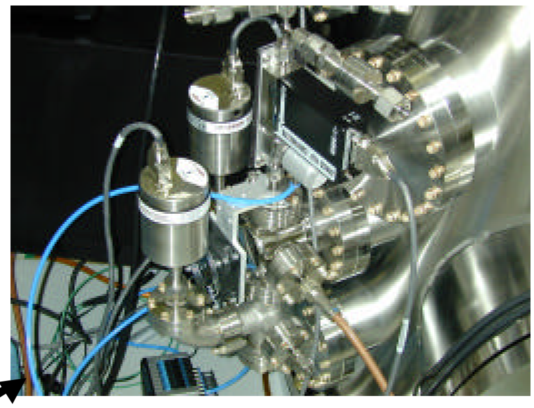
Issues:
- Carbon Removal Rates
- Efficiently clean over large distances
- Buried/obstructed optics



RF Oxygen Cleaning Using Model Geometry

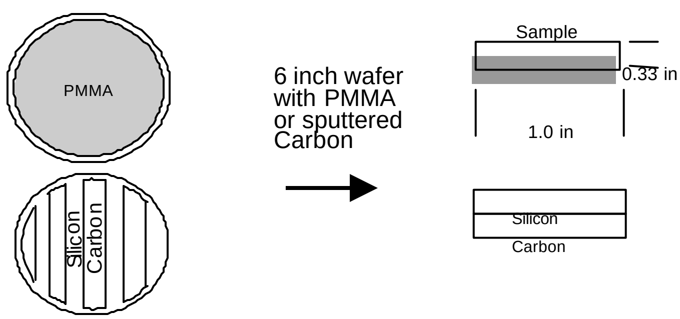
Multi-use Vacuum Chamber:
8ft tall, 33 inches wide

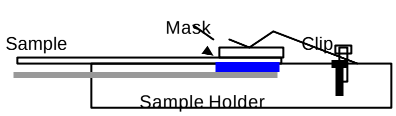
RF Appendage Cell



Samples for Model Geometry

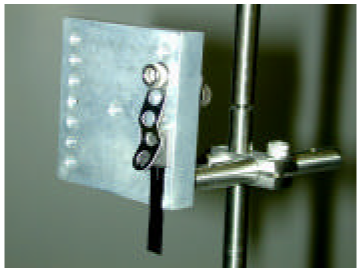
• Samples: 6 inch Si wafers coated with Carbon or PMMA.

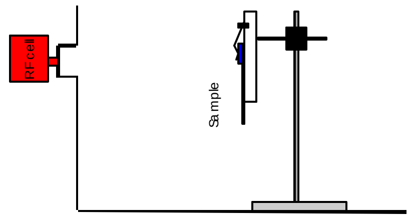


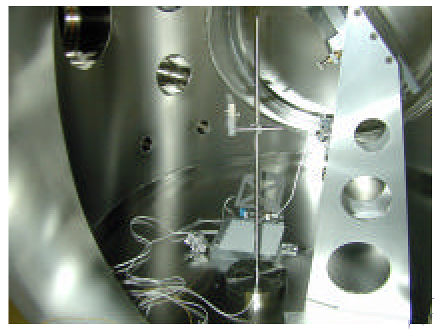


•Control Region created by masking part of the sample…..No Cleaning

Mounting Configuration

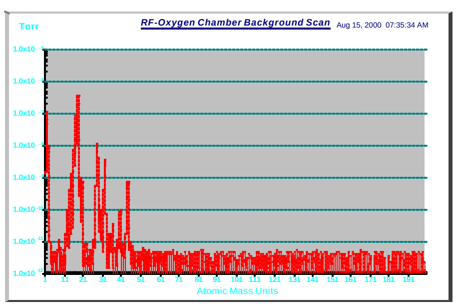






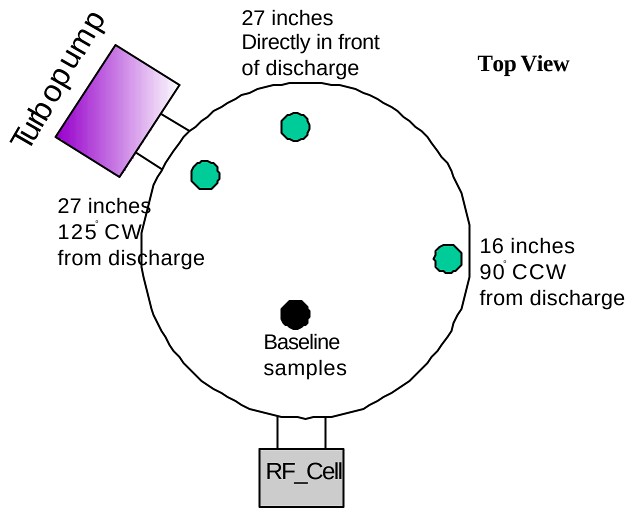
Tests and Analysis Methods

- Research Purity O_2: 99.998%
- Background Environmental Conditions exceptionally clean chamber.



- Carbon cleaning efficiency determined by Auger Electron Microscopy.
- Resist Removal rates determined by white light spectroscopy (Nanospec AFT 4000)
- Background Environmental Conditions determined using RGA.

Sample Locations



Resist Removal Rates : Baseline Study

Oxygen/ RF Discharge 10 inches from source

Primary Reaction: C + (2)O → $CO_{(2)}$

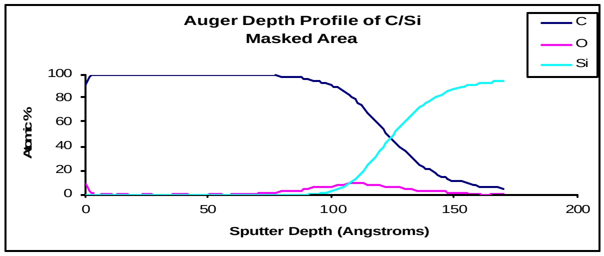
	50sccm (11 mTorr)	100 sccm (19 mTorr)	150sccm (27 mTorr)
50W	58 Å/hr	85 Å/hr	81 Å/hr
100W	65 Å/hr	90 Å/hr	96 Å/hr
200W	92 Å/hr	106 Å/hr	113 Å/hr

Accuracy: +/- 1%

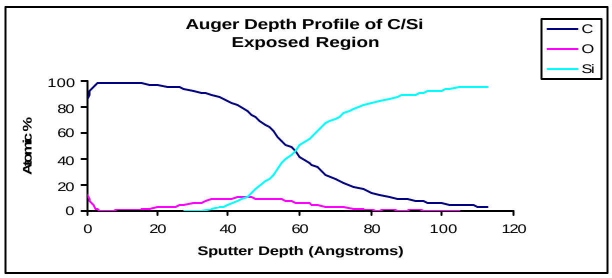
Carbon Removal Analysis

1Hr @ 50W/ 100 sccm 10 inches from port

Masked



Exposed

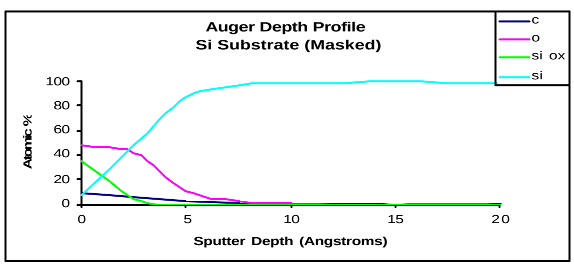


» 70 Å/Hr removed

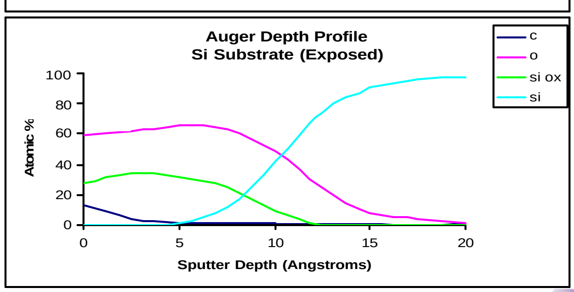
Silicon Oxidation Analysis

4 Hrs @ 50W/ 100 sccm 10 inches from port

Masked



Exposed



» 2.5 Å/Hr oxidation rate

Carbon Cleaning vs Sample Position

150 sccm O_2, 100 W RF Power

Position	Orientation	Removal Rate (Ang./ Hr.)
16” away, 90° CCW	Facing	50
16” away, 90° CCW	Not Facing	31
27” away, 125° CW	Facing	40
27” away, 125° CW	Not Facing	30
27” away, 0°	Facing	20
27” away, 0°	Not Facing	5

Conclusions

- Oxygen RF Discharge cleaning can remove carbon from optic surfaces.
  - High Removal Rates: sufficient for ETS
  - Cleaning is effective at least up to 27 inches downstream.
  - LOS/NLOS variations observed.
  - Si oxidation an issue
- Future tests on “Buried” Optic Geometries are planned.