Preparing Templated Silicon Surfaces for III-V Epitaxy

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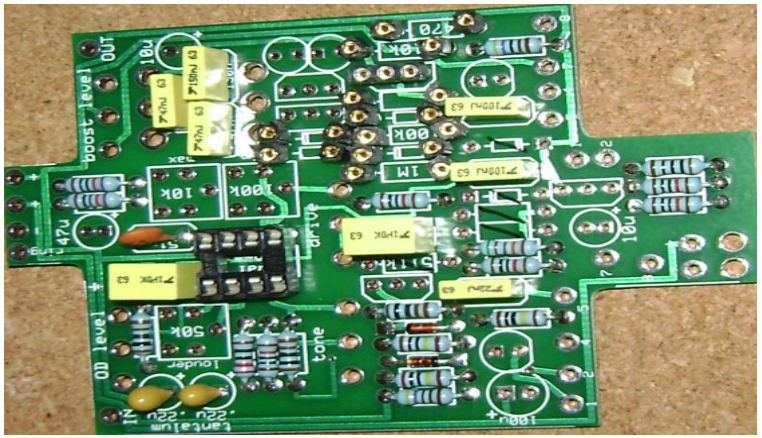
Reducing waste energy during data transfer using photonics

- Electrical wires produce heat
- Silicon is cheap and used in electronic devices
- Big problem: Silicon is an inefficient light emitter
- III-V materials used in lasers to emit light
- Solution: III-V material on Si

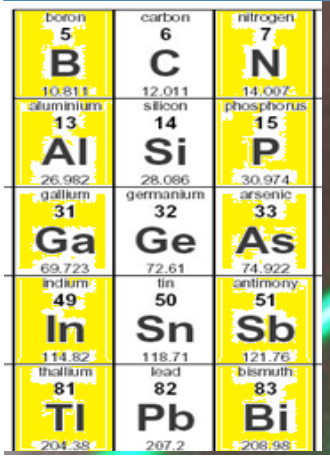
http://tech.blorge.com/wp-content/uploads/2014/04/Samsung-Galaxy-S4-vs-iPhone-5.jpg



http://www.plyojump.com/classes/images/hardware/transistor_pcb.jpg

https://www.semiwiki.com/forum/attachments/content/attachments/11601d1405647406-300mm-450mm-wafer-comparison-jpg

III-V materials



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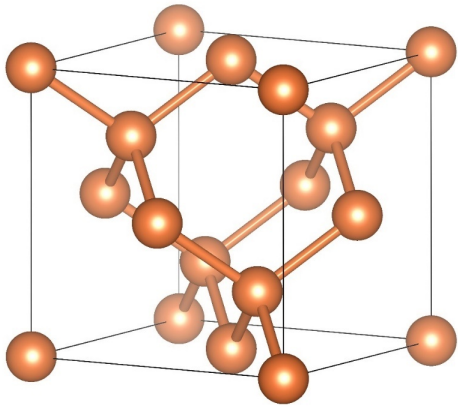
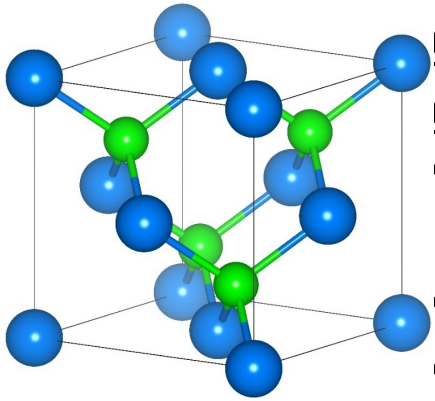


Courtesy of Dan Pennachio

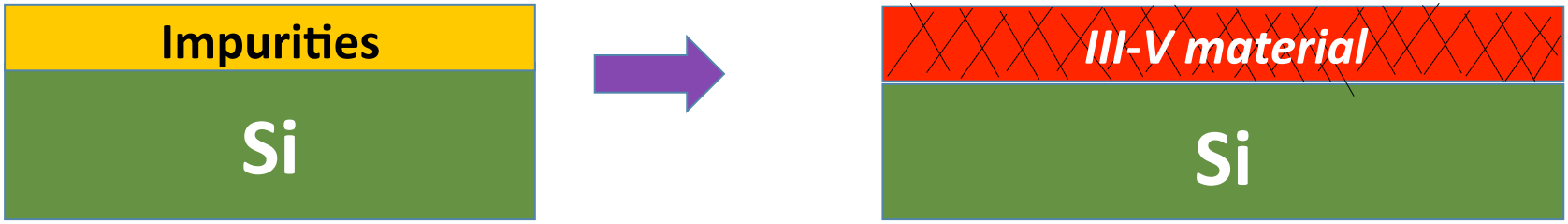
Si: diamond crystal structure

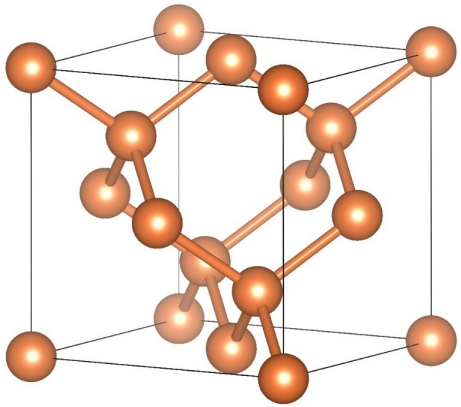


III-V: Zinc blende crystal structure

Clean interface avoids defects on III-V crystals

- Grow III-V material on top of the silicon
- Impurities on the silicon surface
- Selectively clean the wafer to remove the native oxide
- Growth III-V epitaxy on selected areas





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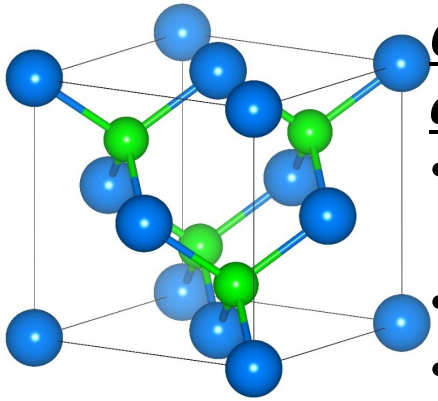

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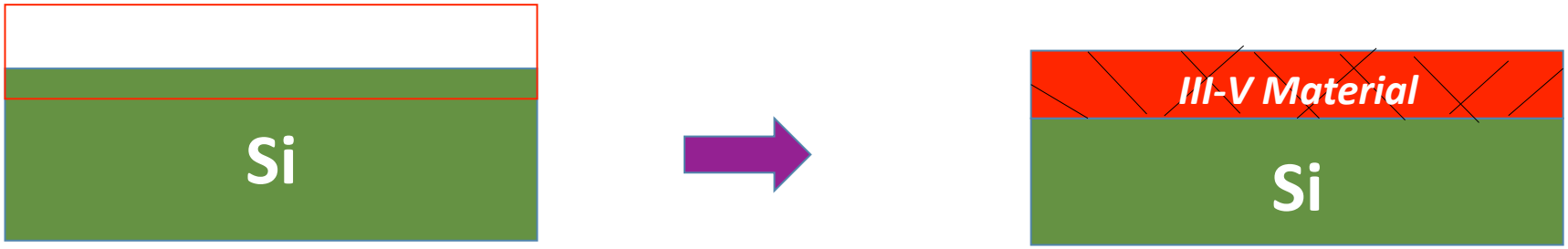
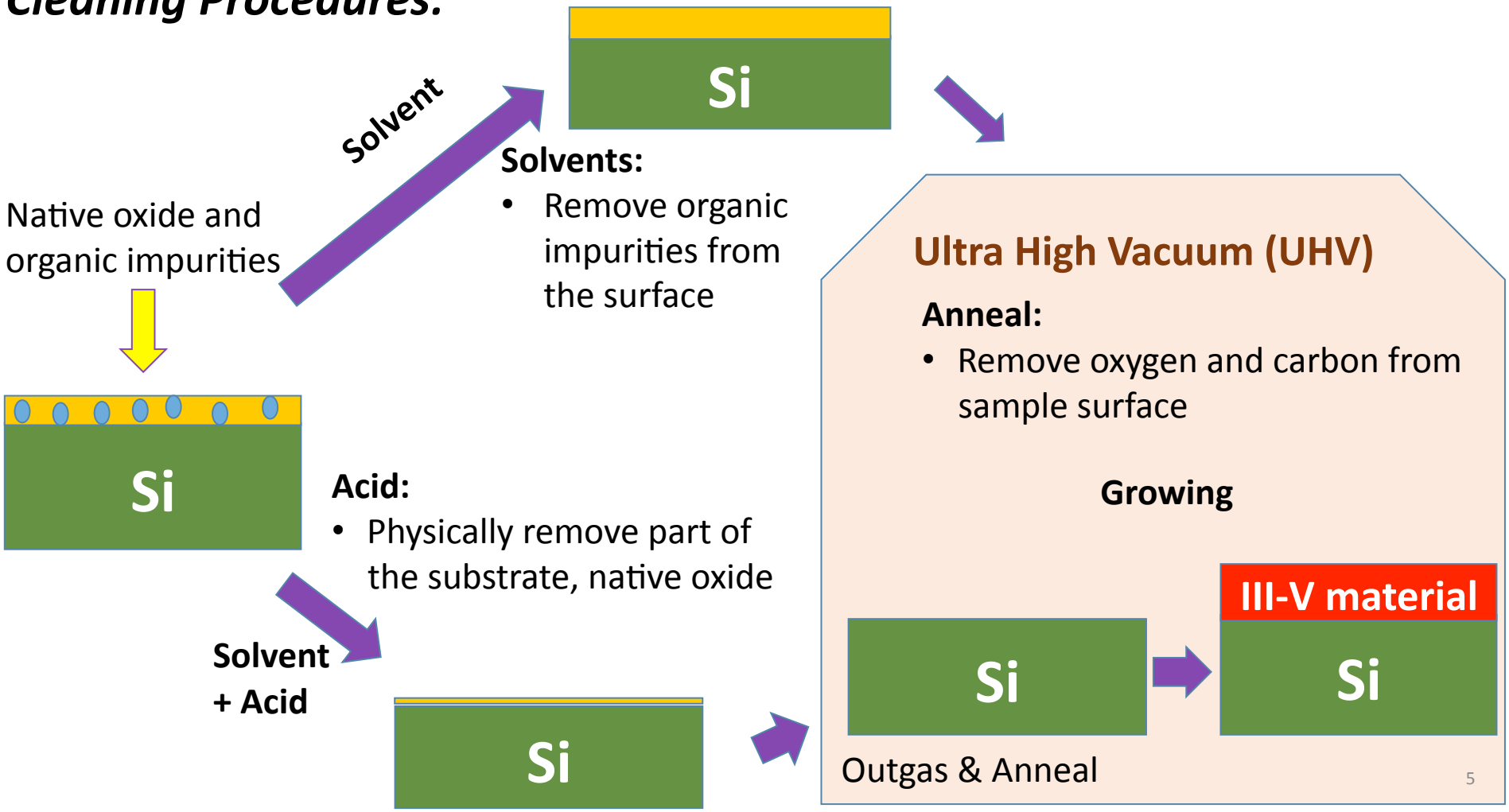
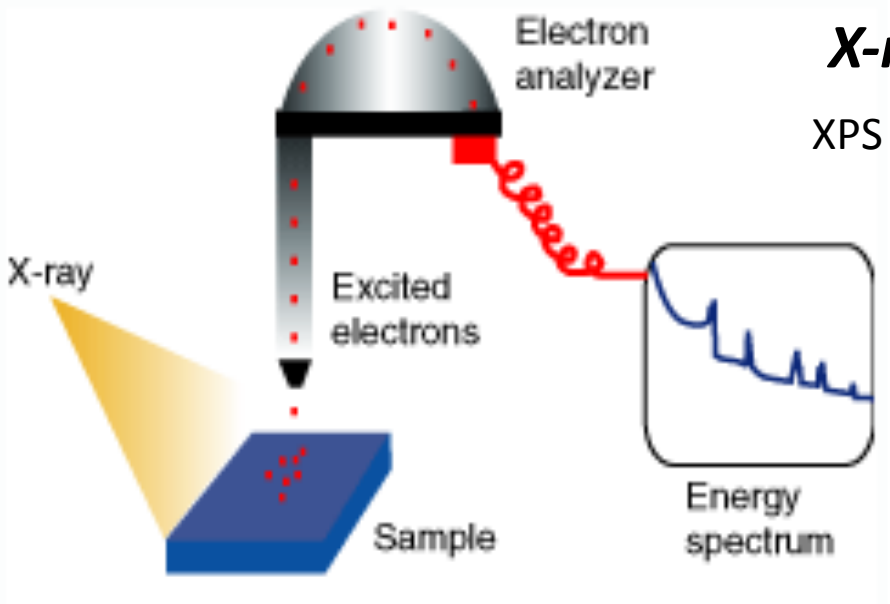


Cleaning Procedures:



X-ray Photoemission Spectroscopy (XPS)

XPS is conducted in ultrahigh vacuum (UHV)

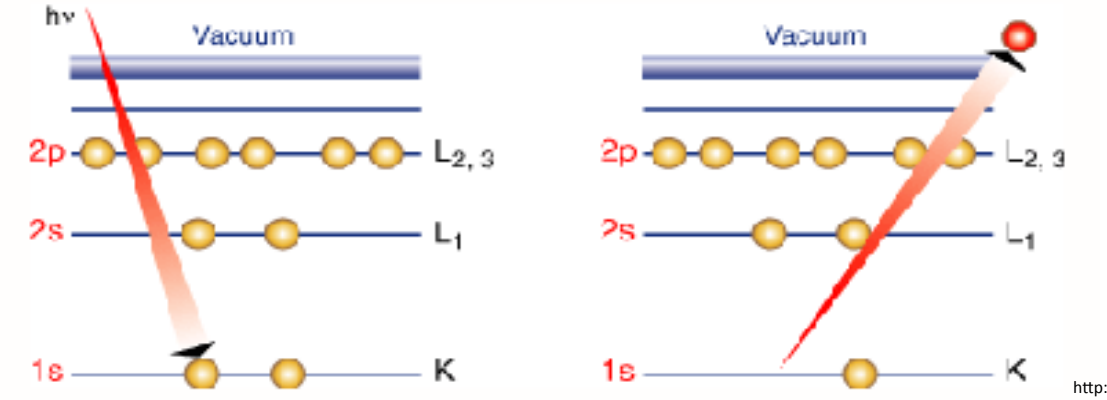


http://www.lanl.gov/orgs/nmt/nmtdo/AQarchive/04summer/gifs/XPS2.gif

Total Energy — **Binding Energy**

$$E_{X-ray} - KE_{e-} = BE$$

Kinetic Energy of the electron



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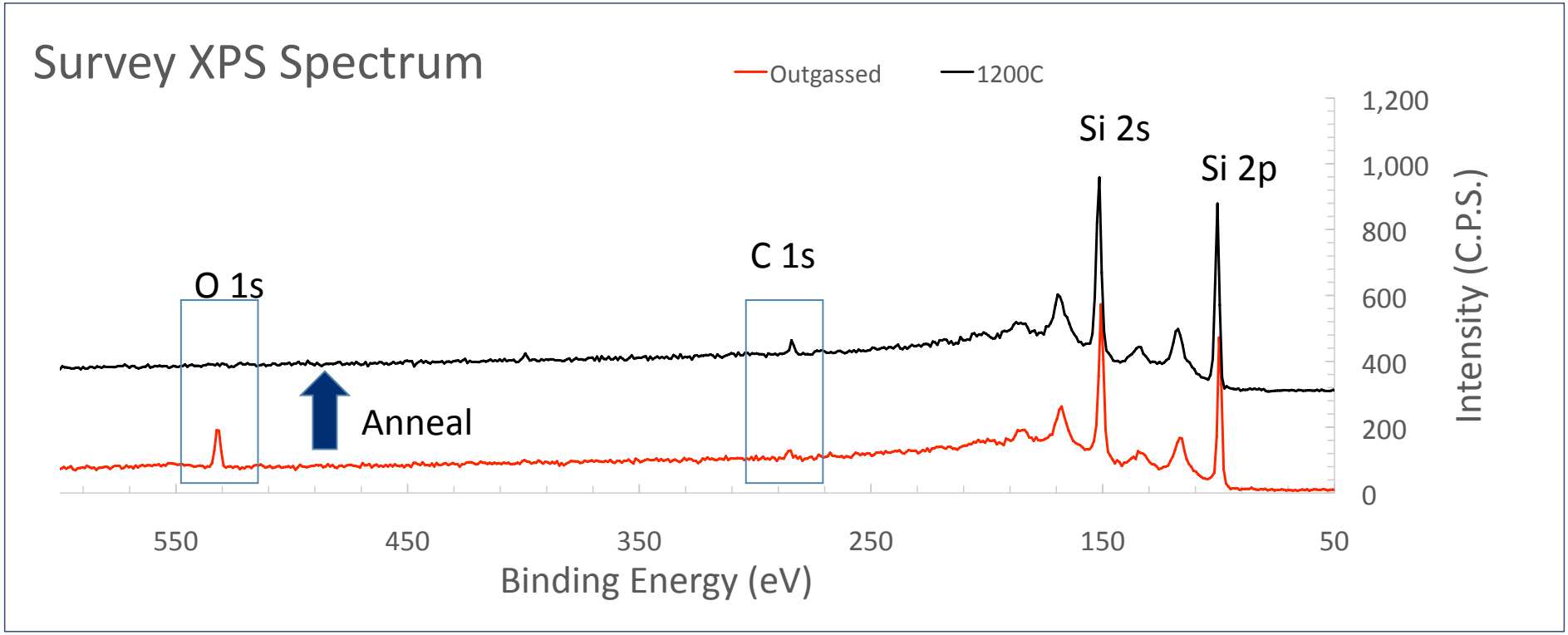
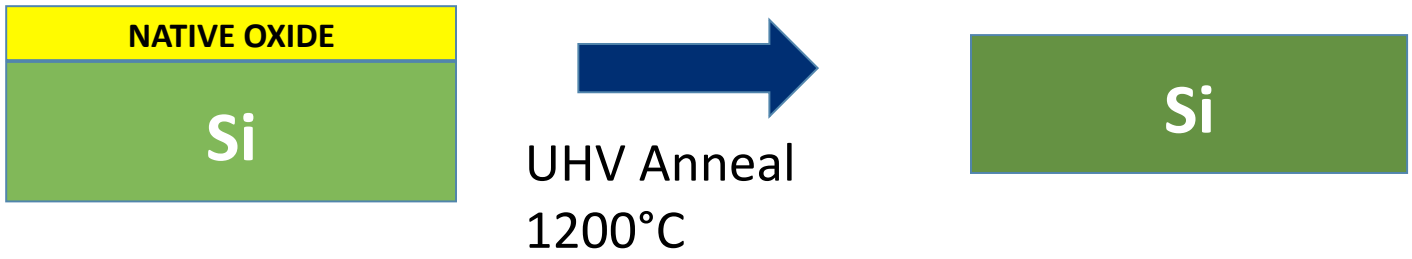
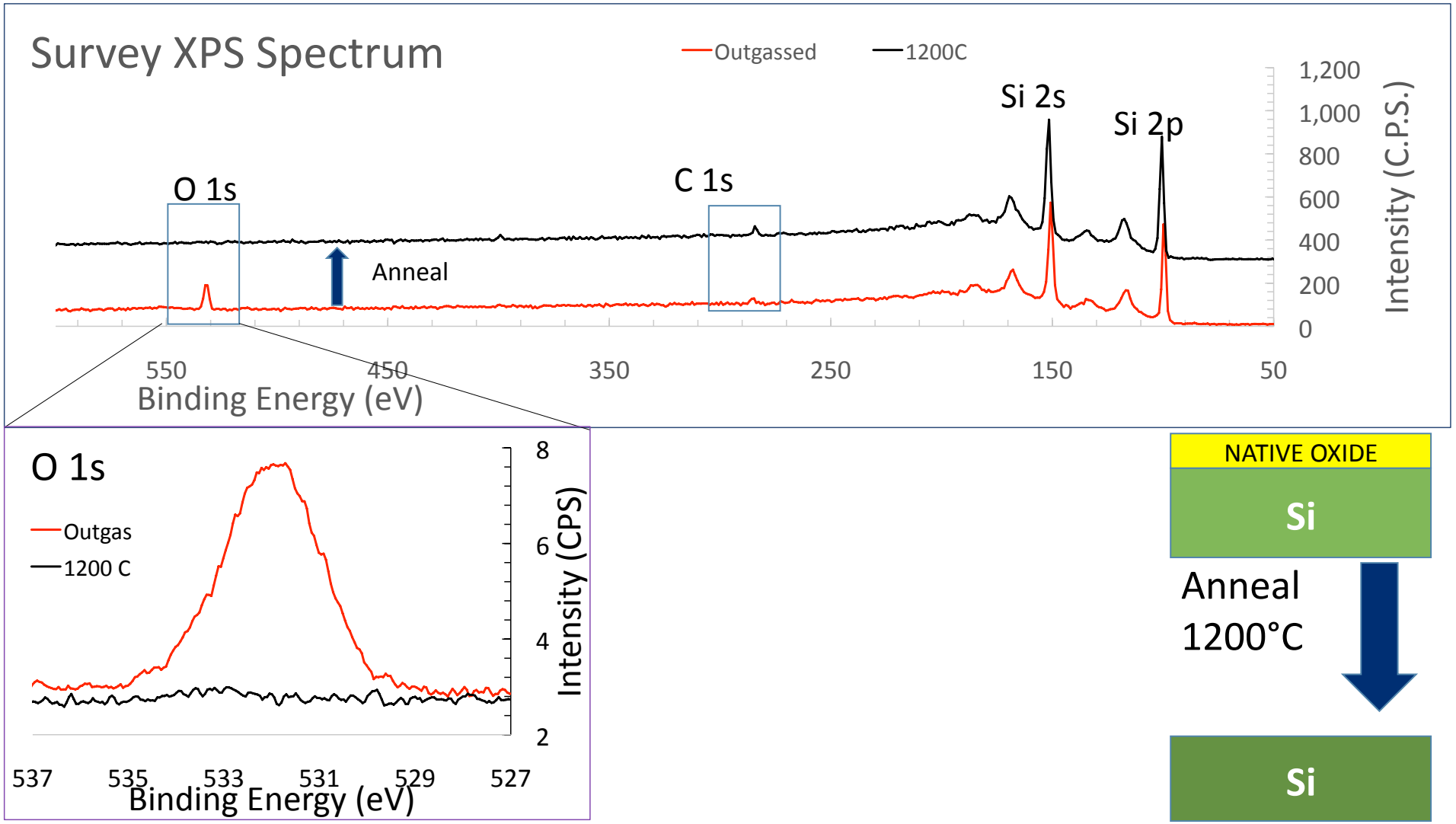

Survey XPS Spectrum
Outgassed
1200C
Si 2s
Si 2p
C 1s
O 1s
Anneal
1,200
1,000
800
600
400
200
0
Intensity (C.P.S.)
550
450
350
250
150
50
Binding Energy (eV)


NATIVE OXIDE
Si
UHV Anneal
1200°C
Si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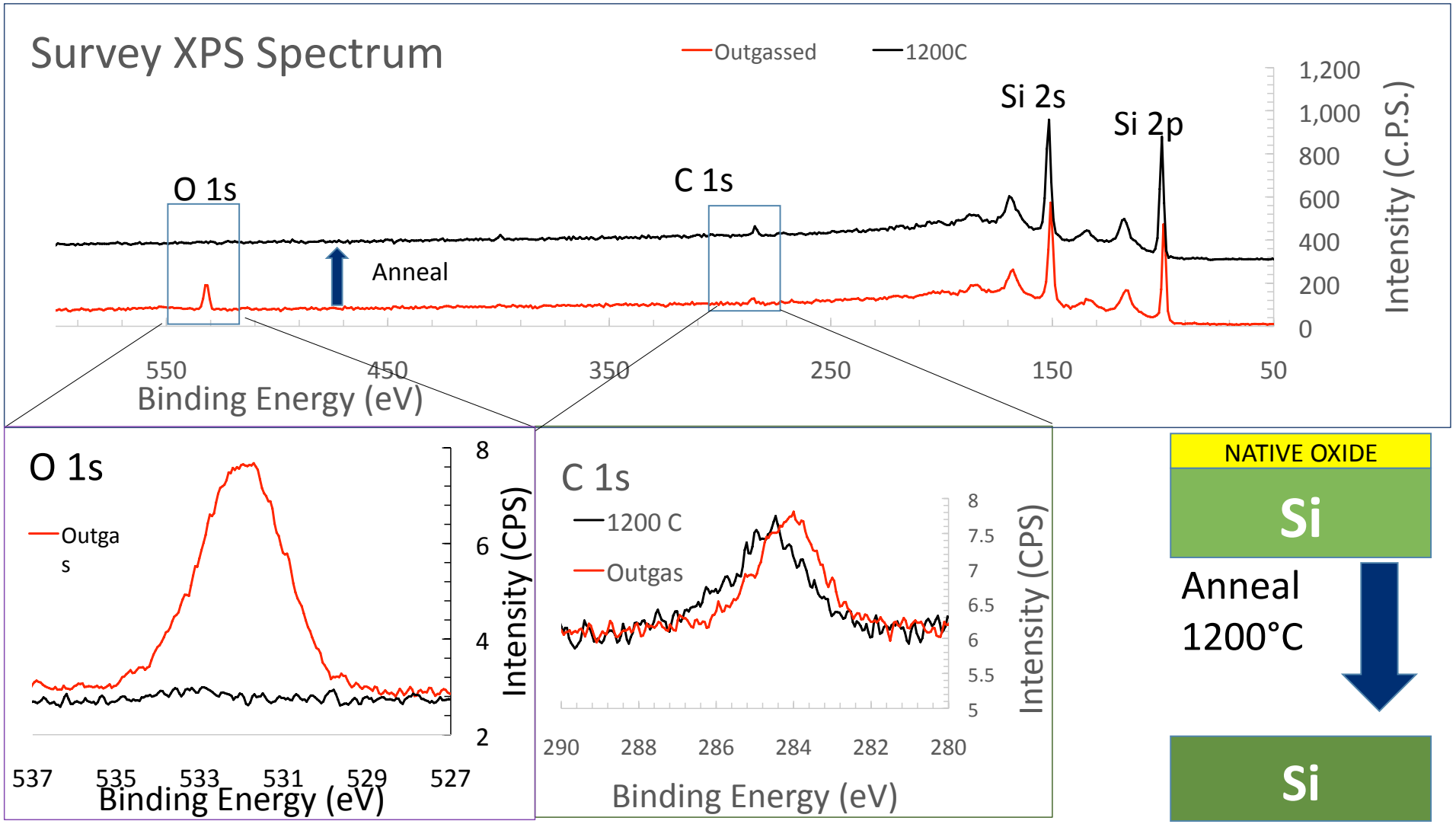
Intensity (C.P.S.)
550
450
350
250
150
50
Binding Energy (eV)
O 1s
Outgas
1200 C
8
6
4
2
Intensity (CPS)
537
535
533
531
529
527
Binding Energy (eV)
NATIVE OXIDE
Si
Anneal
1200°C
Si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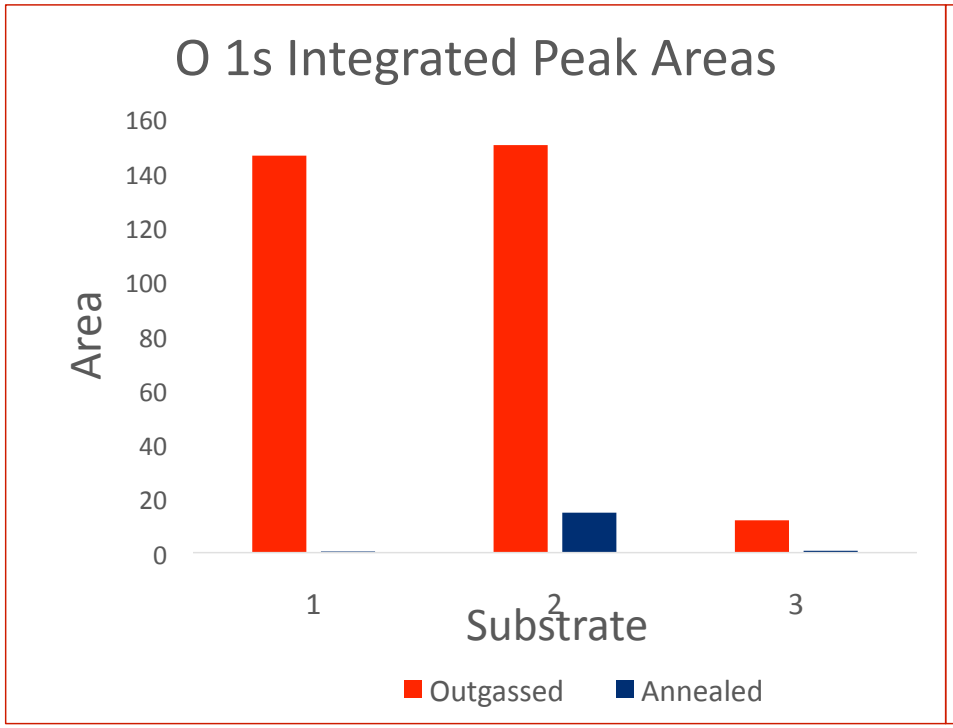
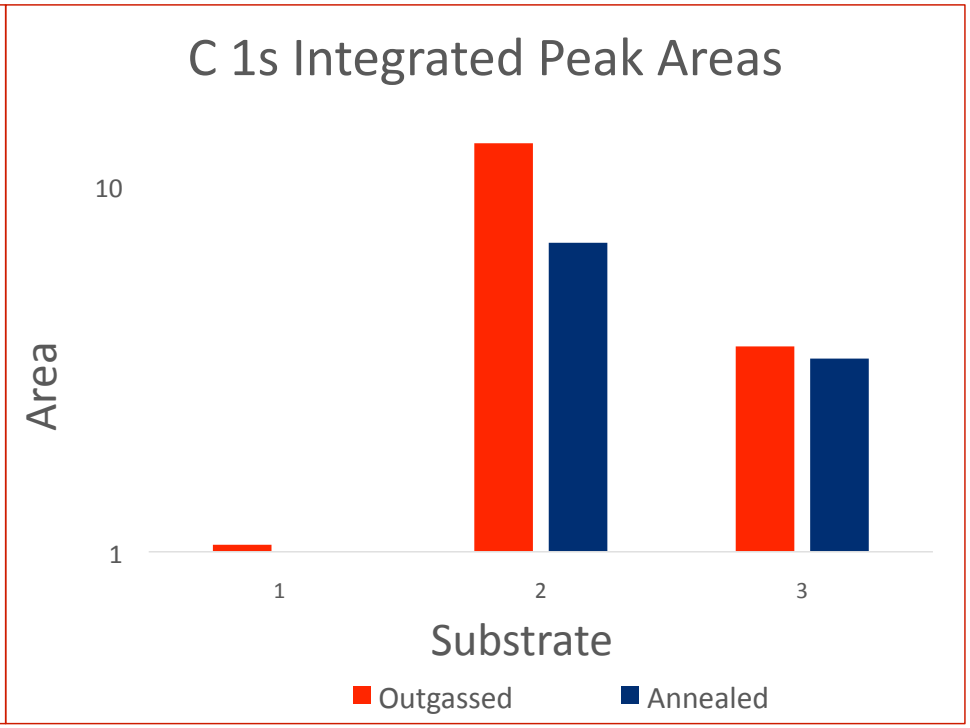
535
533
531
529
527
Binding Energy (eV)
C 1s
1200 C
Outgas
8
7.5
7
6.5
6
5.5
5
Intensity (CPS)
290
288
286
284
282
280
Binding Energy (eV)
NATIVE OXIDE
Si
Anneal
1200°C
Si





For all samples in UHV

- *Outgas: ~300°C overnight*
- *Anneal: 1200°C 5 minutes*

Substrate 1

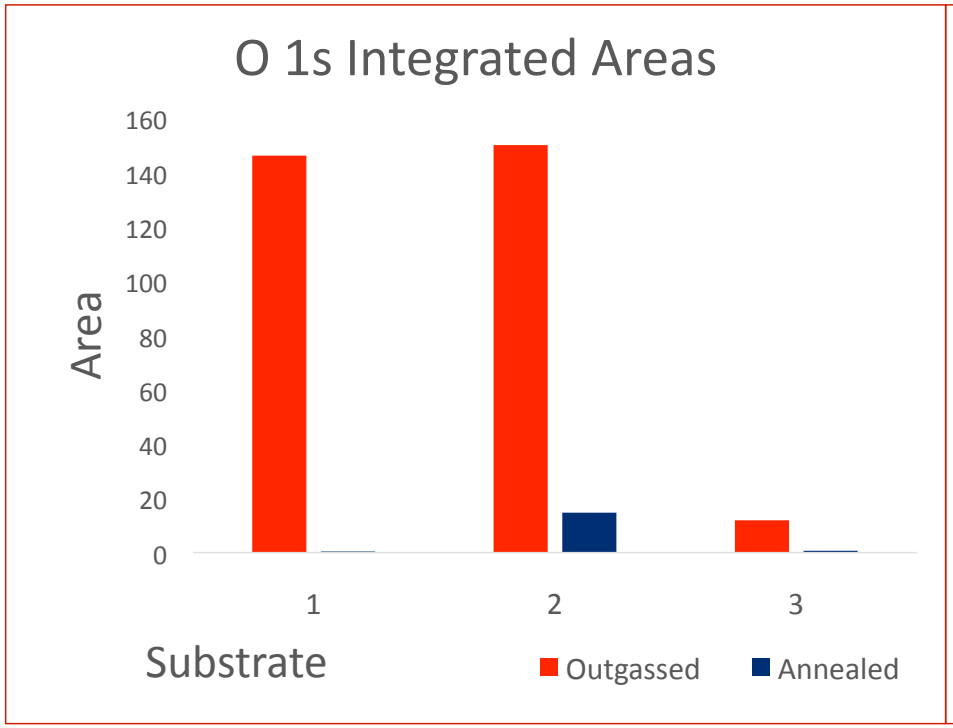
- Solvent

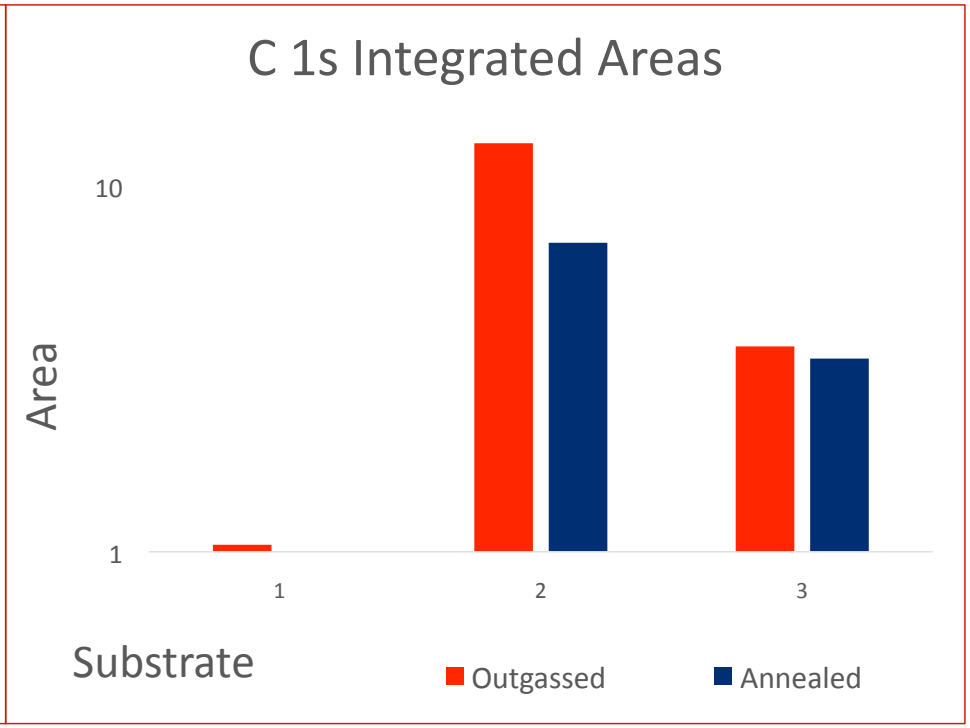
Substrate 2

- Photolithography
- Acid
- Solvent

Substrate 3

- Solvent
- acid



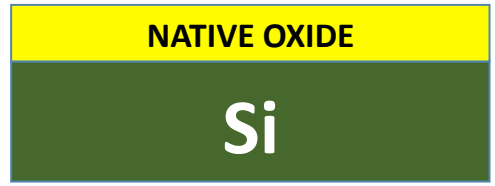


Substrate 1
- ❖Solvent

Substrate 2
- ❖Photolithography
- ❖Acid
- ❖Solvent

Substrate 3
- ❖Solvent
- ❖acid

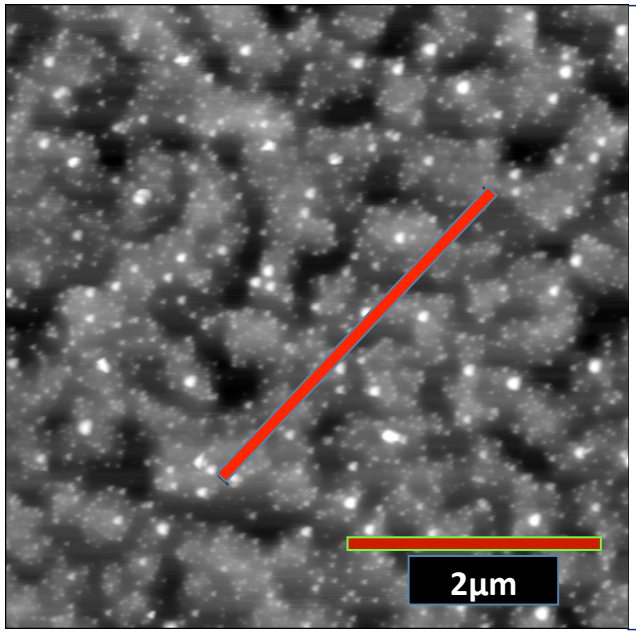
Atomic Force Microscope (AFM)

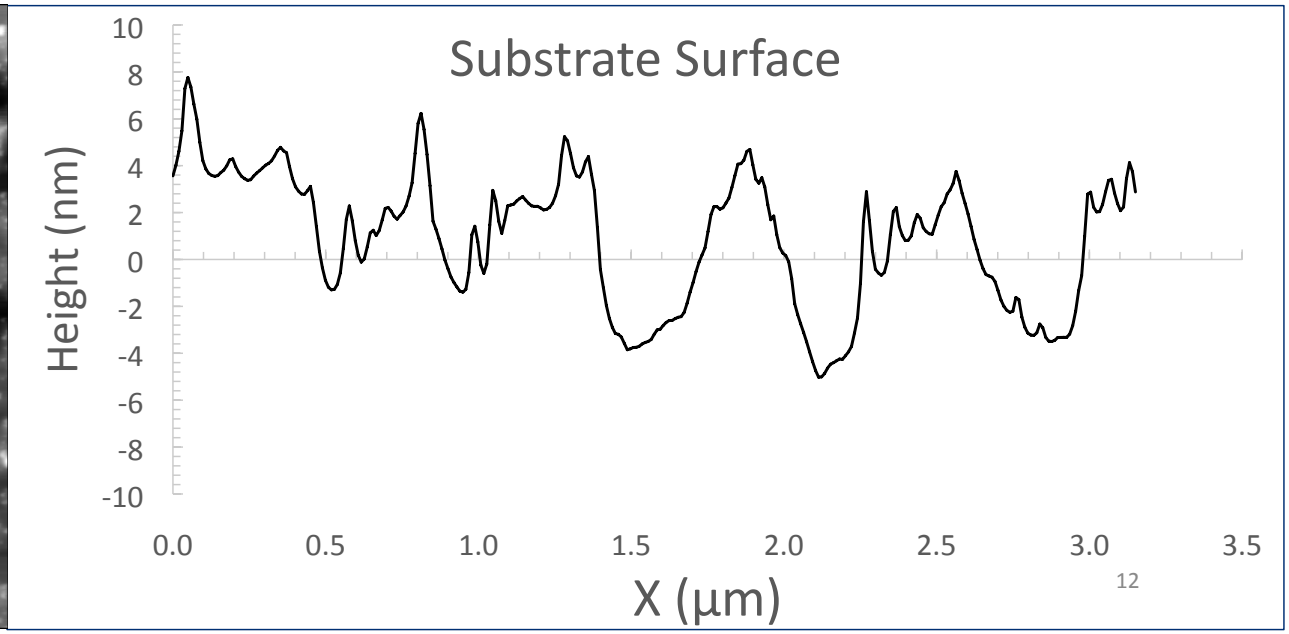


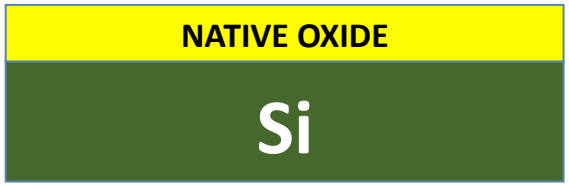
Substrate 1

- ❖Solvent
- ❖Outgas
- ❖Anneal 1200°C

Topographic image of the surface



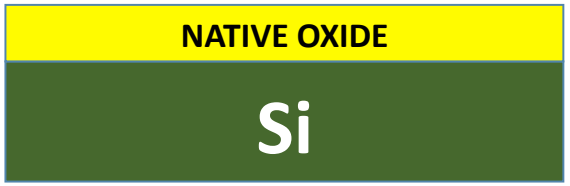




Substrate 1

- Solvent
- Outgas
- Anneal 1200°C

- Anneal roughened the surface
- Silicon carbide (SiC) formed by incomplete carbon removal.



Low Temperature Substrate

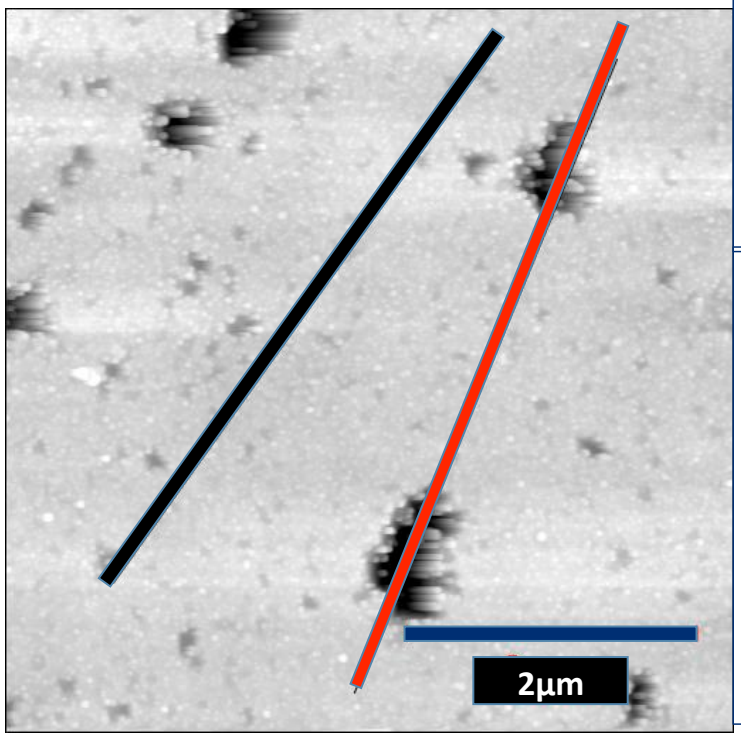
- Solvent
- Outgas
- Anneal 950°C

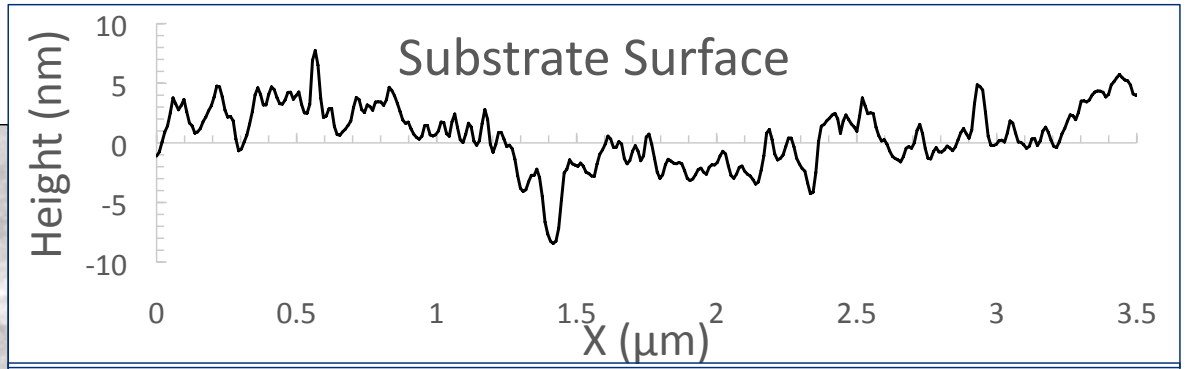
- Lowering anneal to 950°C
- What is going to happen to the surface?

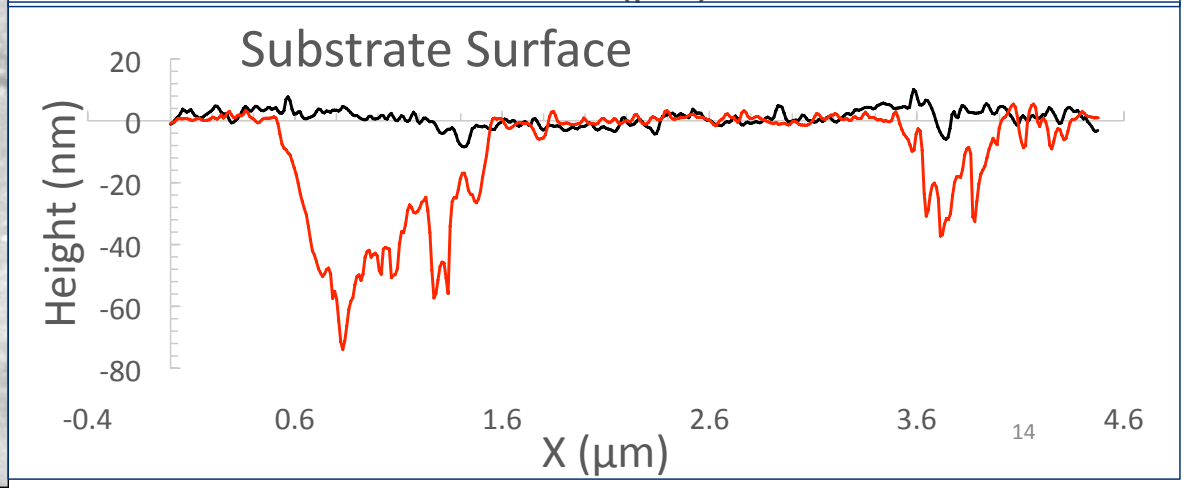
Low Temperature Substrate

- ❖Solvent
- ❖Outgas
- ❖Anneal 950°C

Minimize defects on the surface

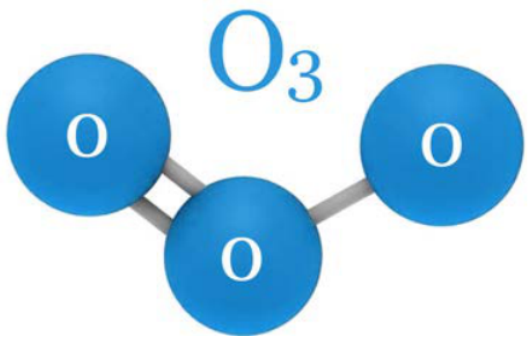






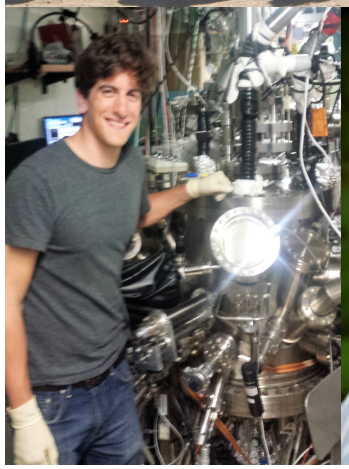
Future plans:

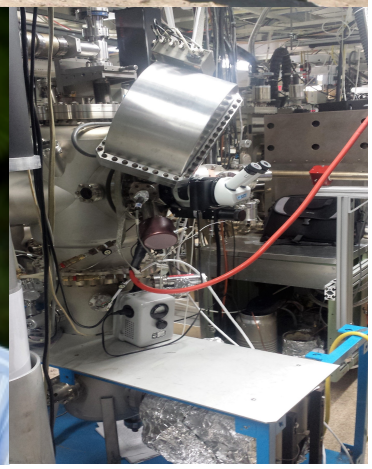
- Find the correct time and temperature for anneal to avoid surface roughening
- Cleaning substrates with ozone before outgassing to remove carbon
- Repeat ozone ad remove oxide multiple times to completely remove carbon



http://www.resonateintowellness.com/wp-content/uploads/2016/02/ozone.png

Acknowledgements:





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