

Camille Bean, Harvard University

Evaluation of Ex-Situ Ozone Cleaning of SrTiO₃ Substrates for Molecular Beam Epitaxy

Acknowledgements

Principal Investigator:



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Funding and Resources:



Investigation Questions:

- Is there a preferred SrTiO_3 etching method?
- Does ozone cleaning significantly reduce carbon contamination on SrTiO_3 substrates?

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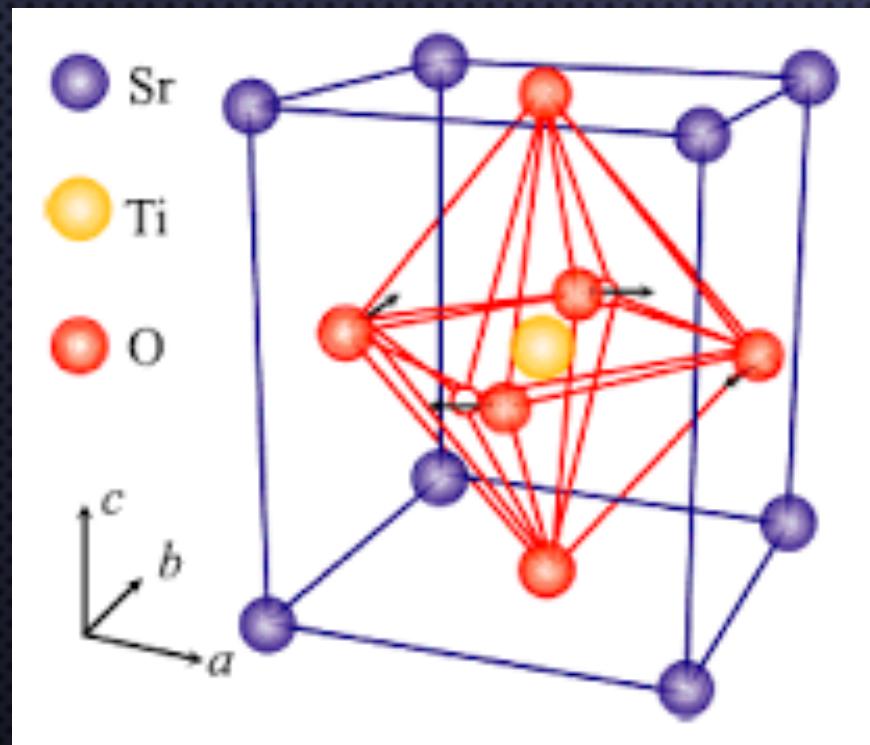
- Is there a preferred SrTiO_3 etching method?
 - HF-etched samples were much cleaner than HCl-etched samples
- Does ozone cleaning significantly reduce carbon contamination on SrTiO_3 substrates?

Investigation Questions:

- Is there a preferred SrTiO_3 etching method?
 - HF-etched samples were much cleaner than HCl-etched samples
- Does ozone cleaning significantly reduce carbon contamination on SrTiO_3 substrates?
 - No, any carbon reduction was not statistically significant.

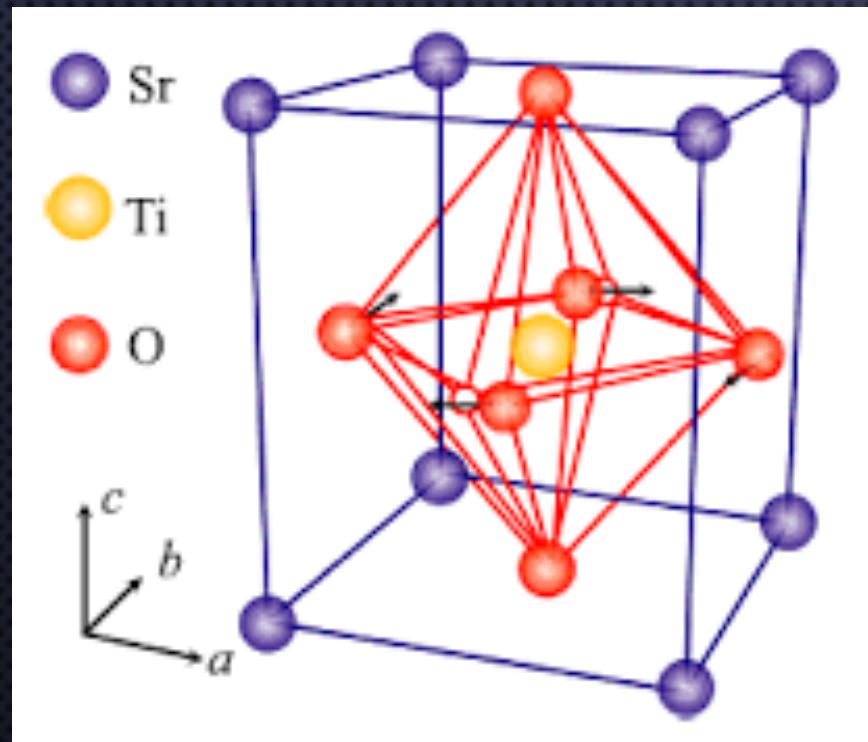
SrTiO_3 is a substrate used for thin film growths

STO Unit Cell



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STO Unit Cell



Monolayer FeSe on STO

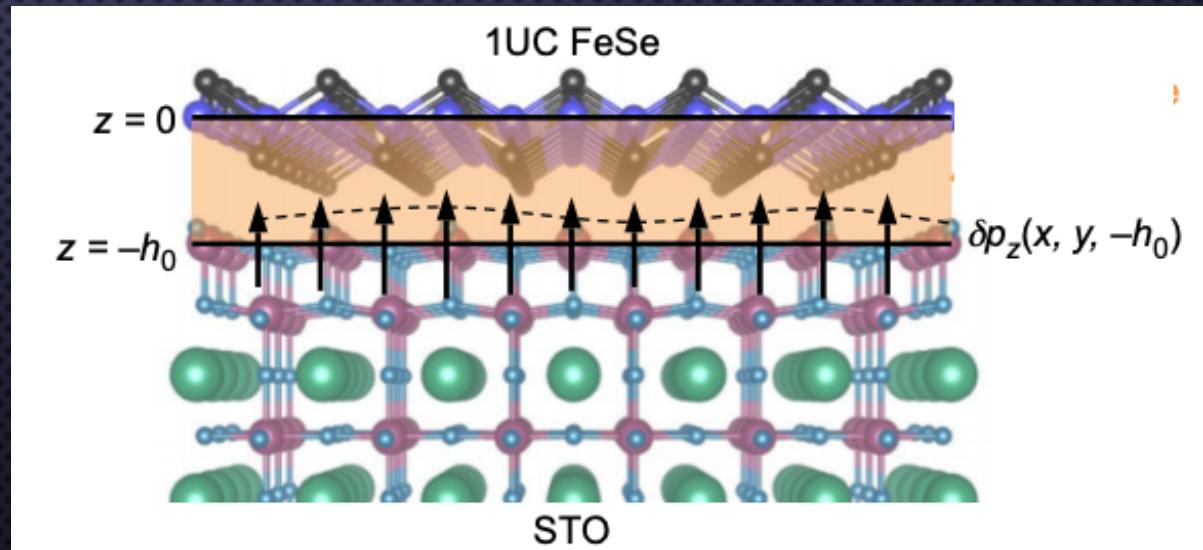
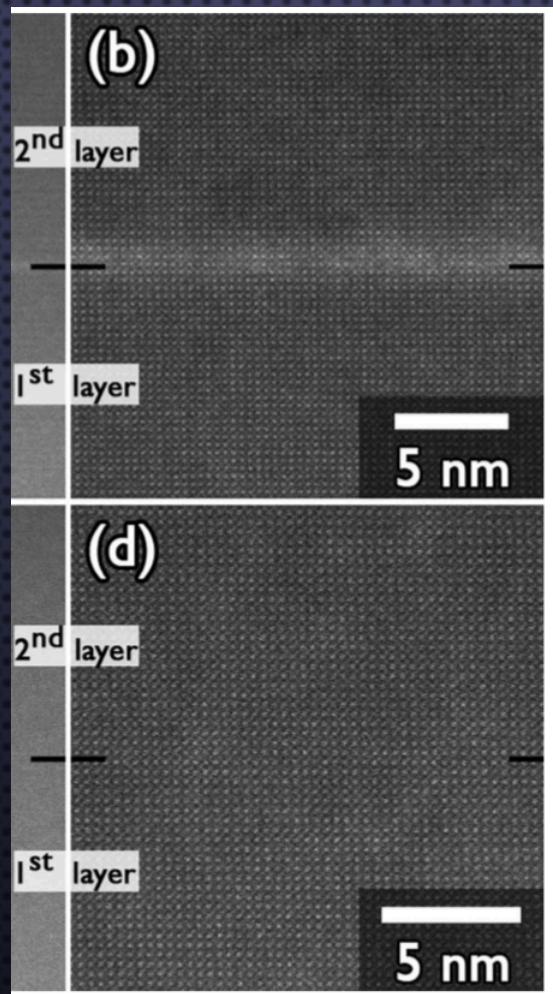


Image: Huang, Annual Reviews of Condensed Matter Physics 8, 311-336 (2017)

STO surface cleanliness is critical for quality growth

STO grown on STO
exposed to
atmosphere



STO grown on
not-exposed STO

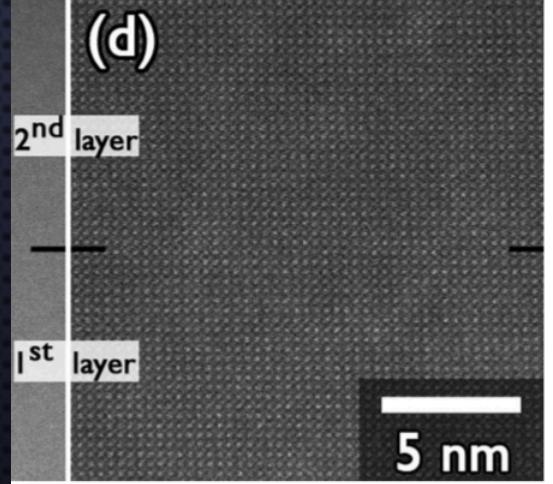


Image: Jalan, Journal of Vacuum Science & Technology A **27**, 1365 (2009)

STO surface cleanliness is critical for quality growth

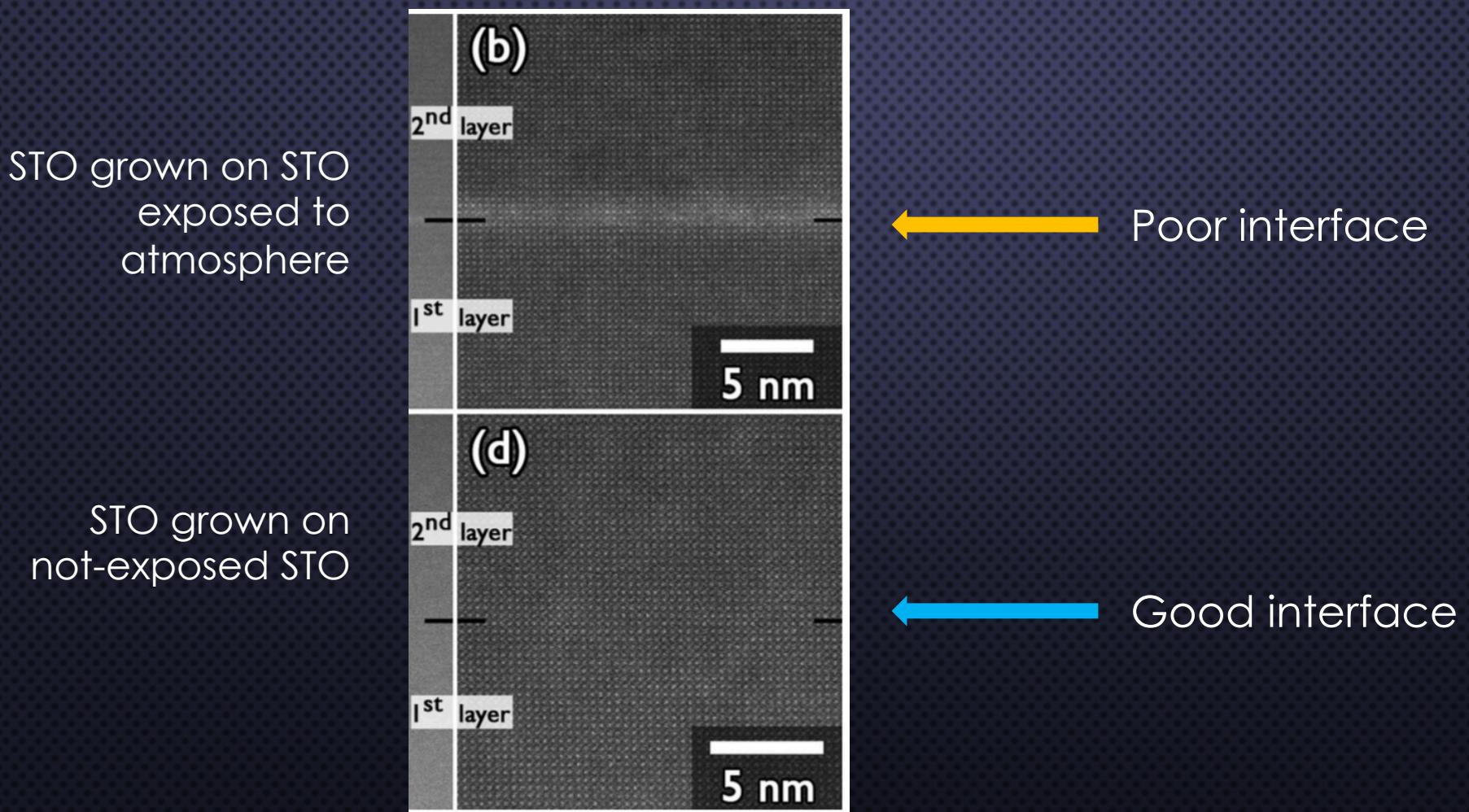


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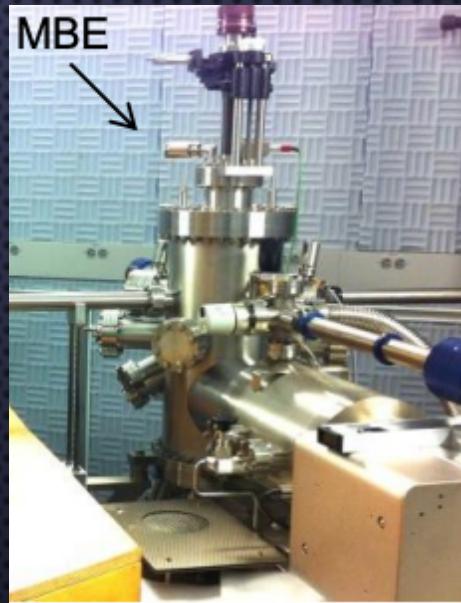
STO has a well-developed preparation procedure



HF or HCl Etching



Oxygen Anneal



Molecular Beam Epitaxy

Method:

Kawasaki, Science **266**, Issue 5190, 1540-1542 (1994)

Koster, Appl. Phys. Lett. **73**, 2920 (1998)

Hatch, Journal of Vacuum Science & Technology B **33**, 061204 (2015)

STO preparation cleanliness can be improved



HF or HCl Etching



Oxygen Anneal



Molecular Beam Epitaxy

STO preparation cleanliness can be improved

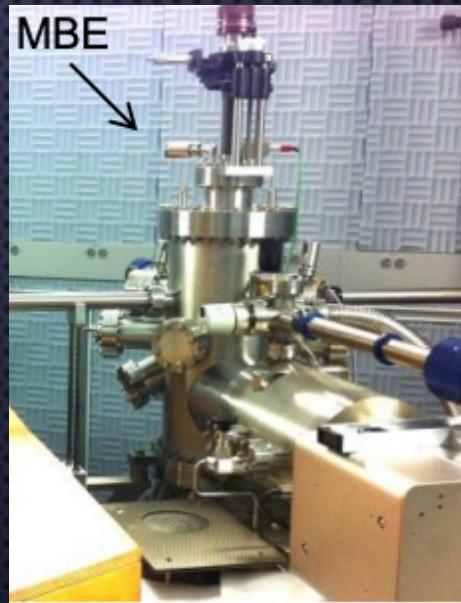
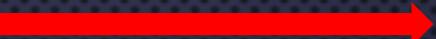


HF or HCl Etching



Oxygen Anneal

Timescale:
hours or days



Molecular Beam Epitaxy

The goal of this project is to investigate:

- a) Whether HCl or HF preparations yield cleaner samples for MBE
- b) Possible ex-situ cleaning techniques to improve cleanliness

Ozone cleaning is a promising ex-situ method

- In-situ cleaning techniques are best, but not easily added
- From exposure to air, we expect carbon contamination
- UV light generates ozone, which binds to and removes organic contamination

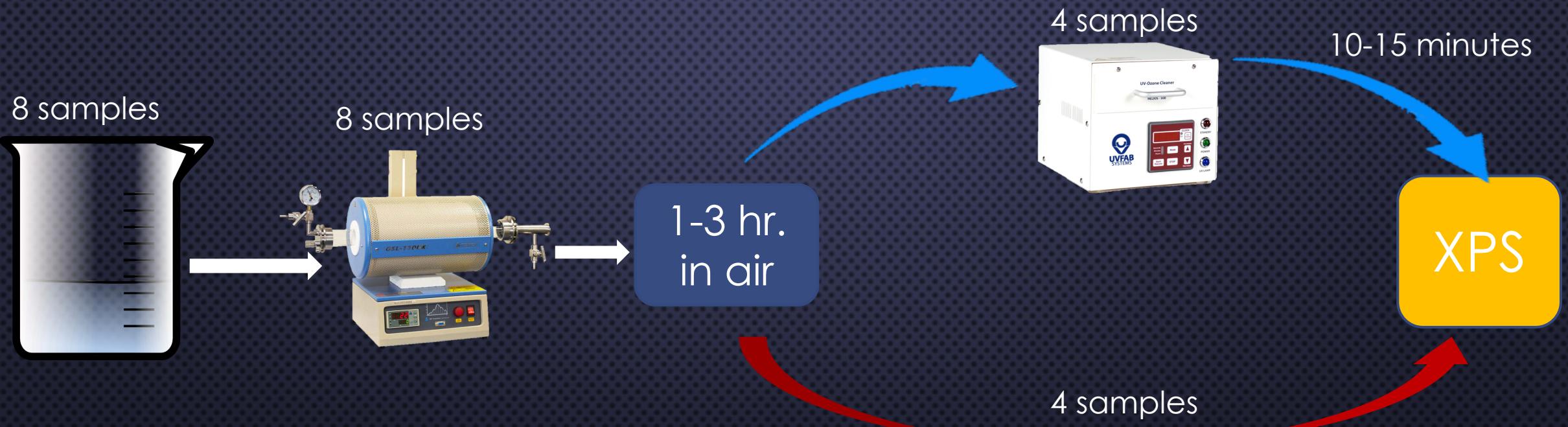
Ozone cleaning is a promising ex-situ method

- Procedure can be completed in 15 minutes
- Compact systems are available

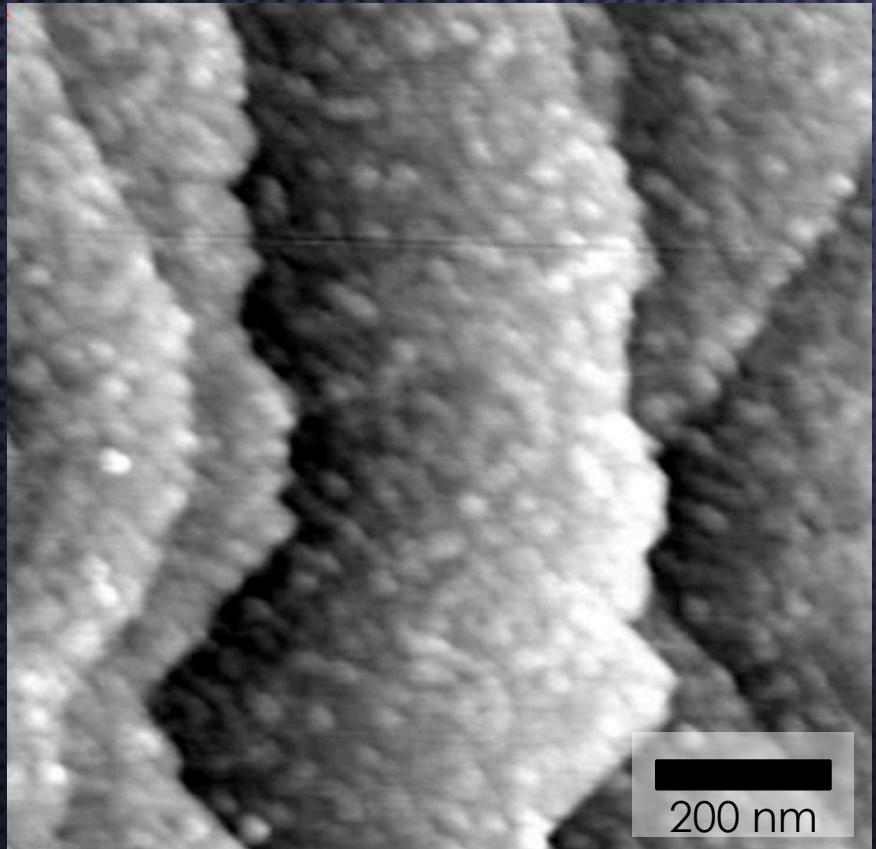
UVFAB Helios-500



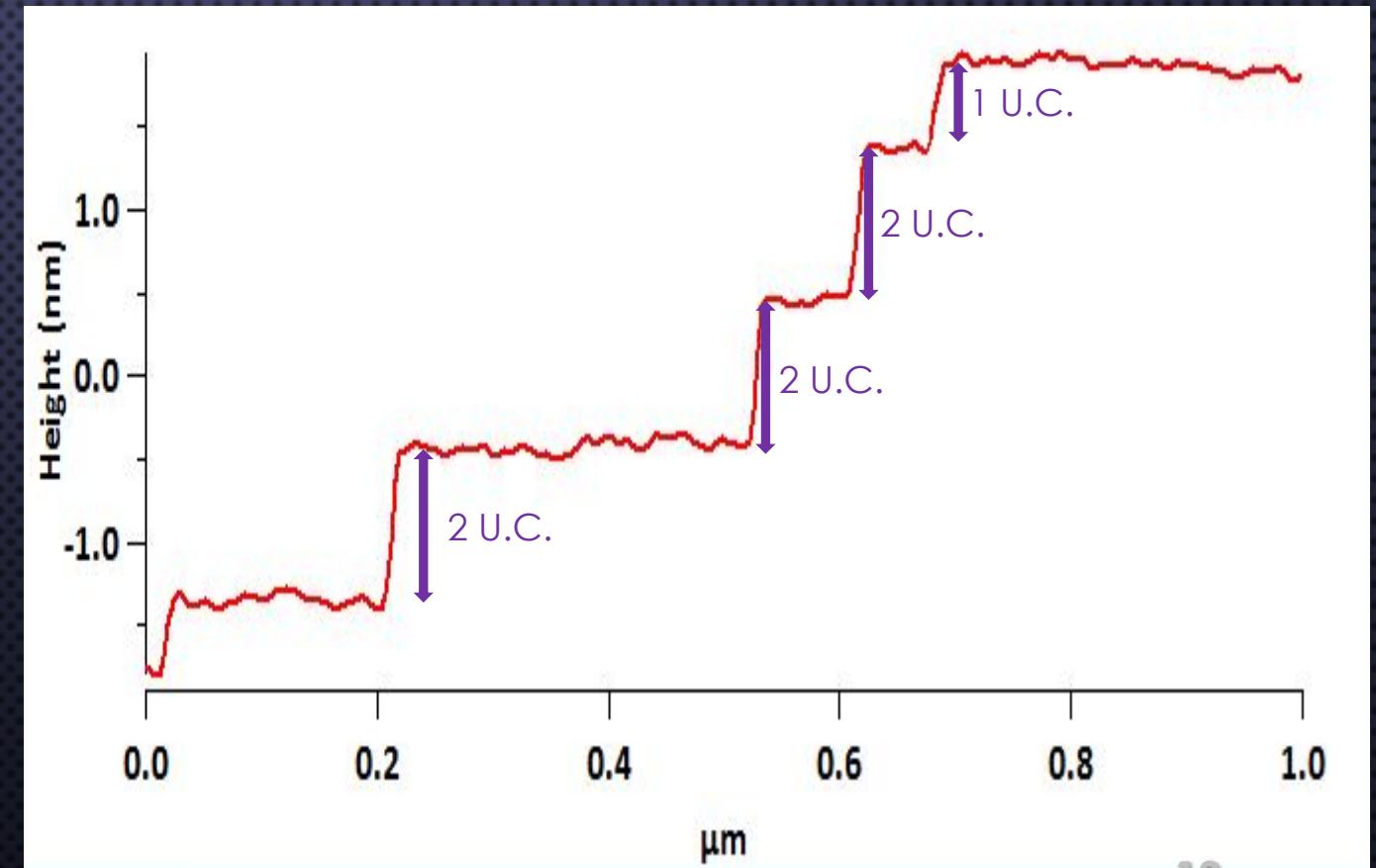
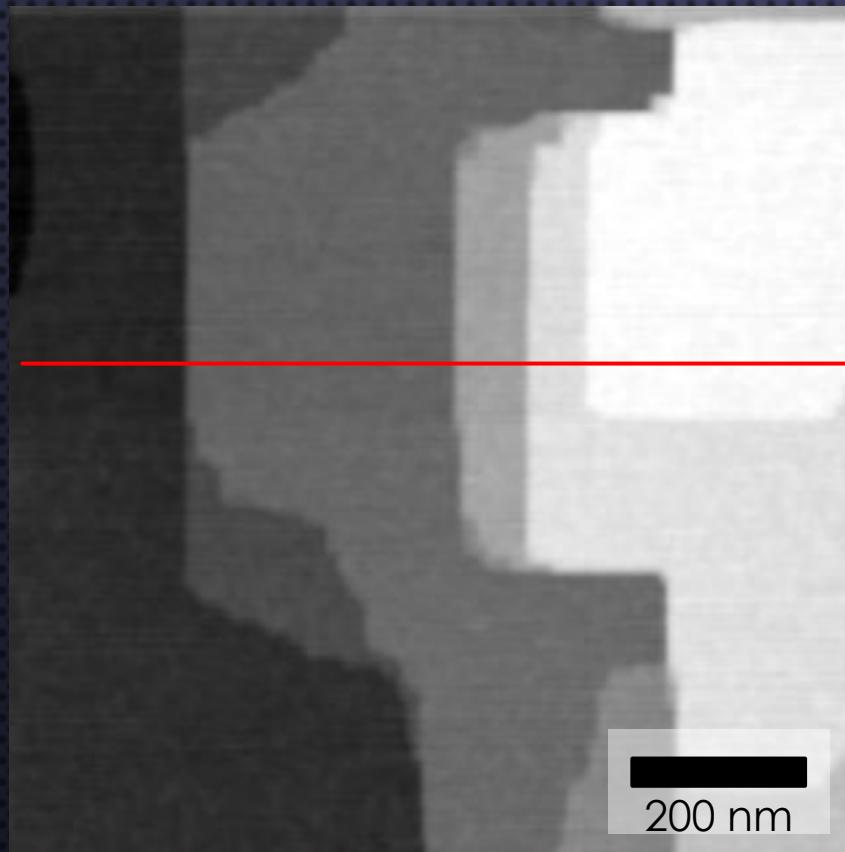
Investigation Procedure



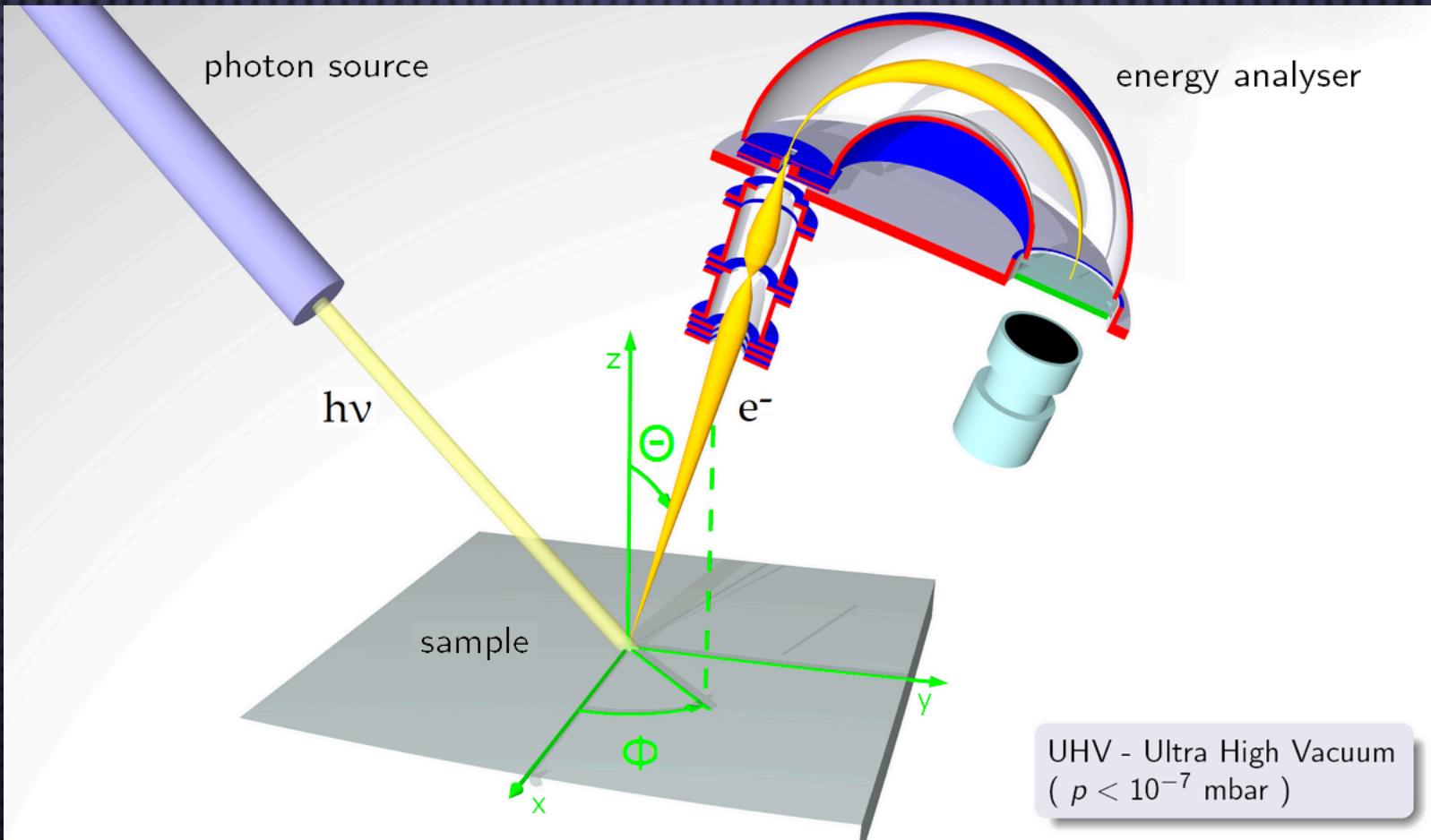
Atomic force microscopy (AFM) can detect surface roughness



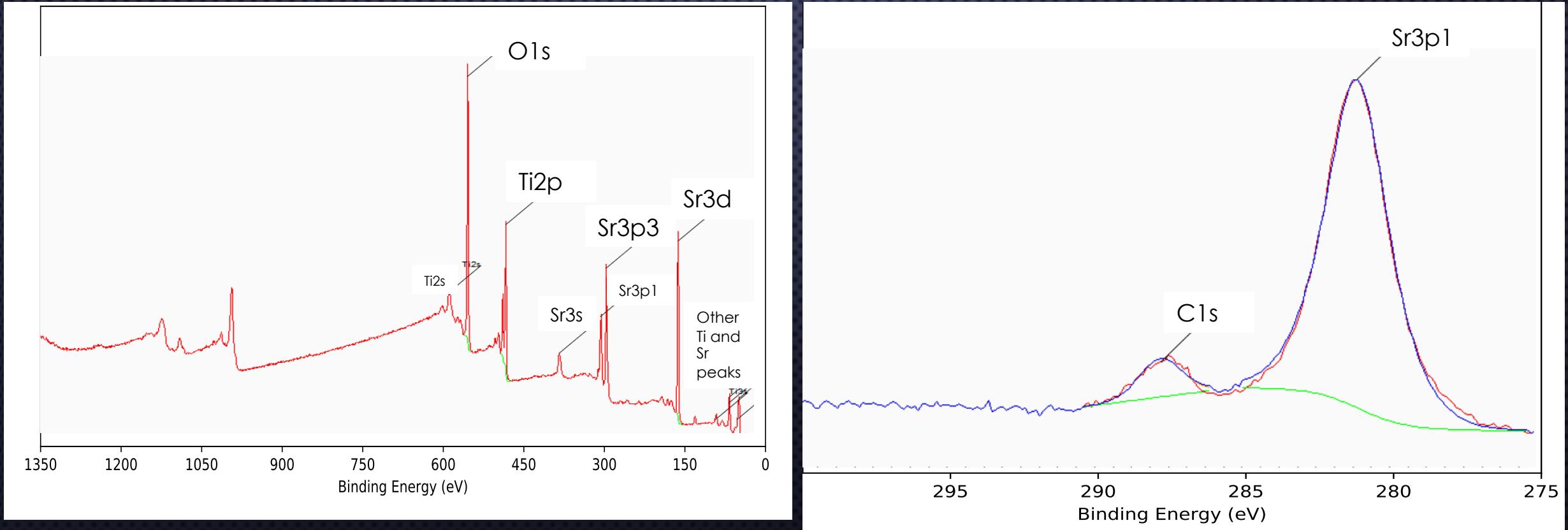
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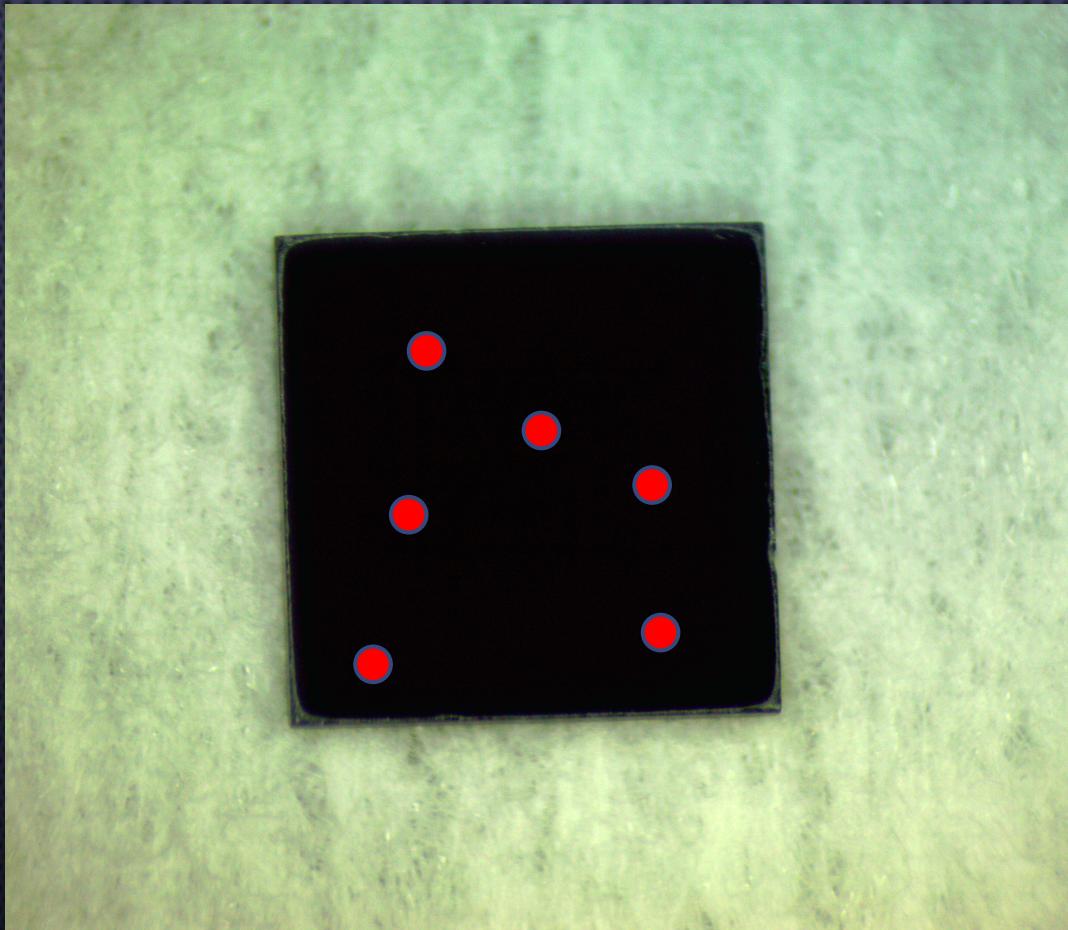
XPS is a surface-sensitive analysis technique



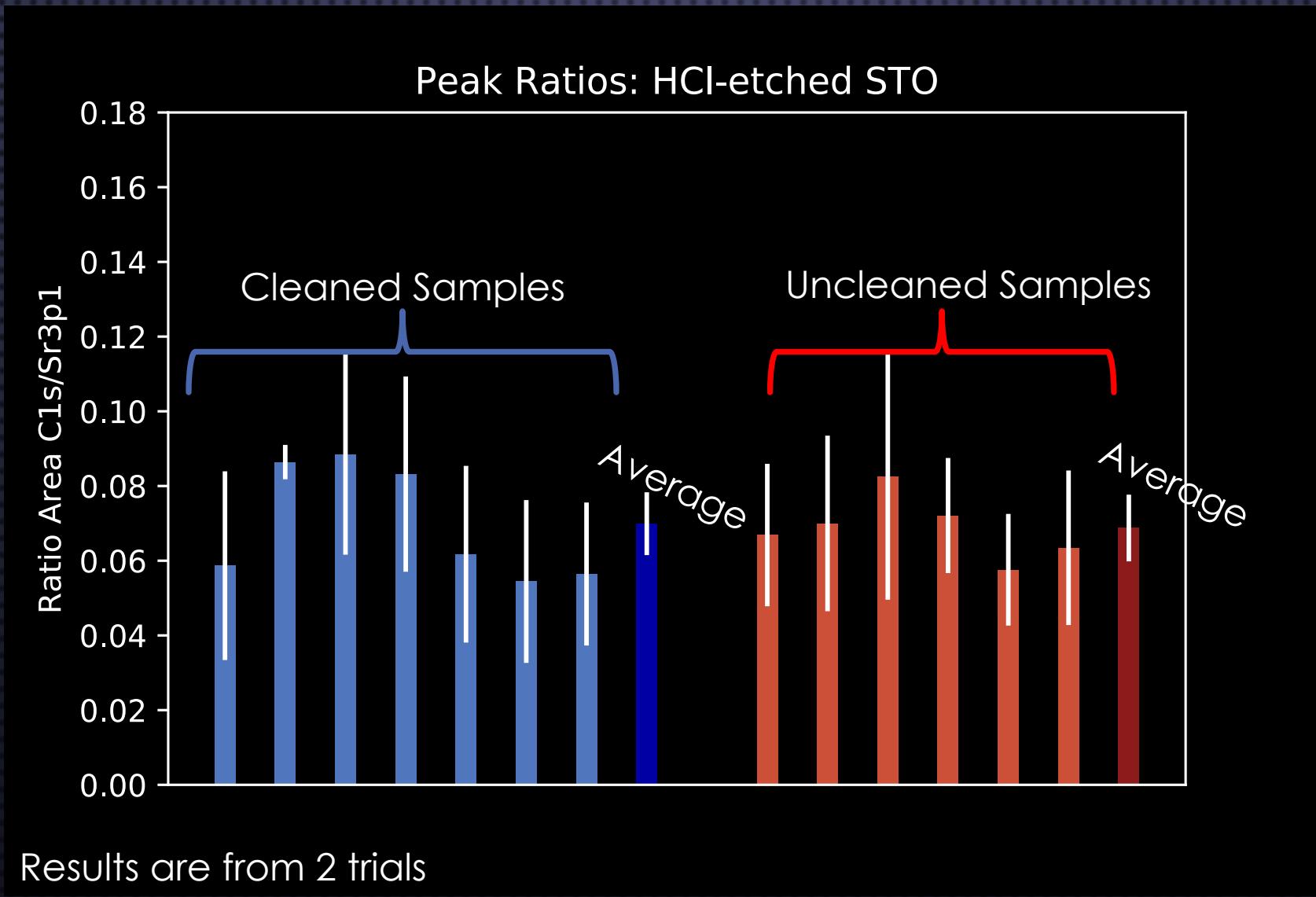
XPS can detect carbon contamination



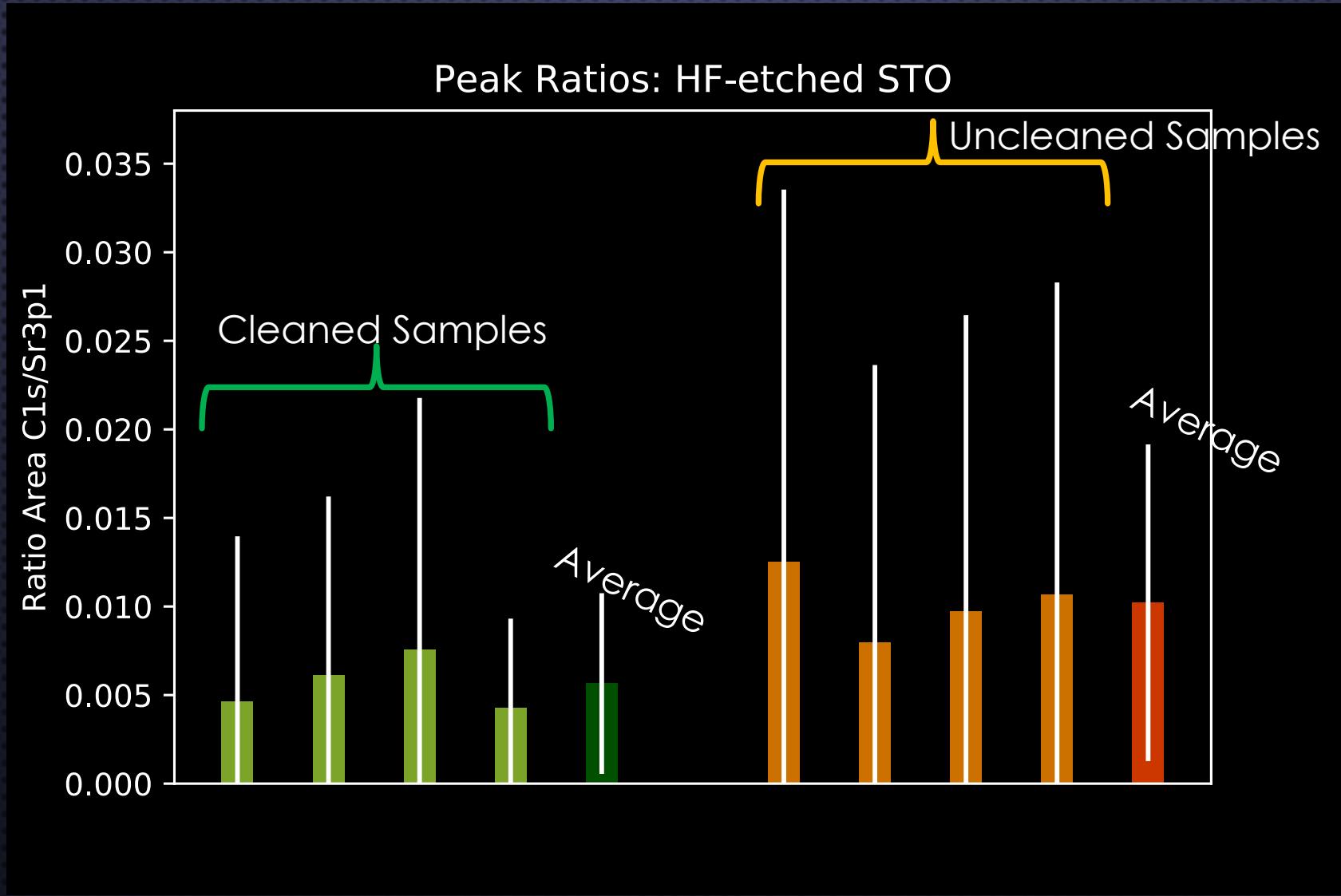
XPS scans are taken at multiple points



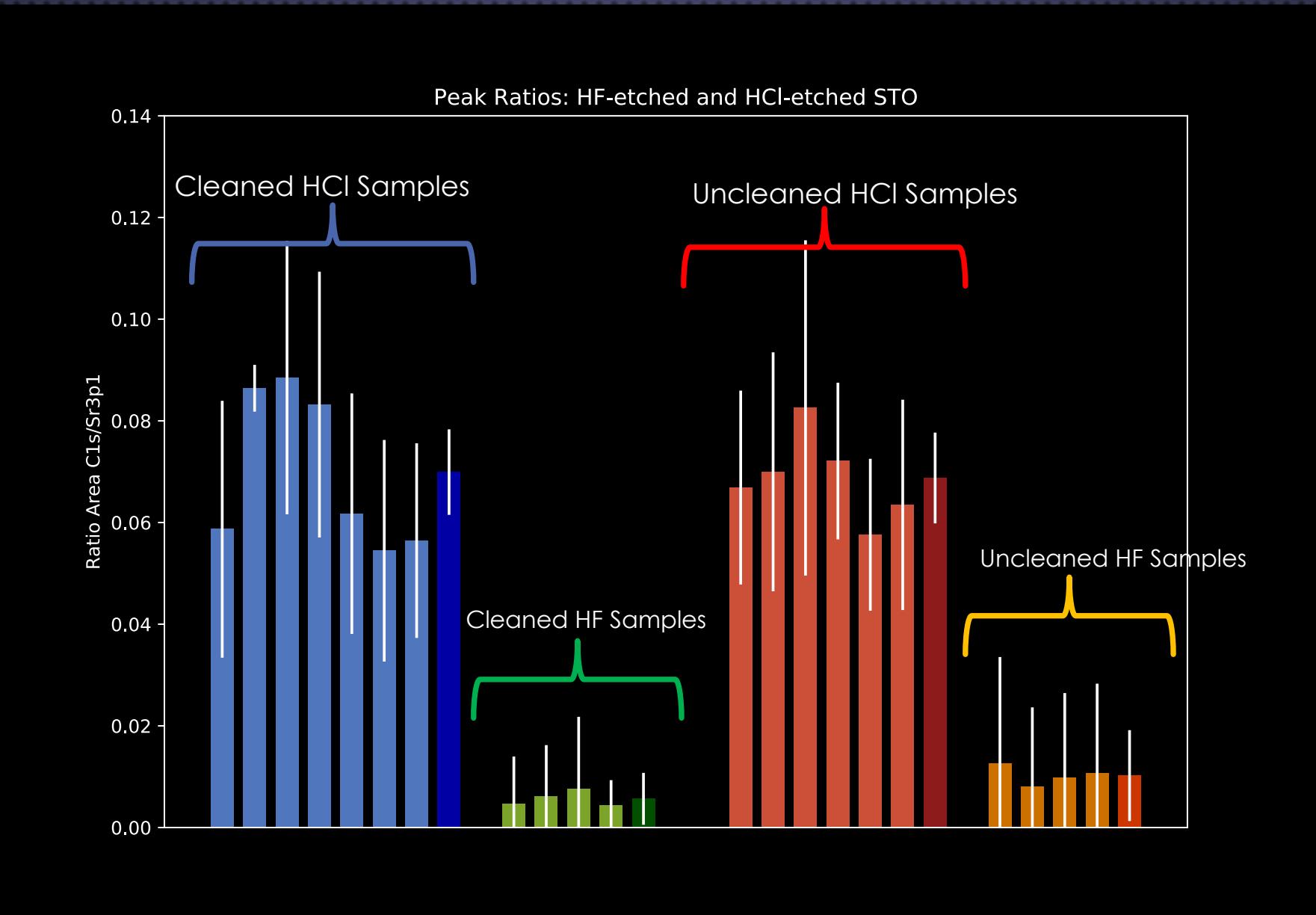
HCl-etched samples: ozone cleaning is ineffective



HF-etched samples: no significant carbon reduction



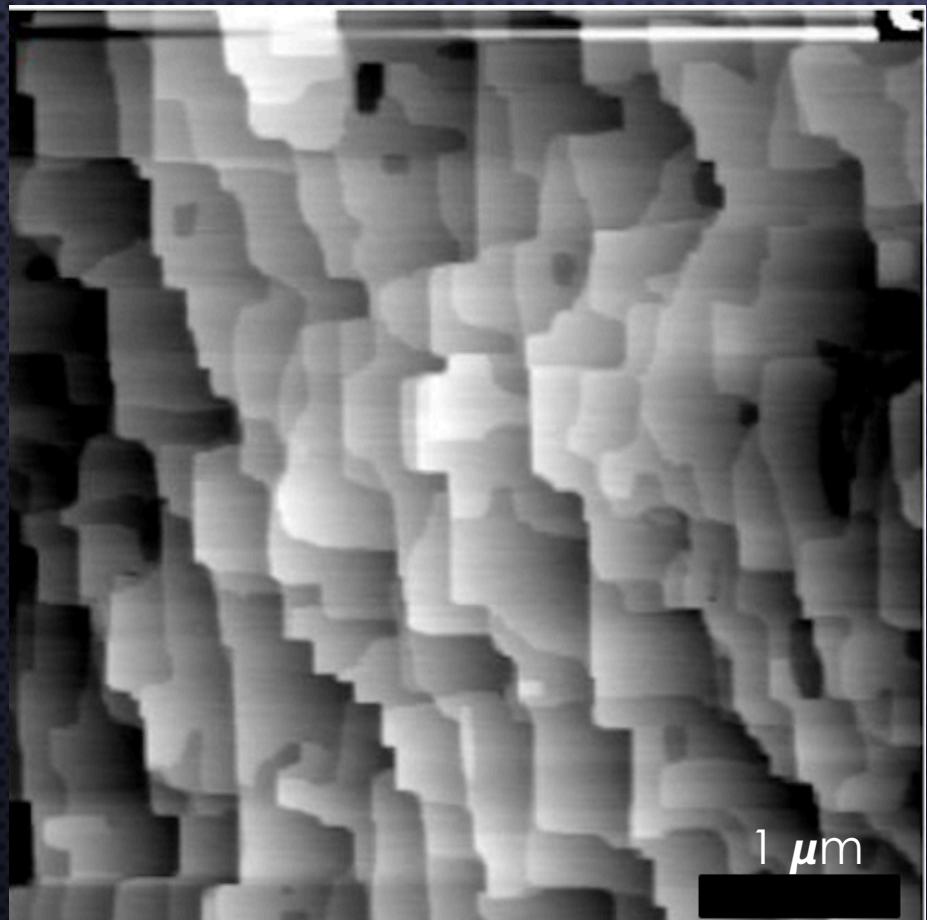
HF-etched samples much cleaner than HCl-prepared samples



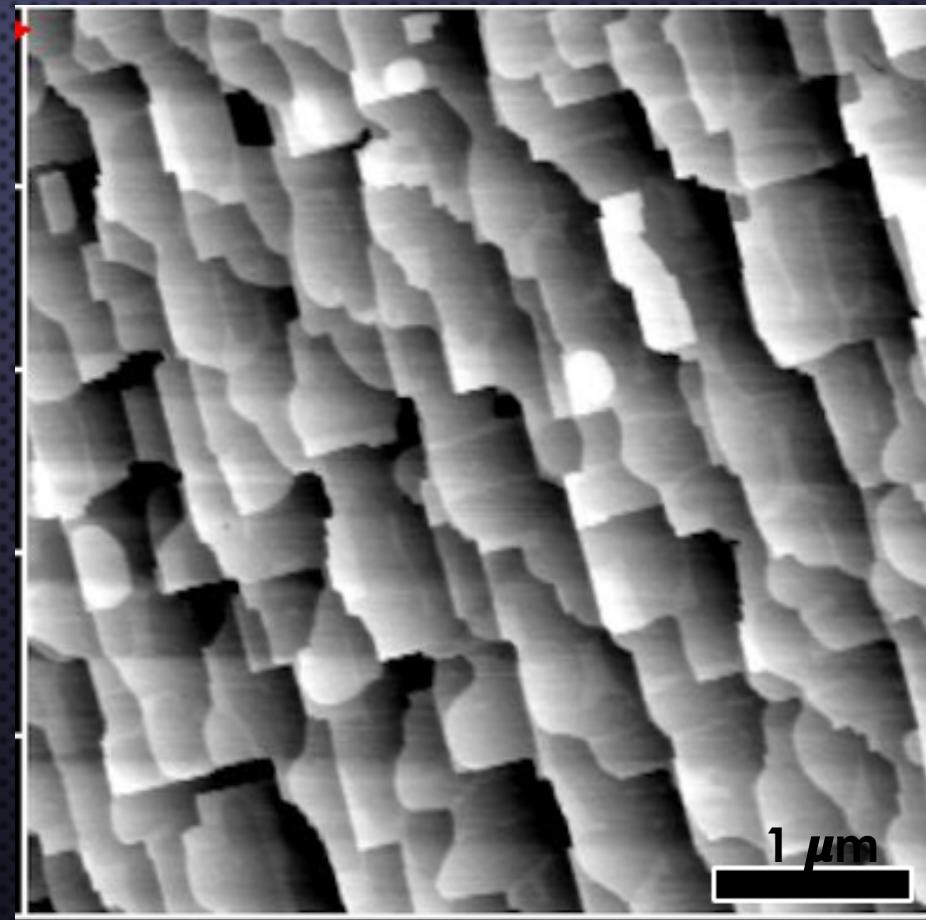
Conclusion and Recommendation

- Ozone cleaning, while not harmful, is ineffective as a final post-annealing cleaning step
- HF-etched STO samples were significantly cleaner than HCl-etched STO samples

AFM: HCl and HF



HF Preparation



HCl Preparation

Sr/Ti Ratios for HCl and HF-etched samples

