In-Situ Plasma Processing of SRF Cavities

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The Collaborators

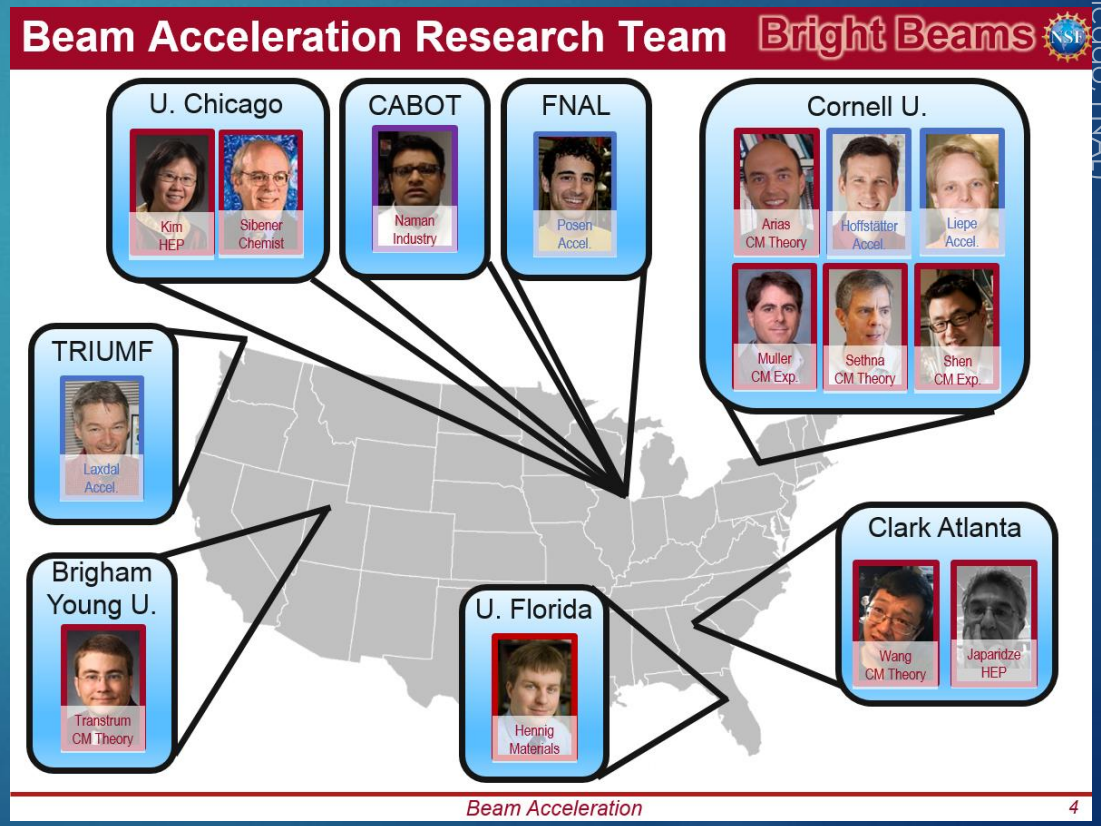
DOE-BES LCLS-II Initiative

OAK RIDGE National Laboratory

Fermilab

SLAC NATIONAL ACCELERATOR LABORATORY

Center for Bright Beams (NSF)



Field Emitters

B. Barber (UChicago, FNAL)
10/12/2016

- Tunneling of electrons out of surface
- Enhanced emission due to local field enhancements is problematic
  - Density of emitters dependent on cavity preparation technique
  - Potentially increased during accidental exposures
  - Increased current from electron emission increases refrigeration costs
- Emission onset gradient determined by both emitter and local conditions

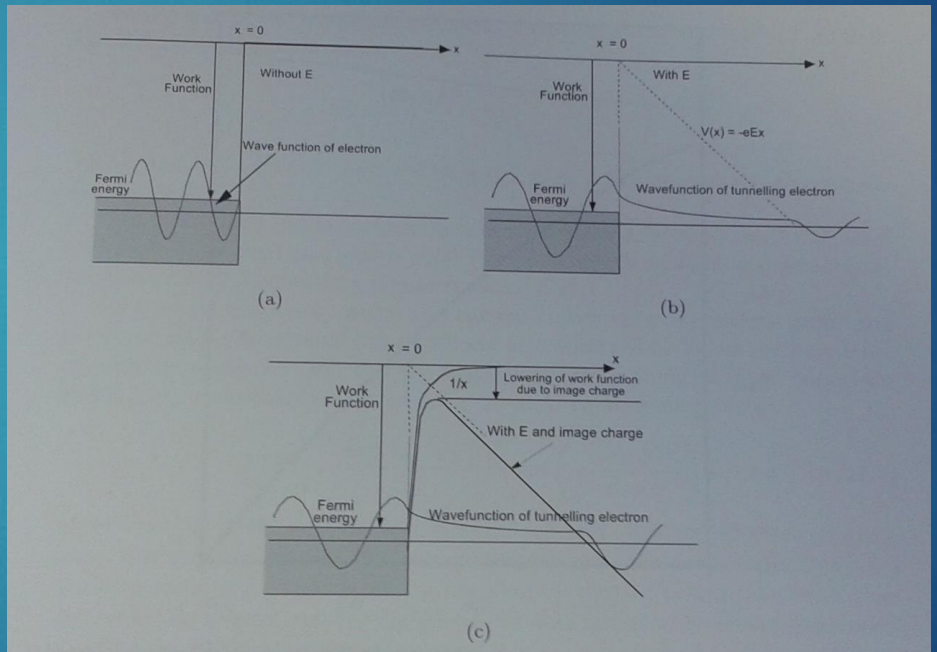


Figure 12.3: (a) Electrostatic potential at a metal surface. (b) With an applied field, electrons can tunnel from the metal into the vacuum because the barrier is lower. (c) Effect of image charge on the potential.

Padamasee, RF Superconductivity for Accelerators, 2nd Edition

Motivation: Why Plasma Cleaning

- Currently, recovering cavity performance has few options
  - Helium Bombardment
  - Conditioning
  - Reprocess the Cavity
    - Requires removing the cavity from cryogenics support
    - Very Expensive
- Plasma cleaning should be simple as an in situ technique
  - Cavity already designed to store RF power
  - Minor cryomodule design modifications should allow the in situ cleaning

Plasma Cleaning

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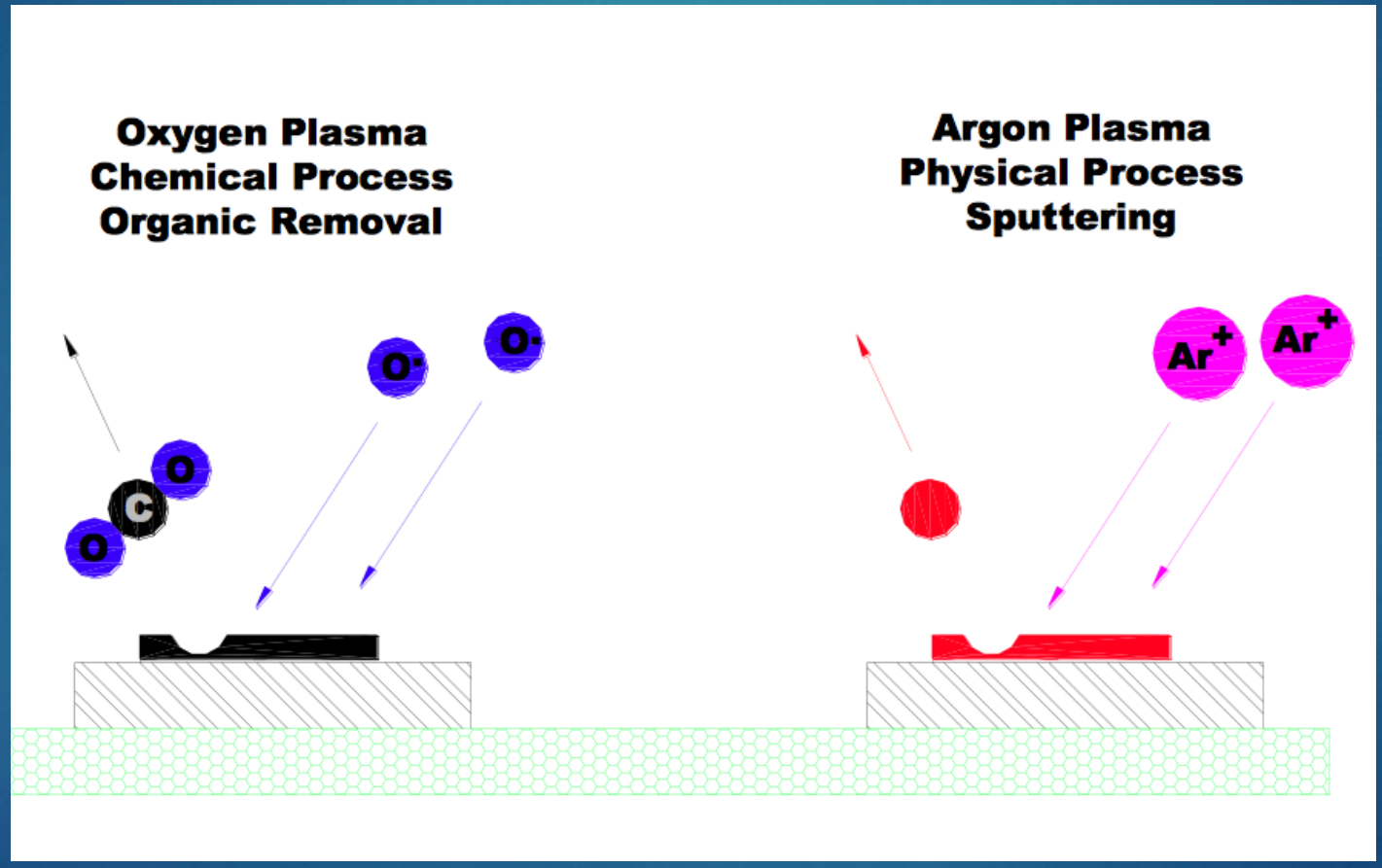
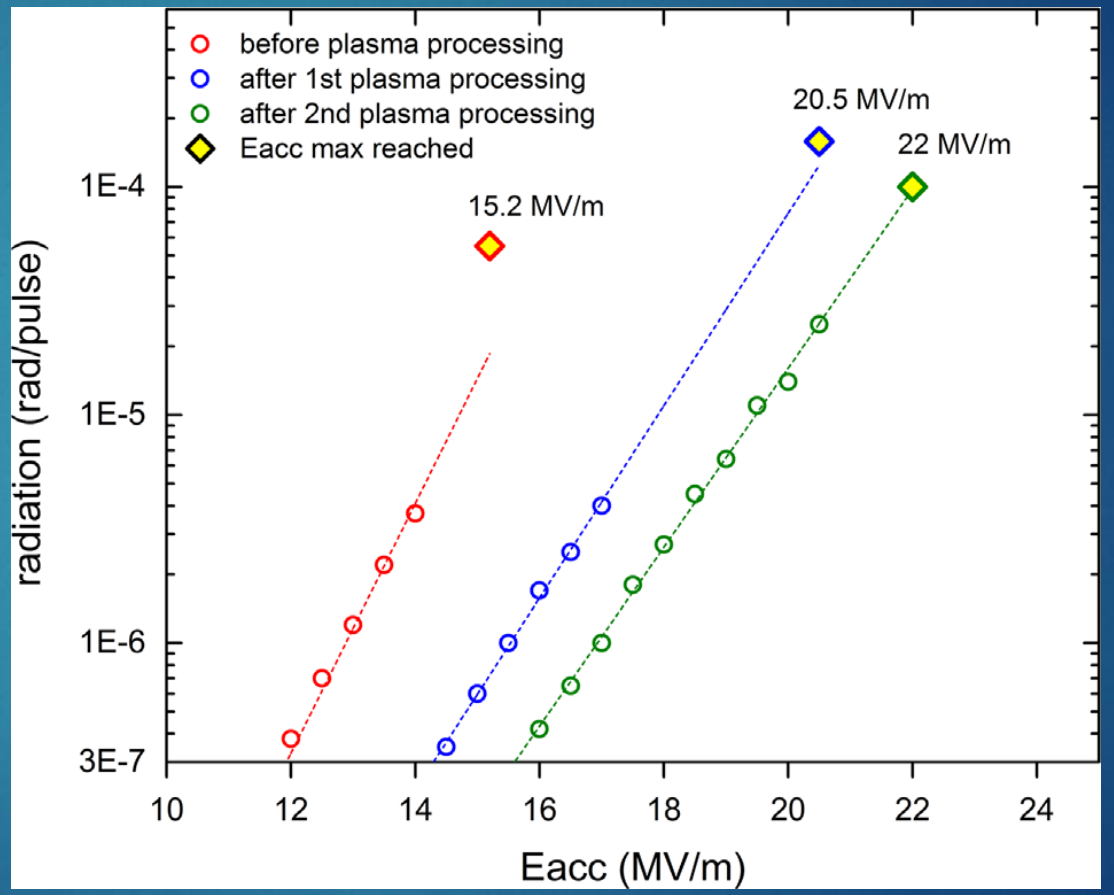


Proof of Concept (ORNL)

- Has been implemented on the SNS beamline
  - Treat during accelerator scheduled maintenance periods
  - Most treated cavities have shown some level of improvement



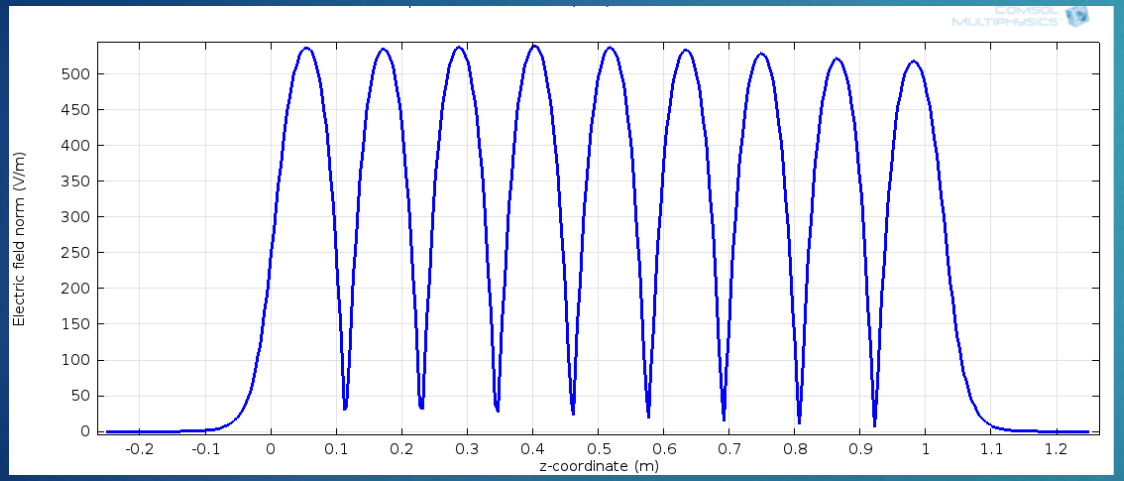
M. Doleans et al. Nuclear Instruments and Methods in Physics Research A 812 (2016) 50– 59

Extending Plasma Cleaning

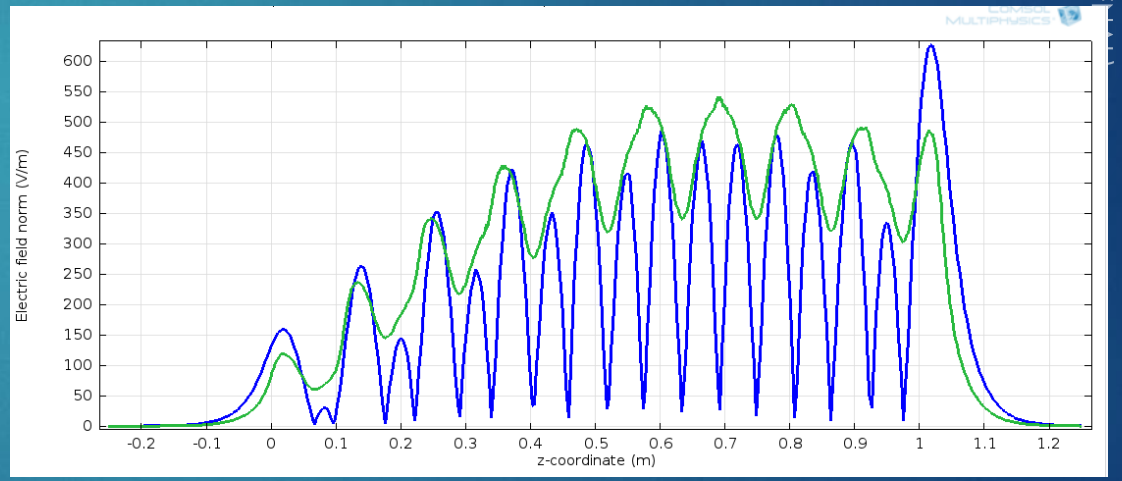
- Currently use 1st passband
  - Plasma most dense at the equator of the cavity
  - Extension: Can we use other cavity resonances to prioritize the iris? (FNAL)
- Currently use an oxygen/neon plasma
  - Chemical mixture allows us cleaning without much risk of machine damage
  - Extension: Can we use a similar technique to clean particulate contamination generated during operation? (FNAL)
- Improving modelling of plasma/niobium surface interaction (SLAC)

Higher Order Passbands (P. Berrutti)

1st Passband

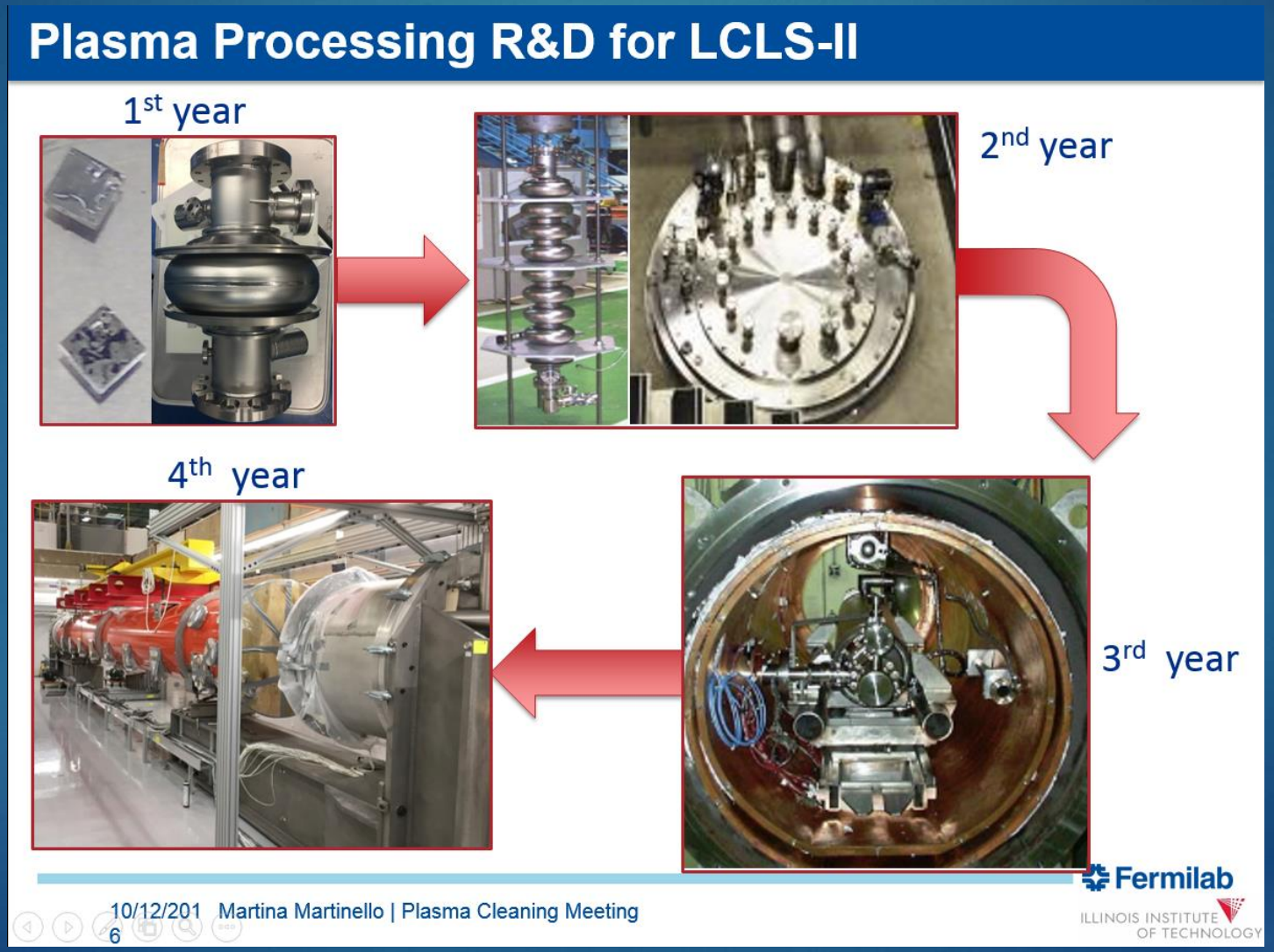


Higher Order Passbands



Higher harmonics can potentially move the peaks in the electric field from the equator to near the irises of the cavity.

FNAL 4-Year Plan



Pritzker Nanofabrication Facility at the University of Chicago

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Sample Tests @ PNF at U.Chicago

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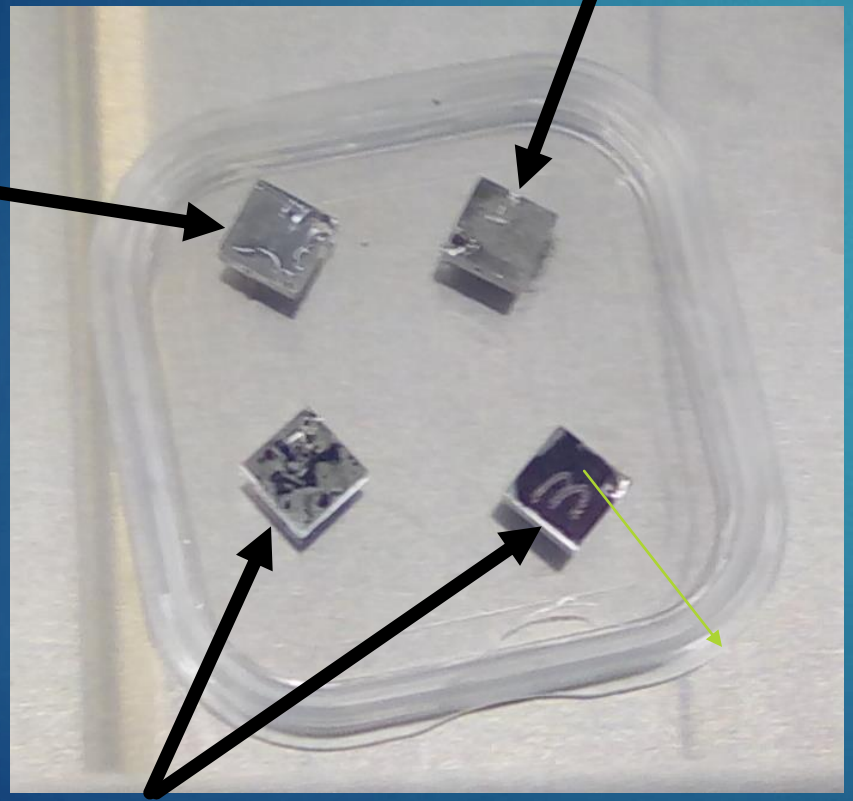
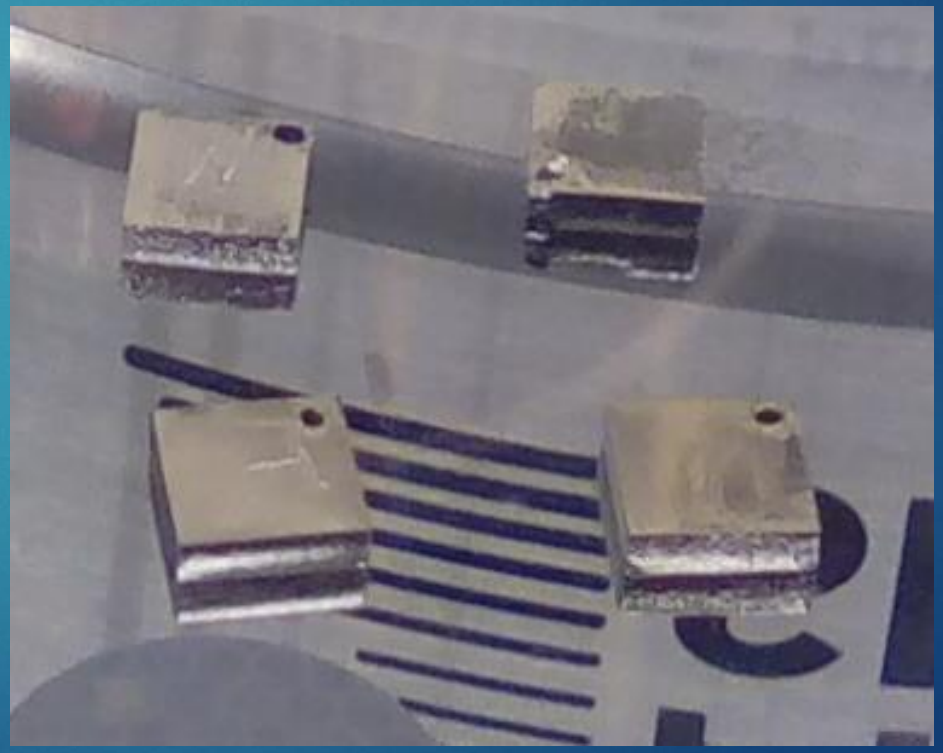
10/12/2016

Pre-Cleaning



Post-Cleaning



State and Next Step

- Pure oxygen plasma tested
  - Carbon contamination (simple and complex) is removed with oxygen
  - Metallic contamination (Al, Cu, Fe) survives short pure oxygen cleaning
  - Plasma methodology should be tested
    - So far have been using an inductively coupled cleaner
    - Implemented solution will be more like an immersion cleaner
- Need to try physical cleaning
  - Should clean anything loosely adhered to the surface
  - May lead to surface geometry challenges
- Need to try alternate chemistries

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