Response to 2nd GP Review of the In-Situ LAPPD

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for the Chicago PSEC Team

Timeline

- December 2016 - 2nd GP Review
- January 2017 - GP Committee sends recommendations to the Chicago team (thank you!)
- May 2017 - Chicago team writes response, but waits for significant progress to send it out
- March 2018 – Chicago team updates the response

What took us so long?

That "one last thing" that we'd like to finish

- Move to the PRC and re-building new lab
- Building and commissioning Margherita-2
- Unexpected issues with ceramic tiles
  - worked with 4 vendors to identify best quality
  - major setback due to bad coatings of precious parts
  - leaky brazed Cu tubes and pins
  - leaks in the indium seal: we found that our recipe developed on glass may need adjustments
- Other issues solved now but difficult at the time
  - CTE mismatch between ceramic and fused silica
  - resistive buttons don't work after Cs-ation
  - indium seems to form In-Cs-X flakes in the tile

"Simple Experiments" Recommended by GP

1. Characterize current Sb window depositions (are the current samples of sufficient quality e.g. can the oxidation acquired in transport be handled with in situ thermal cycling?)

We have done XPS studies of the Sb layer as received from vendor (air exposed for 3 months)

We haven't gotten to the post-bake characterization

Sb XPS Studies

Sb test coupon:
fused silica microscope slide with
200nm of NiCr + 200nm of Cu + 10nm of Sb

UChicago XPS details

(XPS expert support by Alexander Filatov at UChicago)

X-ray gun:

- 10 mA at 15 kV
- high resolution mode step size 0.1 eV
- area of the analyzed spot 300x700 mum

Ar ion beam (for depth profiling):

- beam size 6x6 mm
- beam energy 2 kV
- beam density 7.78 A/cm2

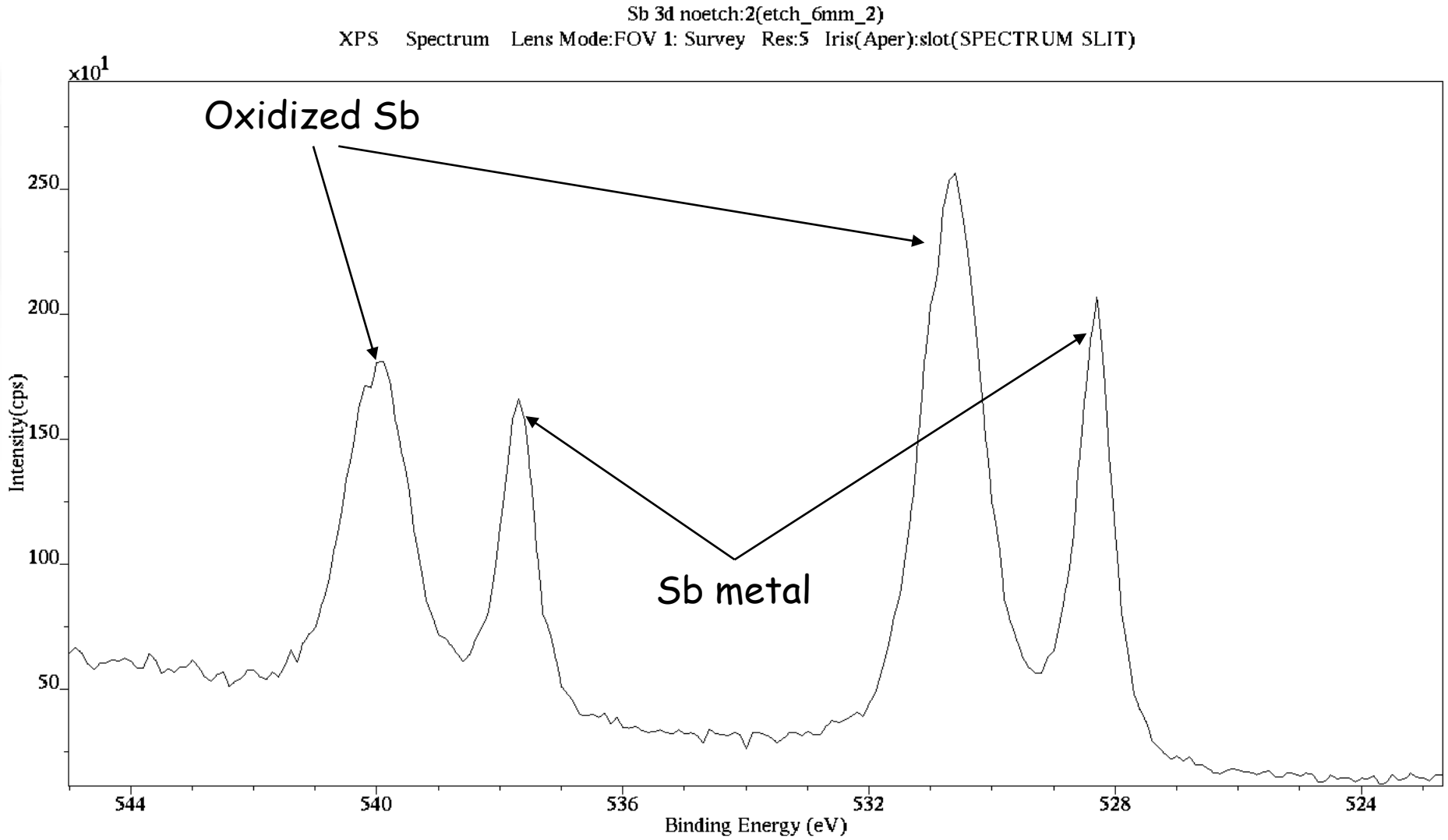
Side note on thin film coatings

- Good quality films are expert's territory
- Sb deposition in particular:
  - H.L. Clausing Inc.,
  - Bing Shi at the Argonne Thin Film Deposition Lab
  - Eileen Hahn at Fermilab
- NiCr-Cu isn't easy, but we have one more commercial vendor for that

Depth profiling was performed using 5 sec etches by the Ar ion beam.
We estimated that a 5 sec etch removes on average 0.25 nm
of the surface material.

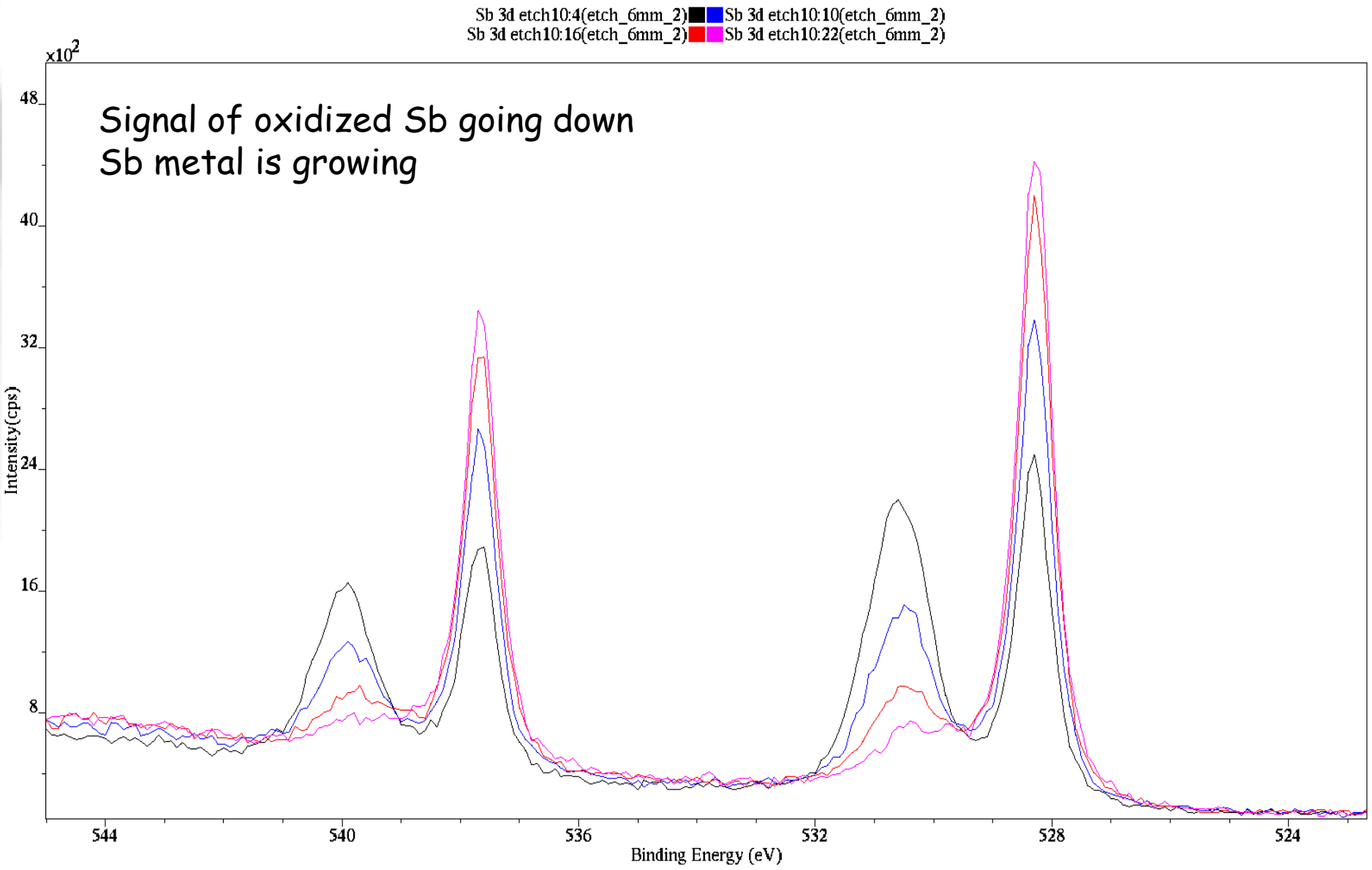
Sb XPS Studies

XPS scan before any ion etching



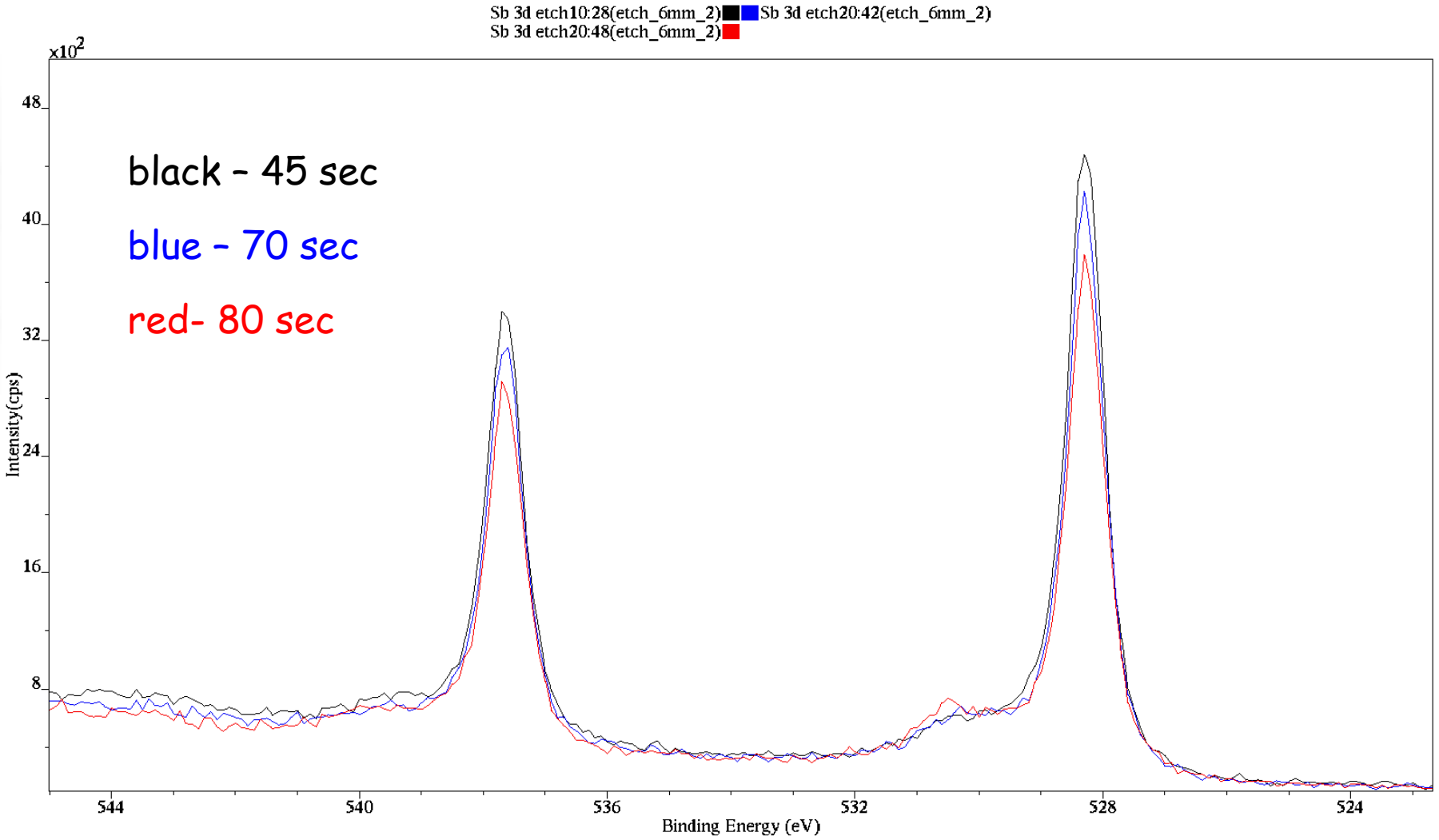
Sb XPS Studies

Intermediate scans within first 35 seconds of etching



Sb XPS Studies

After 40 seconds we see pure Sb metal (preferential sputtering of oxygen can't be excluded, but it has to be very strong)



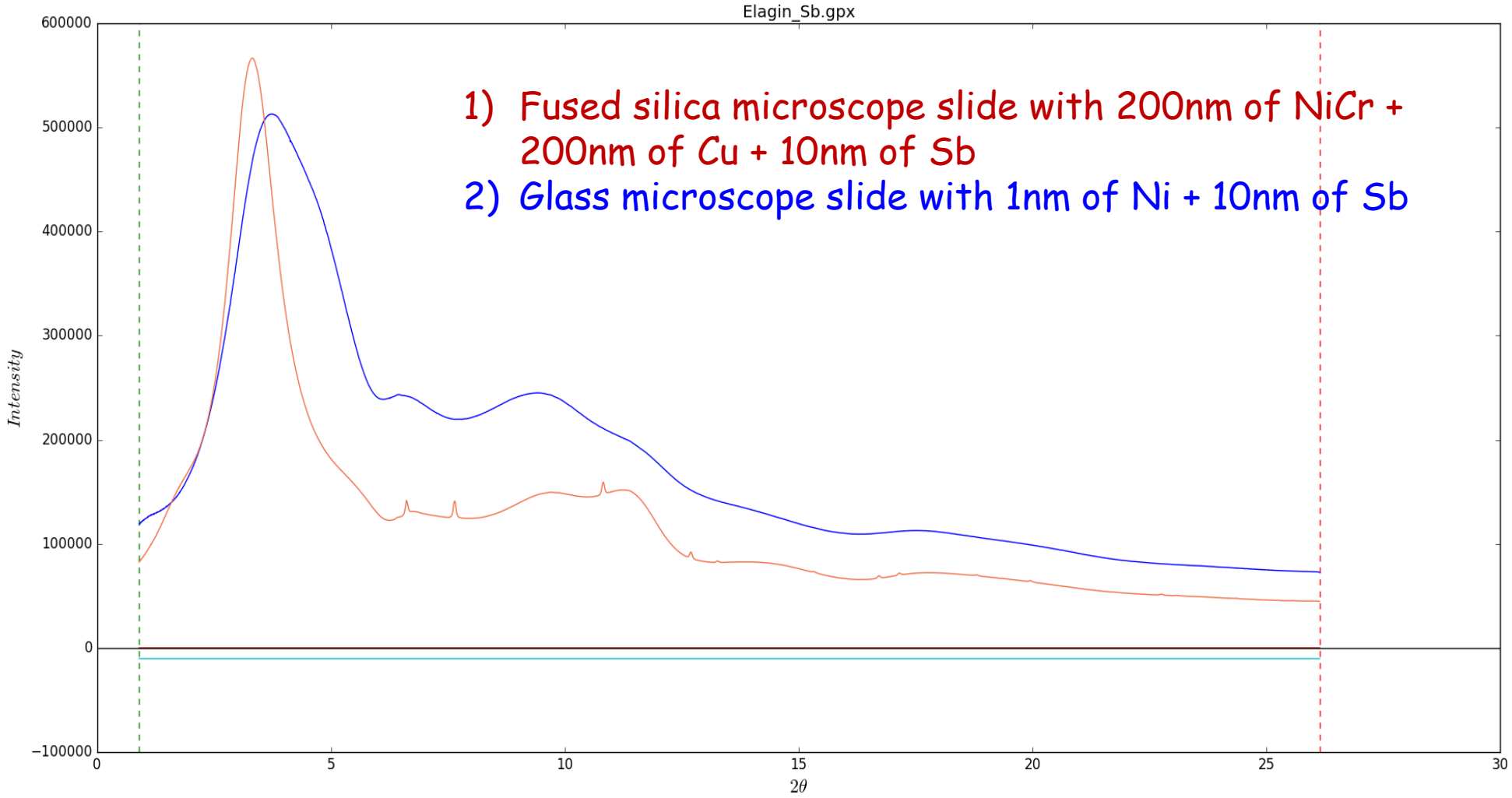
No Sb metal is seen after 200s

Assuming initial 10nm Sb thickness the average etch rate is 0.5A/sec

Therefore Sb-oxide thickness is ~40sec x 0.5A/sec = 2nm

Sb XRD Studies

See Cu crystals, but not Sb



XRD at APS 17-BM beamline:
E = 51 keV, beam spot 0.5mm, intensity 2×10^{10} ph/s
(Expert support by Andrey Yakovenko, Argonne XSD)

"Simple Experiments" Recommended by GP

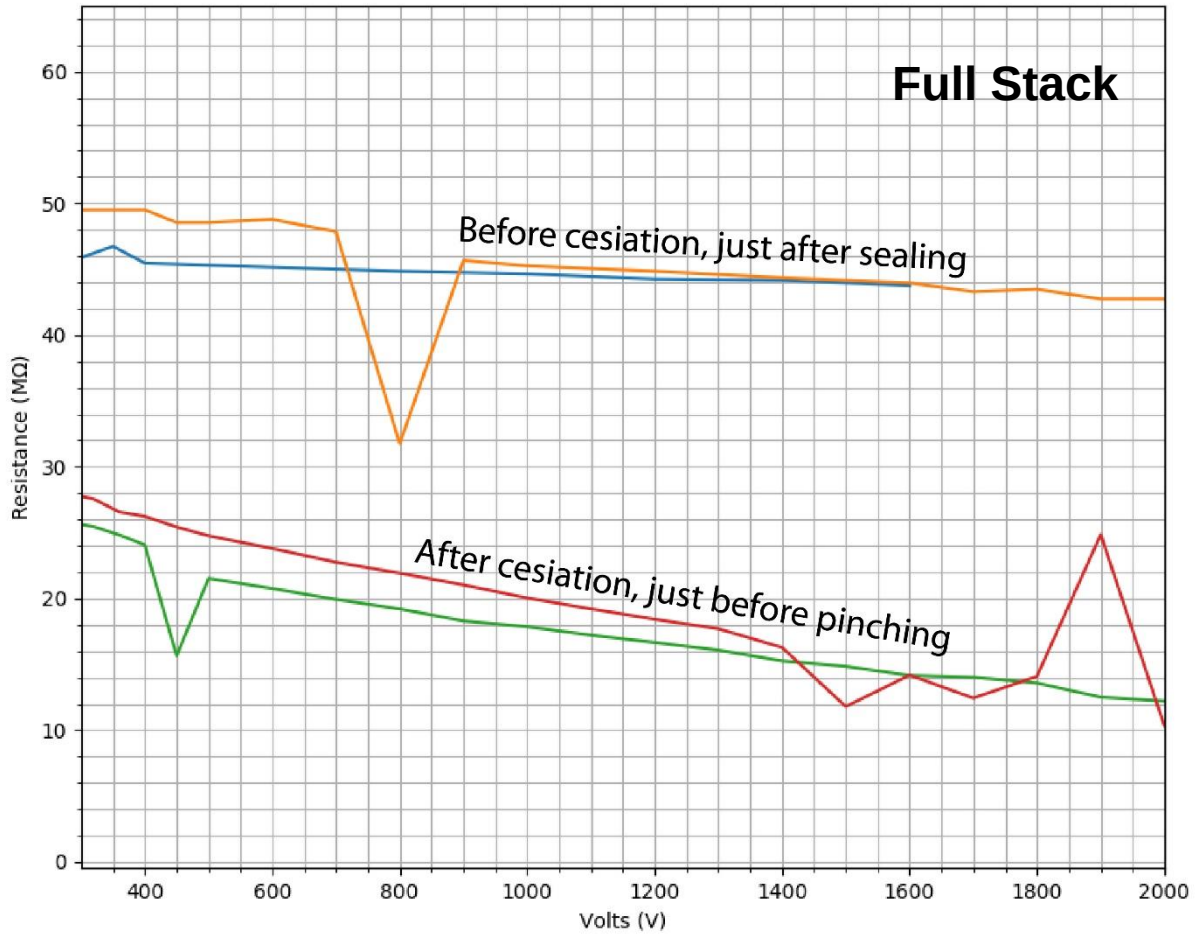
2. Trial Cs deposition (to what QE and with what uniformity over the tile?) and how selective can be? Consider doing this in an empty tile without MCP. Perhaps even in a SS vessel with similar pumping rather than the ceramic tile.

Given the ongoing seal problems we now think this may be the right move.

We have reserved time today to discuss this.

"Simple Experiments" Recommended by GP

3. What is impact on the MCP of Cesiation? Can be done independently of photocathode growth, but it should be tested to the level of Cesiation and under the conditions necessary for efficient photocathode production.



Specific Recommendations by GP

1. Calculate from first principles estimates of how much Cs is needed? At first guess here is to assume stoichiometric amounts of Cs with a ½ monolayer on the surface. How does this compare to a monolayer coverage on the channel plates and walls of the tile?

Detailed calculations by Eric are included in our written response

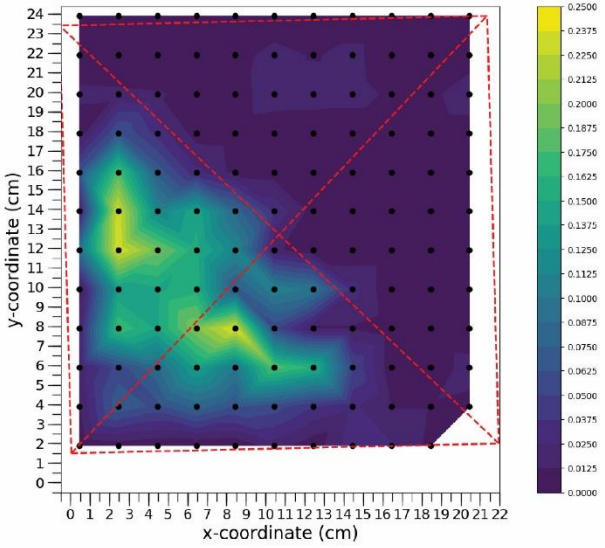
Photo-cathode takes the majority of Cs (details in Session 5)

Specific Recommendations by GP

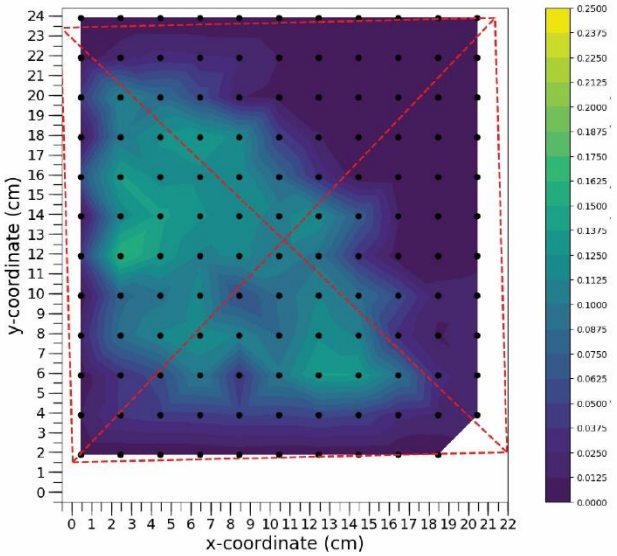
2. Instrumentation for process monitoring should be as extensive as possible, and be able to address questions such as where did the Cs end up? and is it evolving in time? and is the Cs deposition self-limiting?

- Major effort to improve instrumentation
- Continuous 2D computer-controlled monitoring of photo-response during Cs deposition
- Until leak is solved it's not clean enough to answer

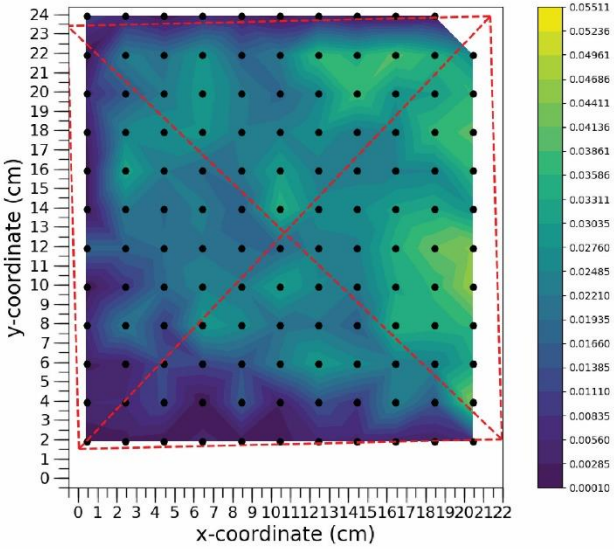
After 24 hours of cesiation



After 48 hours of cesiation



Increase j-tube from 145C-190C, cesiate for 2 hours then close source, and sit for 50 hours



Specific Recommendations by GP

3. To reiterate, suggest limiting complexity and evaluate along the way:

a. Cesiation of existing Sb sputtered window in Gen II tile tubulation and evaluate QE, uniformity

Yes- we are making detailed photo-response maps now. We have a lot more of this to do with a completely sealed tile

b. Characterization of the Springer process (both on simple test samples, and then in LAPPD tile context)

We haven't got to this with KsCs yet- need more Cs trials.

GP Concluding Remark

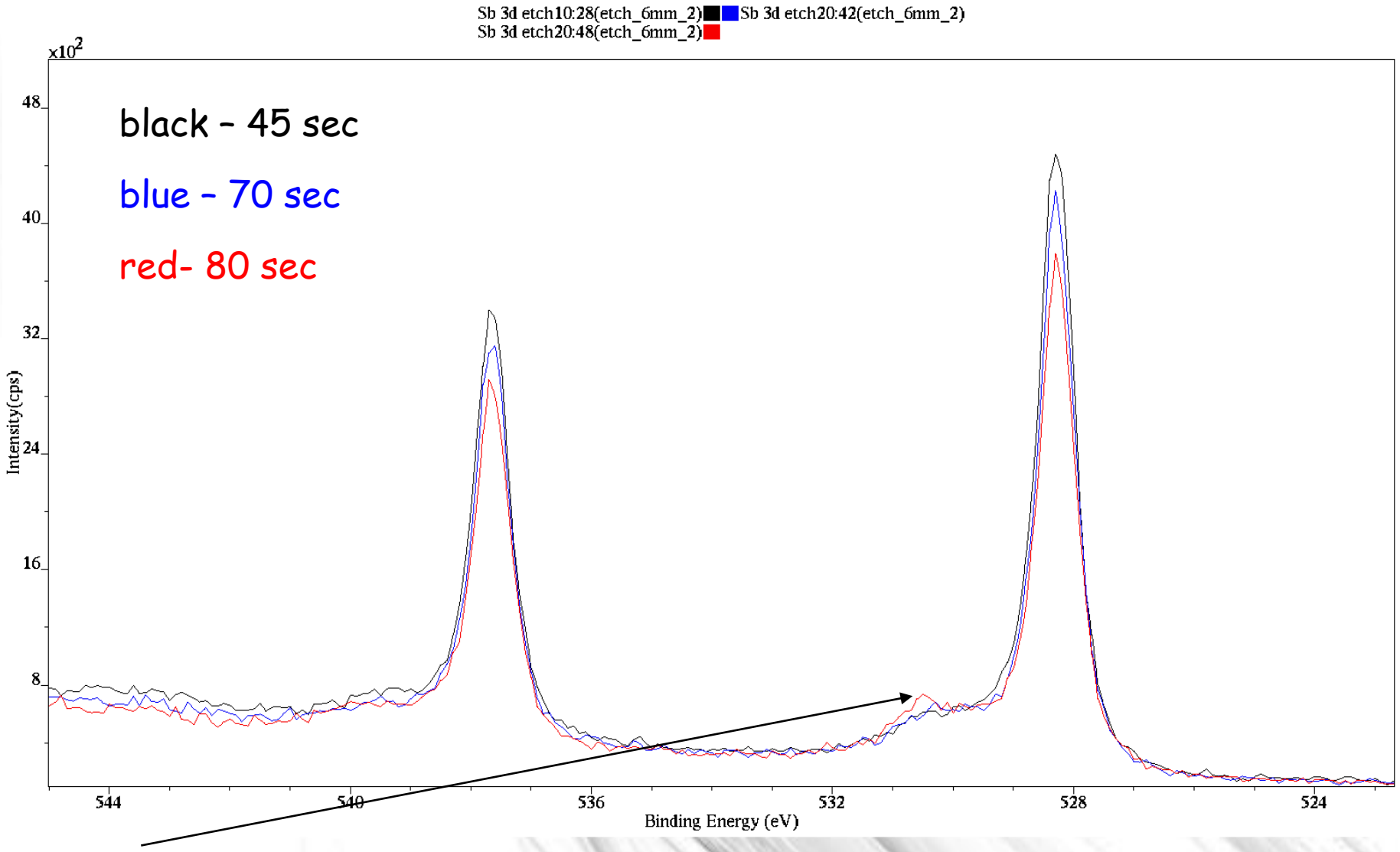
Independent of any efforts of formal collaboration, members of the committee encourage measurements and observations to be shared regularly, as well as soliciting opinions on details of process parameters to try (temperatures, times, sequence, etc.). It seems plausible that these "critical decision point" steps above could be addressed in a 1 year program. However to confirm this meaningfully involves resource-loaded scheduling (including manpower requirements for currently funded efforts on topics such as validating the "inside out" readout approach), and therefore beyond the scope of this in-situ review.

Yes

Back-up

Sb XPS Studies

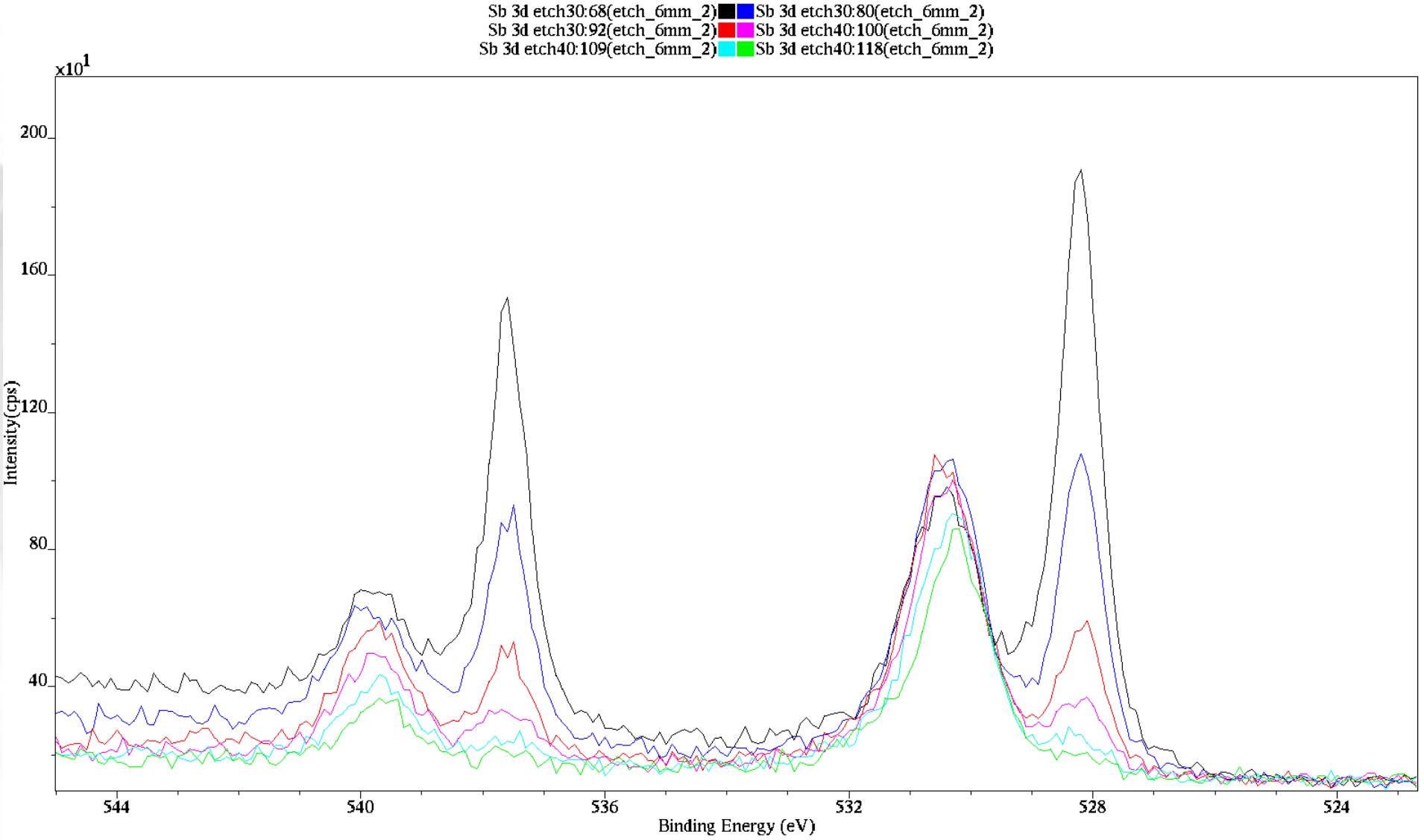
Between 45 seconds and 80 seconds we see pure Sb metal (preferential sputtering of oxygen can't be excluded, but it has to be very strong)



Peak at 530.4 eV belongs to Auger signals of a Cu metal underlayer

Sb XPS Studies

Continue ion etch: Sb metal goes down, Auger Cu goes up



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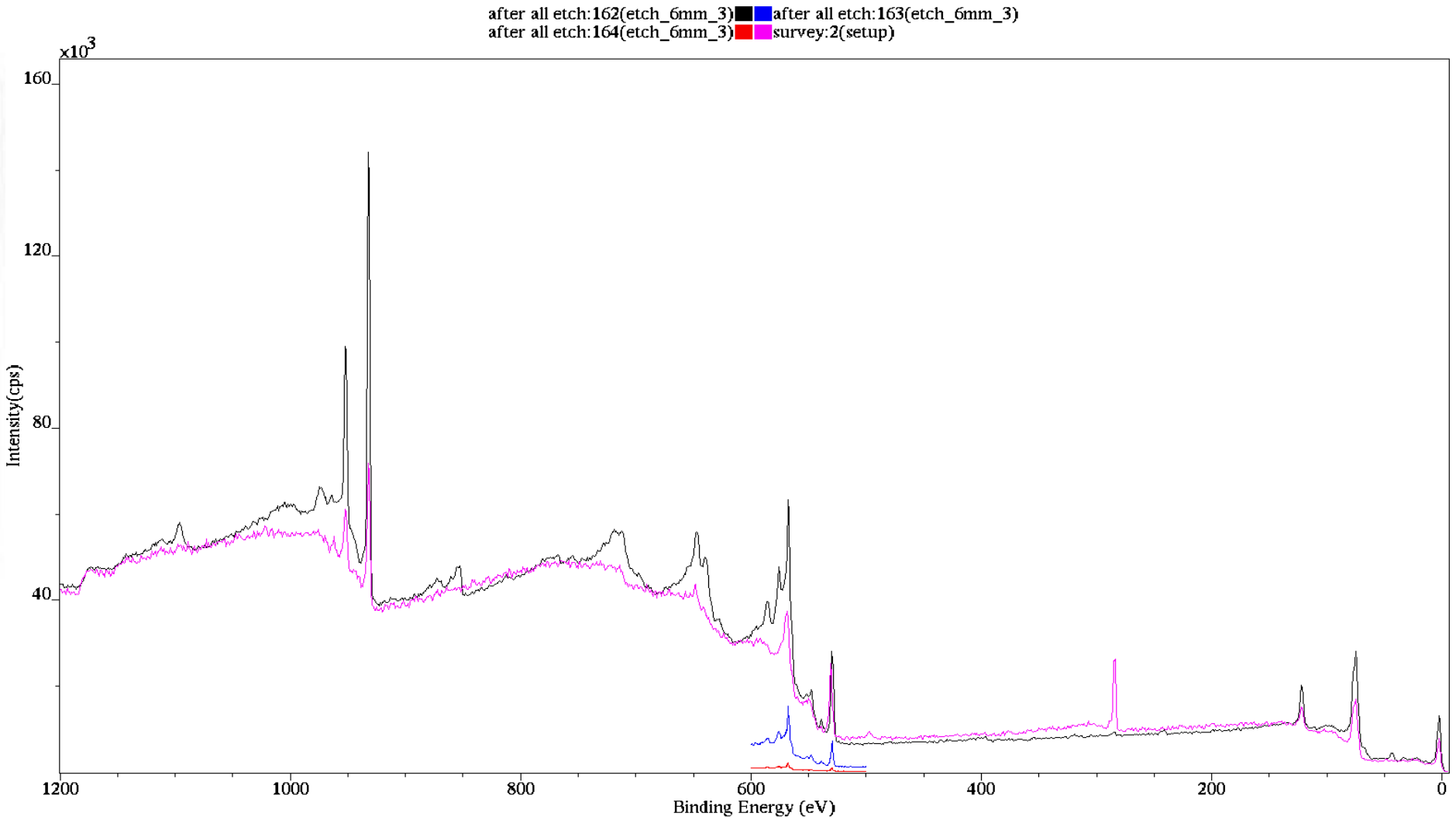
Sb XPS Studies

Assigning the ~530eV and 540eV peaks to Auger Cu



Sb XPS Studies

Assigning the ~530eV and 540eV peaks to Auger Cu