NSTX-U

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Lithium wetting of stainless steel for plasma facing components

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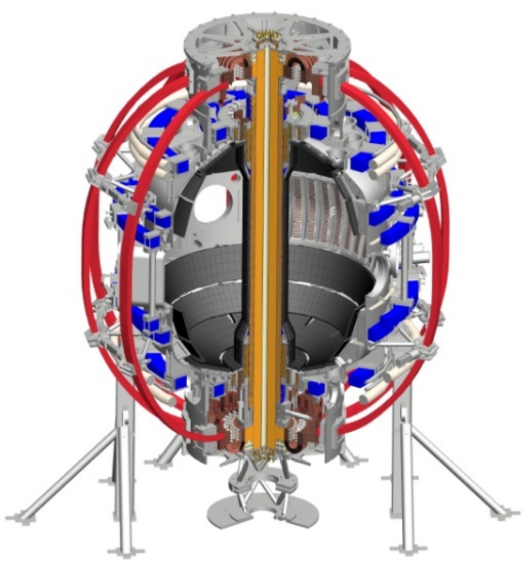
56th Annual Meeting of the APS DPP
New Orleans, Louisiana
October 27-31, 2014



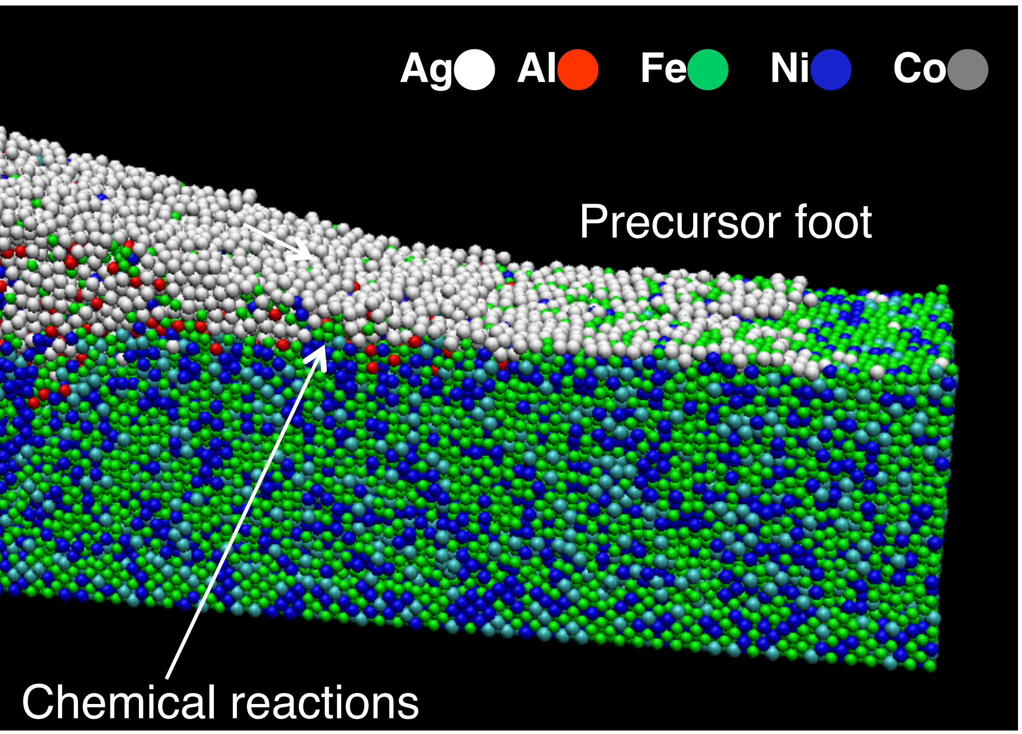
Motivation

- Liquid metals avoid issues with neutron damage, erosion, melting, brittleness, thermal fatigue of plasma facing materials
- Lithium has enhanced plasma performance on many tokamaks
- Understanding liquid metal / container wetting is important for design of liquid metal plasma facing components.
- Fundamental relation between atomistic surface diffusion and macroscopic wetting is important scientific topic.

Chemical bonds control Li wetting

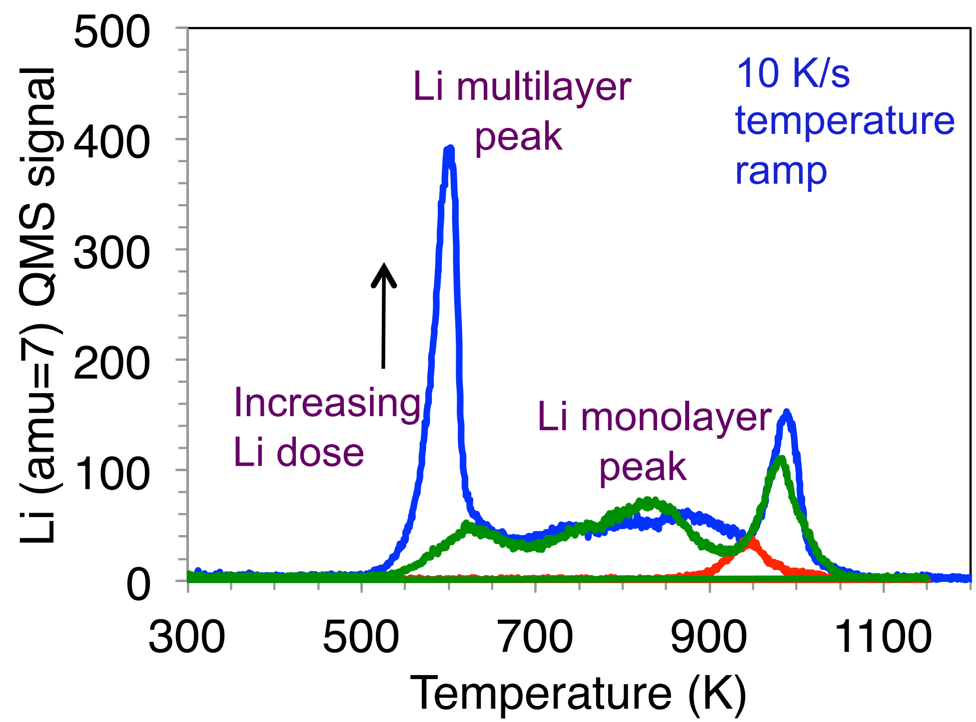
Molecular dynamics calculations can reveal wetting process in atomistic detail.

MD simulation of brazing AgAu on Fe alloy



M. Chandross, "*Simulations of Active Brazing,*" Welding Journal, 2014, in press.

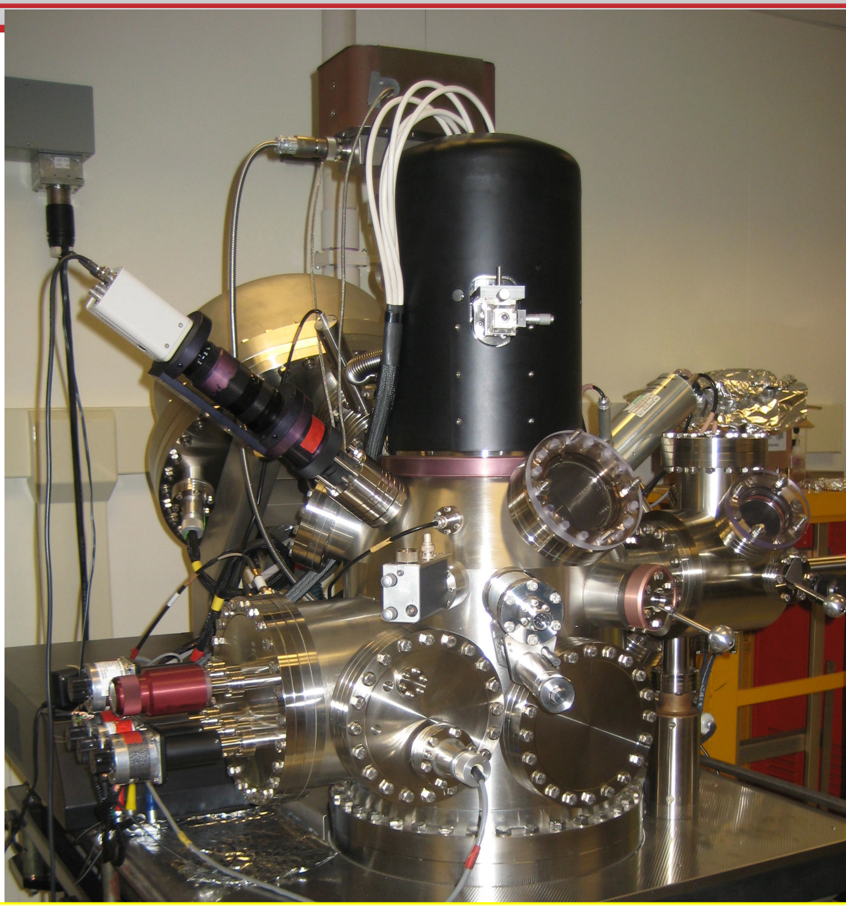
Temperature programmed desorption (TPD) reveals Li-stainless steel (SS) chemical bonding.

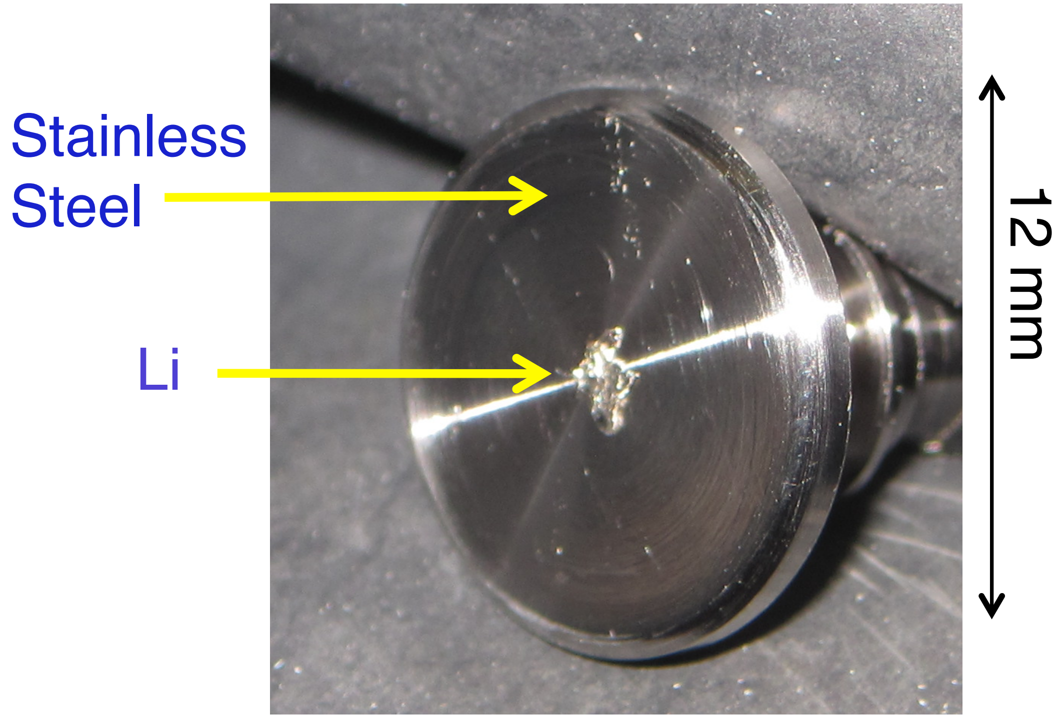


- Formation of Li monolayer and multilayer films is observed in thermal desorption spectrum of clean Li films on stainless steel.
- Li – SS bond much stronger than Li-Li bond

TPD results on D uptake in Li: A. Capece invited talk YI2.00005 Friday 11:30

Scanning Auger Microscopy





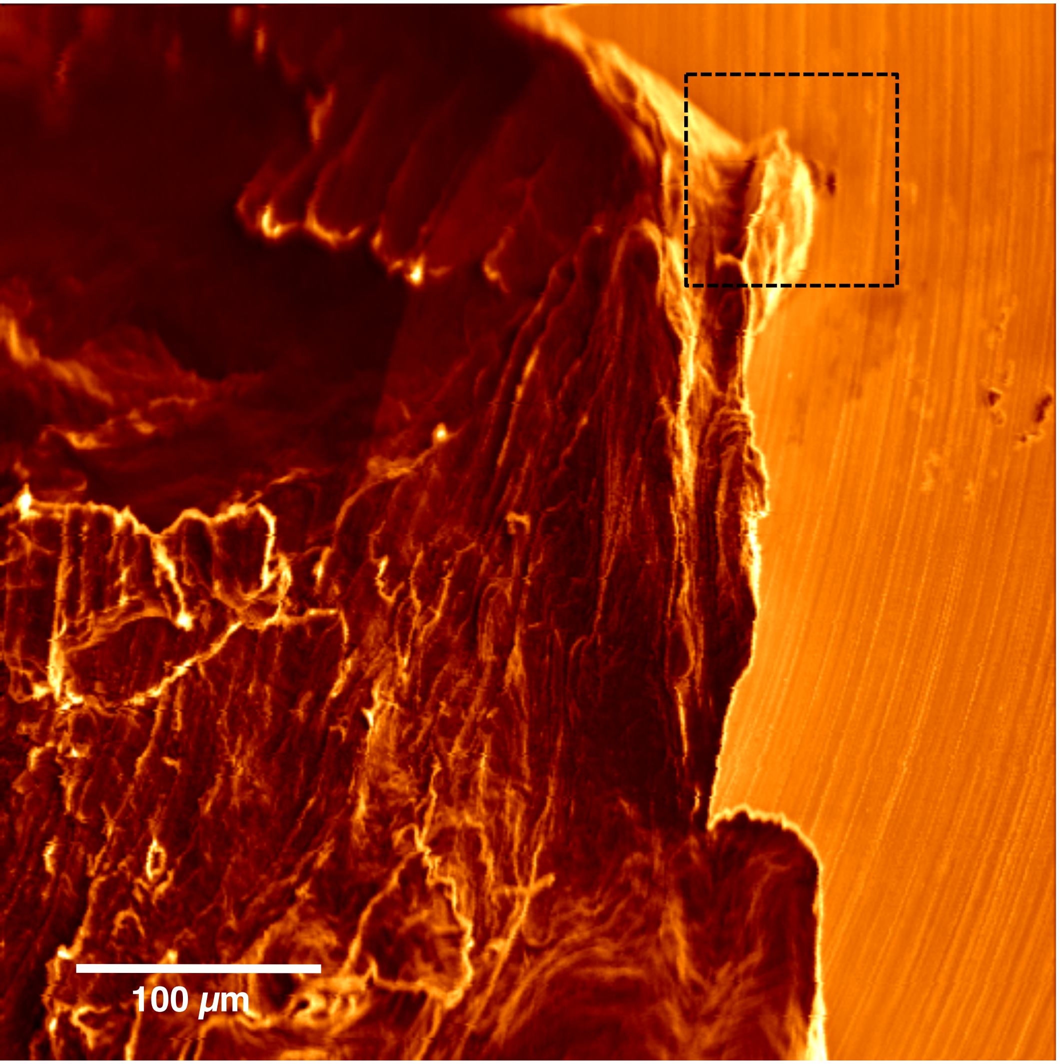
Scanning Auger Microprobe (SAM) combines:

- Secondary electron microscopy (SEM)
- Auger electron spectroscopy (AES) for 2D elemental mapping (SAM)
- Ion sputtering for surface cleaning and depth profiling

~ ½ mg sample of metallic lithium transferred from a freshly cleaved Li rod to a stainless steel SEM stub in argon glove box
[H_2O < 6 ppm, O_2 < 0.1 ppm]

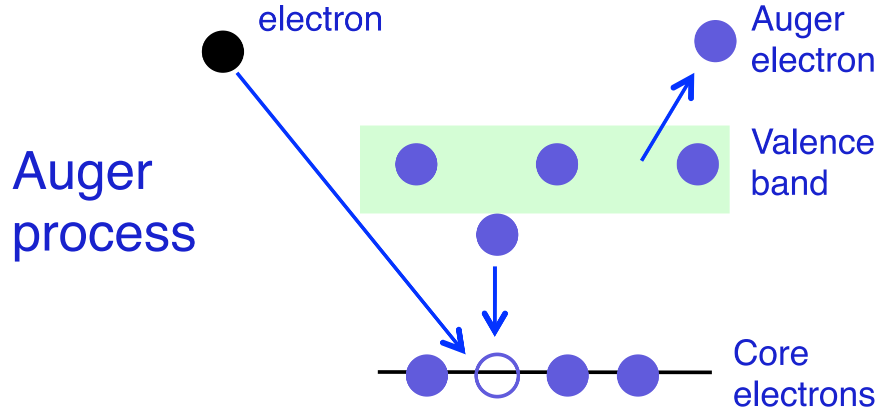
Experiments at room temperature so far

SEM image of Li particle

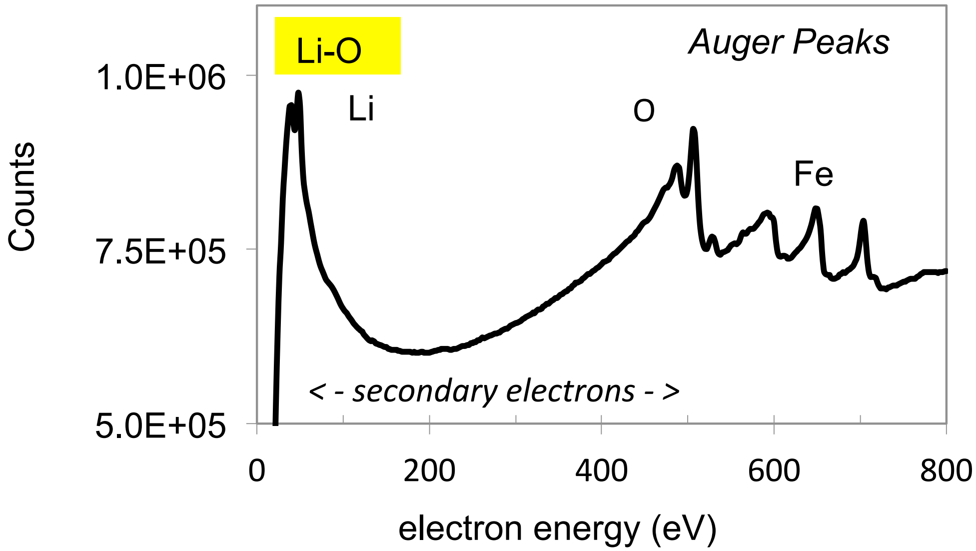


False color image of edge of Li particle formed from secondary electrons.
Zoom into dashed area in next slides.

Auger electron spectroscopy

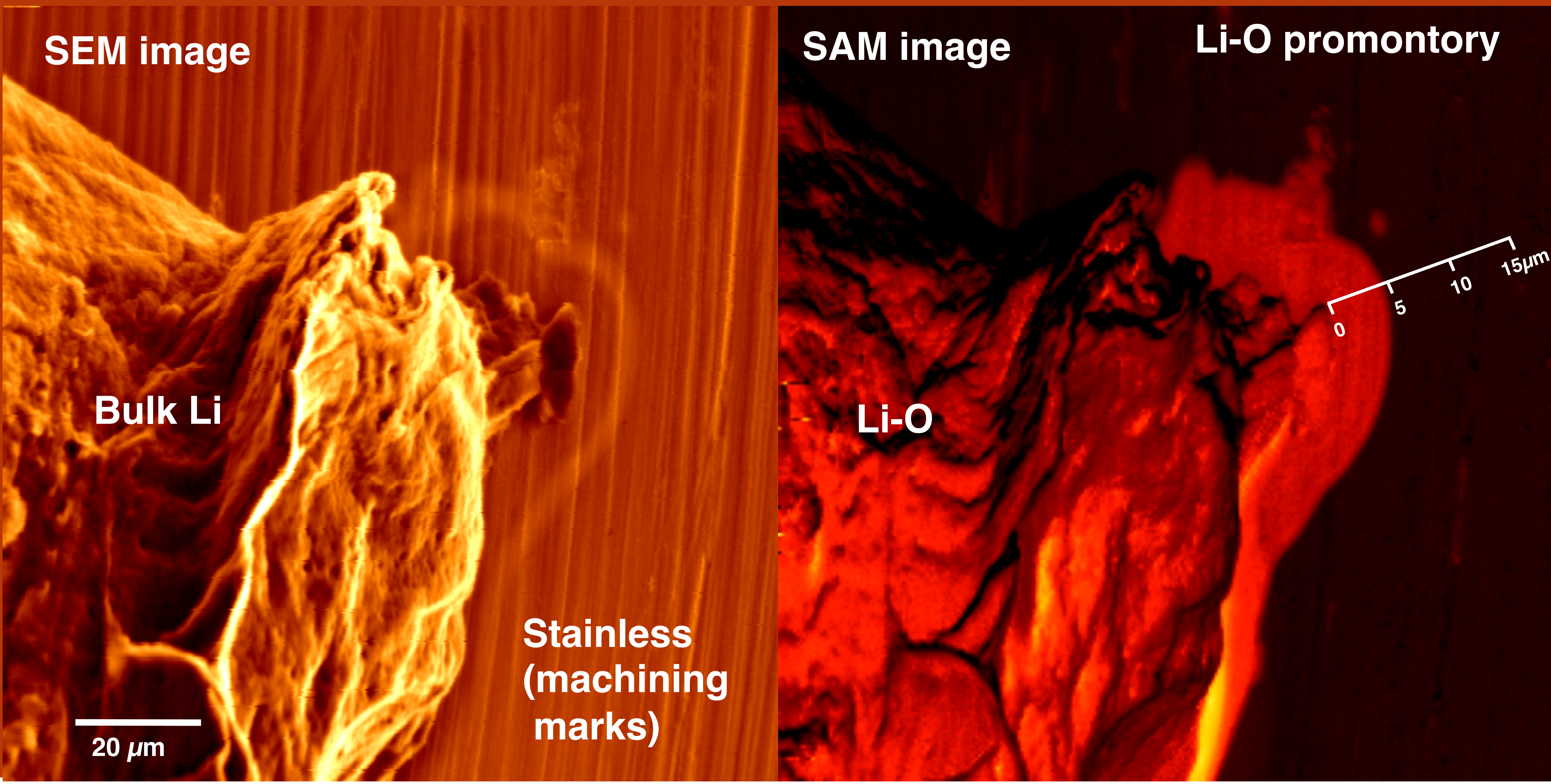


10 keV electron beam ejects core electron
- atom relaxes via 2-electron transition
Auger electron energy is characteristic of element



Li-O Auger electrons used to build an element specific image at SEM resolution

Surface diffusion of lithium oxide + 15 d

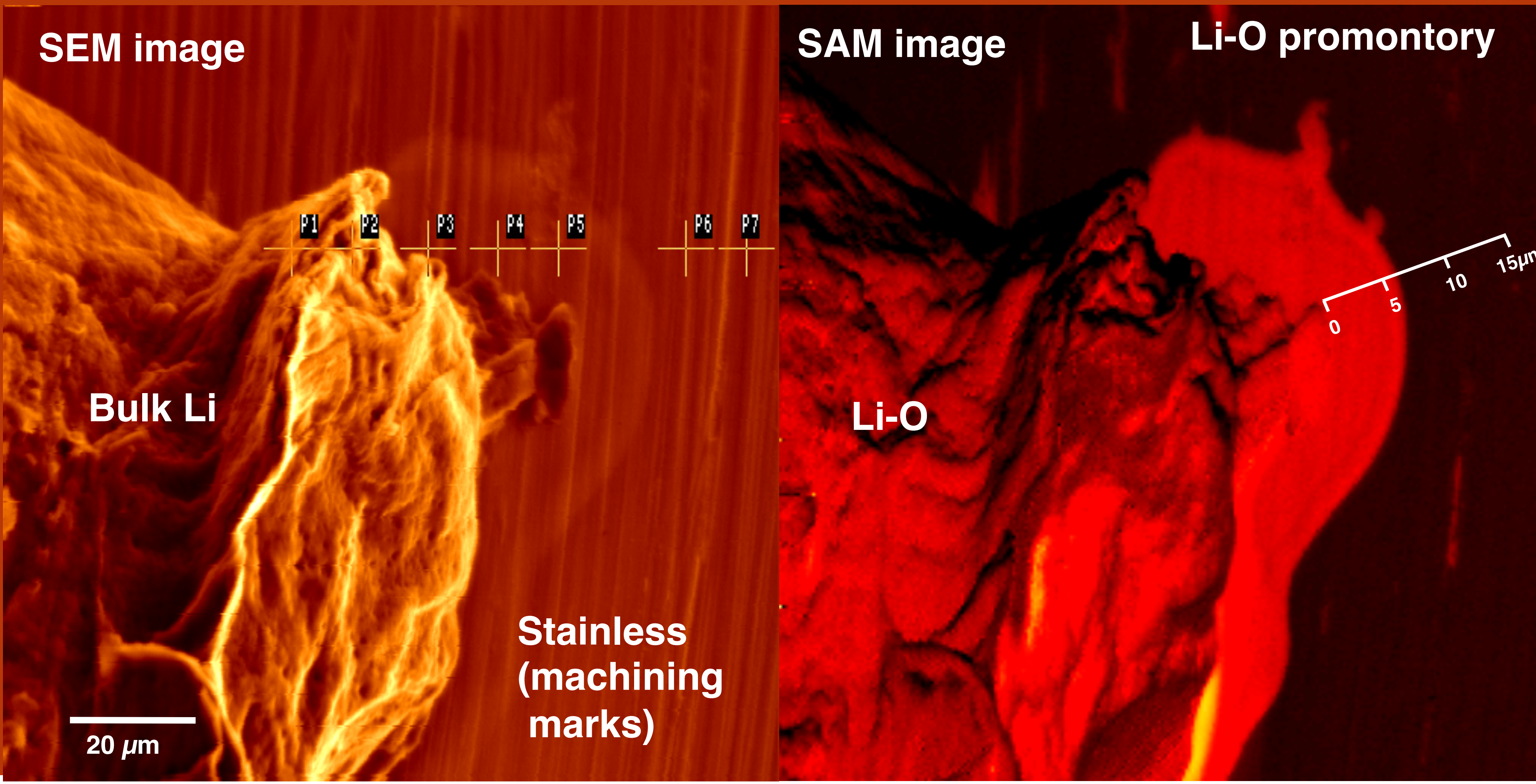


SEM image

SAM image of Li-O

6 days after last Ar etch

Surface diffusion of lithium oxide + 17 d

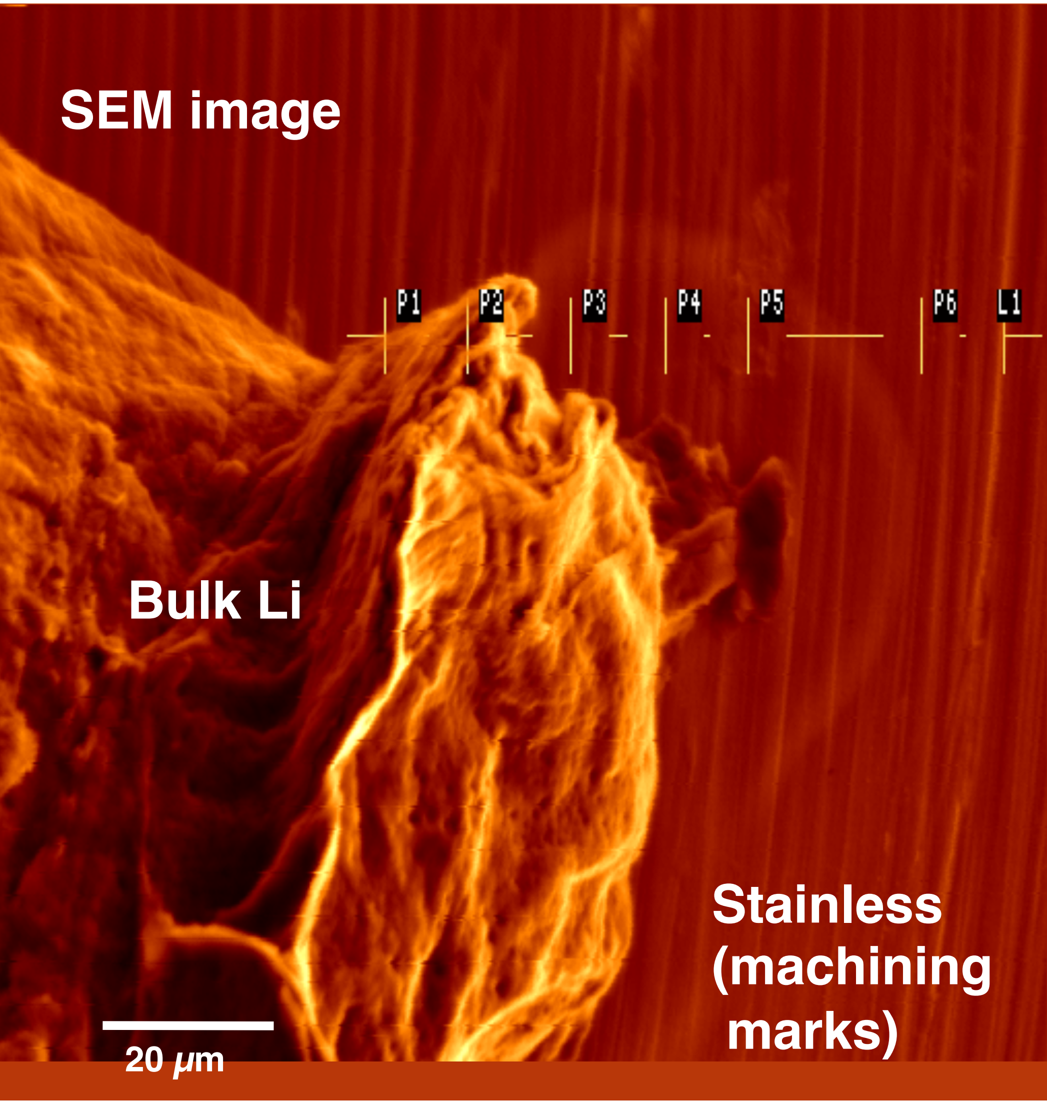


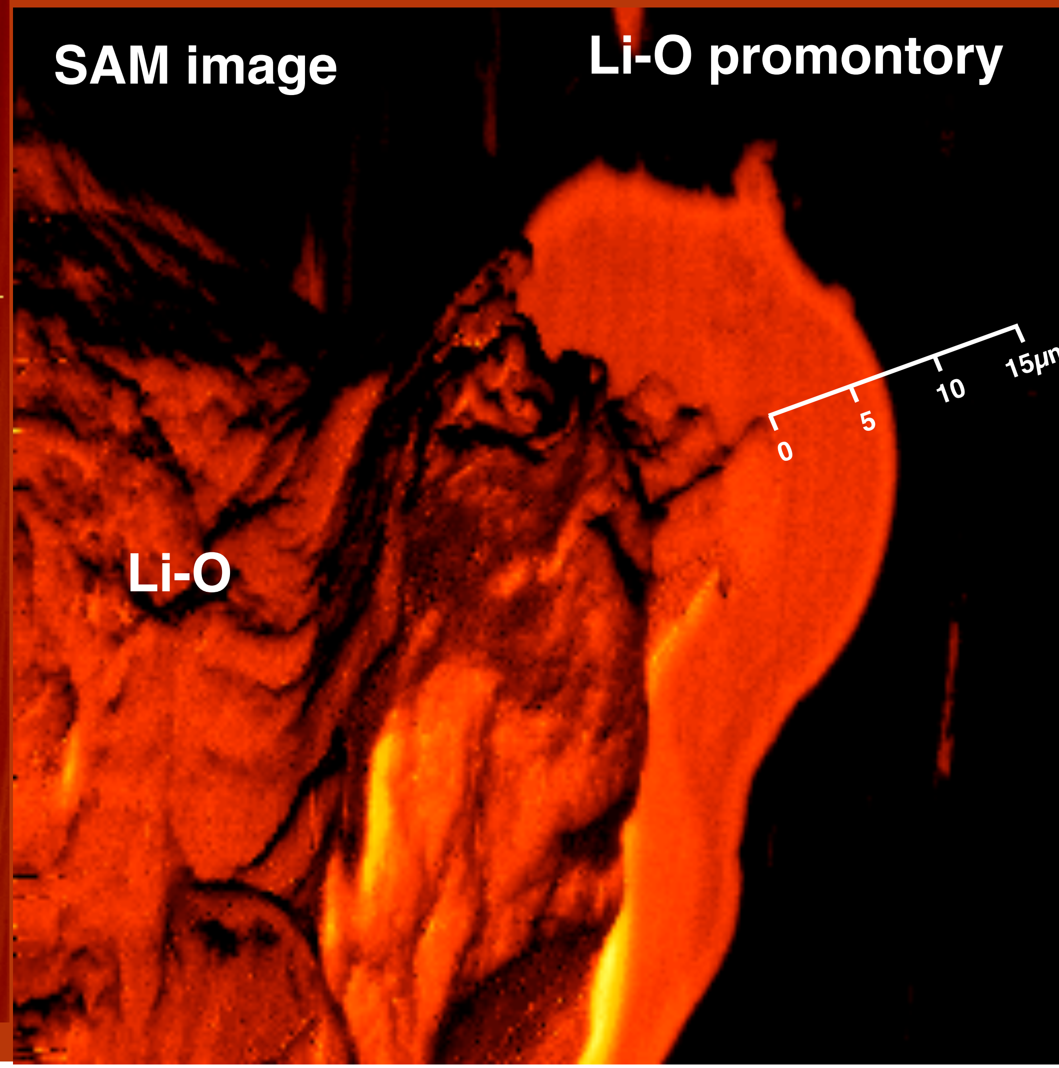
SEM image

SAM image of Li-O

8 days after last Ar etch

Surface diffusion of lithium oxide + 18 d



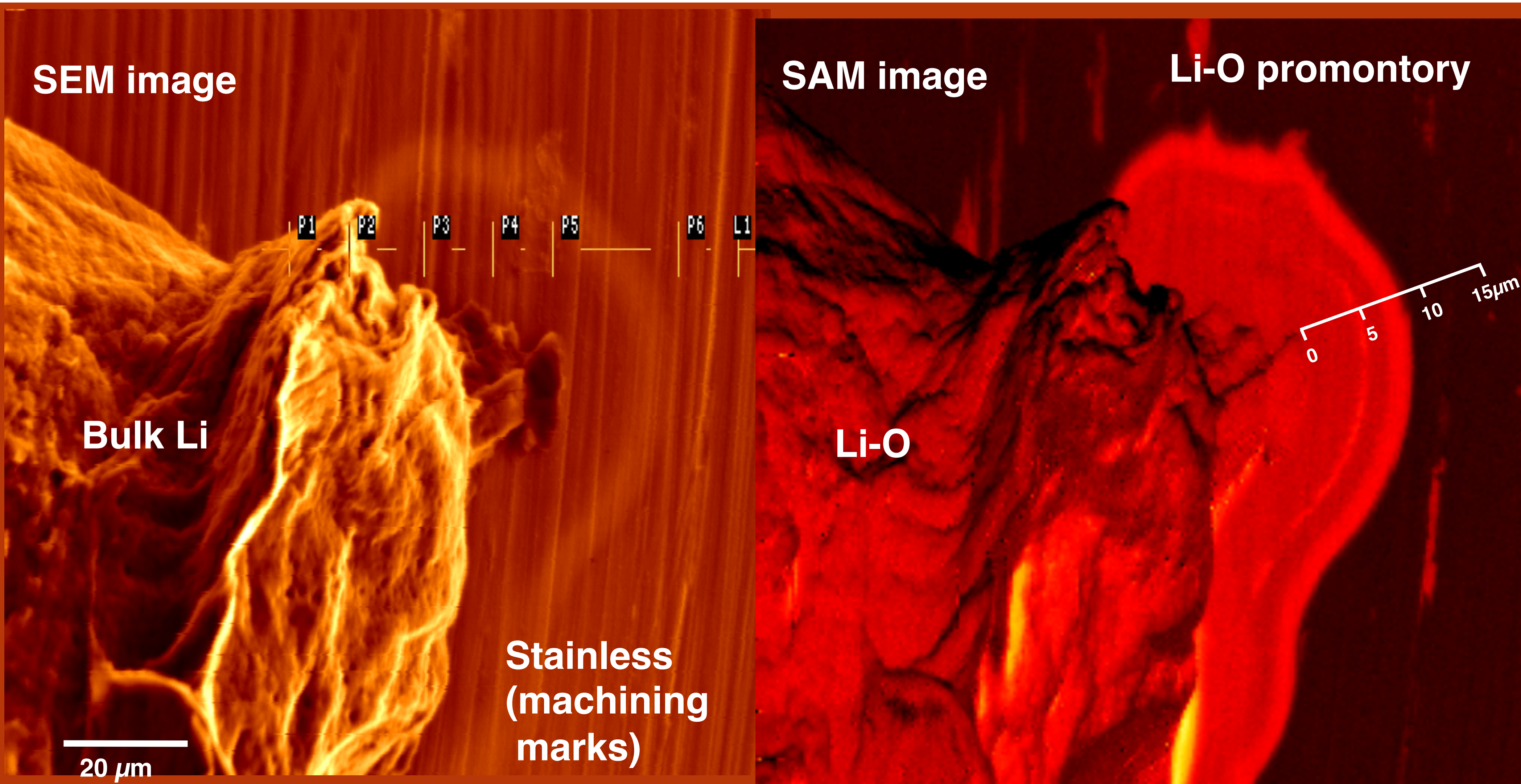


SEM image

SAM image of Li-O

9 days after last Ar etch

Surface diffusion of lithium oxide + 21 d

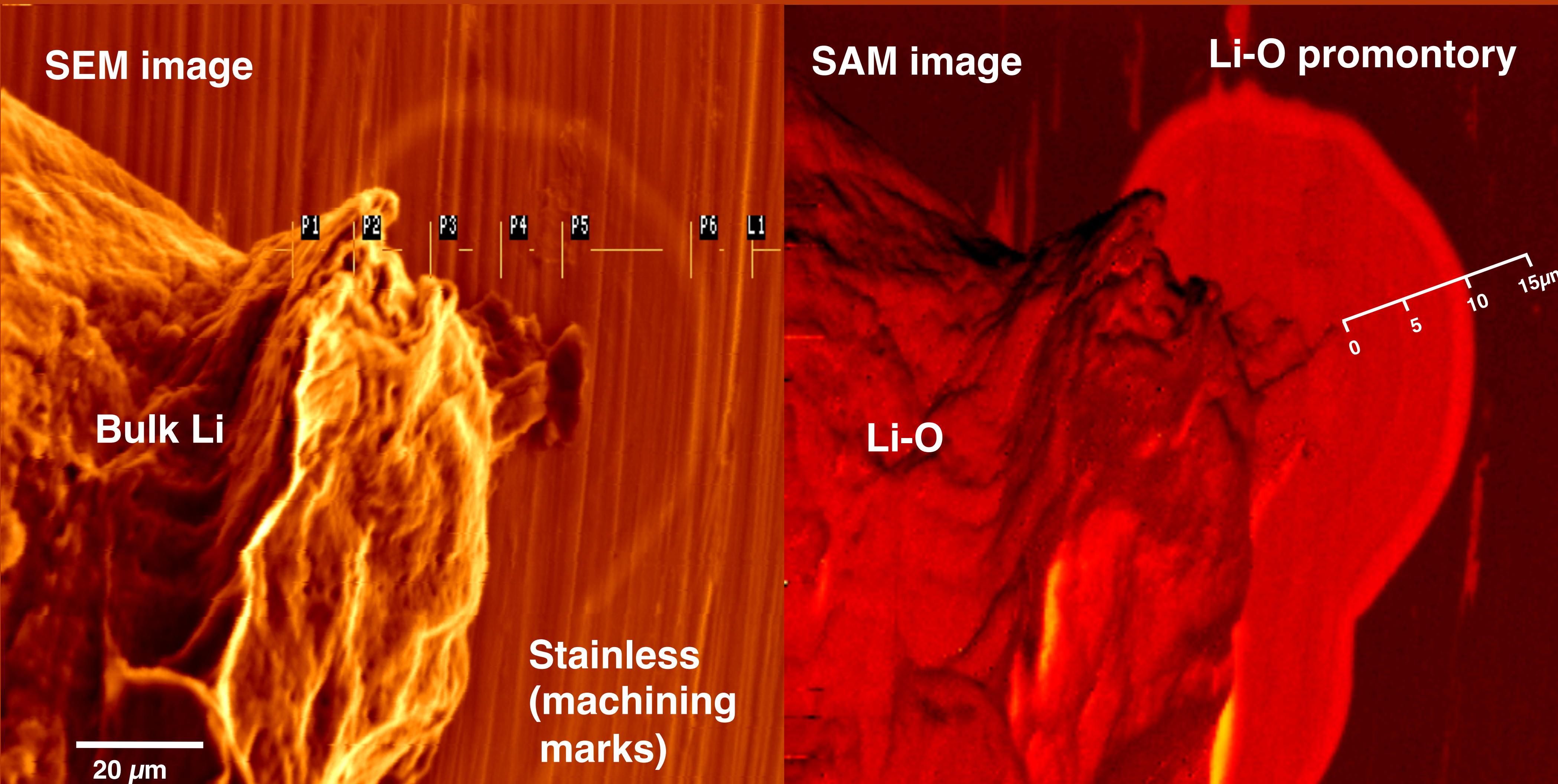


SEM image

SAM image of Li-O

12 days after last Ar etch

Surface diffusion of lithium oxide + 23 d

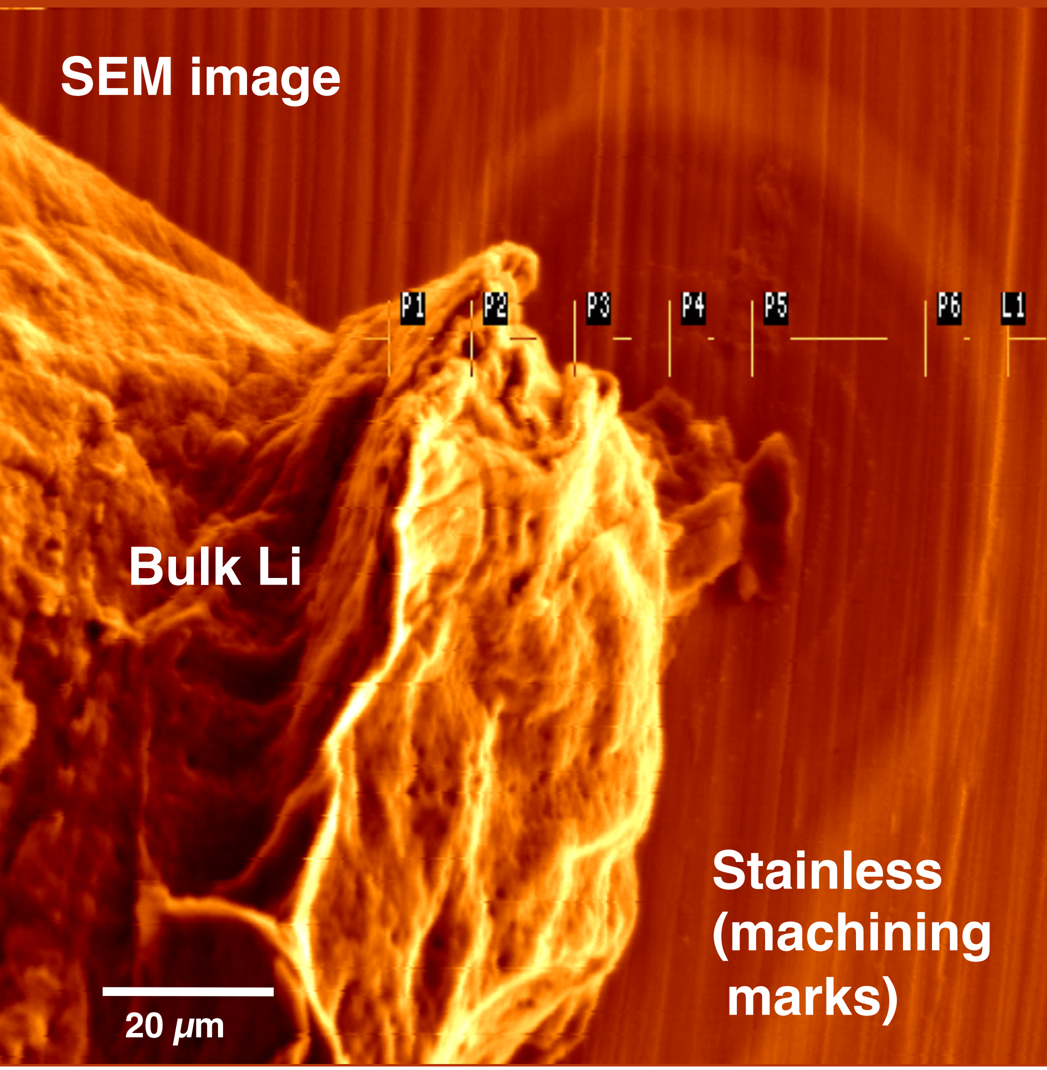


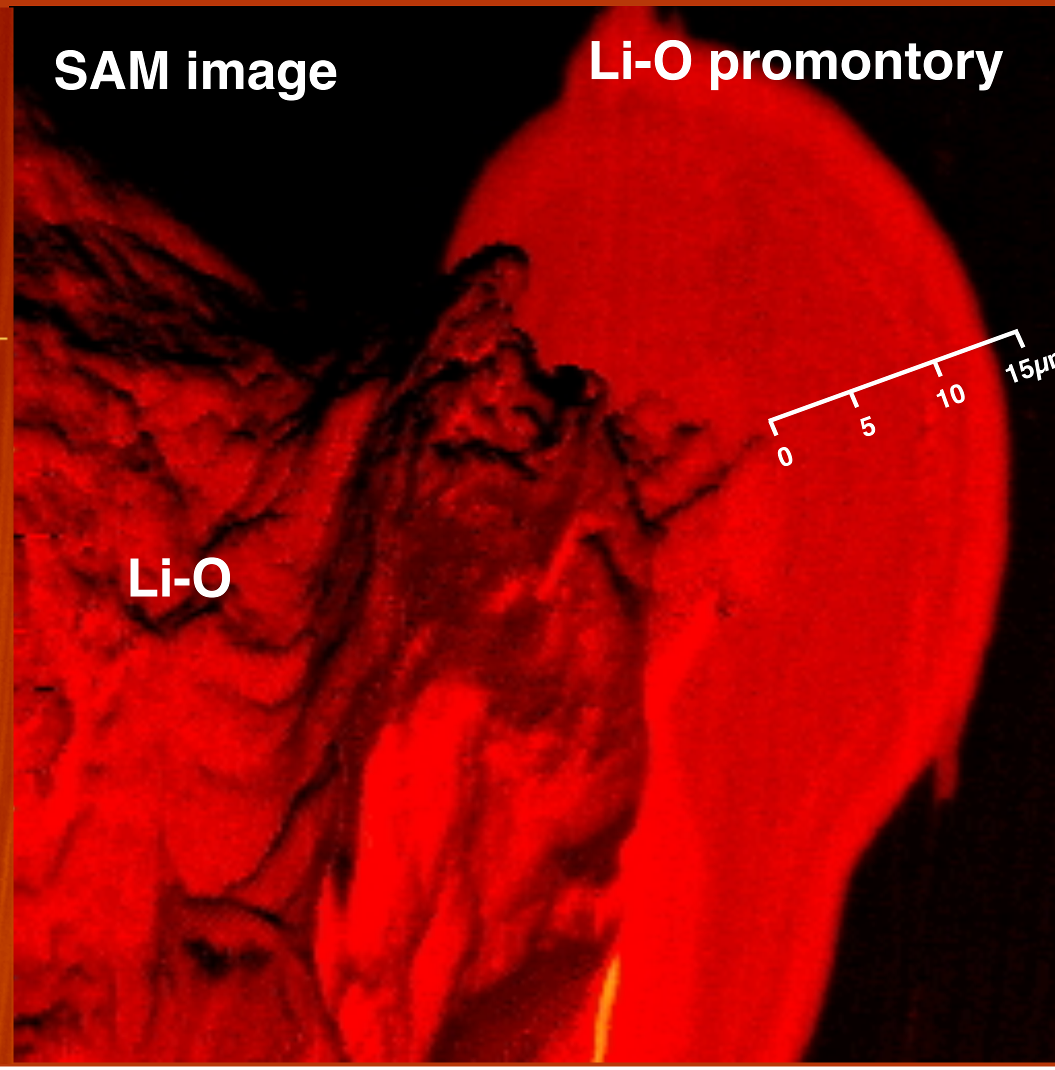
SEM image

SAM image of Li-O

14 days after last Ar etch

Surface diffusion of lithium oxide + 44 d





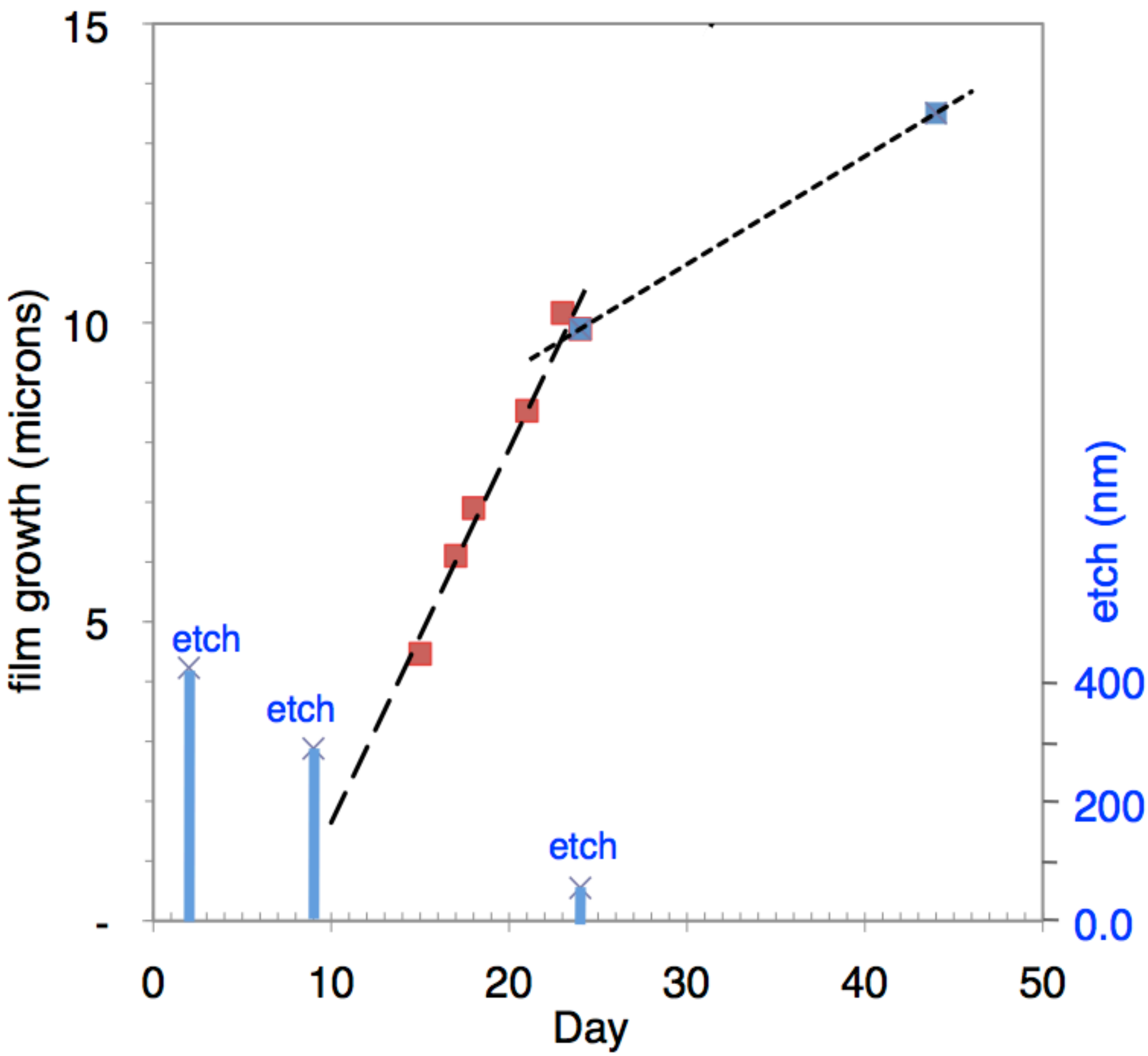
SEM image

SAM image of Li-O

20 days after last Ar etch

Lithium film is spreading from solid Li at room temperature

- Li particle mounted on SS on Day 0
- Lithium film growth linear at 0.6 μm/d after 2nd etching, then 0.2 μm/d after 3rd etch.
  - sensitive to surface conditions
- Film thickness is > 6 nm (stops Fe Auger electrons)



Summary

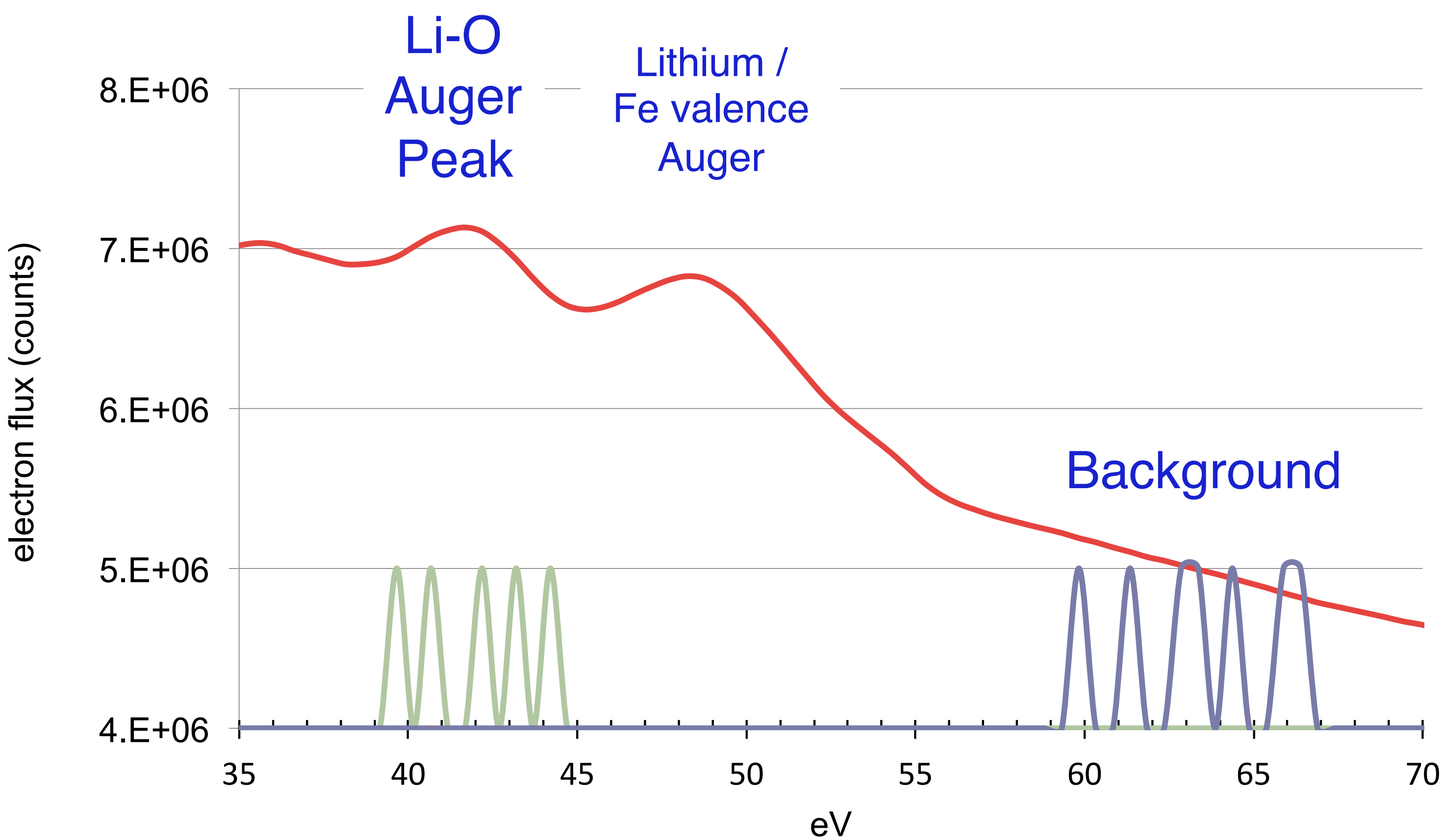
- Spreading of a solid Li film on a stainless substrate was observed using Scanning Auger Microscopy (SAM).
- Spreading occurred at room temperature after surface was etched with an Ar^+ ions.
- Liquid metal wetting of plasma facing components can be very sensitive to surface conditions.
- Future plans are to study temperature dependence of film spreading and other substrates such as TZM

See also:
Tues PM JP8.00042: Measurements of the Absorption of Atmospheric Gases in Bulk Lithium Metal using a Mass Balance
Wed PM: PP8.00046: Plans for Conditioning Plasma-Facing Components at Initiation of NSTX-U Operations
PP8.00081: Suppressed gross erosion of high-temperature lithium films under high-flux deuterium bombardment
PP8.00083: Overview of results from the Lithium Tokamak eXperiment (LTX)
Fri AM: YI2.00003: High Performance Discharges in the Lithium Tokamak eXperiment (LTX) with Liquid Lithium Walls
YI2.00005 : The Effects of Temperature and Oxidation on Deuterium Retention in Solid and Liquid Lithium Films on Molybdenum Plasma-Facing Components

Back up slides

SAM Imaging of Li-O and Lithium

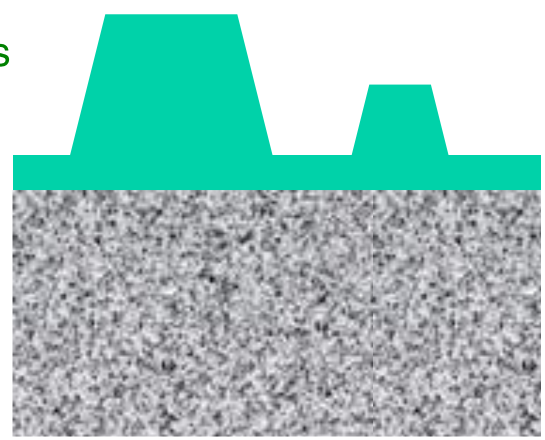
Channeltron settings for Li-O imaging



$$\text{Image formed from Constant} + \frac{\text{Peak} - \text{Background}}{\text{Background}}$$

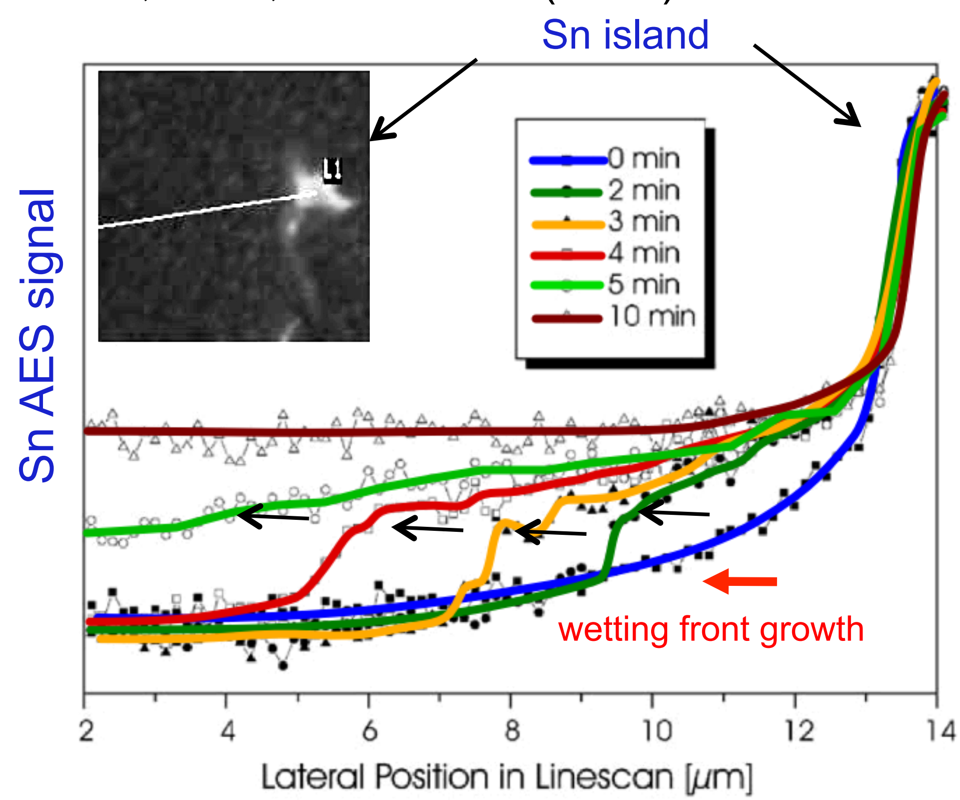
Chemical bonds will affect Li wetting

- Strong Li-Mo and weak Li-Li bonding suggests lithium wetting of Mo proceeds by layer + island growth
- Thermally activated surface diffusion - influenced by impurities and surface roughness
- Experiments with Li on SS or TZM underway with scanning Auger microprobe at PPPL



Wetting of Sn on Al revealed by scanning Auger microscopy:

Klein, et al., Vacuum 80 (2005) 74-80.



- Sputter deposition of Sn, then etching of wetting layer, then re-wetting from Sn islands.
- Auger linescan shows Sn re-wetting on Al surface @ room temp. (< Sn melt temp of 231°C)