NSTX-U

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The Effects of Contamination by Residual Gases in NSTX on D Uptake and Retention in Li Films

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54th Annual Meeting of the APS Division of Plasma Physics
Providence, RI
October 30, 2012

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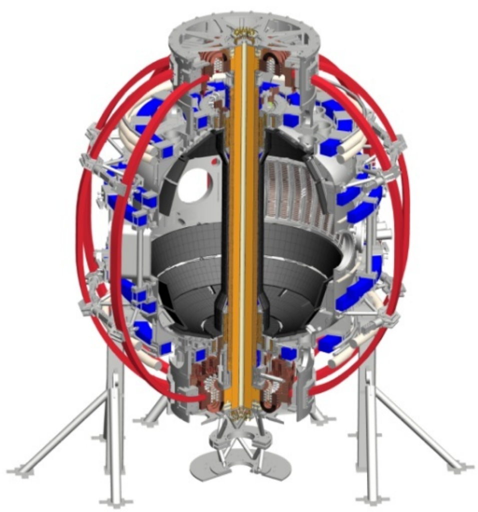

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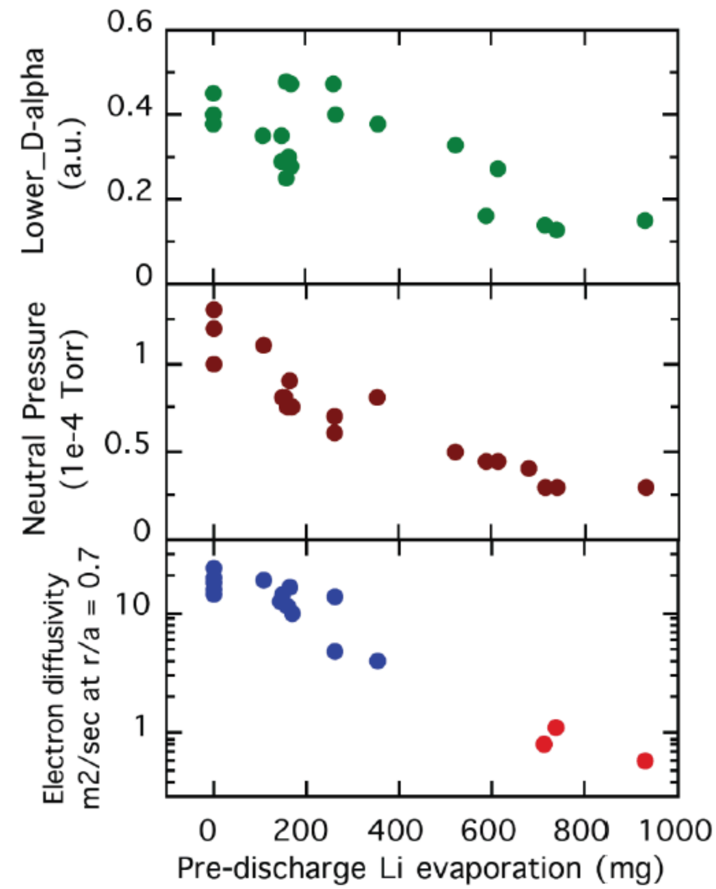
Surface Science Analyses of Lithiated PFCs is Motivated by Improved Plasma Performance

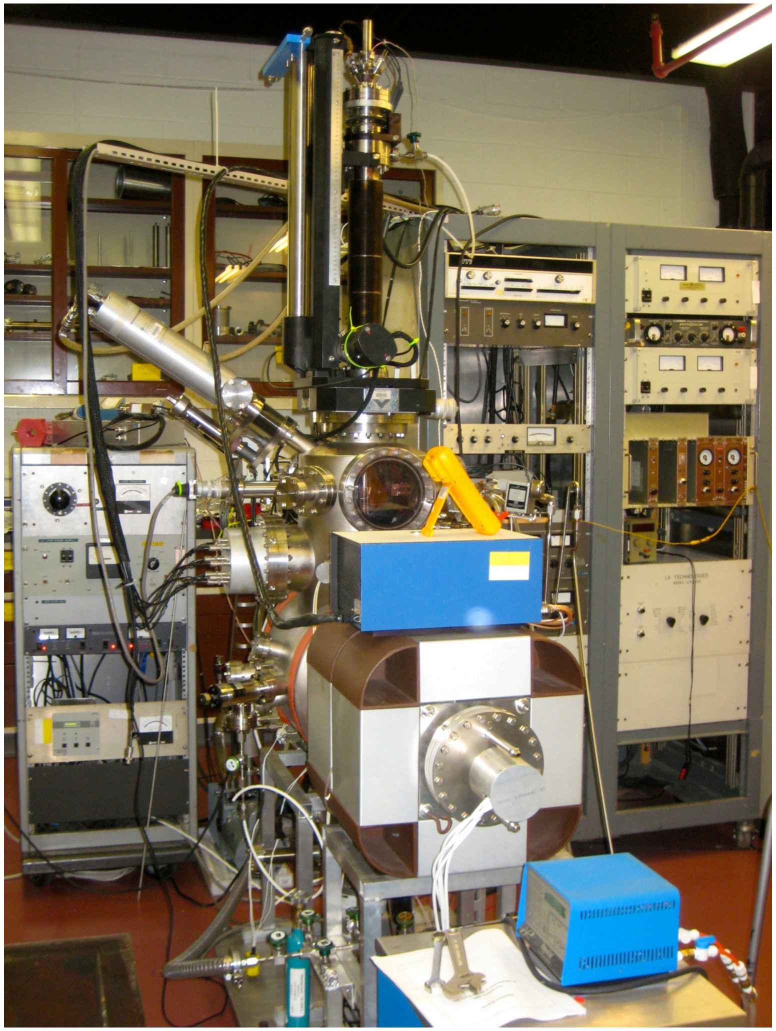
- Liquid metals considered for PFCs
  - Advantages of liquid metals:
    - No neutron damage
    - No erosion
    - No thermal fatigue
- Li improves plasma performance and confinement
  - Increasing Li doses cause reduction in:
    - Divertor recycling
    - Edge neutral density
    - Electron transport
  - Li concentration in plasma core is low
  - Liquid Li resilient against high heat flux



R. Maingi et al., Nucl. Fusion, **52** (2012) 083001

PP8.00007: The effect of progressively increasing lithium coatings on plasma performance, and the underlying role of collisionality, in the NSTX

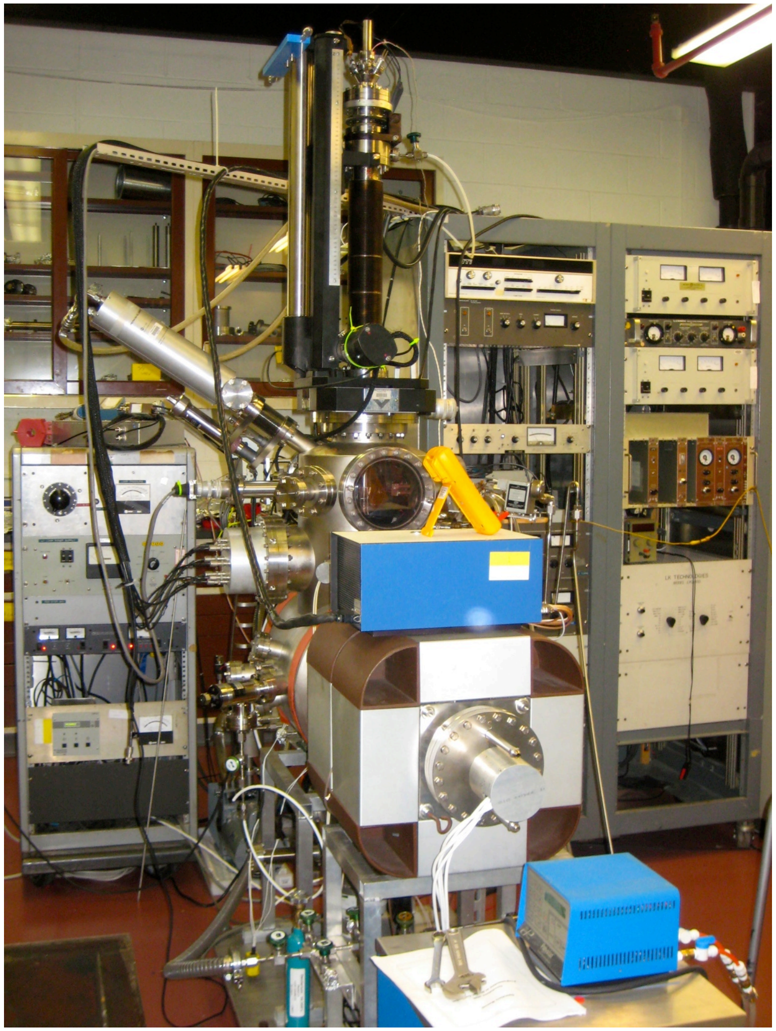
Surface Science Approach to Understanding D Retention at the Plasma-Surface Interface



Surface science chamber at PPPL's Surface Science & Technology Lab

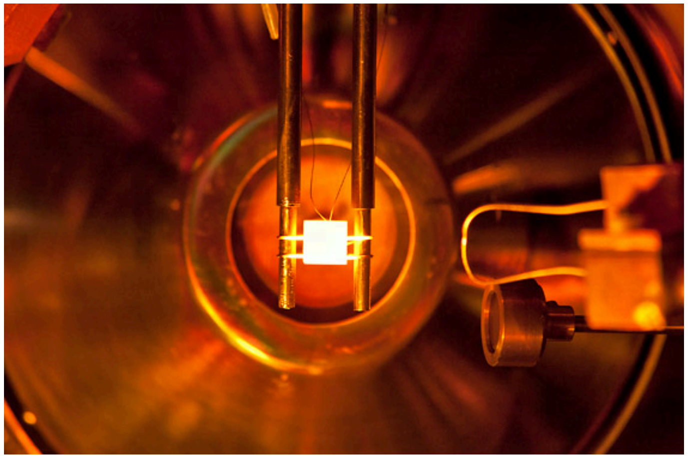
- D retention in lithiated PFCs is key component to improved plasma performance
- Surface science approach seeks to understand D retention at the plasma-surface interface
- Key variables affecting chemistry at the surface:
  - Pressure
  - Temperature
  - Composition (Mo, Li, D^+, residual gases, etc.)
- Must isolate the effects of chemistry, plasma, temperature, etc.
- Surface science experiments allow us to independently control all variables --- This is something we cannot achieve in the tokamak!

Surface Science Approach to Understanding D Retention at the Plasma-Surface Interface



Surface science chamber at PPPL's Surface Science & Technology Lab

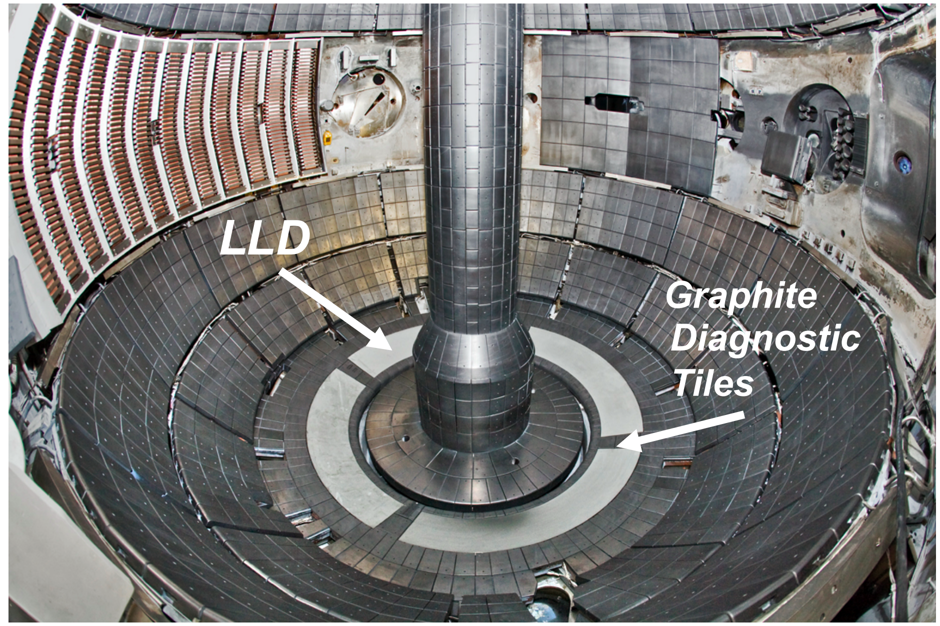
- Surface Science Techniques:
  - Auger Electron Spectroscopy (AES)
    - Chemical composition (oxidation state)
  - Temperature Programmed Desorption (TPD)
    - Desorption products
    - Amount of material retained
    - Binding energy
- Current Goal: To isolate the effects of C and O contaminants on D retention in Li coated PFCs



Li coated TZM being heated during TPD

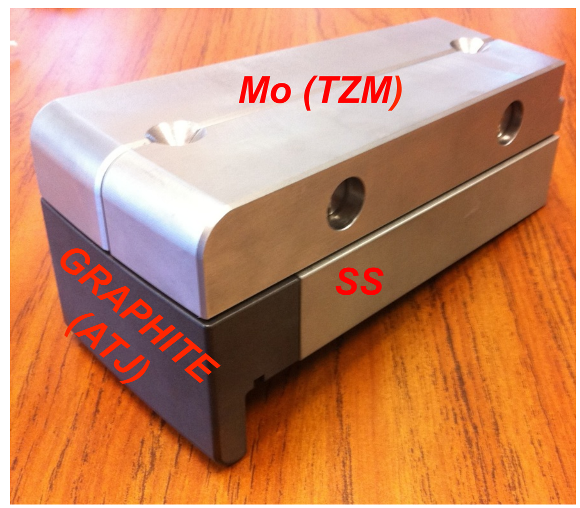
Study of Mo as a Substrate Material is Motivated by LLD and the move to all-metal PFC with TZM Tiles

- Liquid Lithium Divertor (LLD) installed in NSTX in 2010 with porous Mo plasma-facing surface

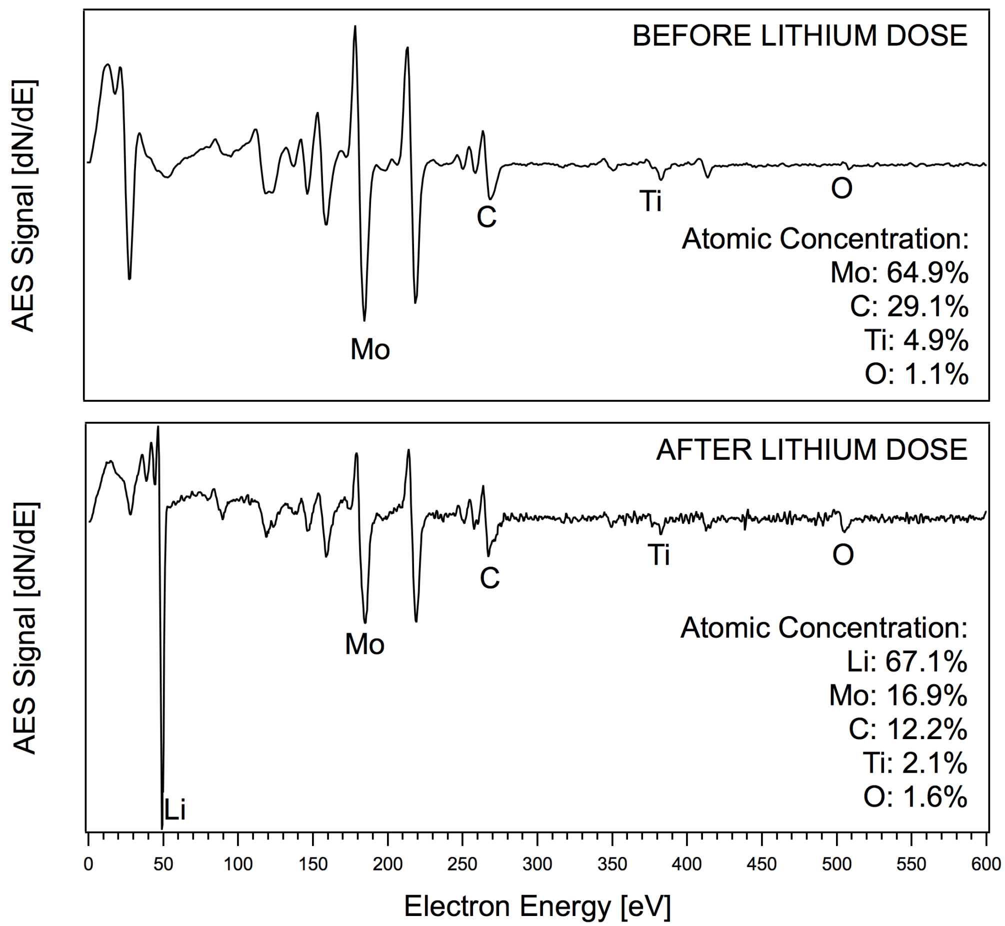


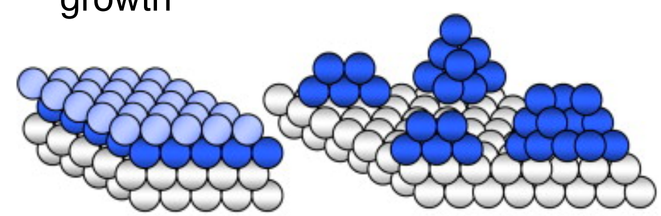
- Mo (TZM) tile installed on inner divertor in 2011

- First step toward future all-metal PFC with TZM tiles



Composition and Uniformity of Li Films on TZM is Important

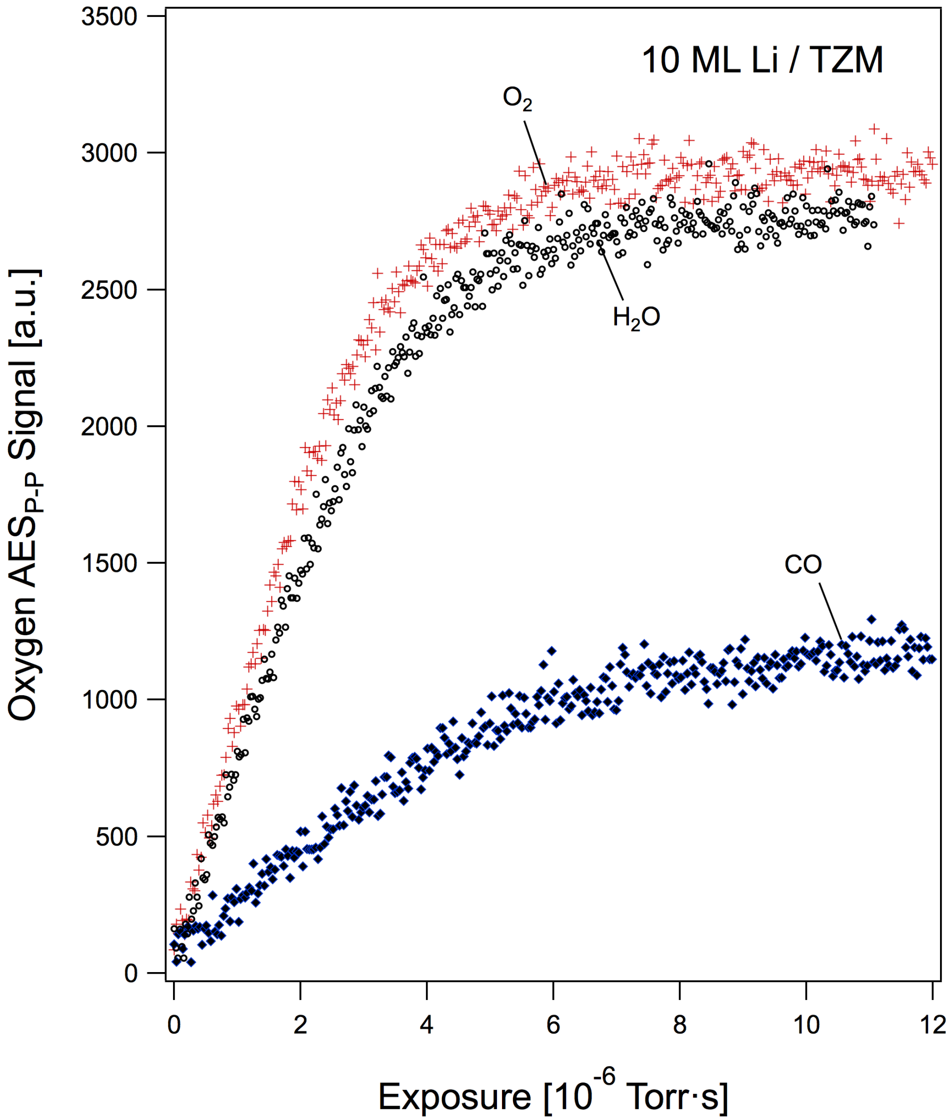




J.G. Chen et al., Surf. Sci. Reports, **63** (2008) 201.

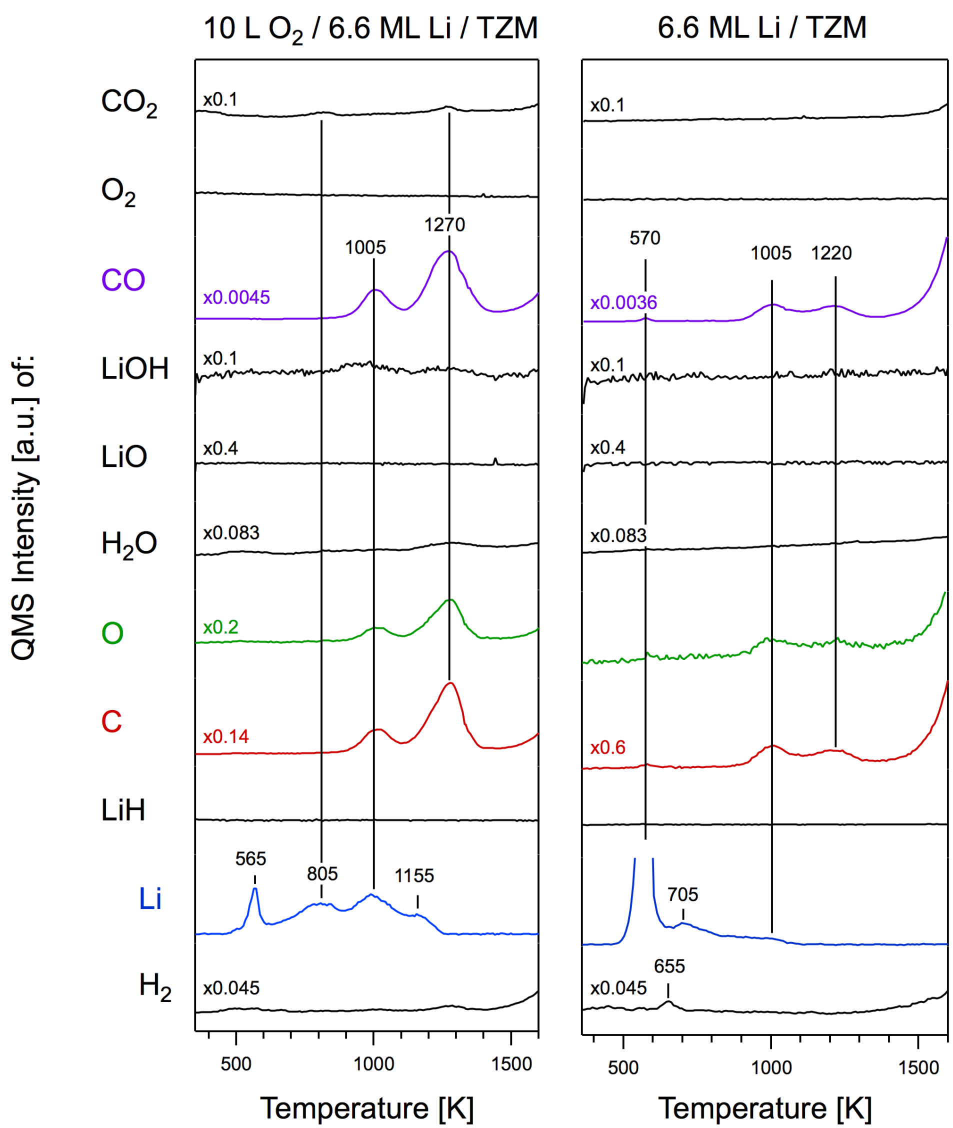
- Auger electron spectroscopy of 6.6 ML Li film shows Mo signal not attenuated
- TZM surface may not have uniform coating
- D may also react with Mo substrate
- TZM surface may behave differently than plasma-sprayed Mo

Li Film Oxidizes in 100 s at 10^{-7} Torr of Water Vapor



- Uptake curves show that H_2O and O_2 oxidize the surface at the same rate.
- Typical NSTX intershot pressures are ~10^{-7} Torr.
- PFC coating will oxidize in this environment. Saturation will occur in 100 s at 10^{-7} Torr of water vapor.
- Plasma sees mixed material, not pure Li coating

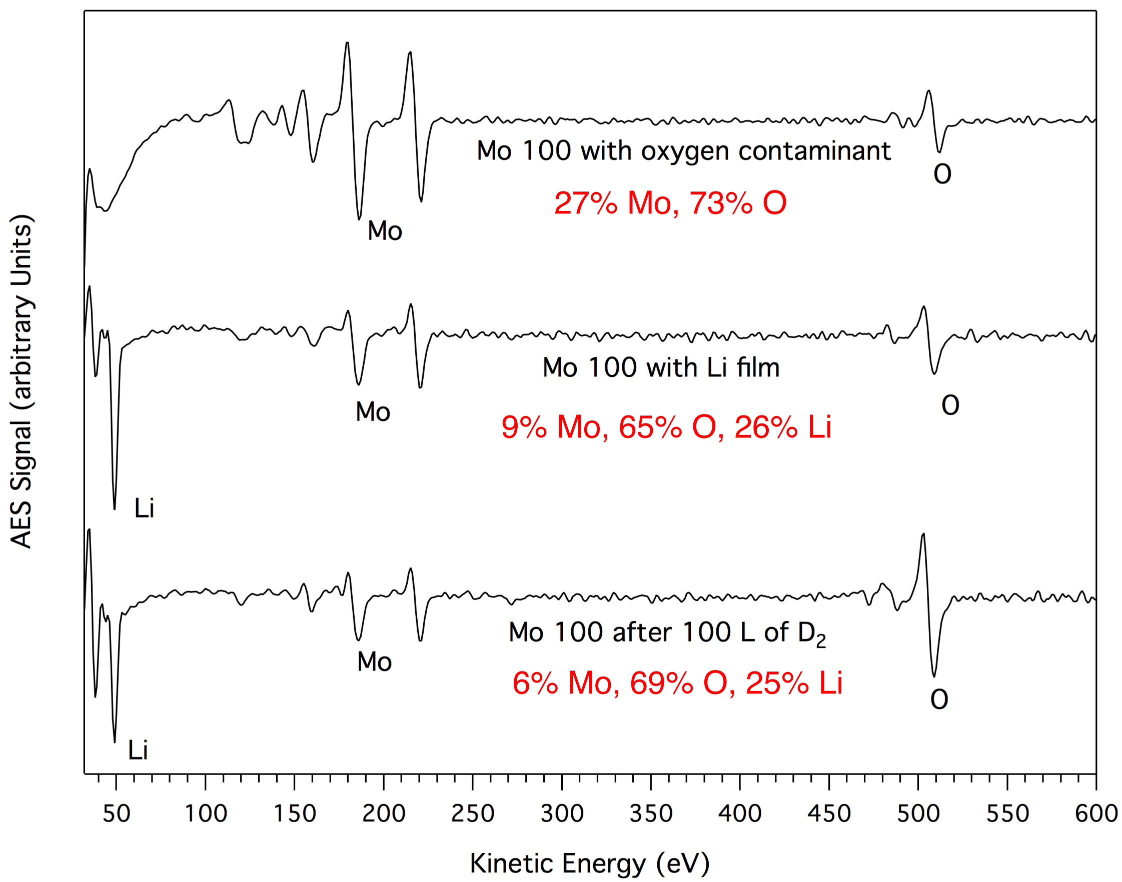
Temperature Programmed Desorption Yields Information on Surface Chemistry



- Multilayer Li desorbs from TZM at 570 K
- Oxygen holds Li on the surface as Li_2O
- Oxide decomposes at 1000 K to liberate Li and O
  - O reacts with C to form CO and CO_2
- Carbon contamination in TZM adds complexity to the chemistry

D Exposure to Li-Coated Mo Single Crystal Increases Oxygen Surface Coverage

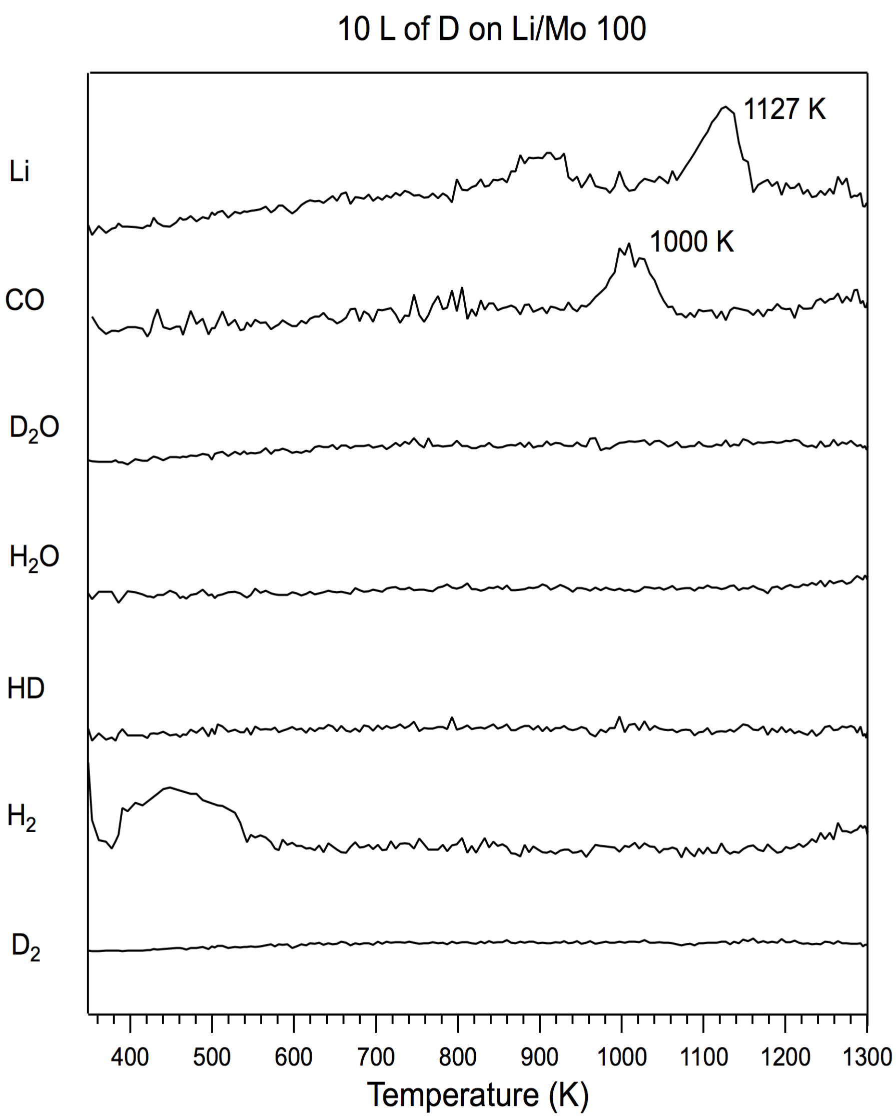
Auger electron spectroscopy results before and after D dosing



- Understanding D uptake process can help to optimize it
- Presently unknown if C and O contamination helps or hinders D uptake
- Study Mo crystal to reduce C contamination and understand TZM results
- Mo crystal –solid material where crystal lattice of entire sample is continuous and unbroken with no grain boundaries
- Oxygen initially present on the surface
- D exposure increase oxygen coverage on the surface – water contamination or real effect?

See also:
PP8.00034: Deuterium Retention via Highly Oxygenated Lithium Coatings

Main Species Evolved from Li-Coated Mo Surface After D Exposure include H_2, Li, and CO



- Only H_2, CO, and Li observed to desorb
- Li on TZM with O contamination desorbs at 1000 K
- For D/Li/Mo system, Li desorbs at 1127 K
    - Enhanced Li bond to surface?
- Broad H_2 peak expected at low temperatures based on other studies
- Further work to be conducted on:
    - D/Mo system (as benchmark)
    - D/Li/Mo system (to clarify results)
    - D/Li/Mo with controlled amounts of C and O to determine effect of these species on retention

Conclusions and Future Work

- D retention in lithiated PFCs is key component to improved plasma performance
  - Understanding D uptake process can help to optimize it
- Tokamak plasma will interact with mixed material at the plasma-surface interface
  - Plasma may see Li metal/Li oxide and substrate material
  - Li Film oxidizes in 100 s at 10^{-7} Torr of water vapor
  - Lithium coating on TZM may not be uniform
- Oxygen holds Li on the surface as Li_2O
  - Li metal desorbs at 570 K; Li oxide decomposes at 1000 K
- D Exposure to Li-coated Mo Increases Oxygen Surface Coverage
- Further study is needed to determine the role of C and O in D uptake/retention