Lithium Film Growth and Oxidation on Mo(110) Single Crystal

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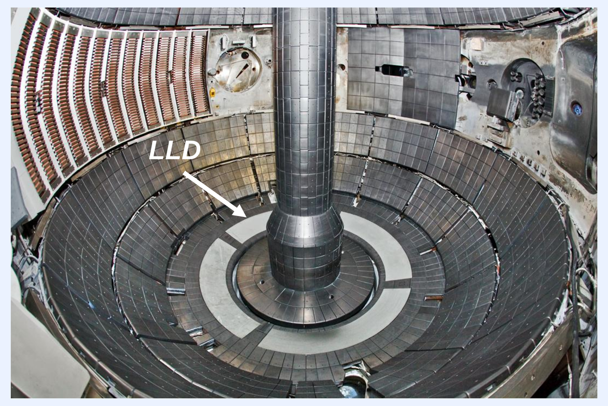
Motivation

- Current solid plasma facing components (PFCs) present issues such as neutron damage/activation, thermal fatigue and erosion.
- Liquid metal surfaces avoid these issues as they are self healing.
- Lithium has a high chemical affinity for hydrogen, which has resulted in reduced recycling of D and enhanced plasma performance on TFTR, NSTX and other tokamaks.
- Tokamaks do not have ultrahigh vacuum (UHV) conditions; lithium will react with residual gases creating oxides and other compounds quickly after deposition.
- It is important to characterize the chemical composition of the lithium surface to provide a design basis for PFCs.
- Mo(110) single crystal is used for comparison with TZM (machineable Ti-Zr-Mo alloy) to elucidate the effect of grain boundaries and alloying components of TZM.



Study of Mo as a substrate material is motivated by the Liquid Lithium Divertor (LLD) installed in NSTX in 2010 and the move to all-metal PFC with TZM tiles.

Surface Science at PPPL

Facilities:

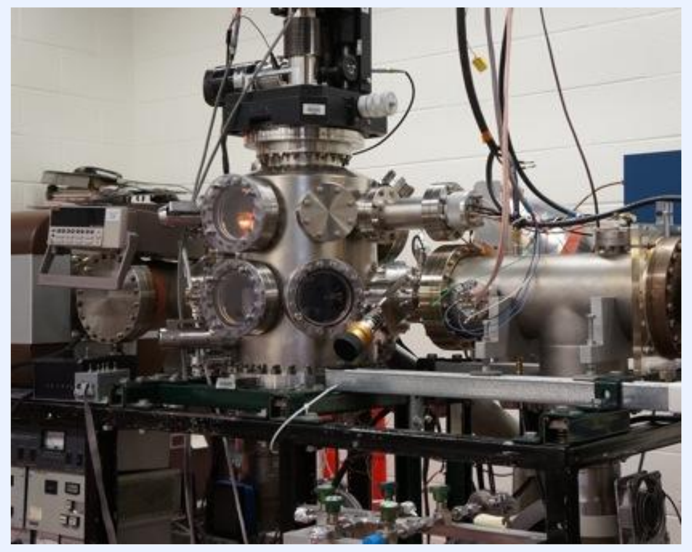
- We use atomic-level diagnostics to investigate the surface processes and chemical reactions that occur at the plasma-surface interface.

Approach:

- Probe surface composition, chemistry, and morphology while independently controlling the vacuum conditions, surface temperature, and incident neutral/ion flux to simulate the environment in a fusion device.

ALISS chamber:

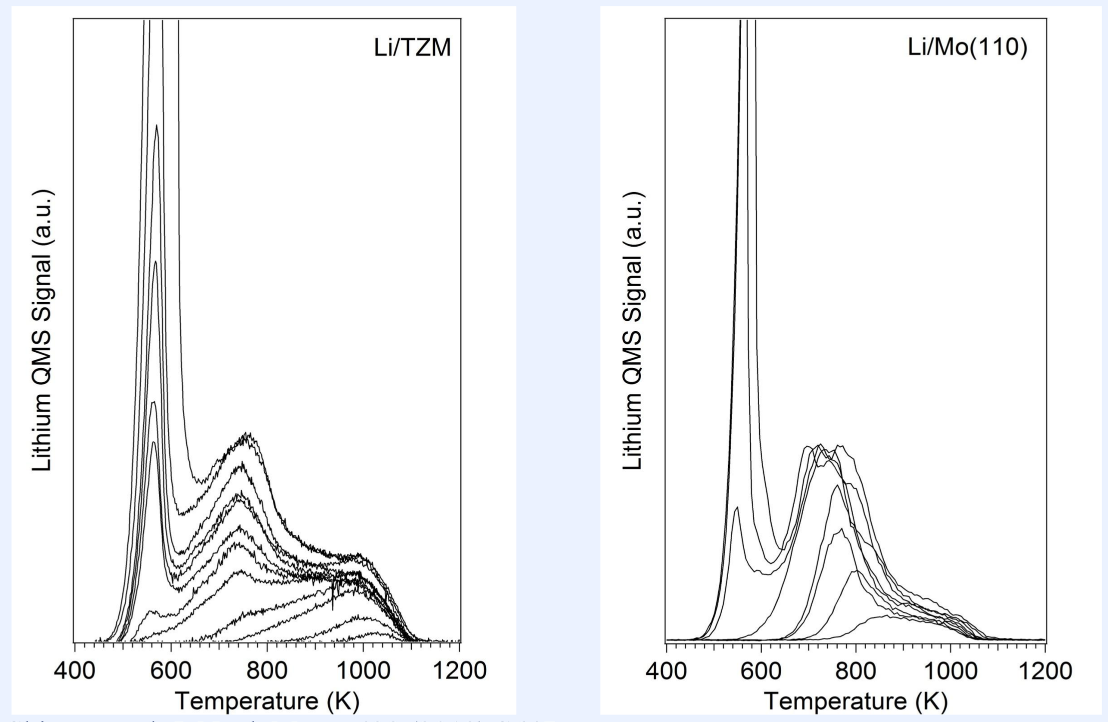
- The ALISS chamber is an ultrahigh vacuum (UHV) surface analysis chamber with a range of diagnostics and surface preparation techniques. Main capabilities and instrumentation include:



- X-ray photoelectron spectroscopy (XPS)
- Auger electron spectroscopy (AES)
- Temperature Programmed Desorption (TPD)
- Low energy ion scattering (LEIS)
- Low energy electron diffraction (LEED)
- Alkali ion scattering spectroscopy (ALISS)

- Samples mounted in vacuum chamber operating at 10^{-10} Torr with LN_2 cooling and e-beam/resistive heating capable of achieving a wide temperature range (<200 K to >1600 K)
- Ultrathin Li layers, <10 monolayers (ML) deposited with sub-monolayer control
- Mass analyzed, differentially pumped ion source produces a clean consistent ion source for hydrogen retention studies

Li Desorption from TZM and Mo(110)



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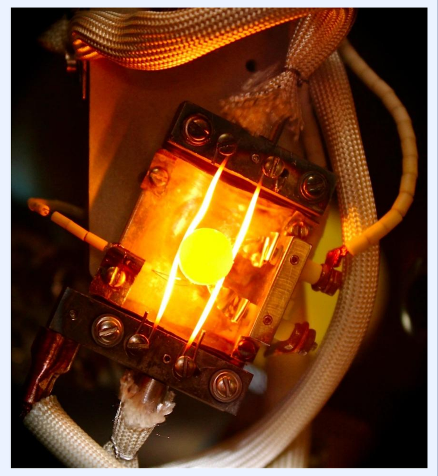
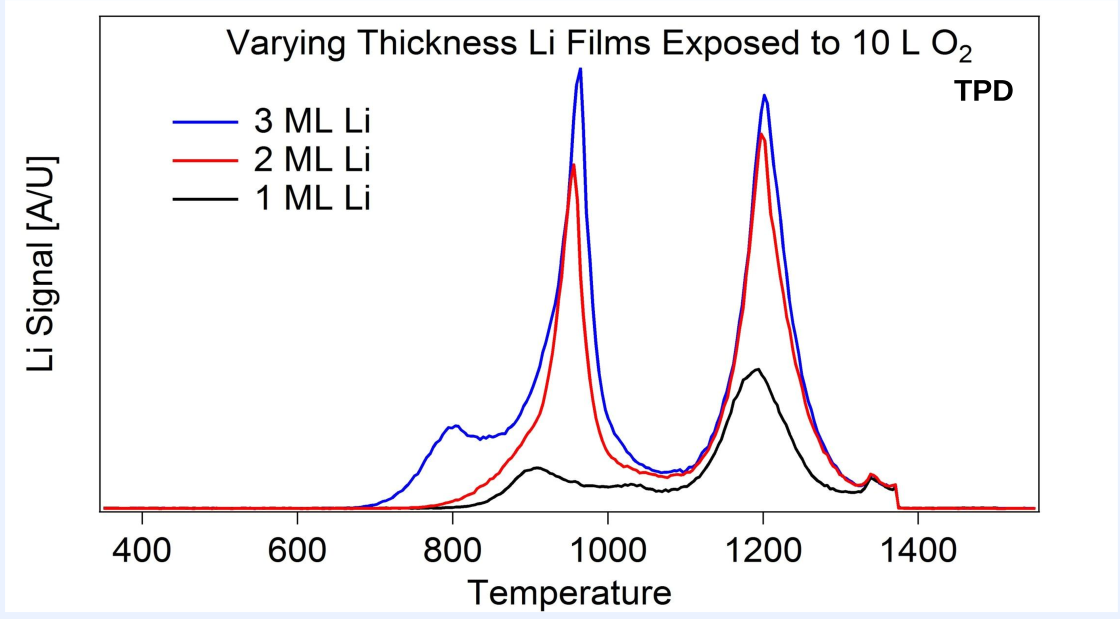
- TPD spectra show Li (7 amu) desorption from films of increasing amounts on TZM and Mo(110)
- Peak at 560 K is attributed to multilayer Li desorption while 750 K peak is attributed to Li monolayer
- Li TPD are similar for TZM and Mo(110); Li desorption shoulder is larger and extends to slightly higher temperature on TZM



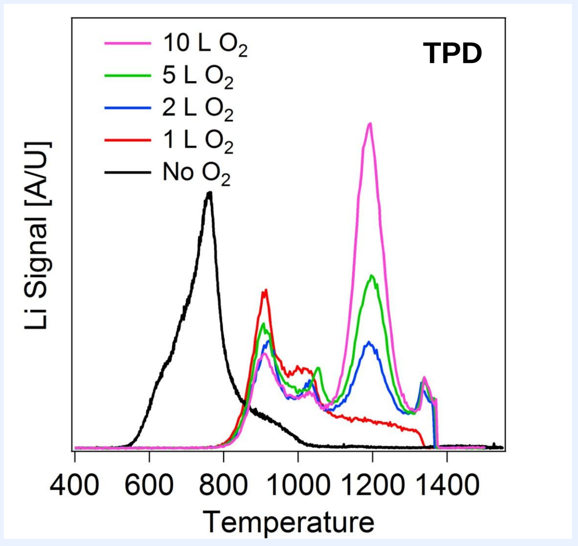
Mo(110) is resistively heated in UHV.

Oxidation of Li Films on Mo(110)

- Li films of varying thickness were exposed to 10 L (Langmuir: 1 s at 10^{-6} torr) O_2 to observe oxide formation as a function of Li film thickness
- 5 peaks were observed: 800 (only for 3 ML Li deposition), 950 1050, 1200 and 1350 K
- Each peak represents Li on the surface with a different thermal stability; this can be caused by changes in bonding (e.g. Li-Mo vs Li-Li) or compound formation (e.g. Li, Li_2O)



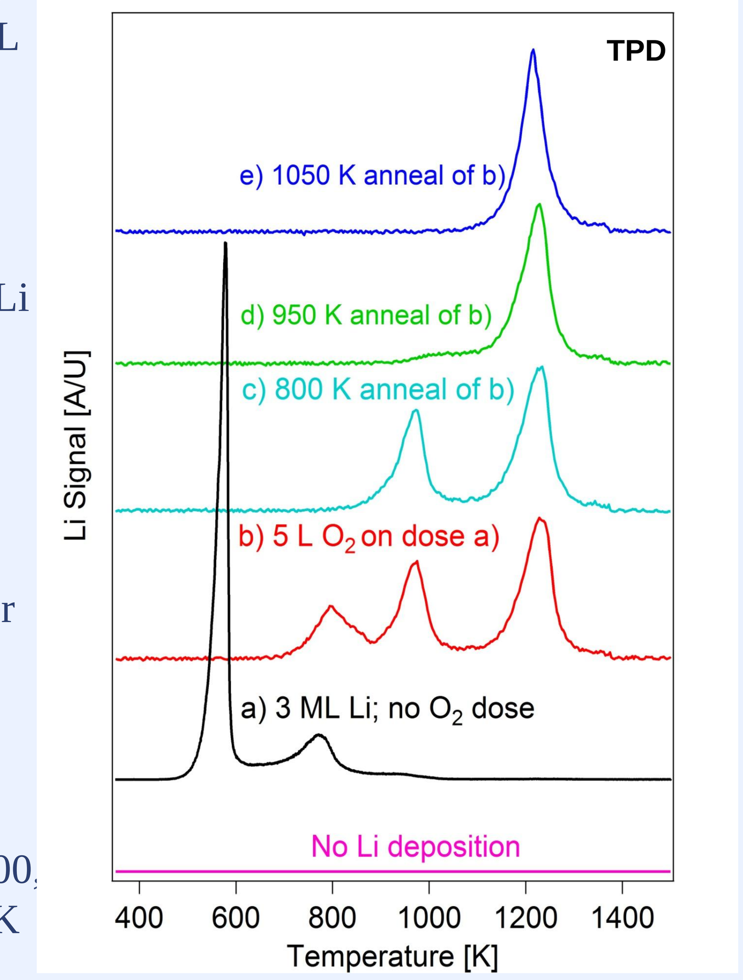
Oxidation of Li monolayer on Mo(110)



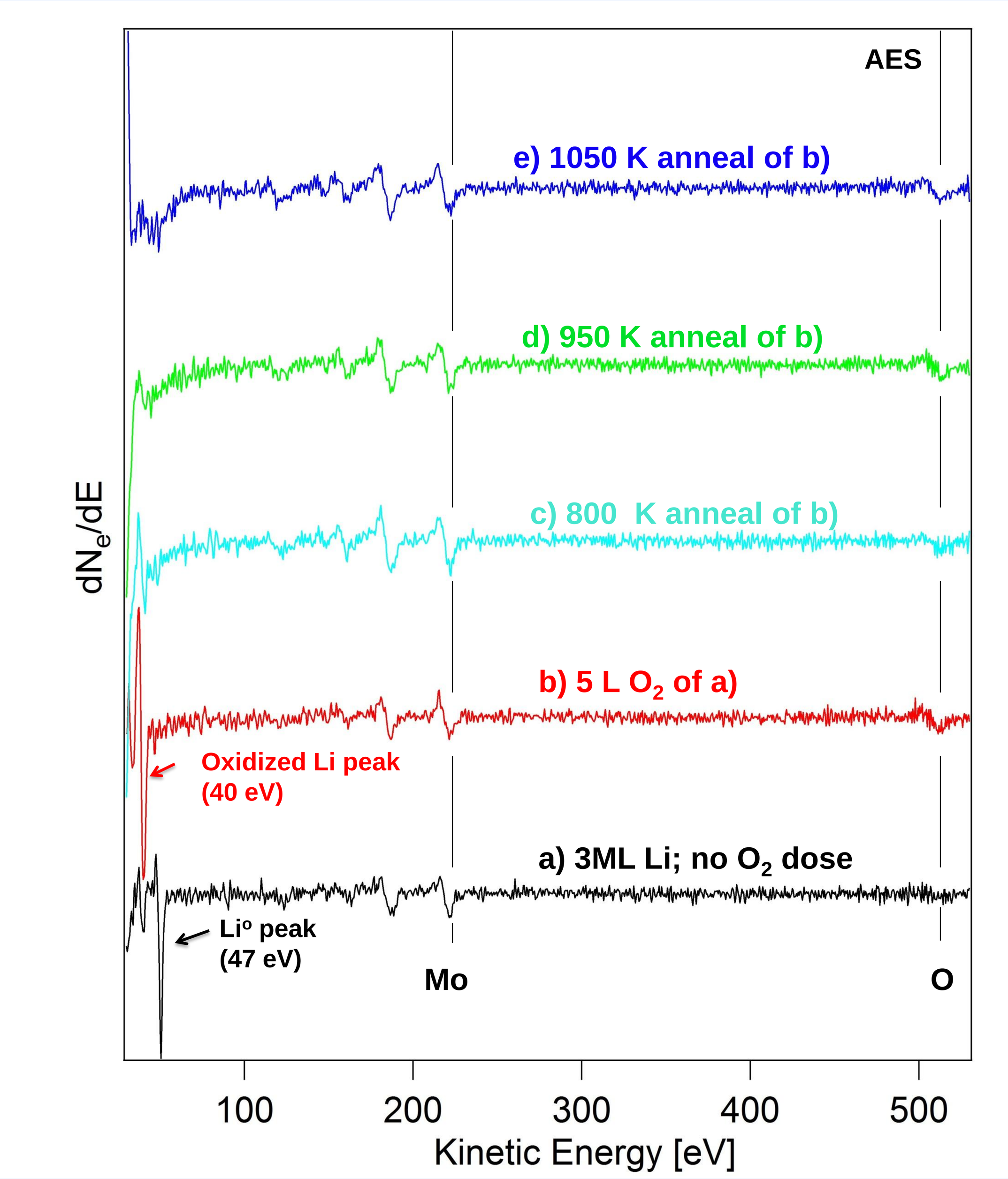
- Li oxidation was measured on 1 ML films
- At 1 L dose, TPD curve shifted to higher temperatures with new peaks: 950, 1050, 1200 and 1350 K
- 950 K peak decreased, 1200 K peak increased with increasing O_2 dose

Characterizing Different Li Compounds

- TPD spectra show Li desorption from 3 ML Li films on Mo(110) exposed to a 5 L O_2 dose
- Bottom curves show TPD of un-oxidized Li and no Li dose for comparison
- Heating (annealing) films to near a peak temperature removes that peak allowing for study of individual peaks
- TPD curves showing annealing of 3 ML oxidized Li film at 800, 950, 1050 and 1200 K are shown



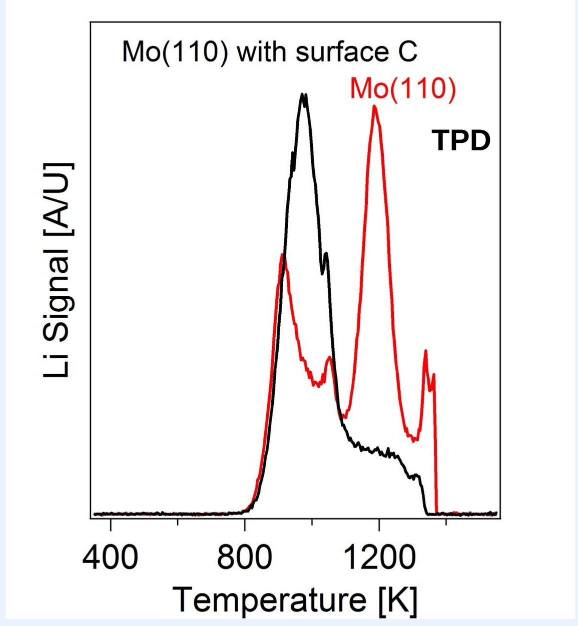
AES of Li films After Annealing at Various Temperatures



- AES was performed after deposition and annealing to measure changes to the surface composition
- AES of clean lithium film shows no oxygen (510 eV) or carbon (272 eV) on the surface. Mo (186 & 211 eV) and Li (47 eV) are both prominent
- After oxidation, Li peak shifts from 47 eV to 40 eV.
- Comparing peak heights of AES spectra provides elemental composition at surfaces for the TPD peaks observed
- Further study planned using XPS and vibrational spectroscopy to identify Li compounds desorbed at each TPD peak

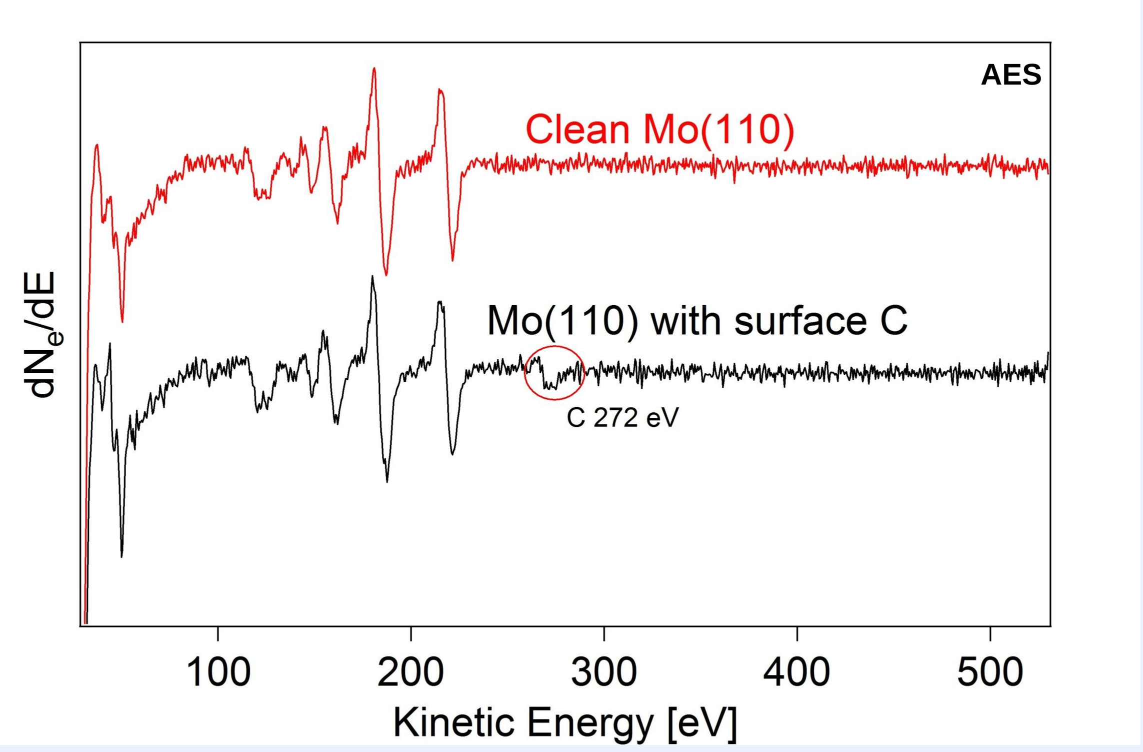
Oxidation of Li on Mo(110) with Surface C

- TPD shows Li desorption from an oxidized Li monolayer film on clean Mo(110) and Mo(110) with surface C exposed to a 10 L O_2 dose.
- Li desorption from Mo(110) with surface C has larger peak at 1050 K and reduced peak at 1200 K
- Surface carbon does not significantly affect un-oxidized Li TPD (TPD not shown)



- How does C on surface affect Li oxidation? Plans to study chemistry of oxidized Li films on C coated Mo(110) with XPS.

AES of Li films on Clean and C Contaminated Mo(110)



Summary

- Li desorption from Mo(110) is similar to that observed for Li on TZM; differences in high temperature shoulder could be due to grain boundaries in TZM.
- Multiple TPD peaks are formed by oxidation of Li films on Mo(110). Peaks represent thermal stability of different Li-oxides
- Individual Li TPD peaks analyzed by annealing sample to remove Li compounds desorbing at lower temperature peaks.
- Surface C does not affect thermal stability of Li film on Mo(110)
- Surface C has significant effect on the interactions of Li film with oxygen

Near term plans:

- Expand study of composition of oxidized and carbon contaminated Li films on Mo(110) with XPS and vibrational spectroscopy
- Study effect of hydrogen ion implantation on pure and contaminated Li films.

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