The Influence of Temperature and Oxygen Surface Contamination on the Adsorption of Deuterium on Lithium-Coated Molybdenum Substrates

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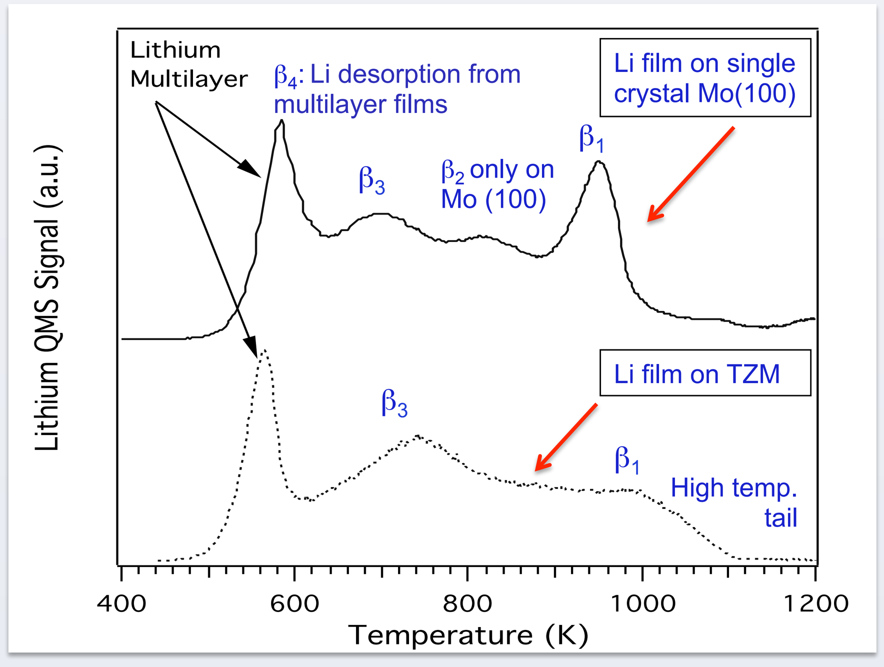
Motivation

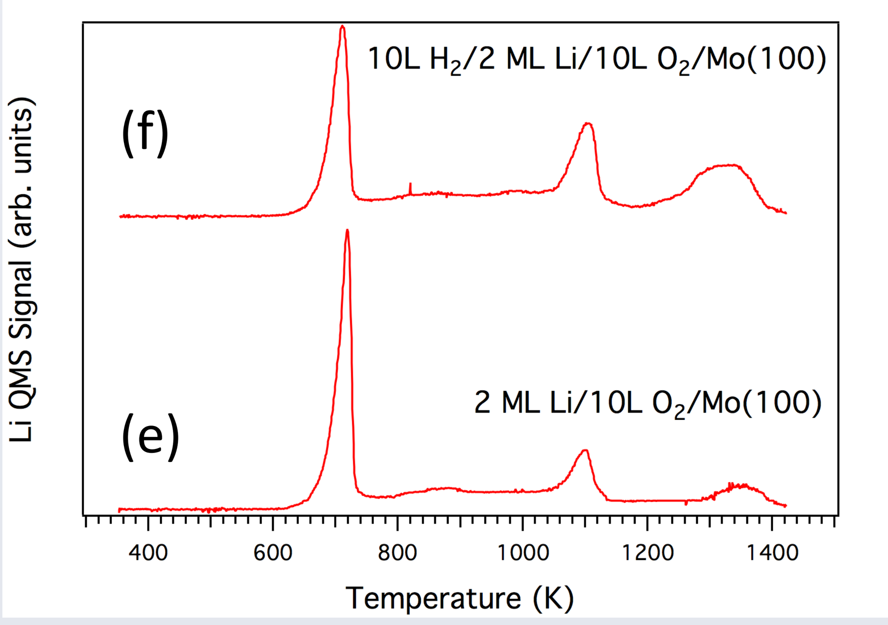
- Manipulating the plasma-material interface (PMI) is one of the most critical challenges in the realization of fusion energy.
- Solid materials such as tungsten experience erosion, thermal fatigue, and embrittlement from neutron damage.
- Liquid metals enable in-situ renewal of the surface to circumvent such issues.
- Lithium has a high chemical affinity for hydrogen, which has reduced recycling of D and enhanced plasma performance on TFTR, NSTX and other machines.
- The goal of this work is to determine mechanisms for H/D retention in Li on Mo using temperature programmed desorption (TPD).
- The 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 Mo alloy tiles.

Effect of Grain Boundaries on Li Desorption from Mo

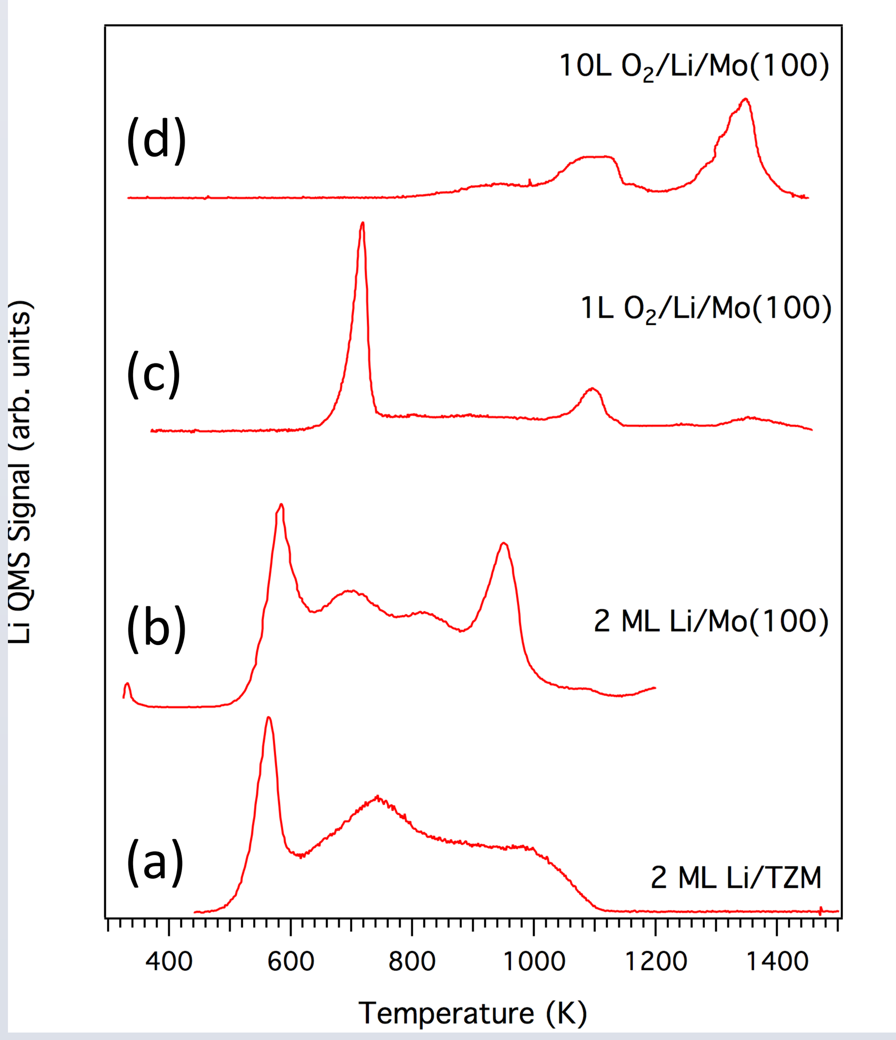
- Mo(100) and TZM comparisons probe the role of carbon contamination and grain boundaries.
- Changes in β_1-β_3 states indicate changes in bonding of the lithium monolayer on TZM compared with TZM.
- β_1 peak is more defined for Mo(100). The tailing on β_1 for TZM may indicate other chemical bonding or enhanced diffusion of Li into the subsurface region of TZM via grain boundaries.



Li and H_2 TPD of Li/Mo(100) with Exposure to O_2 and H_2 Gas

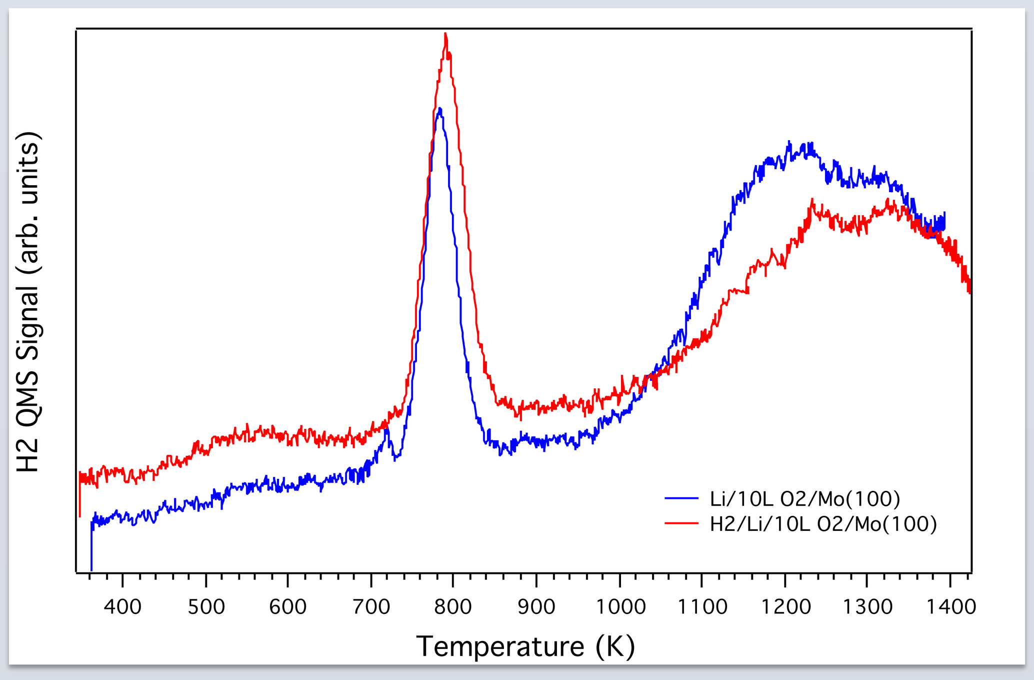


- Curve (f): H_2 gas at low exposures is not retained by the lithium oxide film on Mo(100) at 350 K.
- Curve (e): Decomposition of a lightly oxidized Li/Mo(100) surface was not affected by 10 L H_2.

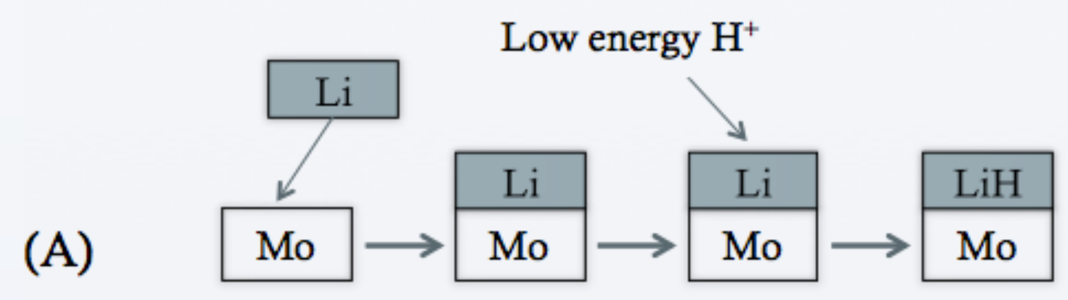


- Curve (d): 10 L O_2 exposure to Li/Mo(100) surface results in complete oxidation with peaks at 1100 and 1350 K.
- Curve (c): 1 L (1 L=1e-6 Torr-s) O_2 on Li/Mo(100) results in formation of lithium oxide that decomposes to liberate Li near 700 K.
- Curves (a) and (b): Compare TPD of Li/TZM and Li/Mo(100).

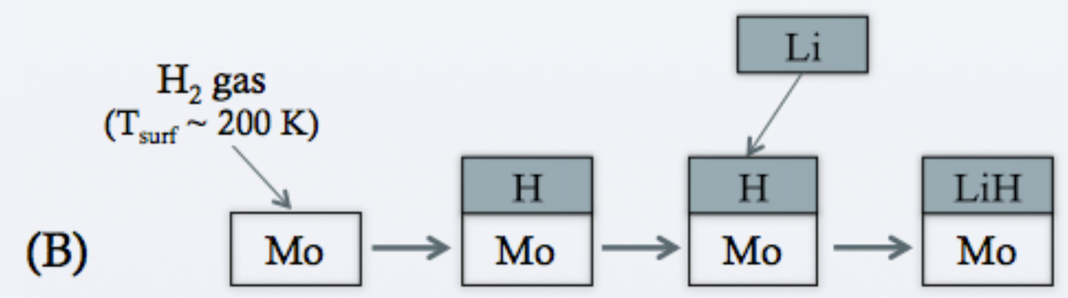
TPD of H_2 gas (mass = 2 amu) from an oxidized Li/Mo(100) surface indicate that H_2 gas is not retained in the Li at low exposures at 350 K.



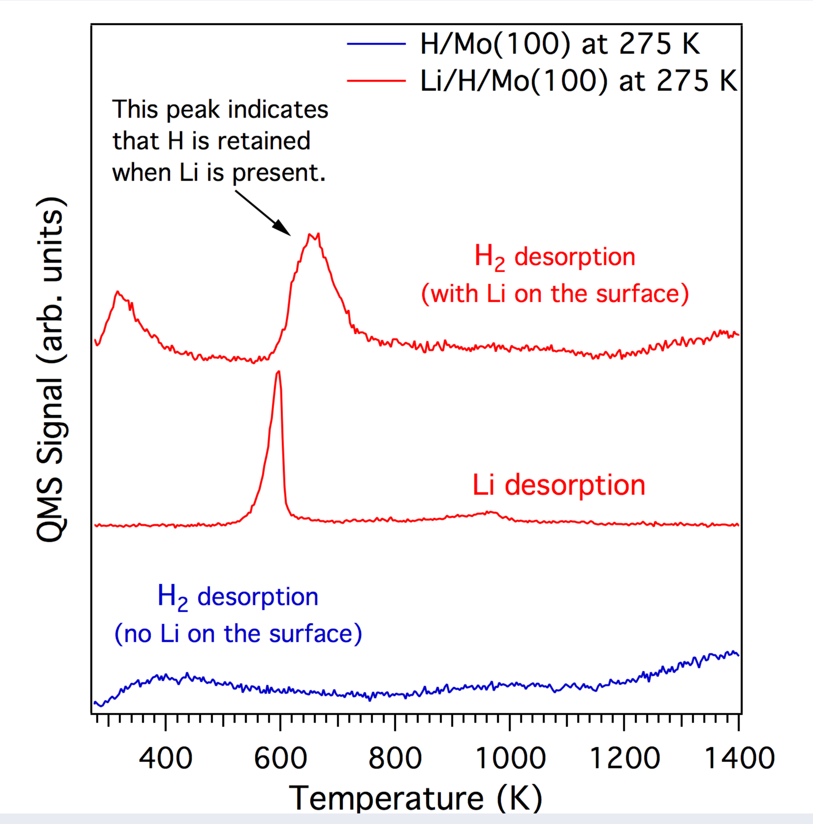
Formation and Decomposition of LiH on Mo(100)

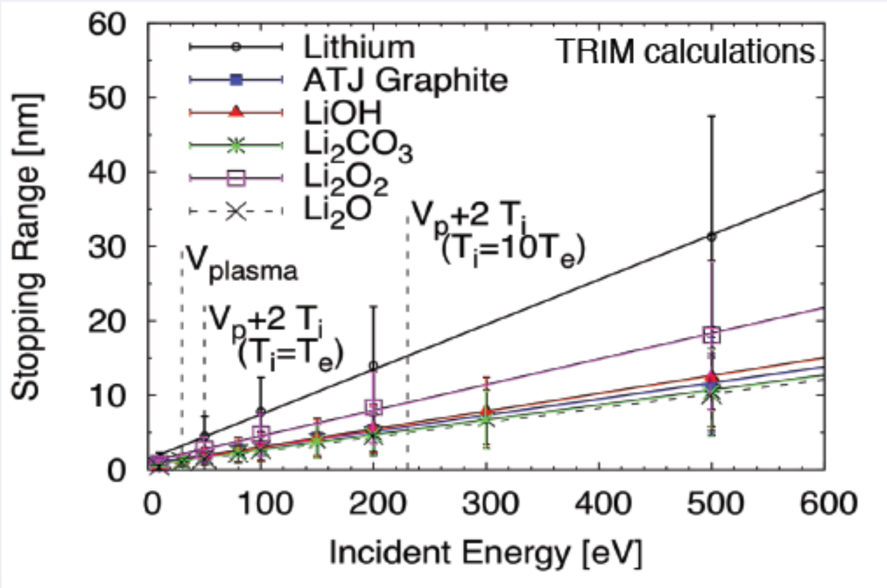


(A) Deposit Li onto Mo(100) and then bombard the surface with low energy H+ ions.



(B) H_2 dissociatively adsorbs onto Mo(100) to form a monolayer of adsorbed H atoms. Deposit Li onto H/Mo(100) to form LiH.





TRIM calculations show that low energy ions are needed to penetrate thin Li films of 1-5 monolayers.

(R. Kaita et al., J. Nucl. Mater., 438 (2013) S488-S492)

- A monolayer of H atoms is adsorbed onto Mo(100) at 200 K.
- H_2 desorbs from Mo(100) at 287 K.
- Li deposited onto the surface to form LiH.
- LiH decomposes near 600 K to liberate Li and H_2.
- Without Li, H_2 TPD shows no H_2 retained at 600 K.
- To investigate H/D uptake from ion bombardment, low energy ions must be used when studying thin Li films (1-5 monolayers).

Conclusions

- Indications of Li diffusion into grain boundaries were apparent in a TPD comparison of Li-coated TZM and single crystal Mo.
- Oxidized Li on Mo substrate does not retain H_2 gas at low exposure and 350 K.
- LiH is formed on a Mo(100) surface via two methods:
    - (1) preadsorbed H onto a cold Mo surface below room temperature followed by Li deposition
    - (2) lithium deposition onto Mo(100) surface followed by low energy ion bombardment
- LiH decomposes near 600 K to liberate Li and H_2.

Future Work

- Uptake and retention of D_2, D, and D^+ on lithium-coated TZM and Mo single crystal will be studied using an ECR plasma source with:
    - Ion energies of 0.02-2 keV; fluxes up to $1.5\text{x}10^{16}$ to $3.0\text{x}10^{17}$ ions/cm^2/s
    - Atom energies < 1.5 eV; fluxes > $2\text{x}10^{16}$ atoms/cm^2/s
- Surface temperature will be varied to determine its effects on H/D uptake.
- Colutron mass-analyzed ion source will also be used to study the effects of low energy H/D ions:
    - Deceleration lens allows for ions as low as 1-2 eV
- Results will be applied to the design of liquid lithium plasma facing components.

Acknowledgments

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