Deuterium Ion Retention as Lithium Deuteride in Thin Li Films on Mo(110)

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PRINCETON School of Engineering and Applied Science

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Motivation and Overview

Motivation

- Lithium coatings on plasma facing components have been shown to improve plasma performance
- Need to understand fundamental chemical interactions between plasma and plasma facing lithium films to help inform observations in more complex systems

Overview

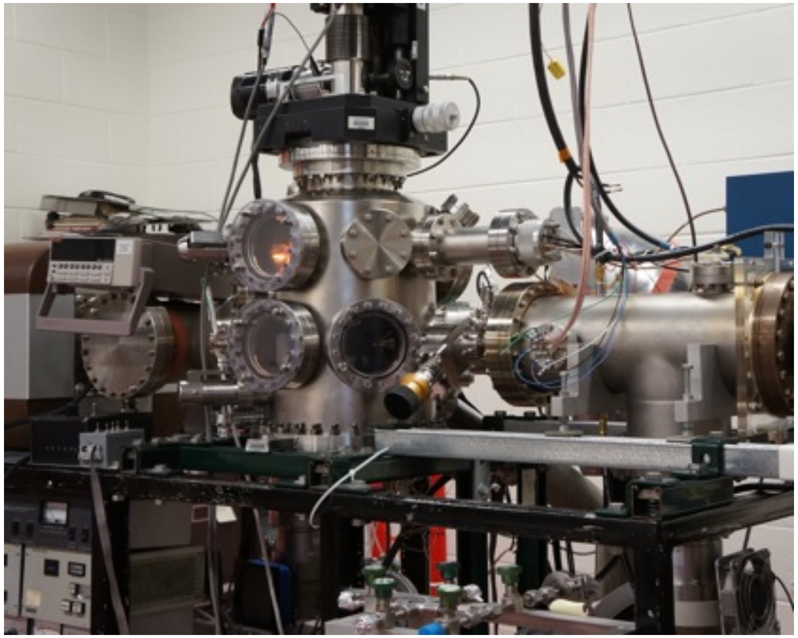
I. A surface science approach to understand D retention in Li

II. Identifying and characterizing LiD formation in Li films

III. D retention in monolayer and multilayer Li films

IV. Quantifying D retention in Li films

Surface Science Approach to Understanding D Retention

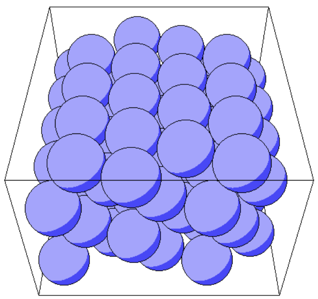


Experimental Chamber in Surface Science & Technology Lab at PPPL

- Surface science experiments enable independent control of all variables --- This is something we cannot achieve in a tokamak or linear plasma device.
- Key variables affecting chemistry at surface are controlled:
  - Pressure (UHV, background 10^{-10} Torr)
  - Temperature (100 – 2000 K)
  - Composition (Mo, Li, D^+, residual gases, etc.)
- Isolate effects of incident particles and their energies
- Start simple, i.e. single effects, and add complexity to bridge gap between model systems and tokamak environment

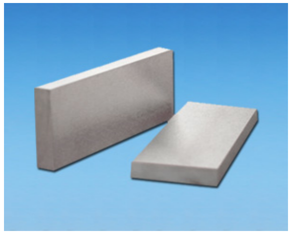
Studying Simple Model Systems

Simple Model Experiments → **More Complex Systems**

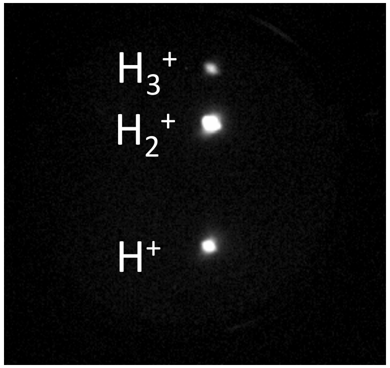


Mo(110) Crystal

- Grain boundaries
- Alloying elements: Ti, Zr, C
- Surface roughness and different crystal facets
- Adsorbed layers: O, C, etc.



TZM Alloy



Monoenergetic Ion Beam
(image of ions on phosphor)

- Multiple species: H^+, H_2^+, H_3^+
- Contaminant molecules: H_2O
- Increased flux: $10^{12} \rightarrow 10^{16}$ atoms/cm^2/s
- Atoms, ions, or atoms + ions

ECR Plasma Source

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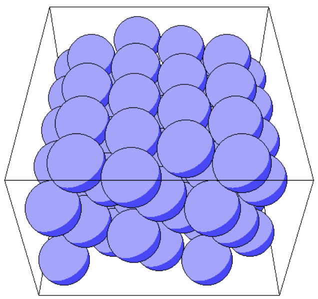

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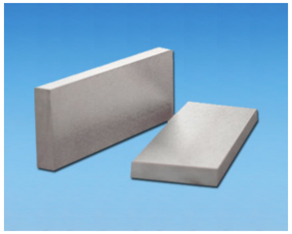

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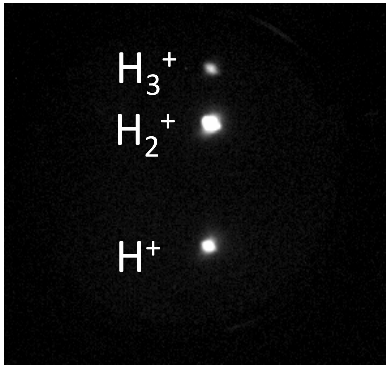

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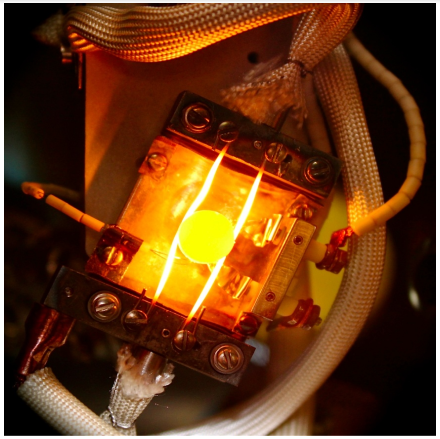
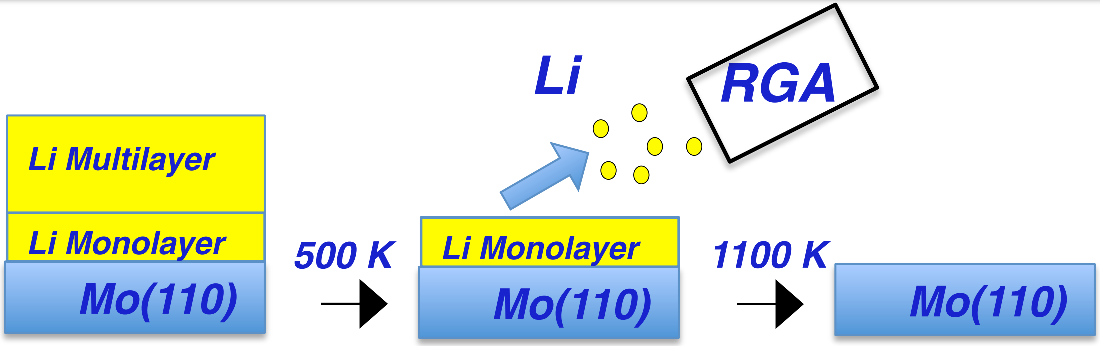
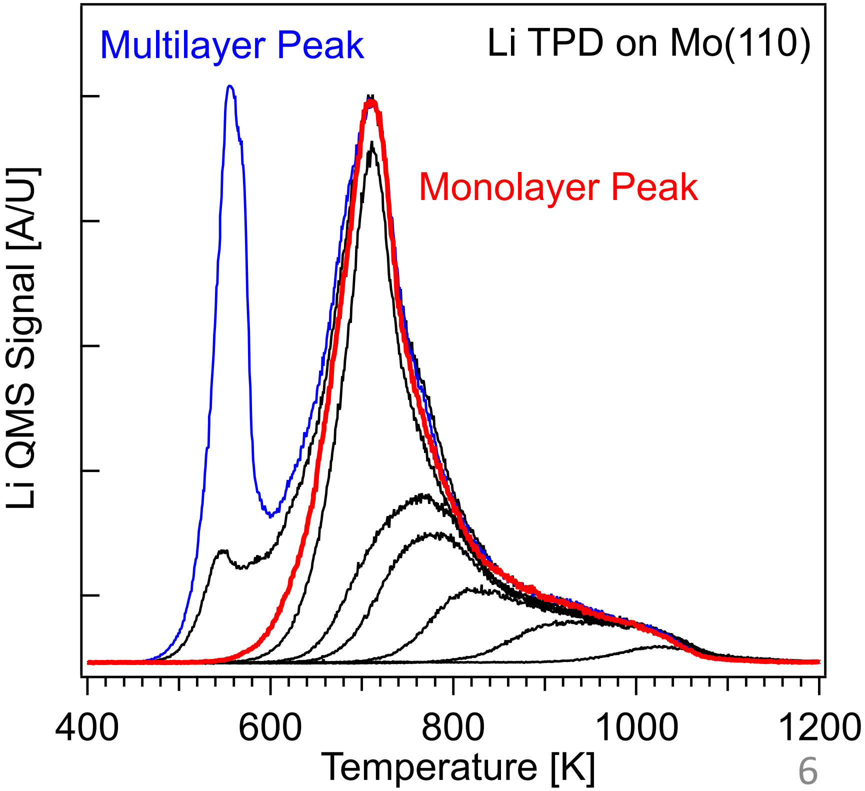
Thermal stability of Li on Mo(110)



Mo(110) resistively heated in UHV

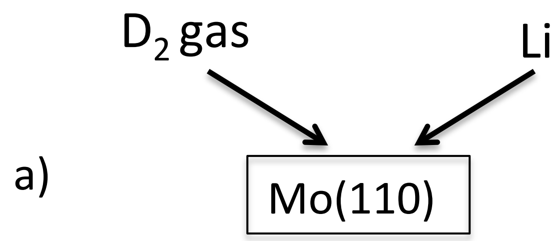


- Temperature Programmed Desorption (TPD) is used to study Li films
- Area under TPD curve is proportional to atoms desorbed
- Sub-monolayer control of film thickness
- Desorption peaks correlated with binding (adsorption) energies

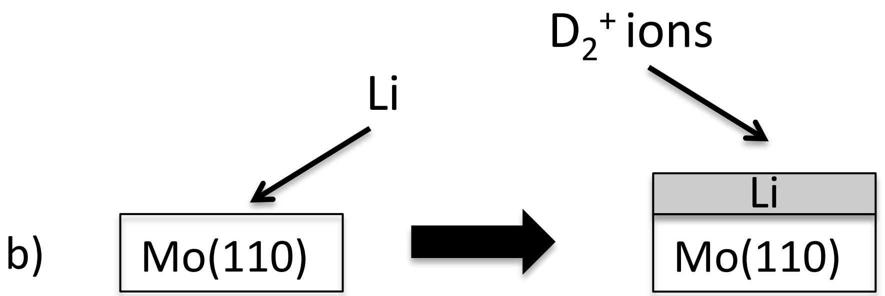


D^+ Implantation Forms Lithium Deuteride

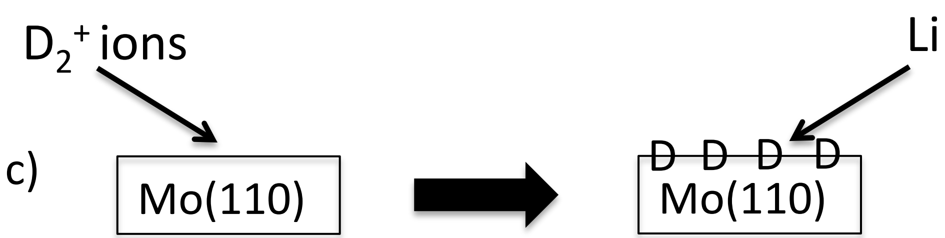
a) Lithium deposited with D_2 gas (P=10^{-6} Torr),
→ minimal LiD created



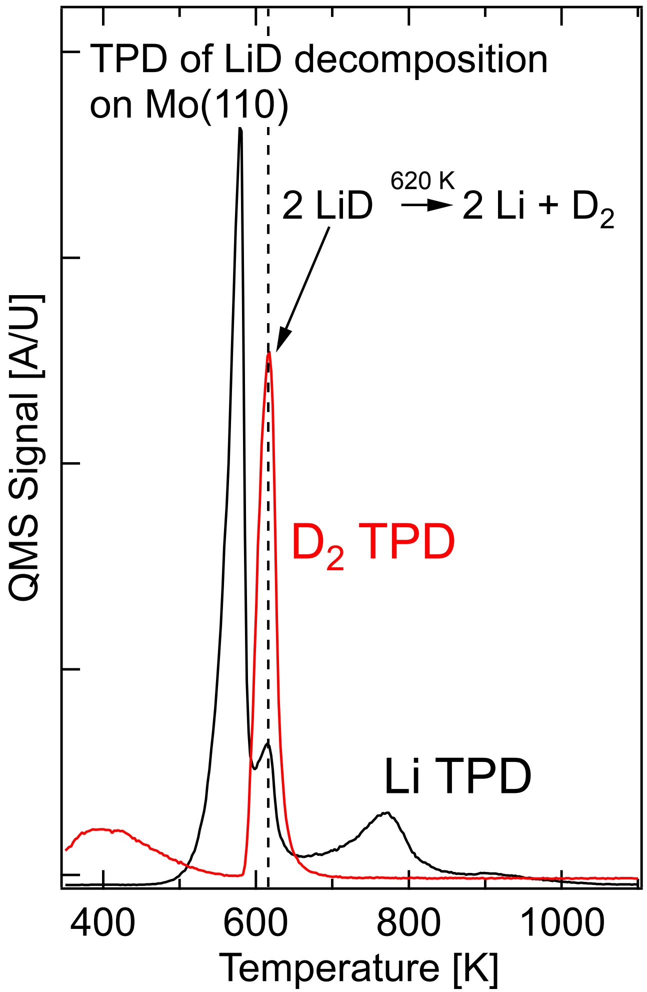
b) Deuterium ions implanted through Li film on Mo(110)
→LiD created

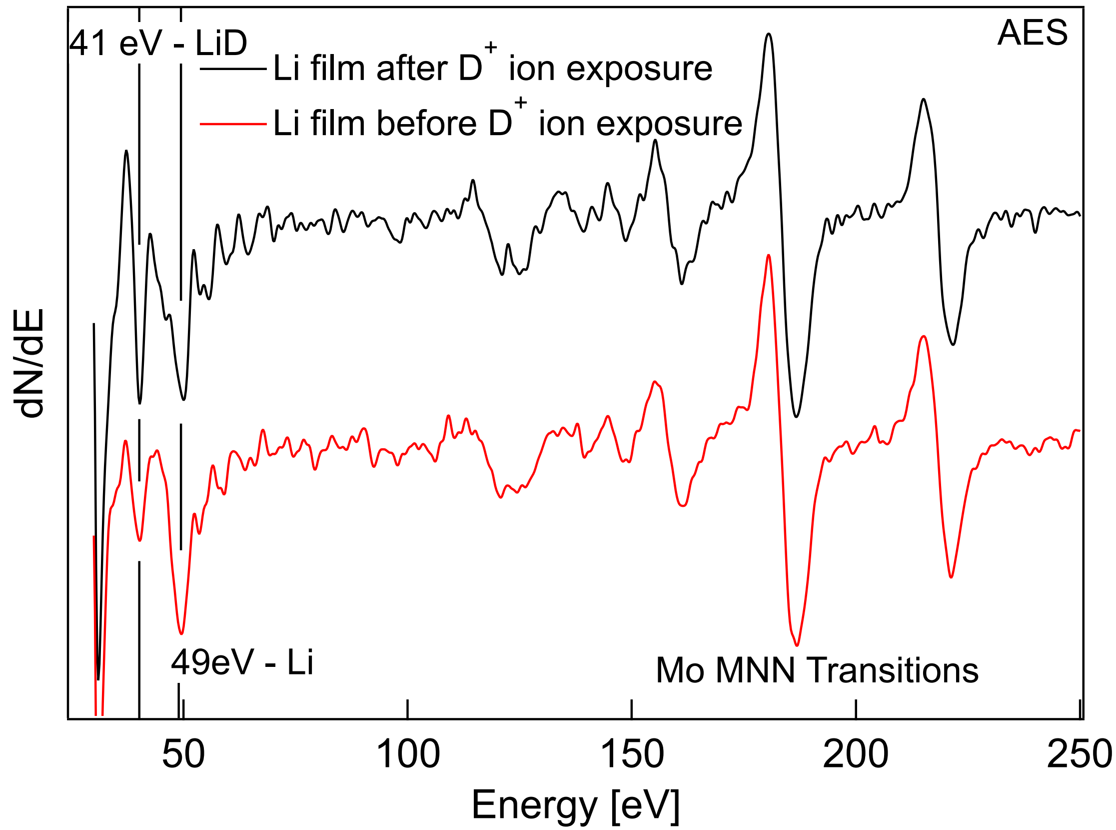


c) Deuterium ions implanted into Mo(110) crystal before Li film is deposited
→LiD created



TPD and AES Indicate LiD Formation

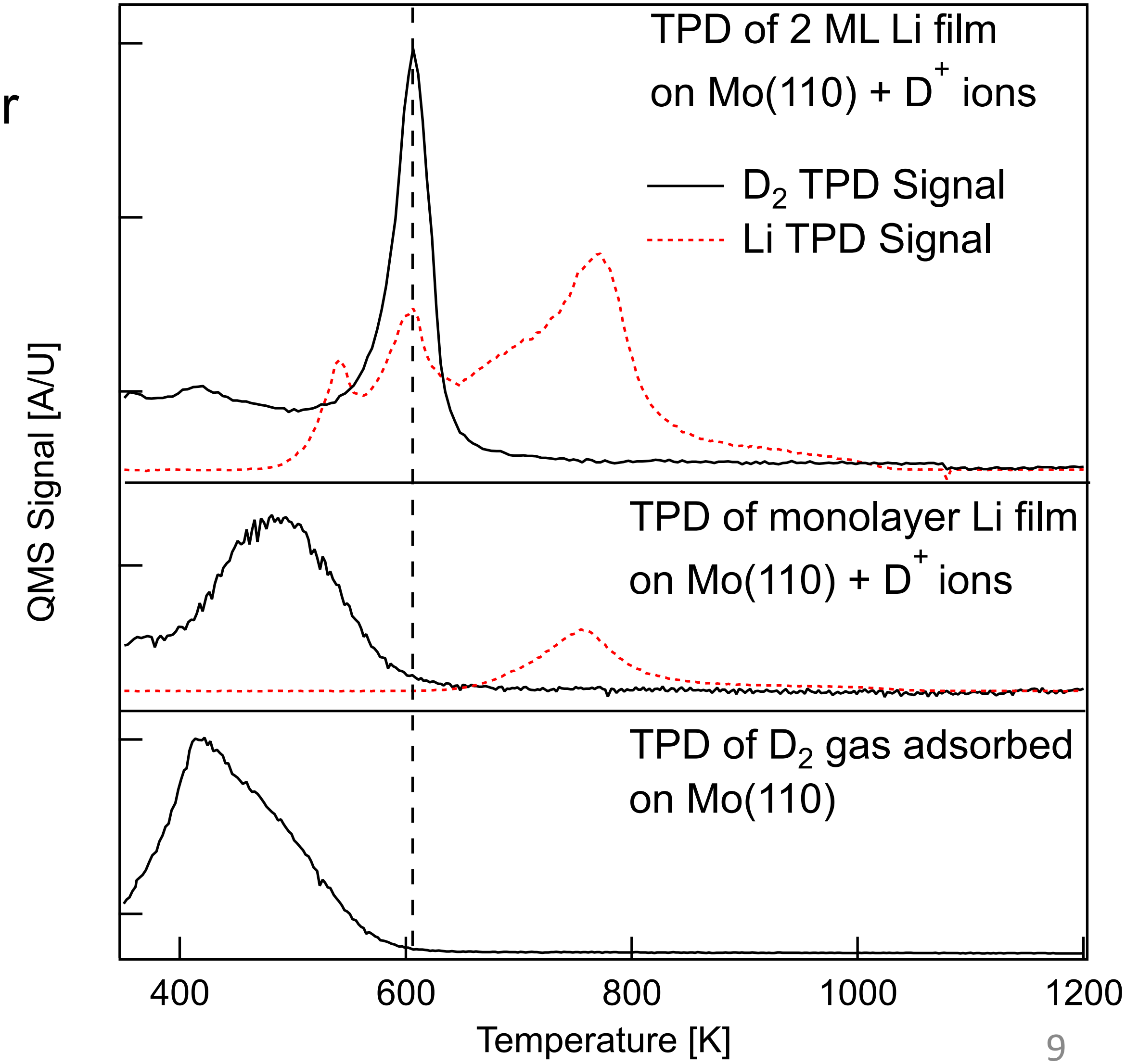




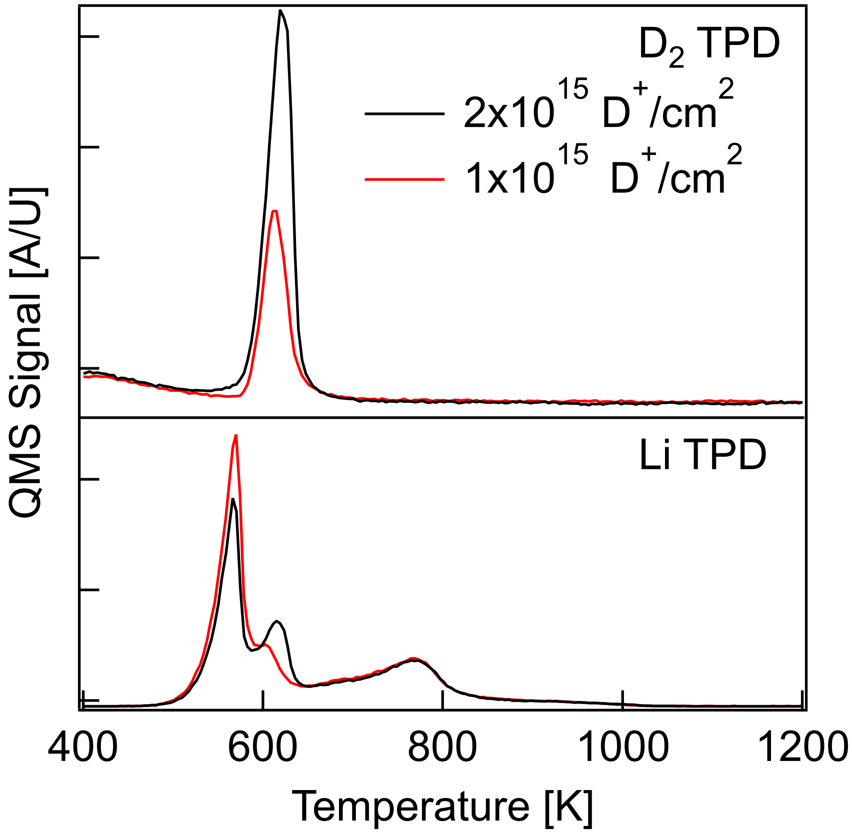
- Simultaneous desorption of D_2 and Li in TPD
- Shift in Li Auger peak from 49 eV to 41 eV

Li Monolayer Does Not Form LiD

- D^+ implanted into monolayer and multilayer Li films on Mo(110)
- LiD forms when ions implanted into multilayer Li films
- LiD decomposition peak not observed in TPD of monolayer Li films
- D_2 desorption from monolayer Li film similar to D_2 desorbing from clean Mo(110) crystal

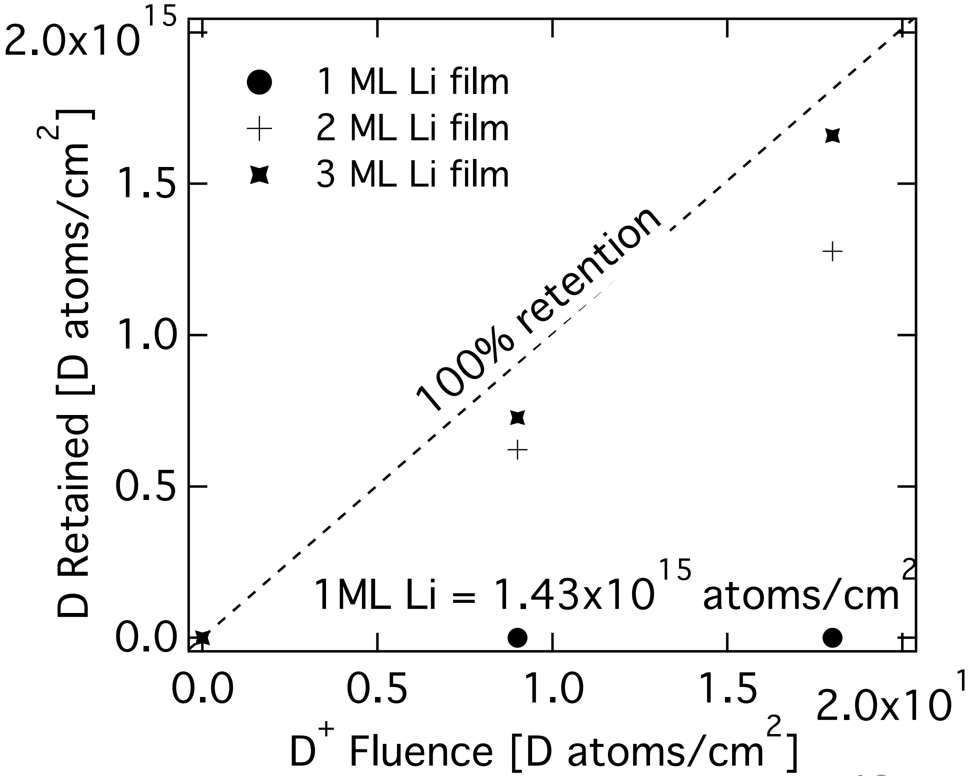


Using TPD to Quantify D Retention



- D retention proportional to area under D_2 TPD curve
- Increased D^+ dose results in larger D_2 TPD area

- No LiD formed in 1 ML Li films
- Nearly all implanted D forms LiD in multilayer Li films
- Fraction of D forming LiD drops as $n_{D\ implanted} \rightarrow n_{Li\ multilayer}$



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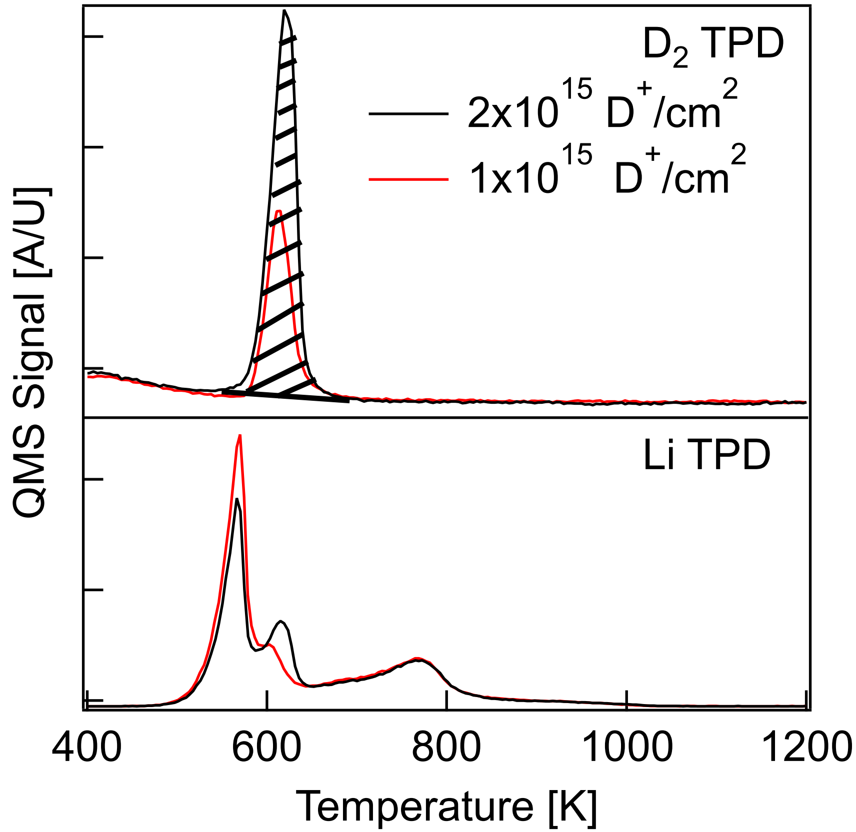

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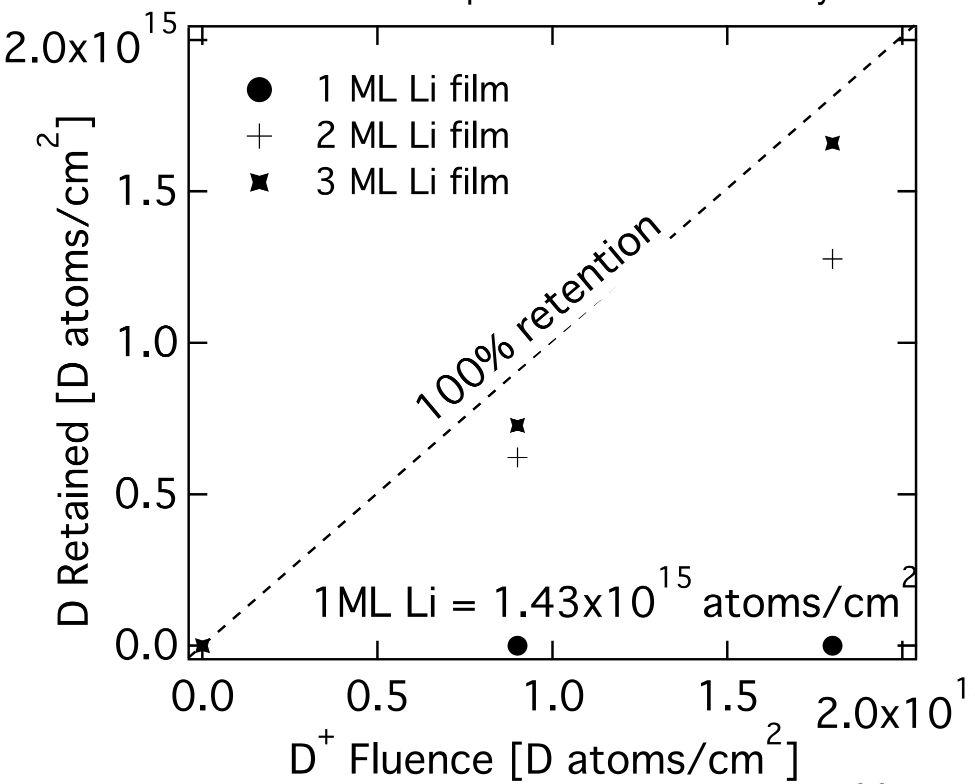

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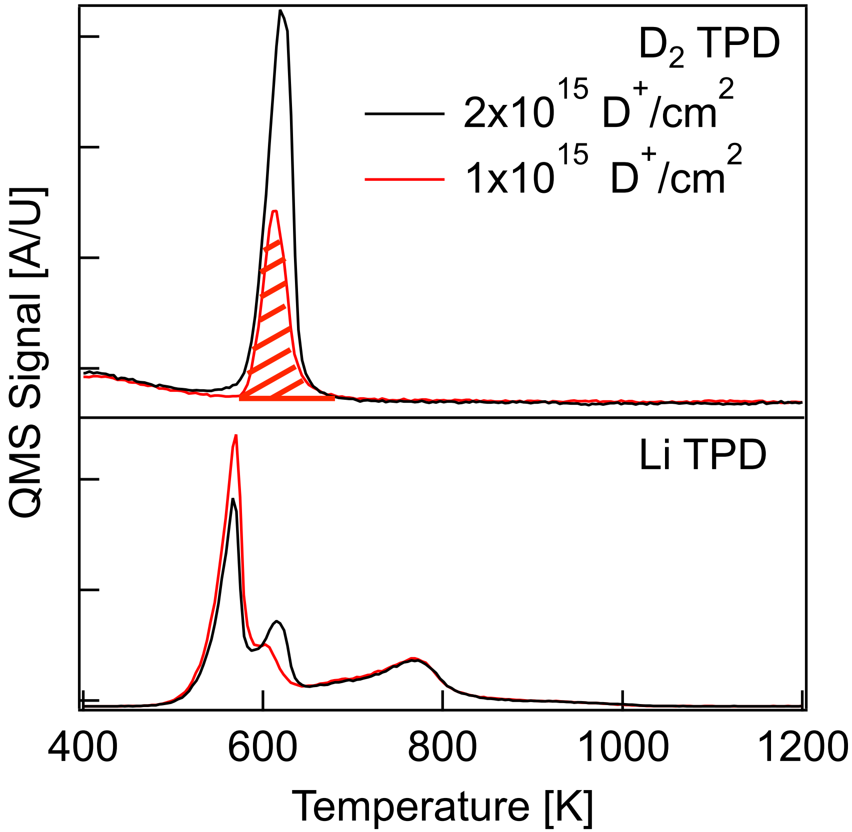

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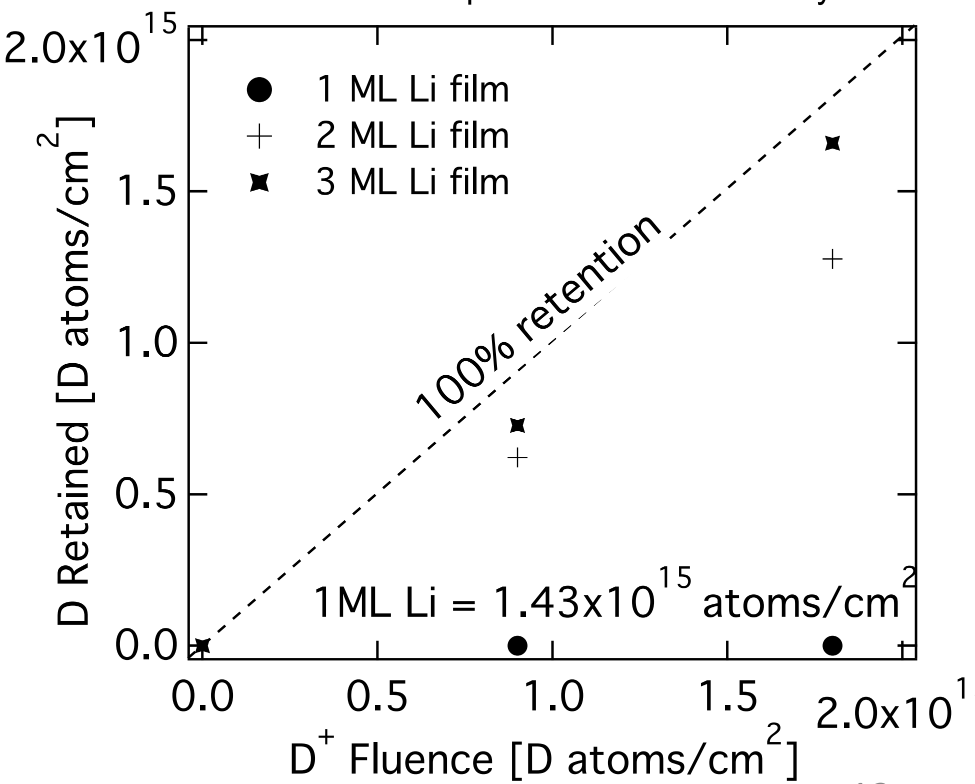

Conclusions

- D^+ implanted into Li covered Mo(110) retained as LiD
- LiD is identified by shift in Li AES peak + simultaneous D_2 and Li TPD peaks
- LiD not formed in monolayer Li films
- Nearly 100% of D implanted forms LiD while $n_{D\ implanted} < n_{li\text{-}multilayer}$
  → agrees with results of Baldwin et al.
  Baldwin et al., Fusion Eng Des, 61-62 (2002) 231-236

See also

PP8.00081 : Suppressed gross erosion of high-temperature lithium films under high-flux deuterium bombardment: Wed afternoon posters
YI2.00003 : High Performance Discharges in the Lithium Tokamak eXperiment (LTX) with Liquid Lithium Walls: Friday 10:30
YI2.00005 : The Effects of Temperature and Oxidation on Deuterium Retention in Solid and Liquid Lithium Films on Molybdenum Plasma-Facing Components: Friday 11:30

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AMC and CHS acknowledge support by DOE (FES), PPPL-036, Fundamental Studies of Deuterium Retention in Solid and Liquid Metals