Understanding Implantation, Diffusion and Surface Contamination of Advanced Fuels with Various Condenser Optics

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Surface Cleaning of Optics by Plasma Exposure: SCOPE Device

- **Multifunctional tool:**
  - Li+ capable Ion Gun
  - Versatile E-Beam Evaporator
  - Helicon Plasma Source

Ion Gun

- Manufactured by Nonsequitur Technologies
- High current density 15 to 50 mA/cm^2 depending on spot size selected, total beam current of 250 nA
- Stable emission.
- Working distance to sample of 25 mm.
- No differential pumping required.
- Integral beam current Faraday cup measurement system

E-Beam Evaporator

- Manufactured by MDC Vacuum
- Rated for 3000 Watts of deposition power
- Li source with Mo liner, capable of using other source material.
- Pneumatic Shutter System
- Cooling roof that acts as a collimator and shield from unwanted deposition
- Integrated with Lab View

Helicon Plasma Source

- Manufactured by PMT
- MORI 200 Helicon Antenna
- Quartz Bell Jar surrounded by a Helicon antenna
- Radiates 13.56 MHz with a max power for 3000W
- External electromagnets provide necessary fields for higher RF power

Sample Heater

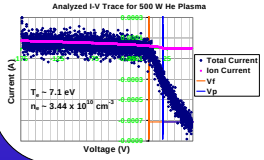
- Manufactured by Heatwave Labs
- Heated up to 1000°C
- DC or RF biasing capable
- Integrated with Labview to monitor temperature
- Removable sample holder to allow sample swapping in vacuum

SCOPE Diagnostic Tools

Quartz Crystal Microbalance

- Manufactured by Inficon.
- Dual Sensor Head.
- Water cooled for signal stability.
- Used as a deposition monitor during evaporation, plasma cleaning, and sputtering measurements.
- Electrically Isolated from the Chamber so that it can be biased and an energy distribution of sputtered particles obtained.
- XTC/2 Deposition controller.

Langmuir Probe Analysis of Plasma



- RF compensated to allow for more accurate T_e and n_e measurement.
- Integrated sweeping voltage.
- Digital data capture and analysis.

Motivation

- Mirror lifetime is based upon the ability to maintain EUVL reflectivity of 60% or greater and less than a 10% loss over the lifetime of the optic.
- Issues of concern that degrade lifetime:
  - Debris contamination buildup on the surface of the optic material matrix.
  - Implantation of contamination within the optic material matrix.
  - Destruction of the optic material matrix due to interaction with debris.

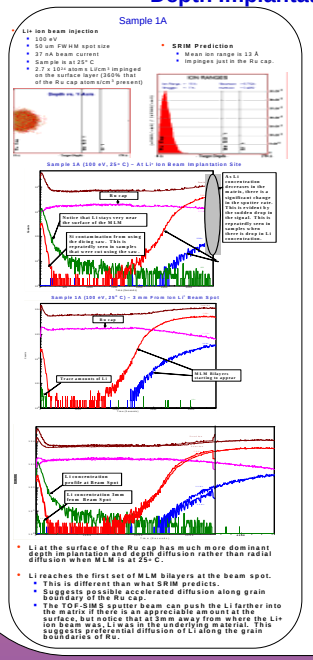
Experimental Matrix

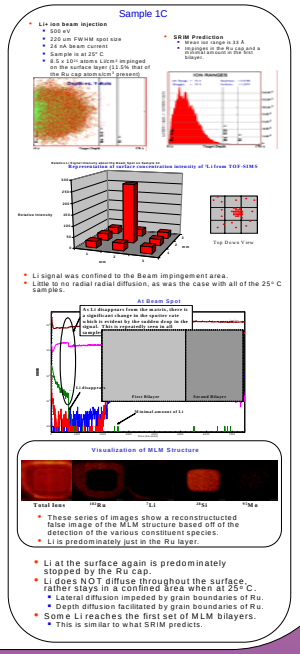
Experiment	Energy	FWHM Spot Size	Beam Current	Sample Temperature	Amount of Lithium Injected to Sample Surface	Mean ion range from SRIM
Sample 1A	100 eV	50 um	37 nA	25 C	2.7 x 10^24 Li ions/cm^3	13 Ang
Sample 1B	200 eV	200 um	10 nA	25 C	7.7 x 10^24 Li ions/cm^3	18 Ang
Sample 1C	500 eV	220 um	24 nA	25 C	8.5 x 10^21 Li ions/cm^3	33 Ang
Sample 1D	1000 eV	220 um	38 nA	25 C	8.x 1021 Li ions/cm^3	51 Ang
Sample 1E	100 eV	50 um	37 nA	350 C	2.7 x 10^21 Li ions/cm^3	13 Ang
Sample 1F	200 eV	150 um	10 nA	350 C	1.4 x 10^21 Li ions/cm^3	18 Ang
Sample 1G	500 eV	150 um	10 nA	350 C	7.2 x 10^21 Li ions/cm^3	18 Ang
Sample 1H	1000 eV	150 um	10 nA	350 C	5 x 10^21 Li ions/cm^3	51 Ang

Characterization Method

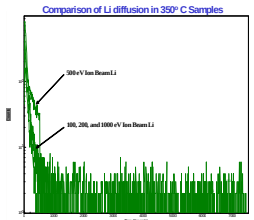
- TOF-SIMS
  - O_2 beam at 1.2 keV to sputter. Oxygen was chosen because of the close mass relation to Li. Cesium would push the Lithium into the mirror material matrix.
  - Au beam at 2.2 keV for analysis.
  - Sputter time of 10s, Analysis time of 3 .

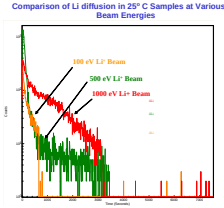
Depth Implantation/Diffusion





Summary

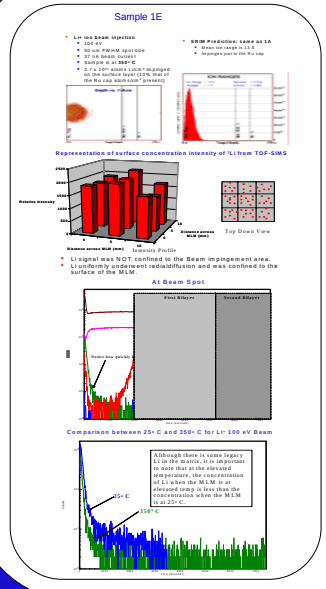


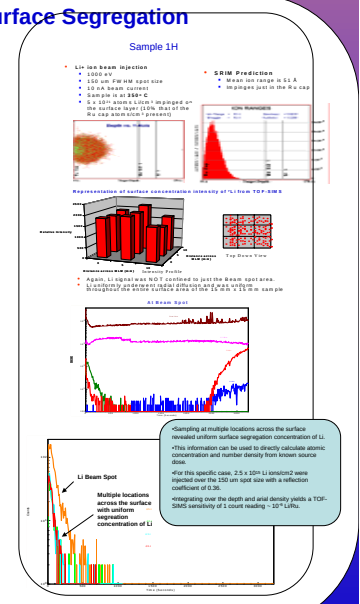


- With the MLM at an elevated temperature, the Li was more likely to segregate in the Ru cap layer, as opposed to diffusing into the matrix.
- A lower concentration of Li was observed in the MLM matrix.
- With the addition of heat energy, the grain boundaries of the Ru cap were not as restrictive and actually favored radial diffusion

- For the 25° C samples, Li at various energies was seen to implant and diffuse into the MLM matrix.
- Looking at surface concentration energy for various energies, the Li was seen to implant and diffuse into the MLM matrix and radial diffusion was minimal

Radial Diffusion/Surface Segregation





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