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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 Nonsequit Technologies
- High current density 15 to 50 mA/cm² 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



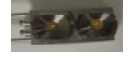
- Manufactured by PMT
- MORI 200 Helicon Antenna
- Quartz Bell Jar surrounded by a Helicon antenna
- Radiates 13.56 MHz with a max power for 3000W
- External electromagnets provide necessary fields for higher RF power

- Manufactured by Heatwave Labs
- Sample Heater
- DC or RF biasing capable
- Integrated with Labview to monitor temperature
- Removable sample holder to allow sample swapping in vacuum



SCOPE Diagnostic Tools

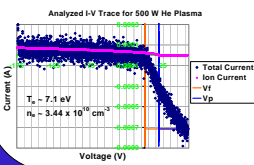
Quartz Crystal Microbalance



- 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.

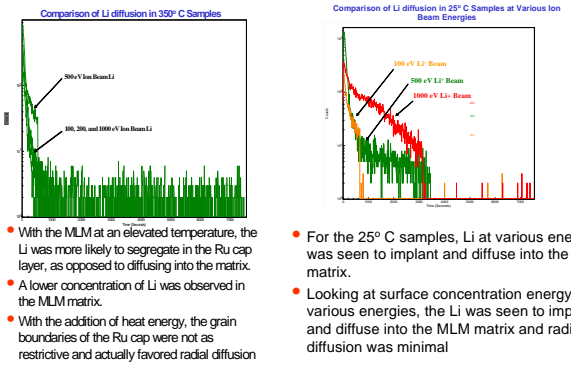
Experimental Matrix

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 ²	13 Ang
Sample 1B	200 eV	200 um	10 nA	25 C	7.7 x 10 ²⁴ Li ions/cm ²	16 Ang
Sample 1C	500 eV	220 um	24 nA	25 C	8.5 x 10 ²¹ Li ions/cm ²	33 Ang
Sample 1D	1000 eV	220 um	38 nA	25 C	8.8 x 10 ²¹ Li ions/cm ²	51 Ang
Sample 1E	100 eV	50 um	37 nA	350 C	2.7 x 10 ²⁴ Li ions/cm ²	13 Ang
Sample 1F	200 eV	150 um	10 nA	350 C	7.4 x 10 ²¹ Li ions/cm ²	18 Ang
Sample 1G	500 eV	150 um	10 nA	350 C	7.2 x 10 ²¹ Li ions/cm ²	18 Ang
Sample 1H	1000 eV	150 um	10 nA	350 C	5 x 10 ²¹ Li ions/cm ²	51 Ang

Characterization Method

- TOF-SIMS
 - O₂ 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.

Summary

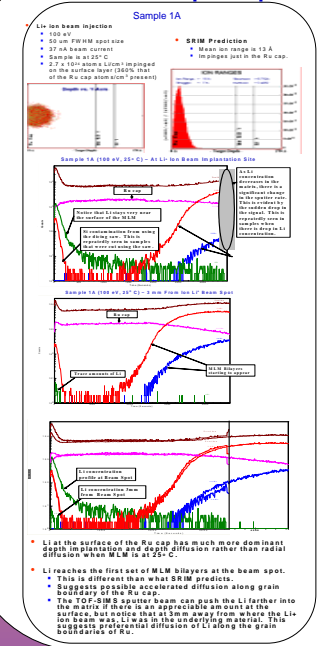


- With the MLM at an elevated temperature, the Li was more likely to segregate in the Ru cap layer, as opposed to diffusing into the matrix.
- A lower concentration of Li was observed in the MLM matrix.
- With the addition of heat energy, the grain boundaries of the Ru cap were not as restrictive and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

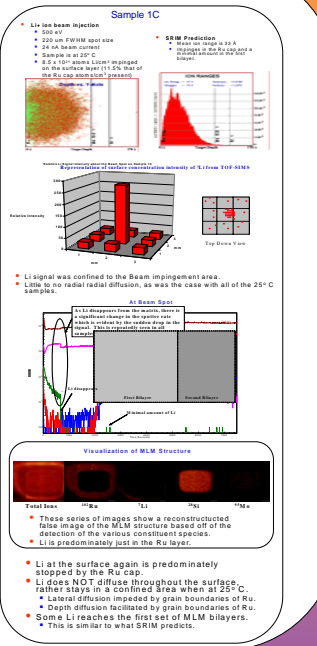
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- International Sematech
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Depth Implantation/Diffusion

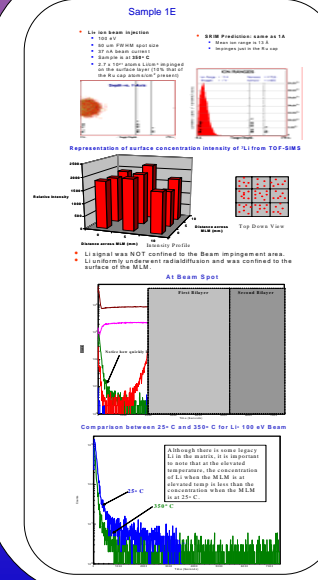


- Li at the surface of the Ru cap has much more dominant depth implantation and radial diffusion rather than radial diffusion when MLM is at 25° C.
- Li reaches the first set of MLM bilayers at the beam spot.
- This is different than SRIM predicts.
- Suggests possible accelerated diffusion along grain boundary of the Ru cap.
- The TOF-SIMS sputter beam can push the Li farther into the matrix of Ru than an appreciable amount at the Li ion beam was Li was in the underlying material. This suggests preferential diffusion of Li along the grain boundaries of Ru.

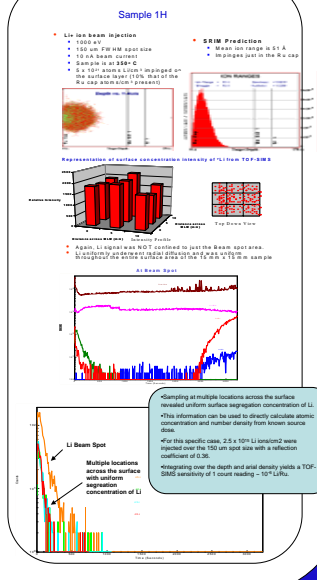


- Li signal was confined to the Beam implantation area. Little to no radial diffusion, as was the case with all of the 25° C samples.
- Li at the surface again is predominantly stopped by the Ru cap.
- Li does NOT diffuse throughout the surface. It stays in a confined area. When at 350° C.
- Lateral diffusion impeded by grain boundaries of Ru.
- Depth diffusion facilitated by grain boundaries of Ru.
- Some Li reaches the first set of MLM bilayers. This is similar to what SRIM predicts.

Radial Diffusion/Surface Segregation



- Although there is some discrepancy in the amount of implantation, the concentration of Li in the MLM is an elevated temp is less than the concentration when the MLM is at 25° C.



- Sampling at multiple locations across the surface revealed uniform surface segregation concentration of Li. This information can be used to directly calculate atomic concentration and number density from known source dose.
- For this specific case, 2.5 x 10¹⁹ Li ions/cm² were measured for the 150 um spot size with a reflection coefficient of 0.36.
- Integrating over the depth and axial density yields a TOF-SIMS sensitivity of 1 count reading = 10¹² Li.