

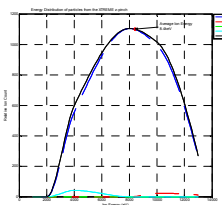
Joshua B. Spencer, Darren A. Alman, Matthew D. Coventry, Brian E. Jurczyk, David N. Ruzic

Department of Nuclear, Plasma, and Radiological Engineering, Plasma Material Interaction Group, University of Illinois at Urbana. Correspondence to druzic@uiuc.edu

Abstract: Both high repetition rate laser produced plasmas (LPP) and discharge produced plasmas (DPP) are promising extreme ultraviolet and soft x-ray sources for next generation lithography applications. LPP sources have the advantages of less debris production and extended mirror lifetimes, a higher repetition rate, and a larger solid angle possible for the collection optics over discharge produced plasma sources, while DPP has the advantage of lower set up costs and simplicity of operation. We analyzed the buildup of debris on a multilayer mirror (MLM) surface, erosion of the mirror due to fast debris ions, implantation of debris ions into the mirror, and ion-induced mixing of mirror layers to estimate the mirror lifetime. Modeling results show the predicted erosion from TRIM-type codes agrees very well with the measured erosion of samples exposed to 10 million shots in a Xe DPP EUV source

Modeling and Comparison to Experimental Erosion and Deposition from a DPP Source

The Goal of this part of the project is to calculate the level of erosion and deposition i.e. damage that is done to a sample of various materials. The first step will be to characterize the ions that are hitting the sample, the second is to calculate the sputtering yields of our ion on those samples then finally we will calculate a Δt or a change in thickness of the sample material.



Characterization of Ion Signal

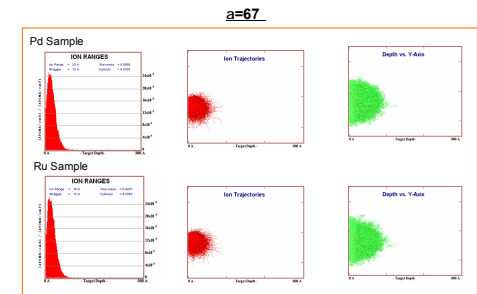
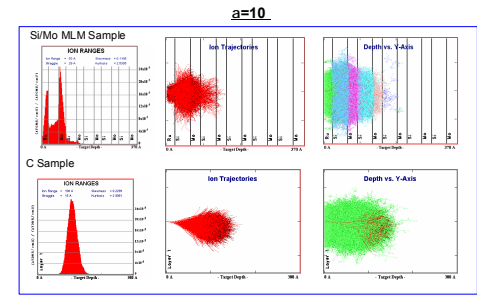
The plot displayed here is the ion distribution that is seen by the sample, when our Z-Pinch, from EXTREME Technologies, is running with a Xe plasma and buffer gas flowing. From this we calculated the average energy of incident ions of 8.4keV. Since the sputtering curve in this region of ion energy is quite linear, and our distribution is could well be approximated as a bell curve, we will assume that this average ion energy will be a good single representative energy of incident ions used in further calculations. Below is a picture of the spherical sector energy analyzer that recorded the experimental data.

A refined calibration needs to be performed however our initial estimates are that 25 "hits" equals 1 ion



SRIM-2003 Calculations

Here we show a sample of some of our SRIM results which give us sputtering yields, ion implantation and layer mixing data. For our Calculations we have two sets of conditions: First we have an approximately normal ($\alpha=10^\circ$) angle of incidence of the ion collision path and the target surface, and Second we have a grazing incidence angle, $\alpha=67^\circ$.



Final Calculation

We now put our new sputtering calculations and our known values from experiment together to find our change in thickness which is given by the following equation: $\Delta t = (Y \cdot t \cdot m) / \rho$ where Δt is the change in sample thickness, Y is the calculated sputtering yield, G is the experimentally derived ion flux on sample, t is time, m is the mass of the target, and ρ is the density of the sample.

Normal Incidence

Target Element	Predicted Change in Thickness (nm)	Experimental (nm) +/- 2
C	1.1	< 3
Au	33	47
Mo	6.5	5
Si	5.8	< 3
Si/Mo MLM	8.5	10

Grazing Incidence

Target Element	Predicted Change in Thickness (cm)	Experimental
Pd	18	4
Ru	11	delamination
Au/Mo	10	11

Table of Calculated and Used Values

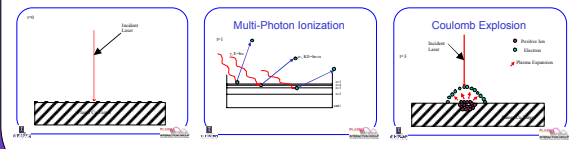
Sample	Yn Sputtering Yield	Angle of Incidence	Mass (amu)	Density (g/cc)
C	1.023	10	12.01	2.253
Au	15.907	10	196.9	19.311
Mo	3.332	10	95.94	10.206
Si	2.262	10	28.68	2.3212
Pd	25.388	67	106.4	12.02
Ru	16.528	67	101.07	12.3
Si/MO MLM	5.036	10	Ru-101.07 Si-28.68 Mo-95.94	Ru-12.3 Si-2.3212 Mo-10.206
Au-Mo	Au-10.86 Mo-6.81	67	Au-196.9 Mo-95.94	18.849

Summary

Given the measured ion flux to the samples, the erosion was predicted using standard TRIM models for sputtering and atomic constants. The predicted sputtering yield matches well with the experimental determined erosion. This work clearly shows that physical sputtering is the dominant damage mechanism in DPP condenser optic materials.

Basic Physics

The cartoon below show the basic idea of how laser energy is coupled to the plasma by simply liberating electrons from or disassociating atoms during multi-photon ionization. This leaves the target with a large net positive charge which will drive a "Coulomb Explosion" that is the driving force of the plasma expansion for laser intensities below 10^{15} W/cm².



Acknowledgements

Support for this project is provided in part by SEMATECH under contract #803808 OF
Additional support for LPP modeling from JMAR, Inc.

*Ref: P. Mora. Phys. Rev. Let., vol. 90, No. 18. 9 May, 2003. pp 185002-1 – 185002-4