3rd International Extreme UltraViolet Lithography Symposium

Particle debris characterization and mitigation from microscopic laser-plasma tin-doped droplet sources

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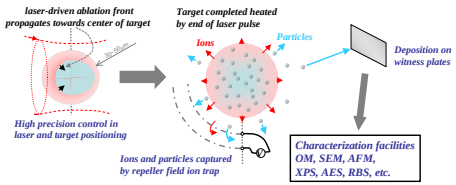
V. Bakshi

SEMATECH

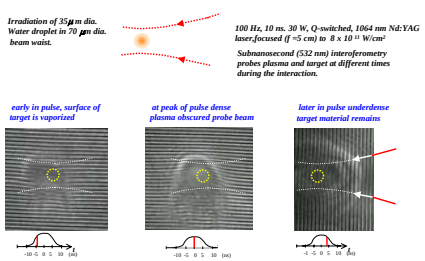
Research Objective

Our approaches to study and minimize particle emission



Background (previously studied)

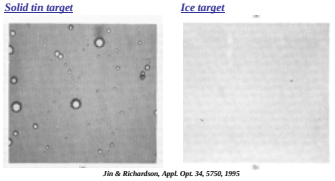
Target dynamics observed by nanosecond optical interferometry



Debris from solid tin and tin-doped microscopic target

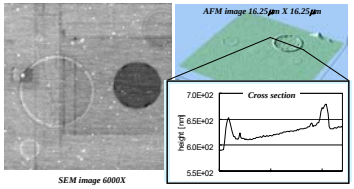
Debris on witness plate

Solid tin target *Ice target*



Jin & Richardson, Appl. Opt. 34, 5750, 1995

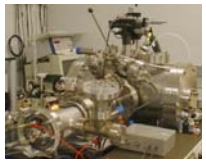
Tin-doped droplet target

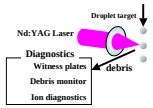


SEM image 6000X

K. Takenoshita, C-S. Koay, M. Richardson, Proc SPIE vol 5037 p792, 2003

Debris study facility and Characterization facilities





Target Chamber
Vacuum: 4x10⁻⁴[Torr]
Laser
1064 [nm], 100[Hz], Max. 300 [mJ], 10 [ns]
Focusing lens
Focal length: 50 [mm]
Target dispenser
Droplet target Diameter: 30~50 [μm]
Witness plates
Mo/Si Multilayer mirror, Si wafer
In-situ debris monitor
SAW device monitor (underway)

Characterization facilities

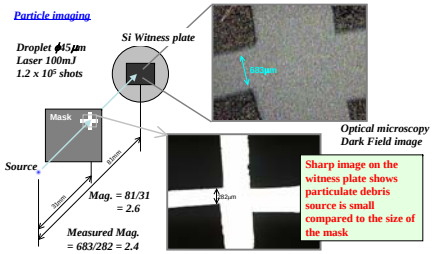
Microscopy

Spectroscopy

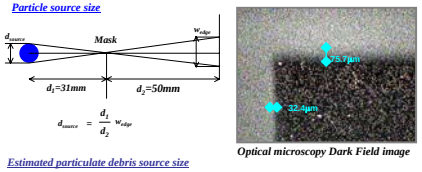
* AMPAC, Advanced Materials Processing and Analysis Center
http://pegasus.cc.ucf.edu/~ampac/home.html

Results
Particle imaging and SEM, RBS analysis

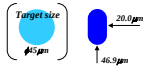
Particle imaging



Particle source size



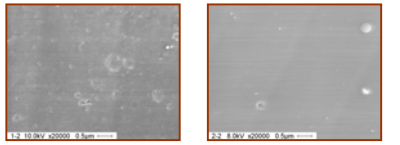
Estimated particulate debris source size



Particulate debris source size is smaller than the target size
Slight droplet movement and adjustment effect are seen in non-spherical source shape

SEM Images

Particle deposition comparison between different X-ray emission conditions



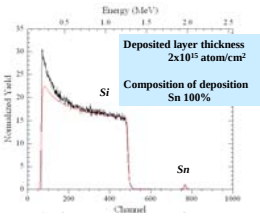
Laser 60mJ low X-ray emission condition *Laser 240mJ high X-ray emission condition*

1.2 x 10⁵ shots
Plate distance 82mm
No mitigation applied

Significant difference of particle deposition between the two different X-ray emission conditions
Controlling plasma condition is the key factor for particle generation

Rutherford Backscattering Spectroscopy (RBS)

RBS analysis



Experimental conditions
Droplet ϕ45μm
Laser 240mJ
1.2 x 10⁵ shots
Plate distance 82mm

RBS conditions
Probe beam 2.25MeV He²⁺
Beam diameter 1.5mm

Tin deposition is measured in terms of number of atoms in unit area

Summary

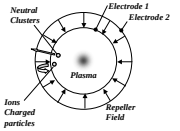
- Progress in understanding debris generation from Sn-droplet target
- Controlled generation of particulate debris from Sn-doped droplet target
- Large numbers of characterization facilities used for particulate debris analysis
- Quantitative debris analysis by RBS
- Spatially resolved surface analysis by AES/AEM
- Particulate debris mitigation demonstrated by Repeller field
- Combinations of debris mitigation methods to be investigated (Repeller field, gas curtain, foil trap, etc.)

Acknowledgments
Zia Rahman, Kirk Scammon (AMPAC)
Greg Shimkaveg, Rob Bernath, Joshua Duncan (College of Optics & Photonics: CREOL&FPCE)

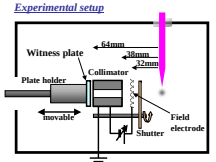
Effect of the repeller field for particles measured by AES and RBS

Repeller field configuration

Concept

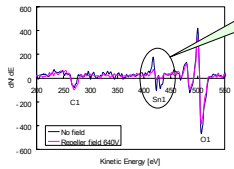


Experimental setup



Witness plates exposed though 6mm dia. collimator.
New plates installed during experiment.
Plate captures debris only during laser-target interaction by opening shutter during laser operation.

Auger Electron Spectroscopy (AES) spectrum comparison with/without the repeller field

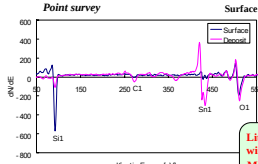


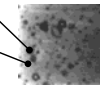
Less tin signal detected on the surface with mitigation than without it.

Laser energy: 240mJ
Number of shot: 3x10⁴
Target: Sn 30% doped
Surface: Si
Sample area: 100μm x 100μm

Spatially resolved AES

Auger electron spectroscopy
Point survey





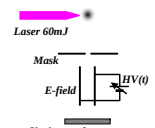
Si 50μm x 50μm
Sn 30% 3x10⁴shots
No mitigation applied

Little tin signal from surface without deposits.
Most of Tin on the surface is in deposited Particles.

Quantitative analysis by RBS for the effect of Electric field

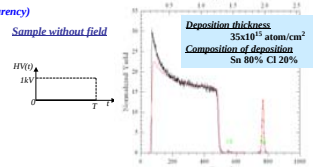
Transverse E-field (complete transparency)

Experimental Setup



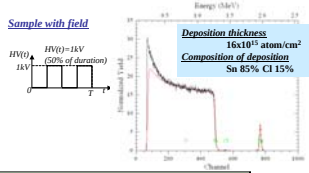
Si witness plate
82mm from source
1.2x10⁵ shots

Sample without field



Deposition thickness
35x10¹⁵ atom/cm²
Composition of deposition
Sn 80% Cl 20%

Sample with field



Deposition thickness
16x10¹⁵ atom/cm²
Composition of deposition
Sn 85% Cl 15%

Reduction ratio of tin deposition = duty ratio of the field applied
The field mitigates all the deposition while applied