

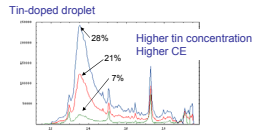
Tin Material Consumption and the Mirror Lifetime for Droplet Laser Plasma Sources

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EUVL source requirements Vs amount of tin in target

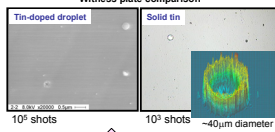
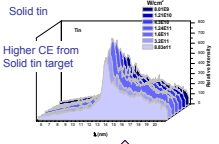
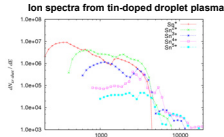
EUV in-band power output

Higher tin concentration \longleftrightarrow Advantages
 Disadvantages \longleftrightarrow Lower tin concentration

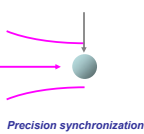
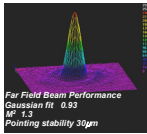


Collector optics lifetime

Low tin concentration



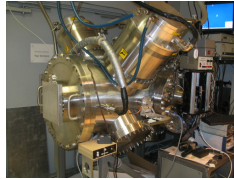
Mass-limited tin-doped droplet target



- No excess target material
- Whole target completely ionized
- Controlled laser intensity
- Controlled plasma temperature
- Thermalized plasma
- No fast ion generation

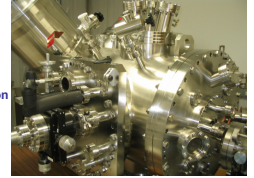
EUV source facilities in LPL

Mass-limited tin-doped droplet target is installed in



- Vacuum: <10⁻⁴ Torr
- Two 3000ips turbo pumps
- Industrial proven high rep.rate
- high power laser
- FFS spectrographs
- EUV energy monitor

Mass-limited tin-doped droplet target will be installed in



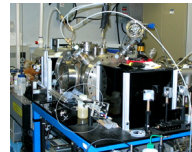
- Activating
- Two 3000ips turbo pumps
- 1Hz precision laser



- Target Chamber**
 Vacuum: ~10⁻⁴ Torr
Lasers
 Custom built, precision Q-switched, Nd:YAG laser, 11.5 ns pulse, 1064 nm, 1-5 Hz, 1.7J max energy
Target dispenser
 Droplet target Diameter: 30-50 µm

- Chamber details:**
 Pressure: 1e-5 Torr
 16 ports

- Plasma diagnostics:**
 EUV energy meters
 Spectrometers
 Ion probes
 Ion spectrometers
 Witness plates
 Quartz Crystal Micro Balances



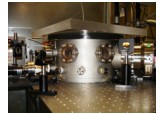
- Target Chamber**
 Vacuum: 4x10⁻⁴Torr
Laser
 1064 [nm], 100[Hz], Max. 300 [mJ], 10 [ns]
Focusing lens
 Focal length: 50, 100 [mm]
Target dispenser
 Droplet target Diameter: 30-50 [µm]
Paraflex Cup Ion Probe
 Distance from source: 50 - 150 [mm]
Ion Spectrometer
 Max. Ion energy: 5.0 [keV] for Z=1
Thomson parabola
 Max. Ion energy: 10 [keV]

Chamber

- 30 cm in diameter, 18 cm in height
- eight ports separated by 45°
- vacuum 1/8 inch NPT feedthroughs.
- Vacuum: 4 x 10⁻⁴ Torr

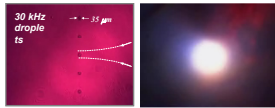
Laser

- Q-switched Nd:YAG laser, 1064 nm
- Repetition rate 2 - 10 Hz
- Maximum Energy ~200 mJ
- Pulse duration 10.5 ns, Gaussian
- Pulse-to-pulse stability < 3%
- Minimum focused spot size is ~30 µm



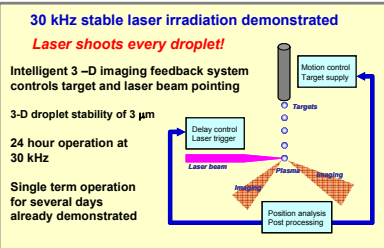
Standard target configuration in Laser Plasma Lab. (LPL)

Ideal source configuration for HVM EUVL

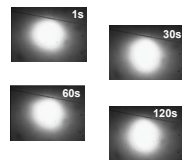


- Continuous droplet delivery at high repetition rate <10 kHz to >100 kHz variable
- Small target size ~35 µm diameter
- Limited number of tin atoms contained
- Only a few % of atoms are tin ~ 10¹³ atoms of tin
- Large separation between targets > 500 µm

High stability

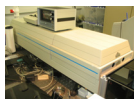
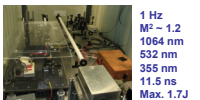


Even without control



- 100 Hz laser operation
- Captured single plasma
- No control, No feedback applied
- Visible images

Adapted various laser systems



Estimated tin consumption and mirror lifetime

Example based on LPL source

- Target delivery at 100 kHz
 10¹³ atoms/target
- Laser operation at 30 kHz
 1kW laser operating at 3 kHz
 10 modules multiplexed
 Laser input energy 300mJ
 CE >2%
- EUV source power at target 180W
- Collector mirror with large collection angle >2x
 In-band power > 100W

- Total tin delivery
 30,000 hours (10yrs) at 100 kHz 10¹³ targets
 20 kg delivered into chamber

- Total tin used
 by laser operating at 30 kHz
 7 kg shot by the laser
TIN CONSUMPTION LESS THAN 1KG/YEAR

- Total tin retrieved
 30,000 hours (10yrs) at 100 kHz 10¹³ targets
 14 kg recycled over 10 years

This amount of tin is not shot by laser

- With exposure cycles (9 sec/wafer)
 168 hrs/week
 120g tin delivered for a week
 only 9.2 g/week consumed to generate plasma
 ~500 g/year

- Total tin handled per year 6.5 kg
 Total tin retrieved per year 6 kg

LESS THAN 10 KG OF TIN INVENTORY IS ENOUGH FOR 1 YEAR FOR EACH SOURCE FACILITY

Mirror lifetime estimation

- The collector mirror lifetime is estimated using quantitatively measured ion kinetic energy distributions
- and calculated surface sputtering yields of Si and Mo under Tin ion bombardment
- There is no sign of fast ion generation from tin-doped droplet plasmas
- For 10% drop in the mirror reflectivity at the end of lifetime, 600 hours at 7 kHz and >100 hours at ~30 kHz are estimated
- High transmission and high ion suppression mitigation scheme extends the lifetime significantly

FUNDING

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Conclusion

- Mass-limited tin-doped droplet target consumes significantly small amount of tin compared to the other source configurations
- The amount of handling tin per week, per year and over the entire source lifetime is reasonably small
- The amount of tin inventory is a very important issue in EUVL for high volume manufacturing