Evaluation of Xe and Sn droplets as LPP targets

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Abstract

Characteristics and behavior of Xe and Sn droplets under Nd:YAG and CO_2 laser irradiation are reported. Especially, the initial explosion process is quite different between Xe and Sn at the two different wavelengths. The application of the droplet target is discussed for a LPP EUV source with respect to CE and debris characteristics.

§ Requirement as LPP targets

1. High Velocity, Stability, Frequency
2. Reduce amount of target material

→ **Droplet target**

3. High Conversion Efficiency for EUV

§ Droplet Technology

Continuous Jet Method [Rayleigh's Theory]

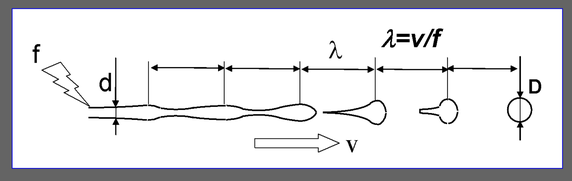
- Uniform droplets generation from continuous jet

Surface Position : r

$r = (d/2) + \alpha e^{qt} \cos(2\pi x/\lambda)$

$q_{max} = 0.97\sqrt{(\sigma/\rho d^3)}$ @ $\lambda/d=4.51$

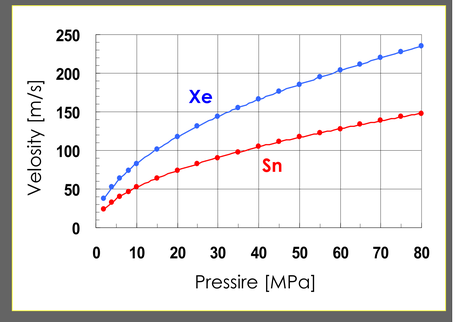
d : Jet dia.
σ : Surface Tension
α : Initial Disturbance
q : Growth rate
ρ : Density
f : Frequency



Bernoulli's theorem

$v = \sqrt{\frac{2\Delta P}{\rho}}$

v : Velocity
p : Pressure
ρ : Density

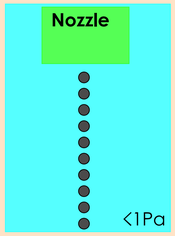


Sn require a higher pressure than Xe for same velocity , but uniform droplet generation is easier ($q_{Sn} > q_{Xe}$).

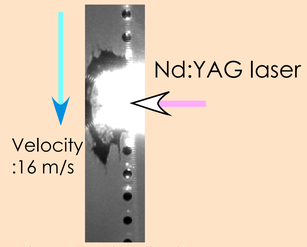
Sn Target

§ Characteristics of droplet

Nozzle Dia. :70 um
Droplet Dia. :130 um
Spacing :290 um
Sn Pres. :18 MPa
Velocity :70 m/s
Stability: σ =18 %

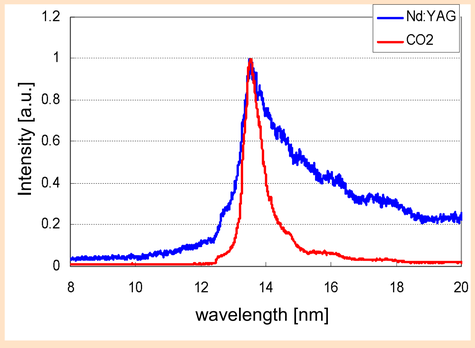


§ Droplet behavior at laser irradiation



Debris : splashing liquid drop
Liquid Sn is blown away without vaporization.

§ EUV emission (plate)



Conversion Efficiency is
2% with Nd:YAG laser
4% with CO_2 laser
※ target is Sn plate not droplet

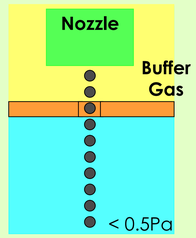
Sn plasma emission has a 13.5nm peak with Nd:YAG and CO_2 laser.
Narrow band spectrum with CO_2 laser compared to Nd:YAG laser.

Xe Target

§ Characteristics of droplet

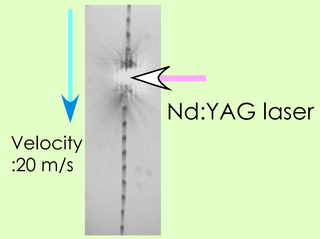
Nozzle Dia. :30 um
Droplet Dia. :56 um
Spacing :130 um
Xe Pres. :15 MPa
Velocity :100 m/s
Stability: σ =35 %

Buffer Pres. 25kPa



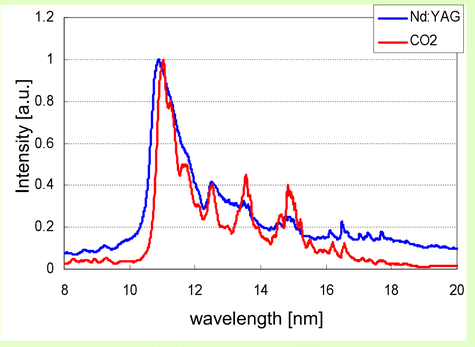
Differential pumping system required in order to avoid rapid boiling and freezing of the liquid xenon jet

§ Droplet behavior at laser irradiation



Debris : expanding neutral gas
Liquid Xe changes direct vaporization.

§ EUV emission



Conversion Efficiency is
0.4% with Nd:YAG laser
0.35% with CO_2 laser with Pre-pulse

Xe plasma emission has a 11nm peak with Nd:YAG and CO_2 laser.
CO_2 laser produced plasma is like GDPP (Gas Discharge Produced Plasma) emission.

Conclusion

§ Sn droplet target
- Not differential pumping system required
- Good position stability
- Debris is splashing liquid drop
- **C.E. is 2% with CO_2 laser**

in order to obtain higher C.E. as plate target by optimized droplet size and laser intensity

Sn Plate target
- High C.E. ~2% (Nd:YAG laser) , ~4% (CO_2 laser)

§ Xe droplet target
- Differential pumping system required
- Higher speed at same pressure
- Debris is expanding neutral gas
- Low C.E. ~0.4% (Nd:YAG laser)
  ~0.35% (CO_2 laser with pre-pulse)

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