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Characteristic of Z-pinch EUV Source with Tin Target

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Abstract

Tin target has significant potential for high conversion efficiency (CE) at 13.5 nm. Several theoretical calculations [1] show that predominantly 4d-4f transitions in a number of adjacent ion stages (Sn8+-Sn13+) produce unresolved transition arrays (UTAs) [2] that are localized in this spectral area.

Here, we report the progress on z-pinch EUV source with tin target. Tin vapor including atoms and ions is produced by the ablation of the solid tin rod (6 mm), which is due to the energy flux from the plasma.

Xenon or helium is used as a background gas. The EUV emission depends on the distance between the plasma and the rod surface (~ 10s mm) and on the pulse repetition rate of the discharge (< 200 Hz).

The z-pinch plasma is driven by the pulsed current with amplitude of 30 kA and duration of 110 ns. The EUV emission from z-pinch discharge is characterized with pinhole imaging, EUV spectrograph and in-band EUV energy monitor.

[1] Gerard O'Sullivan, EUVL Source Workshop, Antwerp 2003; available at www.sematech.org.
[2] Winnie Svendsen and Gerard O'Sullivan, Statistics and characteristics of xuv transition arrays from laser-produced plasmas of the elements tin through iodine, Phys. Rev. A 50, 3710, 1994

1. Ablation of Tin Rod due to Energy Flux from the Plasma

Feature

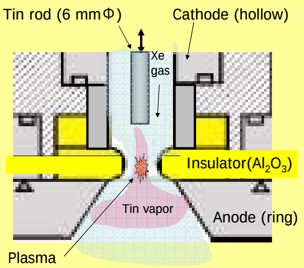
- Tin vapor including atoms and ions is produced by the ablation of the solid tin rod (6 mm ϕ), which is due to the energy flux from the plasma.
- Xe or He gas is used as background gas

Advantages

- Continuous supply.
- No additional device (just placing a tin rod beside the plasma)
- Reduction of debris because of no arc spot

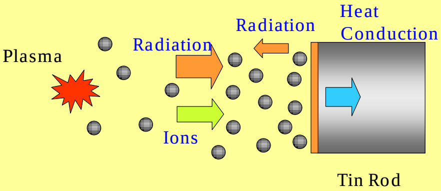
Dependent parameters

- Pulse repetition rate
- Distance between plasma and tin rod
- Background gas an its pressure



Tin rod (6mm ϕ)

2. Theory



Physical Constants of Tin

Atomic Weight M = 119
Mass Density ρ = 7.26 g/cm-3
Melting Point Tm= 505 K
Vaporizing Point Tb= 2753 K
Enthalpy of Fusion dHf = 59.2 J/g
Enthalpy of Vaporization dHv= 2460 J/g
Heat Capacity Cp = 0.228 J/gK
Heat Conductivity λ = 0.666 W/cmK

Energy Flux from the Plasma = Radiation + High Energy Ions

Energy Deposition on the Tin Rod Surface

Radiation is dominant in the energy flux from the plasma. The radiation power from the plasma with temperature T (= 30 eV) onto a tin rod surface is

$$U_s = \int\int_\Omega\int_S \sigma_s T^4 dS d\Omega dt = \{5.67\times10^{-8}\cdot(30\times11400)^4\cdot 4\pi a^2\}\frac{S_0}{4\pi d^2}\Delta t$$

σ_s is Stefan-Boltzmann constant. a, S_0 and d are plasma radius, surface area of the tin target and distance between plasma and the surface, respectively. Duration of the high temperature status Δt is about 30 ns, so that the energy deposition on the rod surface due to the radiation can be **0.1 J/pulse.**

Amount of the Tin Atoms due to Vaporization

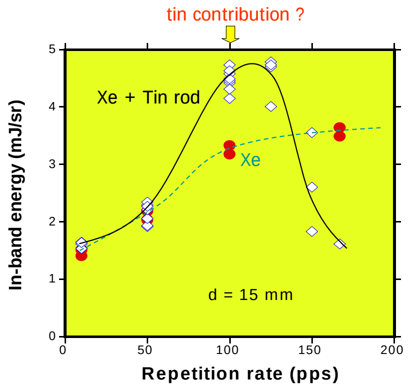
Suppose the energy of 0.01 J (1/10) is deposited on the tin rod surface and the surface is at the vaporization temperature. The number of tin atoms generated per pulse is

$$N_{Sn} = \frac{0.01}{\mathrm{dHv}}\cdot\frac{6.02\times10^{23}}{\mathrm{M}} = 2\times10^{16}$$

This number can be controlled by the position and shape of the tin target.

3. In-band EUV Energy dependent on repetition rate

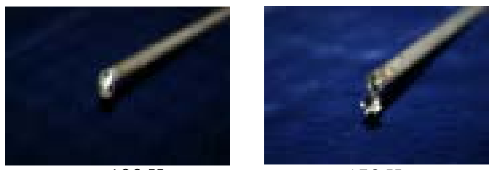
Experiment: Current 26 kA, 130 ns, Insulator wall : Al_2O_3, 5 mm ϕ × 10 mmL
Xe flow rate : 40 cc/min (fixed)
EUV energy monitor : EMON (view from 150)



- In-band EUV energy increases with the pulse repetition rate in both cases. Xe or Xe+tin contributes to in-band energy the same (<50 Hz).
- With the rep rate at 100 Hz, shot with a tin rod gains 30 % of in-band energy.
- With the rep rate operation of 150 Hz, in-band energy is decreased suddenly.

Temperature of tin surface
~ 50 Hz : too low.
100 ~ 130 Hz : appropriate.
150 Hz ~ : too high.

Tin rod surface after10000 shots (d = 15 mm)

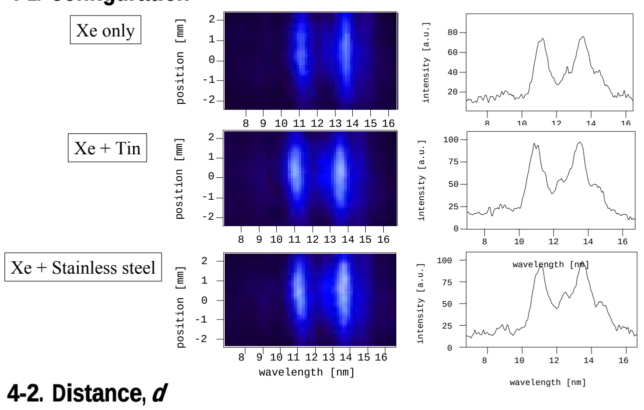


100 Hz 150 Hz

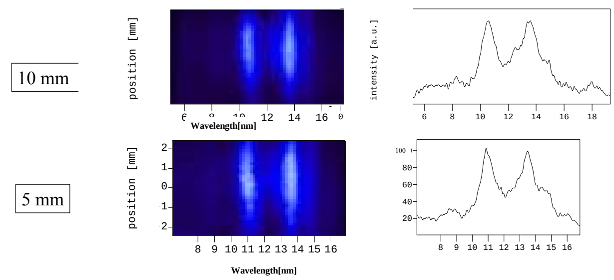
4. EUV Spectra

Transmission Grating Spectroscopy ($\Delta\lambda$ =0.3 nm)

4-1. Configuration



4-2. Distance, *d*



Summary

- In the case of using a tin rod with xenon as background gas, in-band energy was gained 30% for 100~130Hz rep rate operation.
- However, spectroscopic measurements did not show any evidences which tin ions contribute the EUV emission.

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