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Abstract and Summary for submission to CLEO 2003

High conversion efficiency mass-limited laser plasma source for EUV lithography

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Abstract

EUV lithography requires a high-efficiency light source at 13nm that is free from debris. Our mass-limited tin material laser plasma source provides the highest conversion of laser-light to useful in-band EUV emission.

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High conversion efficiency mass-limited laser plasma source for EUV lithography

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Summary

The roadmap for EUV lithography calls for a stable, debris-free, light source producing collectable in-band emission at ~13.5nm with power levels of ~100W[1]. Several source technologies, including small dense-plasma electric discharges and high-repetition-rate laser plasma sources, are being developed.

For a laser-plasma source to succeed, it must operate continually for ~1year at repetition-rates of 5-10kHz with a pulse-to-pulse stability of <2%, in a scheme that prevents the large-NA (>0.25) collection optics from the deleterious effects of target debris in long-term operation. The conversion efficiency from the laser light to useful EUV emission must be sufficiently large to (i) provide the projected required collectable power levels with viable commercial lasers and (ii) permit the overall source cost, including laser, to remain within economic models for EUVL.

Several laser-plasma sources have been considered. High-density Xe, which emits broadband 10-14nm emission from Xe^{9+} - Xe^{17+} ions has been investigated with pulsed and continuous cluster targets[2], liquid jets[3] and droplet targets[4]. The liquid water droplet[5-8] and jet[9] targets have undergone thorough investigation. It emits a bright line at 13.0nm from the 4d - 2p transition of Li-like Oxygen, which is narrower than the bandpass of EUV multilayer mirrors, and has demonstrated extended operating lifetimes without significant debris contamination[10]. Both approaches showed conversion efficiencies <0.8% in 2π, a value too low to meet the required power with available lasers.

Here we report for the first time our studies on a tin material target which demonstrates conversion efficiency greater than 2%[11,12]. This makes possible useful EUV source powers of >60W with current diode-pumped Nd:laser technology[13,14]. Fig.1 compares the spectrum from the tin material to that of a water-droplet target. We describe theoretical and experimental studies of laser-plasma dynamics of this source, its radiation and diagnostics in the EUV region, using a variety of plasma diagnostics and hydrodynamic and atomic physics code calculations.

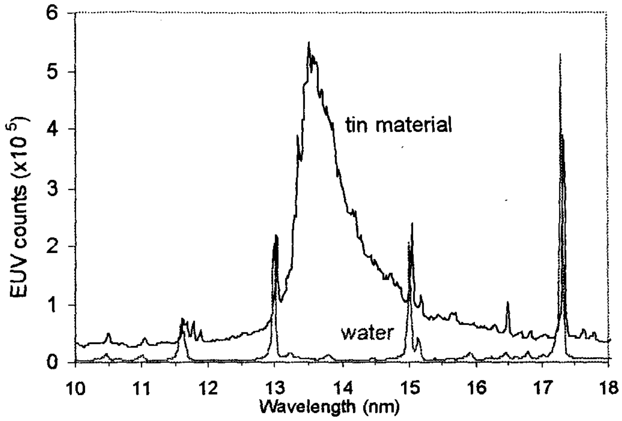

Fig. 1: Spectra from the tin material laser plasma source in comparison to spectrum of the liquid droplet water source.

We are making detailed quantitative studies of debris from laser-plasma sources for EUVL, using a variety of techniques[10]. We analyze deposition of particulate debris collected on witness plates placed closed to the source. Multilayer mirrors are used as witness plates for studying the effects of ions. The witness plates are then analyzed by extensive microsurface and material analysis using SEM, AFM, XAFS, and other instrumentation.

Gas curtains[15], foil-traps[16], and repeller electrostatic fields[17] are some approaches for debris inhibition. We are investigating various embodiments of the repeller field concept. (Fig. 2)

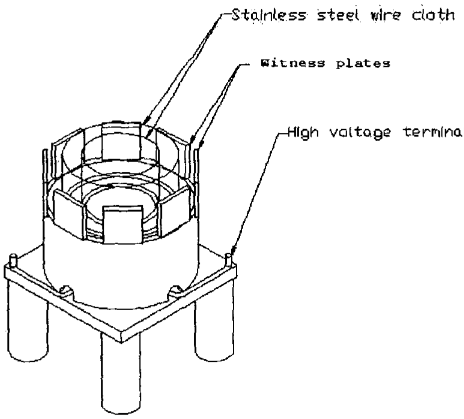

Fig. 2: Configuration of repeller field

We will describe the latest results in the development of sources, and discuss its extendibility to higher powers. This work is supported by JMAR and the State of Florida.

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11. first mentioned in a report by JMAR Research Corp. at the EUVL Source Workshop , March 2, 2001, Santa Clara,
12. M. Richardson, patent pending
13. JMAR laser, diode-pumped 300W, 300Hz
14. TRW laser, diode-pumped Nd:YAG, 1700W, 5kHz
15. A flowing He gas curtain located in front of the source to stop particulate matter
16. A concept devised by FOM in the Netherlands and developed by Cymer Corp.
17. US Patent 6,377,651, B1