Extreme ultraviolet emission characteristics of a laser-produced Li plasma

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A laser-produced plasma (LPP) has been utilized in various applications such as laser fusion, charged particle acceleration, biological imaging, and microlithography. Present requirement for the next generation microlithography is to develop high average power EUV light sources at 13.5 nm. Due to the high-power requirement of the EUV emission, conversion efficiency (CE) from the plasma-initiating laser energy to the EUV emission energy becomes one of the most important parameters. The EUV CE could be improved by controlling various plasma parameters such as its density and temperature. The use of dual laser pulses could realize such a control of parameters. We have chosen a lithium plasma source, which produced unambiguously defined line emission at 13.5 nm with almost no off-band components[1)].

A Li-mixed aqueous jet target with sub-hundred micrometer diameter was provided in a vacuum chamber. A plasma-initiating laser consisted of dual laser pulses with adjustable delays with pulse widths of 8 and 10 ns (FWHM) at 532 and 1064 nm, respectively. The laser intensity of a main laser pulse was optimized at 3×10^{11} Wcm^{-2}. The EUV CE at 13.5 nm was evaluated within the 2% bandwidth (in-band value) and 2π sr solid angle.

The EUV CE increased as the delay between the two laser pulses increased, and reached its peak value of 0.48% around 100 ns. The value increased by a factor of three from its single-pulse value of 0.15%. The optimized delay time of 100 ns corresponded to the hydrodynamic plasma expansion time, when the plasma density decreased its critical value of the main laser pulse. By optimizing the main laser intensity, the plasma temperature was also controlled, so that the Lyman-α emission intensity at 13.5 nm from Li^{2+} ions increased further compared to that of O^{5+} ions at 13.0 nm. The deployment of dual nanosecond pulses thus produced a plasma with adequate conditions for Li^{2+} ions but not for O^{5+} ions, leading to the improvement of the emission CE at 13.5 nm.

1) C. Rajyaguru *et al*., Appl. Phys. B **79**, 669 (2004); Appl. Phys. B **80**, (to appear in 2005).