COMPREHENSIVE 3-D MODELING AND SIMULATION OF LASER PRODUCED PLASMA FOR EUV LITHOGRAPHY AND OTHER APPLICATIONS

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This study presents the first detail 3-D full modeling of all physical processes in laser-produced plasma (LPP) for various applications. The evolution of the target in 3-D full hydrodynamic response coupled with 3-D photon transport in the LPP with detail atomic physics are simulated for multiple-laser on target systems. For example, several concepts are considered in utilizing a high-power laser to generate plasma that emits photons in the EUV region for lithography to support the throughput requirements of High-Volume Manufacturing lithography exposure tools. The typical for most LPP devices is providing the initial heating (with possible simultaneous compression) of solid or liquid targets to the temperatures required for generating the radiation in the EUV region. After a short laser pulse with τ = 10 – 50 ns, the energy of the external laser radiation is partly transmitted deeper into the target, partly absorbed by the target plasma, and partly reflected at the plasma-vacuum interface. An integrated model for the description of hydrodynamics and optical processes in a LPP device has been developed and integrated into the HEIGHTS–LPP computer simulation package. Model development consisted of three main tasks: laser absorption induced plasma evolution and magnetohydrodynamic (MHD) processes; detailed photon radiation transport, and physics of plasma expansion. Advanced numerical methods for the description of target compression in various geometries are used in the HEIGHTS package. For opacity calculations several models have been developed and implemented. Radiation transport of both continuum and lines is taken into account with detailed spectral profiles in the EUV region. A multi-group approximation of opacities with detail resolution of several thousand strong spectral lines is used. Radiation transport in LPP devices is solved using two different methods, i.e., by direct integration of the transport equation and by 3-D Monte Carlo techniques. The models and theories developed in this work and implemented in HEIGHTS-LPP will be used to explain recent LPP experiments to understand role of different physical processes causing fast ions generation and the flux of such ions. In addition, parameters such as target design and laser pulse shape should be optimized to find in future devices better target design and a relevant laser pulse shape. The HEIGHTS-LPP package can also study detailed hydrodynamic and radiation processes in various LPP devices as a function of laser energy, wavelength, and dimensions to optimize brightness throughput.