Topic number

Generating EUV light from tin plasma for chip manufacturing

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Laser-produced tin plasmas are the prime candidates for the generation of extreme ultraviolet (EUV) light around 13.5 nm wavelength for nanolithography. It is our aim to understand this plasma at the fundamental level. I will present results on the plasma-pressure induced propulsion and hydrodynamic deformation of free-falling liquid-tin microdroplets as well as on charge-state-resolved measurement of highly charged tin ions using an electron beam ion trap.

Laser-produced tin plasmas are the prime candidates for the generation of extreme ultraviolet (EUV) light around 13.5 nm wavelength for nanolithography. This light is generated by atomic transitions in highly charged tin ions Sn^{8+}-Sn^{14+}. Due to the complicated electronic configurations of these charge states, thousands of atomic lines contribute to the emission of EUV light from the hot (~100 eV) and very dense (~10^{21} e/cm^3) plasma. It is our aim to understand this plasma at the fundamental level.

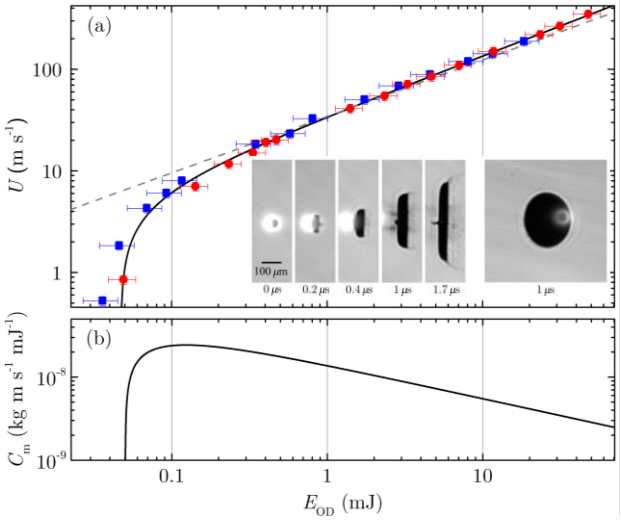

Fig. 1 (a) Propulsion velocity U of molten-metal microdroplets as a function of laser pulse energy E_{OD}. The inset shows shadowgrams of the expanding droplets. (b) Momentum coupling coefficient C_m.

I will present measurements of plasma-pressure induced propulsion and hydrodynamic deformation of free-falling liquid-tin microdroplets (see Fig. 1) by laser pulse impact [1]. These measurements, and the scaling laws obtained from them, serve as precision tests of state-of-the-art plasma simulation and theory predictions. To obtain a better understanding of the atomic processes within the laser generated plasma we performed charge-state-resolved measurement (see Fig. 2) of highly charged tin ions using an electron beam ion trap (EBIT). Combining the EBIT measurements with both the semi-empirical COWAN code as well as ab initio techniques for calculating the level structure, the optical spectra could be assigned [2,3]. We conclude that assignments of EUV transitions in the literature require corrections. EUV and optical spectra are measured simultaneously in the controlled conditions of the EBIT as well as in our microdroplet-based laser-produced plasma source, thus providing information on the contribution of Sn charge states to the EUV emission.

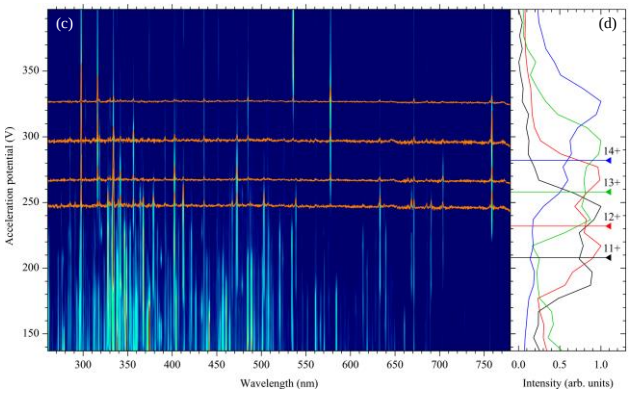

Fig. 2 (c) Composite spectral map from electron beam ion trap (EBIT) spectroscopy of highly charged Sn ions. (d) Fluorescence yield for each charge state as a function of the EBIT's electron beam acceleration potential.

[1] D. Kurilovich *et al*, Phys. Rev. Appl. **6** (2016) 014018

[2] A. Windberger *et al*, Phys. Rev. A **94** (2016) 012506

[3] F. Torretti *et al*, (accepted for publication in Phys. Rev. A) (2016) arXiv:1612.00747