Physics of EUV-light sources: Photons and Ions

R Hoekstra[1,2], A Bayerle[1], L Behnke[1], Z Bouza[1,3], MJ Deuzeman[1,2],
D Kurilovich[1,3], B Liu[1,3], W. Noordam[2], L Poirier[1], S Rai[1,2], J Scheers[1,3],
R Schupp[1,3], J Sheil[1], F Torretti[1,3], W Ubachs[1,3], O Versolato[1]

[1]Advanced Research Center for Nanolithography (ARCNL), Amsterdam, 1098 XG, The Netherlands
[2] Zernike Institute for Advanced Materials, University of Groningen, Groningen, 9747 AG, The Netherlands
[3]Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, 1081 HV, The Netherlands

The next generation of nanolithography machines is driven by Extreme ultraviolet (EUV) light at 13.5-nm wavelength, replacing current technology based on 193-nm light. The step towards EUV is crucial to continue miniaturization of the features on chips. For over 40 years, the miniaturization is well-represented by Moore's law, predicting the number of transistors on an affordable CPU to double every two years. The shorter the wavelength, the better the resolution, therefore much smaller features can be printed with EUV-based lithography. Highly charged tin ions in plasma of exploding Sn droplets are the atomic sources of EUV light. The transient tin plasmas are of high density with temperatures in the 10-100 eV range.

Spectroscopic information on metal ions in low and intermediate charge states, such as $Sn^{1+ - 20+}$ is very scarce. Interaction cross sections are basically non-existent. At ARCNL we started a collaborative research program on gathering and producing atomic data for tin ions. After a short introduction on ARCNL and laser-produced tin plasma, our work on the spectroscopy of tin ions both inside and outside of the laser-driven plasma will be presented. A detailed understanding of the complex atomic structure of tin ions is a prerequisite to characterize the plasma. The EUV spectrum of highly charged Sn ions is dominated by intense unresolved transition arrays (UTAs) from the resonance transitions $4p^6\,4d^m$ - $4p^5\,4d^{m+1}$ + $4d^{m-1}\,4f$ in Sn^{8+}-Sn^{14+} [1,2]. The UTAs from these strongly interacting configurations from several Sn charge states contribute to a remarkably efficient "in-band" production of 13.5 nm (±1%) light. Out-off band radiation [3] at shorter wavelength may be used as a diagnostics tool of the "in band" radiation. A side of the EUV spectrum a start has been made to unravel the optical spectra of tin ions, e.g. Sn^{3+} [4]. Finally I will present first experimental results on charge exchange of tin ions in H_2 and on Sn ion scattering on Mo and Ru. The latter results are compared to standard SRIM simulations showing a remarkable difference in that the single-scattering peak prominent in the simulations appears to be fully missing in the experiments.

References

[1] Windberger A *et al* 2016 *Phys. Rev. A* **94,** 012506 (2016)
[2] Torretti F *et al* 2017 *Phys. Rev. A* **95,** 042503 (2017)
[3] Torretti F *et al* 2018 *J. Phys. B* **51,** 045005 (2018)
[4] Scheers J *et al* 2018 *Phys. Rev. A* **98,** 062503 (2018)