#63

Production of singly charged Sn ions by charge exchange in H_2 gas

Luc Assink[1,2] Klaas Bijlsma[1,2], Lucas Poirier[2,3], Emiel de Wit[1], Subam Rai[1,2], Ismanuel Rabadán[4], Luis Méndez[4], John Sheil[2,3], Oscar Versolato[2,3], Ronnie Hoekstra[1,2]

[1] *Zernike Institute for Advanced Materials, University of Groningen, Groningen, The Netherlands*
[2] *Advanced Research Center for Nanolithography (ARCNL), Amsterdam, The Netherlands*
[3] *Department of Physics and Astronomy, and LaserLaB, Vrije Universiteit, Amsterdam, The Netherlands*
[4] *Laboratorio Asociado al CIEMAT de Física Atómica y Molecular en Plasmas de Fusíon, Departamento de Química, Universidad Autónoma de Madrid, Madrid, Spain*

The evolution of charge-state-resolved kinetic energy spectra of Sn ions ejected from a laser-produced plasma (LPP) of Sn as a function of the density of the H_2 buffer gas surrounding the LPP is investigated. Without a H_2 buffer gas, energetic 1 - 5 keV Sn ions in charge states of 4+ up to 8+ are detected. In this keV regime, lower Sn charge states, i.e., below 4+ are absent. When H_2 is introduced into the system, low-charged energetic Sn ions can be produced by a series of consecutive electron capture processes. However, as electron capture by Sn^{2+} ions from H_2 is endothermic, no significant population of singly charged Sn ions is expected in the keV regime. At H_2 pressures of $6x10^{-4}$ mbar and higher, however, we only detect Sn^{2+} and Sn^{+} ions.
To explain the production of keV Sn^{+} ions, electron capture by metastable Sn^{2+*} ions has been proposed [1]. Semi-classical calculations on Sn^{3+}-H_2 collisions [2] indicate that one-electron capture by Sn^{3+} ions populates Sn^{2+} ions in metastable states. Model simulations (using theoretical 2-state Landau-Zener cross sections to account for capture by each of the three metastable ^3P_J levels) to track the charge states of Sn ions while traversing the H_2 gas agree with our measured data. This underpins the key role of metastable Sn^{2+*} ions as a gateway to the production of Sn^{+} ions. From an LPP-based EUV source perspective, the production of energetic Sn^{+} ions in the buffer gas is of high relevance, as it shifts the charge state balance from Sn^{2+} towards Sn^{+} ions, which have a larger stopping cross section than Sn^{2+} ions [3].

References

1. Rai et al., 2023 to appear in Plasma Sources Sci. Techn.
2. Rai et al., 2022, Phys. Rev. A. **106**, 012804
3. Abramenko et al., 2018, Appl. Phys. Lett. **112**, 164102

Presenting Author Email Address: *l.assink@rug.nl*