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VUV Spectroscopy on droplet-based LPPs for Metrology and Inspection Applications

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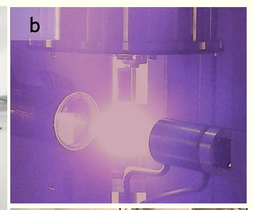
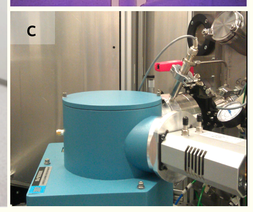
Introduction

At the Applied Laser Plasma Science (ALPS) laboratory, a droplet-based laser-produced plasma X ray source with application in EUV lithography and Metrology has been developed. The main source ALPS II is equipped with a large capacity droplet dispenser and a high power (kW), high repetition rate Nd:YAG laser. In this work, the emission proprieties of the plasma are investigated with a spectrograph operating in the Vacuum Ultraviolet (VUV) range. The emission spectra were recorded for tin, indium and gallium and for different background gases at different pressures levels. These studies are relevant for Out-Of-Band (OOB) radiation emission measurements of an EUV source, and for alternative light sources operating in the sub-200 nm range

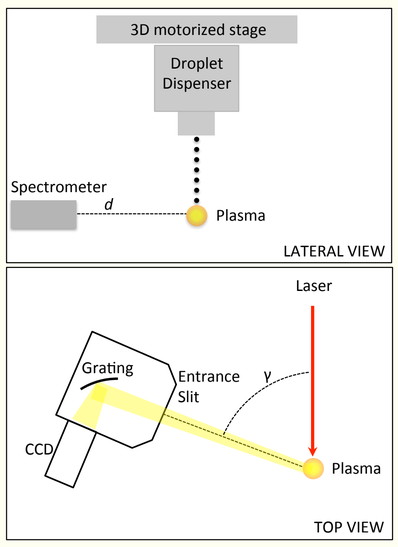
Experimental Set-Up





- ALPSII facility equipped with Nd:YAG laser with 1.6 kW average power, 6 kHz frequency, 1064 nm wavelength and $2x10^{11}$ W/cm^2 irradiance power (Fig.a)
- Droplet dispenser delivering 18 kHz droplet train with 50 um diameter for plasma formation (Fig.b)
- Mc Pherson spectrometer operating from 30 nm to 550 nm (Fig.c)

1) Spectrometer equipped with holographic gratings having 1200 Gr/mm and 2400 Gr/mm to spectrally characterize to EUV source from 100 nm to 550 nm and from 30 nm to 200 nm respectively and back-illuminated CCD at the exit slit
2) Spectrometer placed at d=950 mm from the plasma ignition point and at γ=60° with respect to the laser beam direction
3) Three different plasma fuels, tin, gallium and indium operated in different background gases (Ar, He, N_2) at 0.02 mbar 0.05 mbar, 0.1 mbar and 0.3 mbar
4) Differential pumping section to keep the spectrometer at 5×10^{-5} mbar vacuum level



Conclusions

- For the first time recorded VUV spectra on droplet targets in continuous source operation mode from 30 nm to 550 nm
- Detected broadband and line emissions for ions up to charge states z=4
- Detected best operative source conditions for different background gas type and pressure versus wavelength

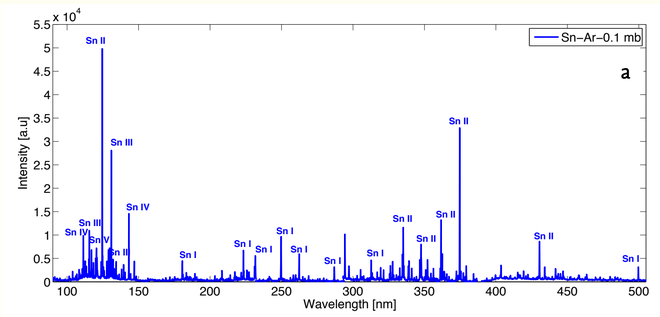
Future Perspectives

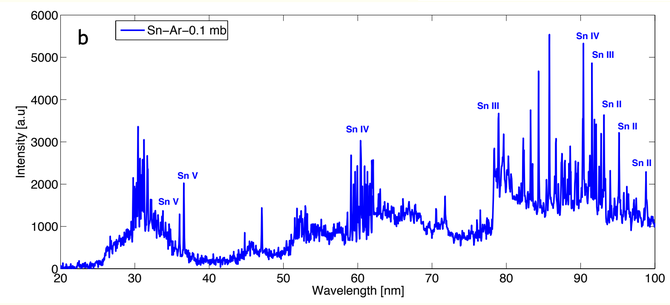
- Absolute measurements in W/nm×sr with calibrated Deuterium lamp
- Spatially resolved measurements and estimation of plasma electron density and electron temperature
- Comparison with numerical simulations

Experimental Results

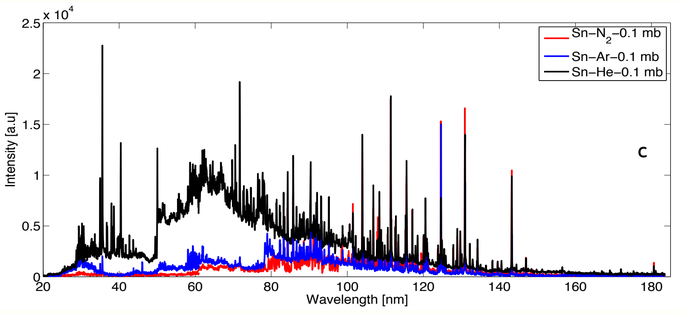
Tin spectra

- from 110 nm to 500 nm with 1200 Gr/mm grating and 30-50 um slit width (Fig. a)
- from 30 nm to 100 nm with 2400 Gr/mm grating and 30 um slit (Fig. b)



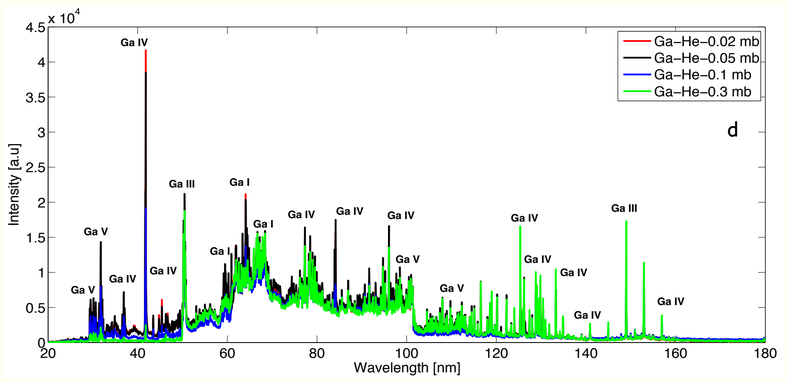


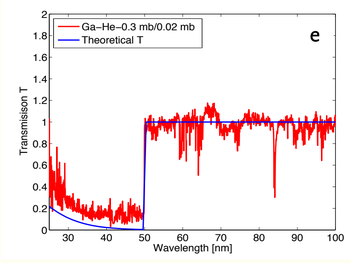
According to NIST database, from 110 nm to 550 nm, most of the emission lines are related to Sn I to Sn III atomic transitions. From 30 nm to 100 nm the emission lines are related to Sn II to Sn V atomic transitions

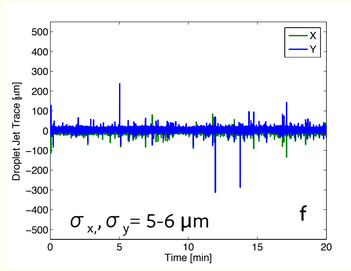


For detection of emission spectra in the VUV region, He gas is preferable. Sn V emission lines are clearly detected at 35.6 nm and 37.01 nm, while a broadband line emission is detected around 30 nm (Fig.c)

Gallium spectra

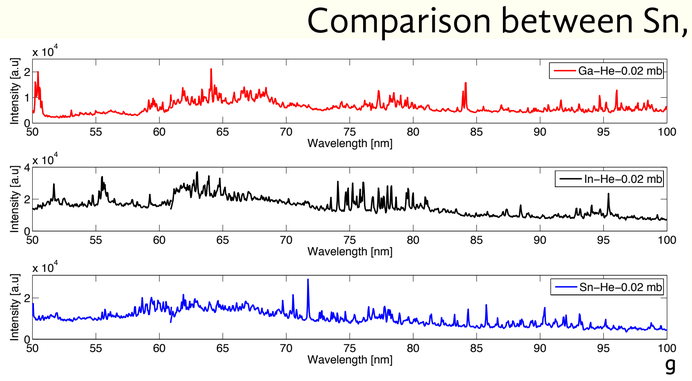






- The Ga spectra show a pronounced line emission at 41.9 nm related to Ga IV ion transitions (Fig.d)
- The ratio of the Ga spectra obtained respectively at 0.3 mbar and 0.02 mbar reflects the He gas transmission curve (Fig.e)
- Ga jet shows excellent spatial stability over the x,y axes (Fig.f)

Comparison between Sn, Ga and In



- No overlapping emission lines for the different fuels
- line emission is not originated from the ionization of the background gas (Fig.g)

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