Photoelectron emission from metal surfaces induced by VUV-emission of filament driven hydrogen arc discharge plasma

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Introduction

- Sources of electrons in plasma: electron emission from filament, ionisation, surface emission (photoelectron and secondary electron emission)
- Cold electrons and vibrationally excited molecules needed for dissociative electron attachment ($e + H_2 \rightarrow H_2^- \rightarrow H + H^-$)

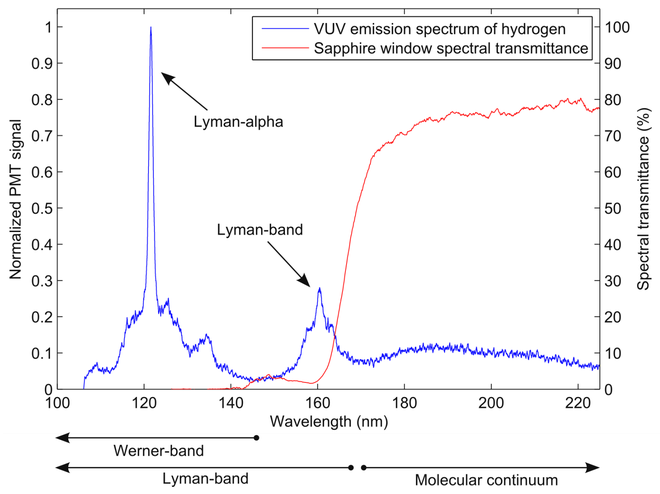

Figure 1. Typical VUV emission spectrum of the LIISA ion source and the spectral transmittance of the sapphire window. The spectrum is not corrected for spectral transmittance.

Measurement setup

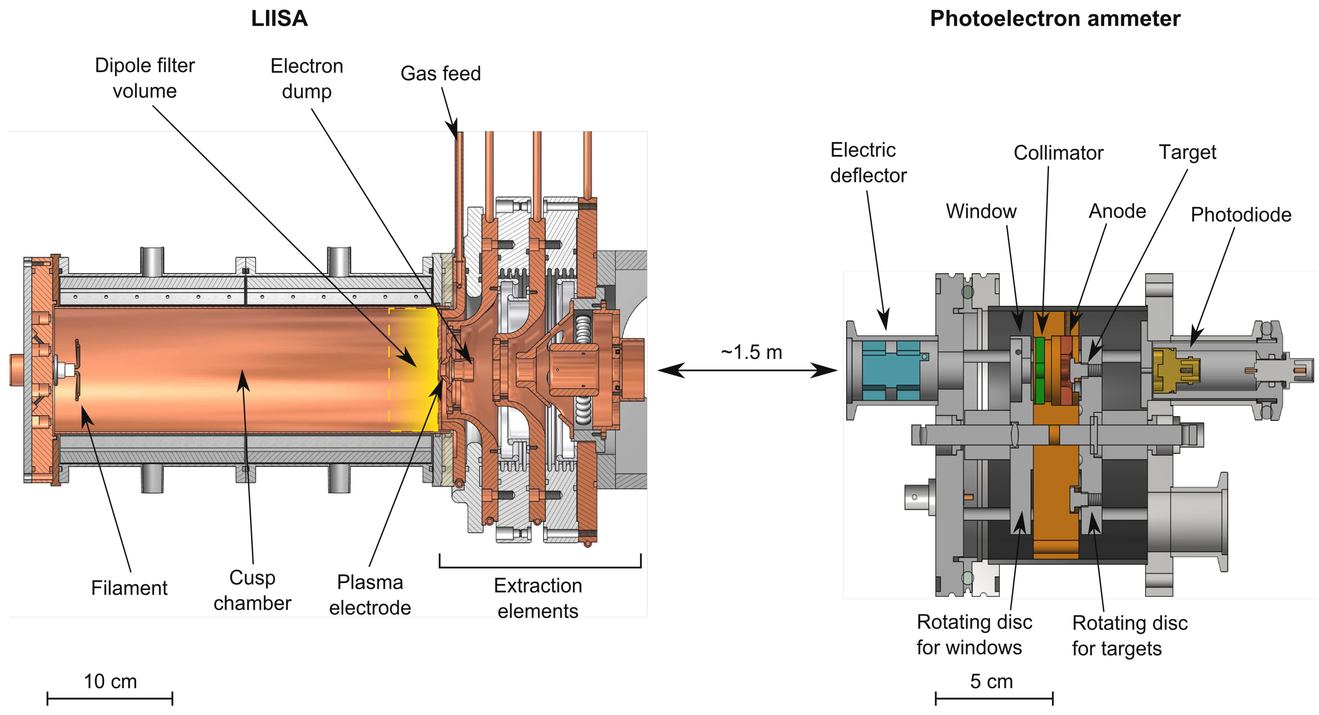

Figure 2. LIISA is a DC (tantalum) filament-driven multi-cusp volume production ion source used as a H^-/D^- injector for the JYFL K-130 cyclotron. Photoelectron current is measured from the target, which is placed axially towards the extraction aperture, and the emitted photoelectrons are collected with a biased anode.

Measured photoelectron currents and estimated total currents

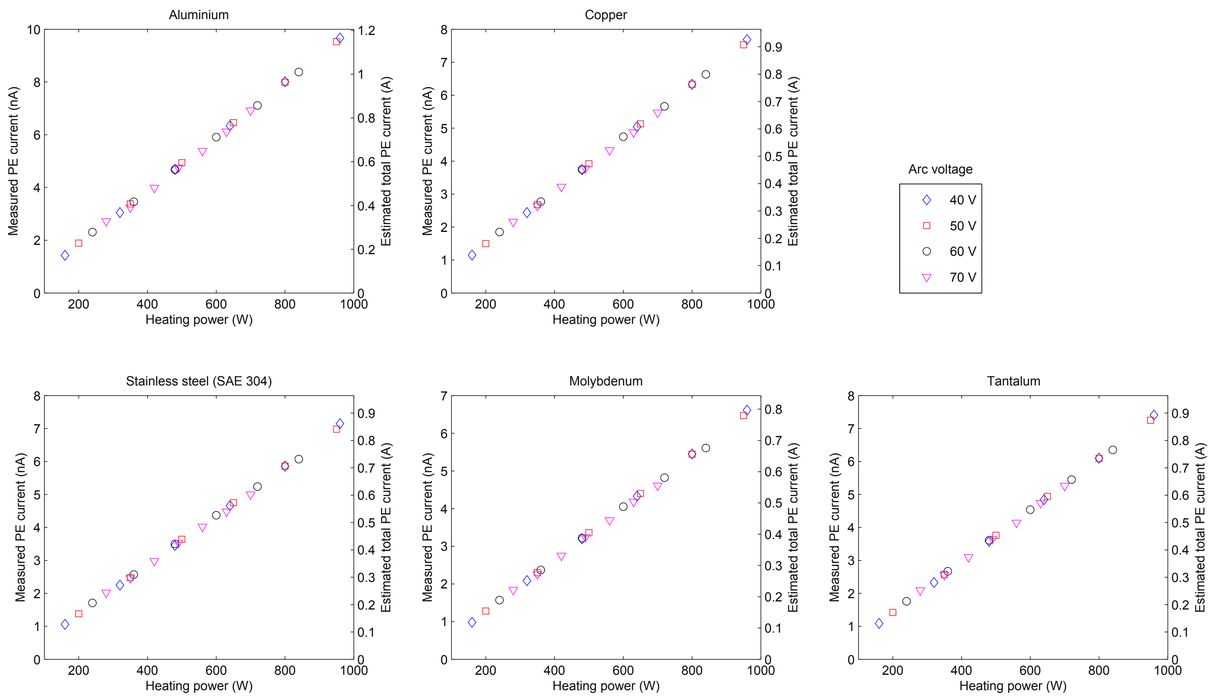

Figure 3. Measured cathode currents and estimated total photoelectron currents as a function of discharge current and voltage in $3.8 \cdot 10^{-3}$ mbar pressure. There was an unfiltered view from the plasma to the target through a 6 mm diameter collimator.

Parameter dependency

- Photoelectron current measured from Al approximately 20-50 % higher than current from Cu, SS (SAE 304), Mo and Ta (Fig. 3, 4)
- Photoelectron currents highly linear functions of discharge power (Fig. 3)
- Neutral hydrogen pressure dependency insignificant (Fig. 4)
- Observed **dependency on ion source parameters is the same for VUV emission** [1]

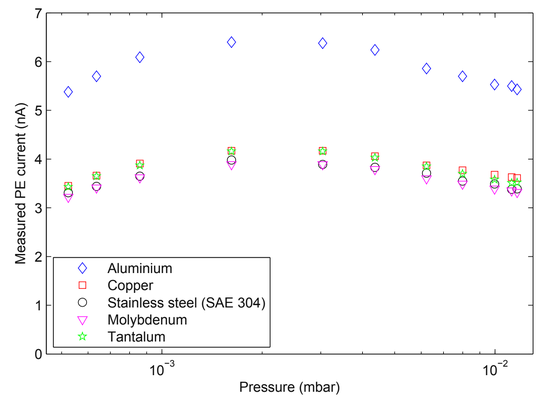

Figure 4. Measured photoelectron currents as a function of neutral hydrogen pressure. There was an unfiltered view from the plasma to the target through a 6 mm diameter collimator. The discharge power was 500 W (50 V / 10 A).

Wavelength filtering

- All wavelengths below 150 nm filtered out with sapphire window (Fig. 1)
- High quantum efficiency at short wavelengths (Fig. 5)
- Current decreased three orders of magnitude by filtering with sapphire window (Fig. 6)

→ **Photoelectron emission predominantly caused by radiation at wavelengths below 150 nm**

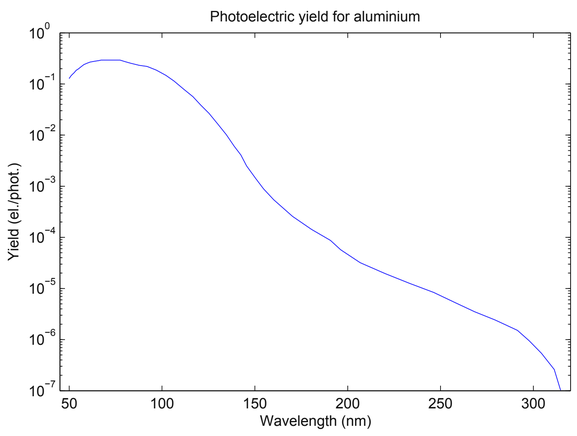

Figure 5. Photoelectric yield per incoming photon for aluminium. Data from [2].

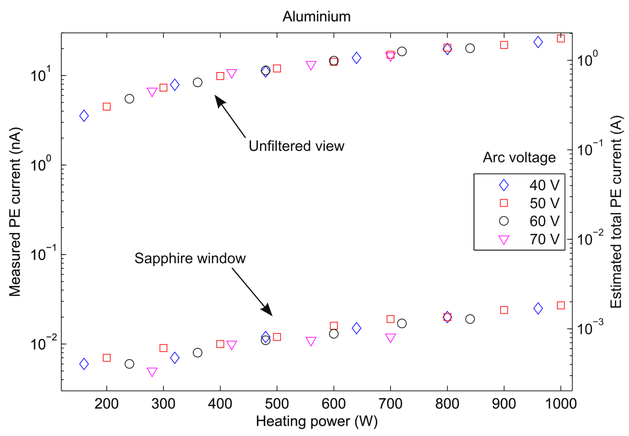

Figure 6. Difference between an unfiltered view and sapphire window. Measured in $4.2 \cdot 10^{-3}$ mbar pressure through a 8 mm diameter collimator.

Discussion

- **Total photoelectron current** estimated for isotropically emitting and spatially homogeneous plasma profile, corresponds to maximum value
- Total photoelectron current in the order of **1 A per kW** of the discharge power corresponding to almost **10 % of arc current** (70 V / 14 A)
- Electrons emitted from the plasma chamber walls may have considerable local effects on plasma properties:
  - Formation of a virtual cathode
  - Decrease of the potential in the plasma volume
  - Onset of ion-ion plasma near the plasma chamber walls
  - High energy electrons destructive for negative ions

References

[1] J. Komppula et al., *AIP Conf. Proc.* **1515**, 66 (2013)

[2] B. Feuerbacher and B. Fitton, *J. Appl. Phys.* **43**, 1563 (1972)