Debris-resistant liquid EUV mirrors

Wouter Soer[1,*], Maarten van Herpen[1], Kurt Gielissen[2], Vadim Banine[3]

[1]Philips Research, Eindhoven, The Netherlands; [2] Eindhoven University of Technology, The Netherlands;

*[3] ASML, Veldhoven, The Netherlands; * wouter.soer@philips.com*

Introduction

Problem Sn-based EUV sources generate Sn debris that contaminates nearby EUV mirrors and thus reduces their reflectivity.

Solution Liquid EUV mirrors: grazing-incidence mirrors with a liquid metal or alloy surface. The liquid surface absorbs incoming Sn debris while maintaining a low surface roughness and hence a high EUV reflectivity.

Applications Dose sensors, reflective debris mitigation tools (e.g. reflective foil trap) and debris-resistant collector optics.

Objectives

- Measure **reflectivity** of EUV radiation and ionic Sn debris on liquid metal surface.
- Obtain good **wetting** of liquid metal on metal substrates to enable tilting of the liquid mirror into arbitrary orientation while maintaining a low surface roughness.

EUV reflectivity

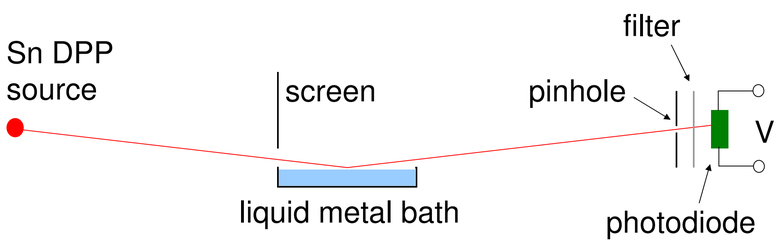

Figure 1: Experimental setup for EUV reflection.

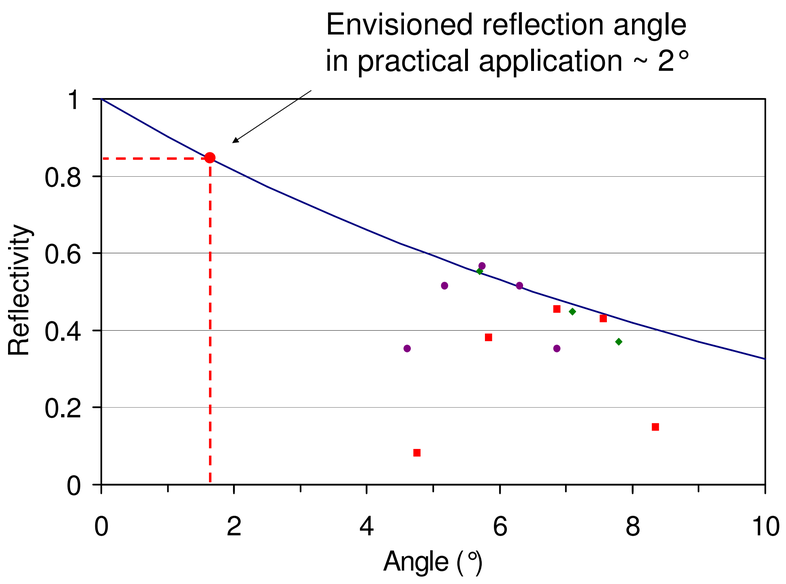

Figure 2: EUV reflectivity of liquid metal surface. Blue curve denotes theoretical reflectivity with zero roughness. Experimental data points from different measurements are shown in different colors.

Results:

- Large variations due to misalignment.
- All measurements on or below theoretical curve → EUV reflectivity qualitatively in agreement with theory.
- Further experiments required to quantitatively determine reflectivity.

Ion reflectivity

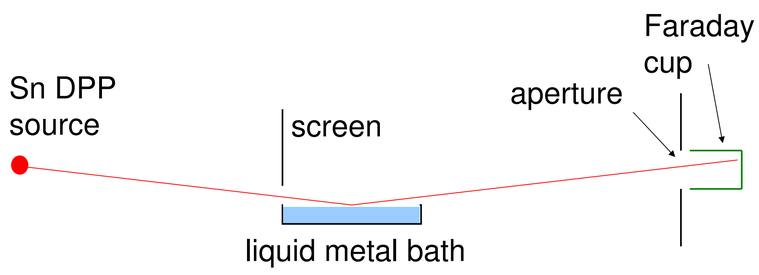

Figure 3: Experimental setup for ion reflection.

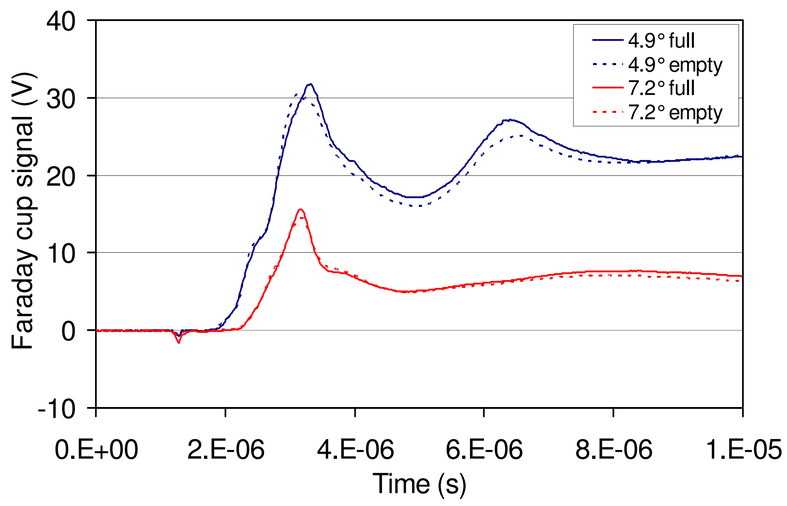

Figure 4: Time-of-flight data from Faraday cup. Solid: bath filled with liquid metal; dashed: bath empty.

Results:

- Time-of-flight data shows energy distribution of Sn ions from EUV source.
- Ions reach Faraday cup even when bath is empty (no reflection possible).
- Probably ions diverge after aperture due to space charge.
- No significant difference between empty and full bath → no ion reflection within measurement accuracy.

Wetting

Liquid metals generally wet most metal surfaces; however, the surface must be cleaned properly. We use a proprietary cleaning treatment that can be incorporated in the EUV lithography tool.

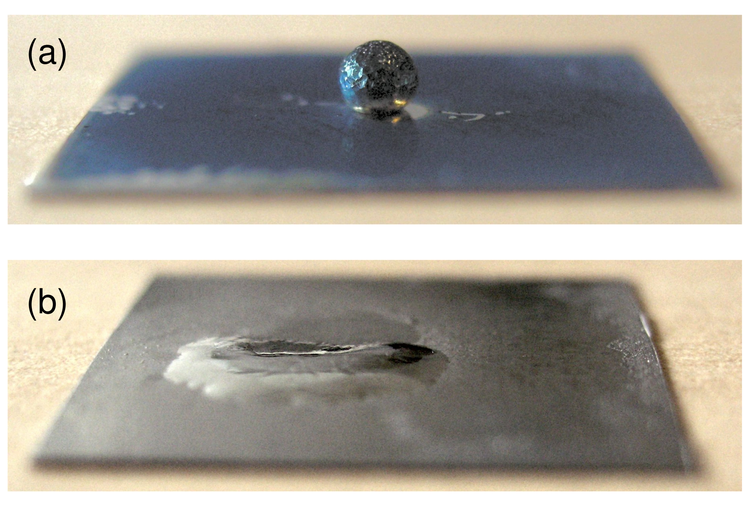

Figure 5: Liquid metal droplet on Mo foil: (a) without cleaning pre-treatment; (b) with cleaning pre-treatment.

Application: reflective foil trap

In a reflective foil trap, EUV radiation can only pass through the foil trap by reflection from the foils. Since there is no line-of-sight from the source through the foil trap, virtually all debris is stopped.

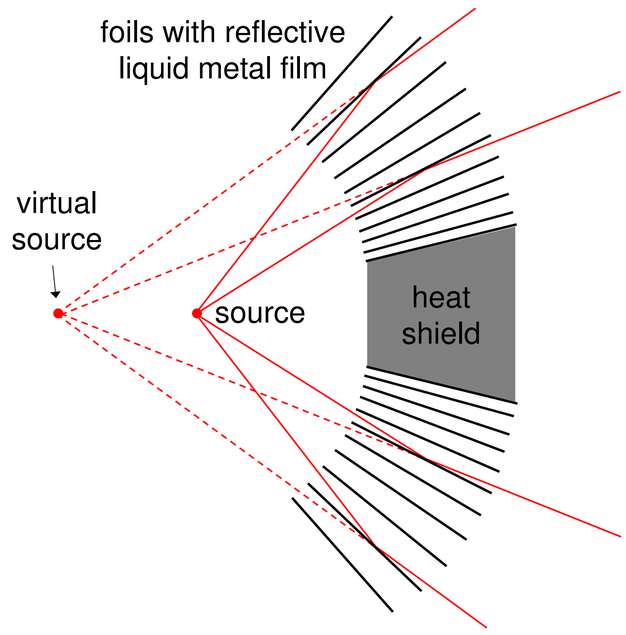

Figure 6: Reflective foil trap.

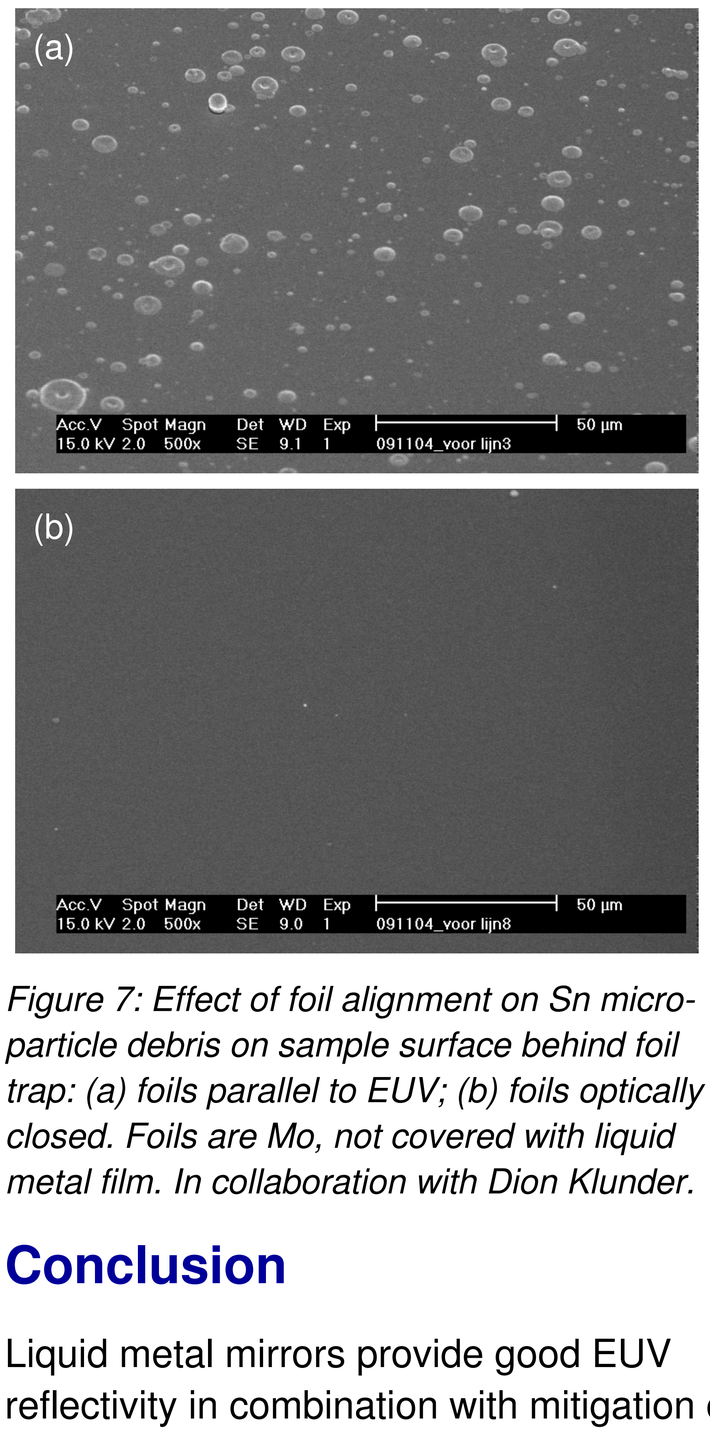

Figure 7: Effect of foil alignment on Sn micro-particle debris on sample surface behind foil trap: (a) foils parallel to EUV; (b) foils optically closed. Foils are Mo, not covered with liquid metal film. In collaboration with Dion Klunder.

Conclusion

Liquid metal mirrors provide good EUV reflectivity in combination with mitigation of Sn debris and are therefore a promising class of debris mitigation methods. Successful wetting on Mo foils was demonstrated, enabling complex mirror geometries such as a reflective foil trap.

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