Plasma-induced Blister Formation and Deuterium Retention in EUV Mirrors

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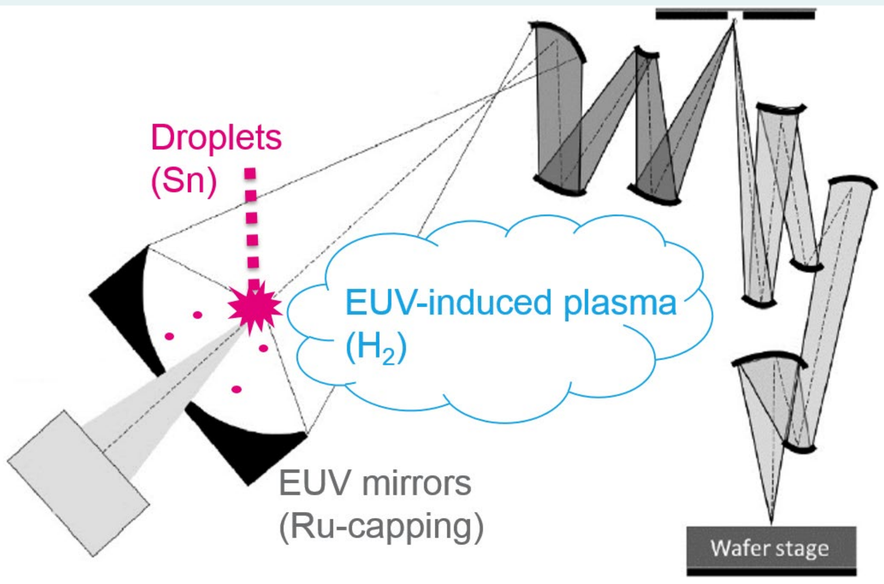
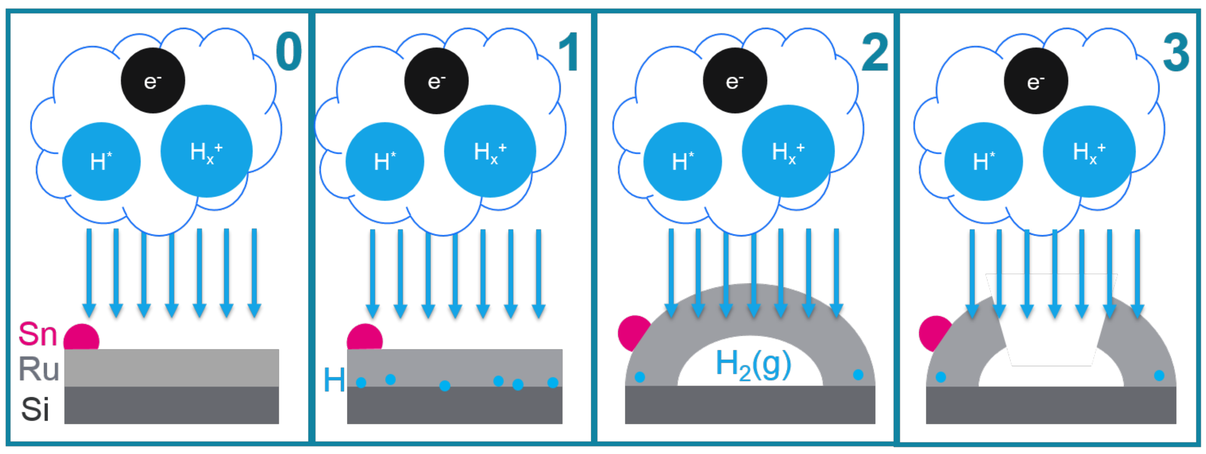
Background

Extreme ultraviolet (EUV) lithography has been considered as a key component to continue Moore's law. Lifetime of EUV optics remains one of the top challenges due to its harsh environment involving Sn droplets and EUV-induced hydrogen plasmas.



Objective

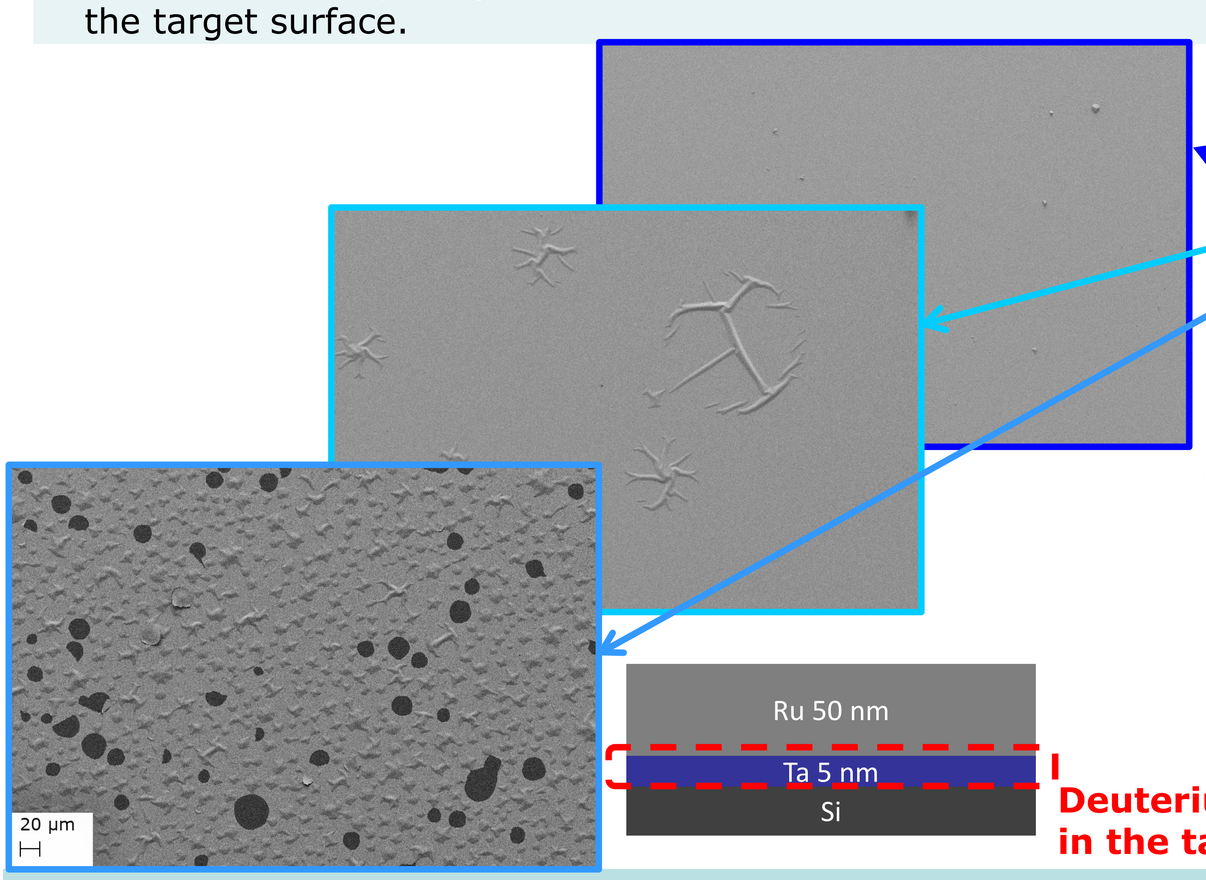
The EUV mirrors are frequently protected by a metallic capping layer such as Ru. Upon exposure to a plasma, blisters may form between layers, and this phenomenon occurs especially for Ru caps in the presence of a (sub-)monolayer Sn coverage. Therefore we would like to study blister formation in a Ru-capped mirror exposed to a low-temperature hydrogen-isotope plasma in the presence of Sn debris.

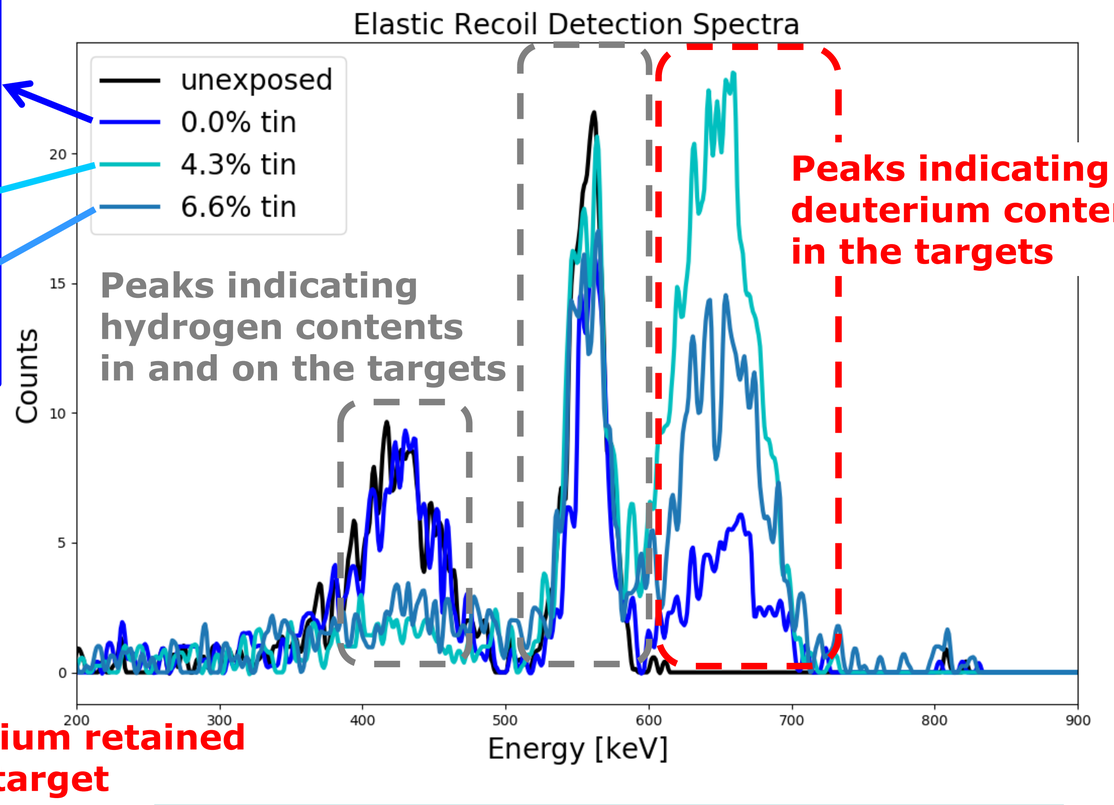


Experiment

- Our targets were Ru-capped Si wafers with Ta as the adhesion layer. Three targets were individually exposed to a deuterium plasma with different amounts of Sn in the environment for 9 minutes at $\Gamma_i \sim 10^{20}$ m^{-2} s^{-1} and $T_e \sim$ 0.2 eV.
- After the exposures, the chemical composition near the target surface was measured using X-ray Photoelectron Spectroscopy (XPS) and the deuterium content in the target was measured using Elastic Recoil Detection (ERD). The Secondary Electron Microscopy (SEM) images below show blisters and raptures on the target surface.

		Unexposed	target 1	target 2	target 3
XPS	Ru 3d	65.0%	59.3%	30.9%	30.4%
	O 1s	35.0%	35.8%	50.1%	48.9%
	Sn 3d	**0.0%**	**0.0%**	**4.3%**	**6.6%**
	Si 2p	0.0%	2.9%	14.7%	14.1%
ERD	D content [TFU]	**0.0**	**3.1**	**12.5**	**8.0**





Conclusion and Outlook

We observed surface modifications on Ru-capped Si targets after deuterium plasma exposures in a Sn-rich environment. Our analysis showed Sn on the Ru surface accelerated blister formation, which resulted from the excessive deuterium content in the target. We would like to further investigate the effects of materials and plasma parameters on deuterium retention in EUV mirrors, in order to mitigate blister formation and delamination of the films.

Acknowledgement

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