

In-situ Cryogenic Cleaning of Tin-Contaminated EUV Optics

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Considerable tin-splash contamination can occur on multilayer-coated optics when used with tin-based plasma light sources in EUV lithography applications. Generally, thick tin deposits cannot be removed sufficiently fast by plasma etching; this requires the development of alternative cleaning techniques. We have investigated cryogenic methods for substrate cleaning.

For high-purity tin drops of ~3 mm diameter, deposited onto various samples, we have studied in-situ cleaning concepts based on the initiation of tin pest leading to a phase transformation during cooling followed by considerable volume expansion and embrittlement of the tin splash. As substrates, both unstructured and structured silicon-wafer and multilayer-coated mirror samples with up to 6 inches in diameter were examined, as well as a thick solid piece of silicon carbide. The temperature-dependent sticking behavior of tin splashes deposited in a vacuum chamber was analyzed on multilayer-coated samples with different cap layers. During subsequent substrate cooling to temperatures of -30 °C and below, initially adhesive deposits were fully converted in-situ to removable brittle gray tin in less than 24 hours. Typically observed growth rates of the α -Sn phase were 10-15 $\mu\text{m}/\text{min}$.

After removal of the detached tin pieces on a Mo/Si-coated sample, analysis of EUV multilayer reflectivity at PTB Berlin showed a reduction by only 0.5 % at a wavelength of 13.5 nm. A ~10 mm diameter splat on a Mo/Si-coated sample with 3 nm thick ZrO₂ cap layer was converted to gray tin in less than 9 hours. The tin-splash transformation on a grating-structured Si-wafer sample was also studied with similar conversion results [1]. In addition to phase transformation, other alternative cryogenic cleaning methods, using strong cooling to temperatures of -120 °C and below, both in-situ and ex-situ, and also ex-situ cleaning by exposure to a high-pressure jet of CO₂-snow flake aerosols, were analyzed.

[1] N. Böwering, Ch. Meier, J. Vac. Sci. Technol. B **38**, 2020, 062602.