Cryogenic cleaning techniques for tin-contaminated EUV lithography optics

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The collection optics lifetime of tin-based EUV plasma light sources for lithography applications is limited considerably by contamination with thick tin deposits that cannot be removed sufficiently fast by plasma etching. Industrial sources therefore require periodic optics cleaning, to be carried out either in-situ or ex-situ.

To develop an efficient in-situ cleaning concept based on the initiation of tin pest, we have studied the temperature dependence of the sticking and the phase transformation of tin drops dripped in vacuum on different unstructured and grating-structured silicon-wafer and multilayer-coated mirror samples with up to 6 inches in diameter. During substrate cooling to temperatures below -30 °C, initially adhesive deposits were fully converted in-situ to brittle gray tin in less than 24 hours. After removal of the detached tin pieces, reflection analysis of EUV multilayer mirrors showed a reduction by only 0.5% at a wavelength of 13.5 nm.

We compared this structure-conversion technique with other alternative cryogenic optics cleaning methods for thick tin deposits based on the application of either cold nitrogen vapor or liquid for direct super-cooling, as well as with tin-drop removal by CO_2 snowflake aerosol impact. These methods also yielded good cleaning results for tin drops; however, CO_2 snow cleaning can only be applied ex-situ, leading to longer system downtime.