Cap layer selection for the collector mirror in tin LPP sources

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Summary

Realization of sufficient collector lifetime is one of the key challenges for current EUV sources. Recent studies have clarified the main degradation mechanisms, and have shown that a protective capping layer can extend the lifetime considerably. Our goal is to identify the optimal coating for current and future sources.

First, a selection of materials based on properties such as EUV transmission and chemical stability was made. Promising candidate capping layer materials were screened in laboratory tests that simulate source conditions. In this paper, we report some key experimental findings.

Main conclusion is that material selection for the capping later is critical for collector lifetime. Key properties include low tin affinity and good tin cleaning, which can now be evaluated in a dedicated test setup. Results from these experiments have helped to understand the contamination processes on the collector, and will be used to further extend collector lifetime.

Figure 1: Cymer LPP EUV source

Source operation principle

Cymer EUV sources are based on laser-produced plasma (LPP). The EUV radiation is produced by a tin plasma, which forms during the irradiation of a small tin droplet with a short IR laser pulse.

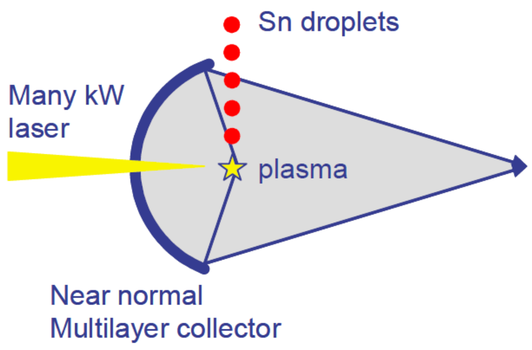

Figure 2: Operation principle of tin-fueled laser-produced plasma (LPP) source for EUV lithography tools

Protecting the collector mirror

The collector mirror reflects the EUV radiation from the tin plasma into the scanner using a molybdenum-silicon multilayer coating. This coating is not inherently stable in the source conditions and thus requires protective measures.

1. Tin contamination is an obvious risk. Tin particle and vapor deposition on the collector will lead to loss of reflectivity. Primary mitigation is a hydrogen purge that directs the tin away from the collector.
2. The hydrogen gas in the source will be partially ionized and dissociated. This hydrogen plasma was shown to selectively remove tin from the collector. The collector coating is thus required to have a low affinity for tin deposition, and must be stable upon prolonged exposure to hydrogen plasma.
3. Another risk is radiation-induced oxidation of the collector mirror. This can be prevented by a protective capping layer on top of the Mo-Si multilayer coating. The collector coating must therefore also be stable in an oxidizing environment.

Cap selection – material selection

Early field tests with capped collectors showed a clear improvement of lifetime w.r.t uncapped collectors. Based on this result, a more systematic study was started to optimize the capping layer for maximum collector lifetime.

First, a pre-selection was made based on:

1. EUV transmission, based on photon-absorption cross section at 13.5 nm.
2. Chemical stability w.r.t oxidation, reduction and sputtering.
3. Simulated ion stopping power for plasma resistivity.

With best ranked materials, an experimental screening program was started:

1. Fabrication of samples with selected capping layers.
2. Tin vapor deposition test.
3. Tin cleaning tests with H-radicals, both during tin deposition and after tin deposition.
4. Exposure to oxygen plasma.
5. Exposure to EUV-radiation in H_2 and H_2O environment .

For experiments 2 and 3, a dedicated setup was assembled at TNO, see figure 4.

Results - Tin vapour deposition test

Clear differences were found in the tin morphology after 50 nm of tin deposition. Caps with high binding energy for tin show monolayer growth followed by island growth, based on SEM, XRF and XPS analysis (fig. 3A). Caps with low binding energy show only island growth (fig. 3B,C).

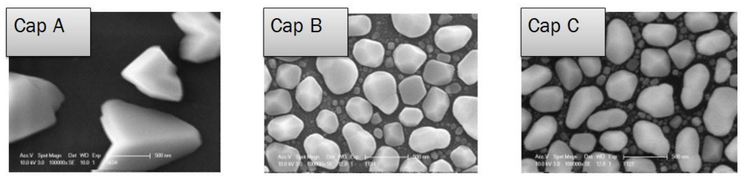

Figure 3: Cap A shows Stranski-Kranstanov Sn growth, i.e. a monolayer tin with islands on top. Cap B and C demonstrate Volmer-Weber growth, i.e. isolated tin islands.

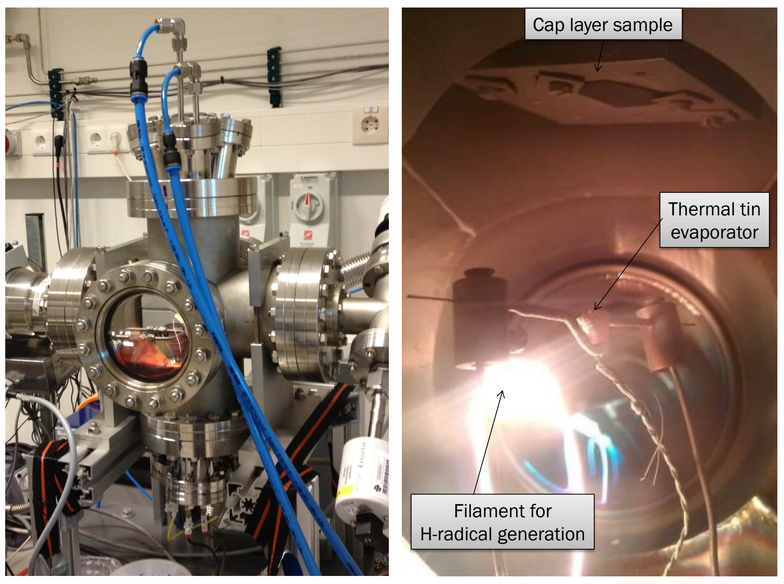

Figure 4: Setup at TNO for parallel tin deposition and tin cleaning tests.

Results - Tin cleaning test

Preliminary tin cleaning tests show large differences in cleanability of the tin, see figure 5. Surprisingly, some caps (B and C) show that cleaning during deposition is much more effective than cleaning after tin deposition. We attribute this to a low binding energy between tin and cap, as compared to tin-tin binding energy. This difference can explain the increased tin removal efficiency for very thin layers. Based on this result, a dynamic equilibrium between tin deposition and tin cleaning appears feasible.

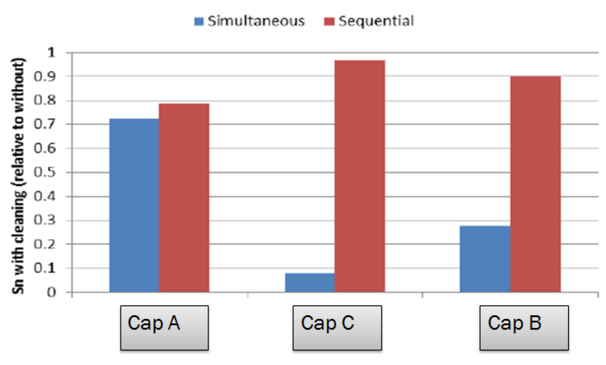

Figure 5: Caps with low cap-tin binding energy show improved tin cleaning for simultaneous tin deposition and cleaning, w.r.t. sequential cleaning (i.e. after deposition).

Acknowledgements

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