Extreme ultraviolet mask surface cleaning effects on lithography process performance

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The reflective, multilayer based, mask architectures for extreme ultraviolet (EUV) lithography are susceptible to surface contamination. As a result, EUV masks are expected to undergo cleaning processes in order to maintain the lifetimes necessary for high volume manufacturing. Several mask cleaning methods are currently being investigated [1]. Mask lifetimes will thus be determined by the number of cleaning cycles that can be supported. The question of cleaning-induced damage is therefore crucial. To date, there are no reported studies that directly compare patterning performance of a mask before and after the surface cleaning applications.

Here we present a study on the impact of repetitive cleaning of EUV masks on imaging performance. We study both critical dimension performances in terms of process window analysis as well as printed line edge roughness (LER). The masks used in this study are comprised of industry standard multilayer and absorber stacks. Two masks are used with one serving as the test mask which will be repeatedly cleaned and periodically imaged in an EUV tool until significant imaging degradation is observed. The second mask will serve as the baseline reference mask used to ensure the stability of the imaging process over the duration of the test.

Preliminary cleaning tests have been performed on an older generation mask after more aggressive cleaning to help establish the parameters for the long term studies to be presented here. Imaging analysis of this mask after a large number of cleaning cycles has revealed a large increase in LER and LWR (table 1). Despite this increase in LER, little impact is seen on the iso-focal positions and exposure latitude. It is hypothesized that the increase in LER is in large part due to damage to the reflective multilayer and its capping layer. In this presentation we will also present modeling results supporting these findings.

1. Chemical effect of dry and wet cleaning of the Ru protective layer of the extreme ultraviolet lithography reflector, Leonid Belau, Jeong Y. Park, Ted Liang, Hyungtak Seo, and Gabor A. Somorjai, J. Vac. Sci. Technol. B 27, 1919 (2009).

Table 1: Results from a process evaluation completed for 40 nm lines and spaces patterns. Data was collected before and after repeated cleaning of a preliminary test mask. Although little effect on iso-focal positions and exposure latitude are observed, large increases in LER and LWR are seen.

Patterning process for 40 nm lines and spaces					
	Iso-focal CD (nm)	**Iso-focal CD (nm)**	**Exposure Latitude**	**LER_ave (nm)**	**LWR_ave (nm)**
Before Clean	41.5	44.0	0.31	5.58	8.54
After Clean	44.0	45.5	0.30	7.30	11.3
LER/LWR increase				**31%**	**32%**