Modification of photomasks substrates by ultrashort laser pulses in modern lithography

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As a result of bulk transparent dielectrics processing with ultrashort laser pulses modification of material takes place which leads to changing optical (transmission, refraction coefficient and birefringence) and mechanical (density, strain) properties of the material. On the other side, lithography process is very sensitive to optical and mechanical properties of photomasks consisting of a pattern placed on fused silica substrates (150x150 mm plates with thickness of 6.3 mm).

In this paper we report the possibilities to improve the yield of the lithography process due to controllable change of photomasks properties by processing the bulk fused silica mask substrate with ultrashort laser pulses. We applied laser processing of fused silica photomasks substrates for intra field critical dimensions uniformity (CDU) improvement, for registration errors correction and for correction of substrates surface flatness.

1. For intra field CDU improvement well-known dependence of CD on wafer level on illumination dose during litho process is used. To adjust illumination dose in accordance with CD ununiformity map the array of light scattering pixels of varying density is created in the mask substrate. The array of pixels is produced by fs or ps laser beam using high speed galvo or acousto-optic scanner. Fig. 1 presents a real production example of Pre and Post Critical Dimensions Control (CDC) process, by measuring delta CD on the wafer and showing improvement both in CDU and CD range.

2. Registration errors correction is based on a controllable displacement of mask pattern by localized change of bulk substrate density and strain formation as a result of ultrashort laser processing of the mask. Fig. 2 and Table 1 show significant improvement of registration and 3σ both in X and Y axis.

3. Processing of the adjacent to the surface substrate layer of the material with ultrashort laser pulses leads to controllable depression or raising of the surface in nm-range without microroughness distortion due to compaction or expansion of the material depending on the processing parameters. This method can be used for correction of low and mid spatial frequency surface flatness errors of substrates of reflective optics and masks for EUV lithography. Fig. 3 shows examples of valley and bump formation on the surface of fused silica sample measured by white light interferometer.