Customised Illumination for Process Window Optimisation and Yield Improvement in mask aligner Lithography Systems

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Since the very beginning of semiconductor industry in the early 60s, proximity and contact lithography systems, so-called mask aligner, were the workhorse of their success. The never ending rush for higher resolution had pushed mask aligners out of front-end lithography many years ago. However, innovation and constant improvement of mask aligners have always opened new applications and markets for cost-effective optical lithography. Today, mask aligners are widely used in research and development, in micro-fabrication, in Advanced Packaging, MEMS and LED manufacturing, for thick photo resist applications, and most recently also for (Nano) Imprint Lithography, Wafer-Level Camera and Watch Making. However, the improvement of the illumination systems of mask aligners was widely neglected. A standard illumination system of mask aligners use a multipole off-axis illumination to reduce diffraction effects (side-lobes), as shown in Figure 1 only.

The novel illumination system for mask aligners provide improved exposure light uniformity and customized illumination. The illumination system, the so-called MO Exposure Optics, is based on two consecutive Köhler Integrators and an exchangeable illumination filter plate. The double Köhler Integrator concept allows homogenizing of both irradiance and the angular spectrum of the exposure light over the full mask area. The exchangeable illumination filter plate allows a free choice of illumination settings, like e.g. ring-illumination, quadrupole, multipole, Maltese cross and free-forms in a standard mask aligner. The MO Exposure Optics significantly improves the depth of focus (DOF) and exposure latitude while reducing mask error factors for full-field proximity lithography in mask aligners. The MO Exposure Optics now allows a free choice of illumination to adapt diffraction reduction to the actual mask pattern, resist type and proximity gap.

As shown in Figure 2, the MO Exposure Optics is based on two Köhler Integrators, also know as fly's eye condensers, made of double-sided microlens arrays in fused silica. Also shown is a library of image filter plates, including well-established illumination settings from existing mask aligners plus additional settings like ring-illumination and Maltese cross (0°, 45°). The image filter plate is placed right before the second Köhler Integrator. The well defined illumination also allows optical proximity correction (OPC) of the mask pattern to compensate for remaining image errors due to diffraction or process effects. Customized illumination and OPC-like structures introduce well-know tools of projection lithography for mask aligners for the first time.

Figure 3 shows experimental results from a grey-level mask pattern (chromium-on-glass structures of 450nm diameter, 2µm period) at a proximity gap of 10 µm printed with different image filter plates in a SUSS mask aligner MA6.

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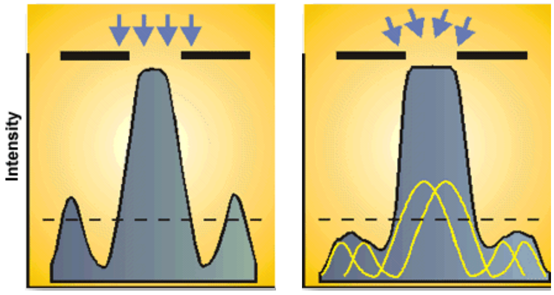

Fig. 1: Side-lobes in aerial images are significantly reduced by off-axis illumination

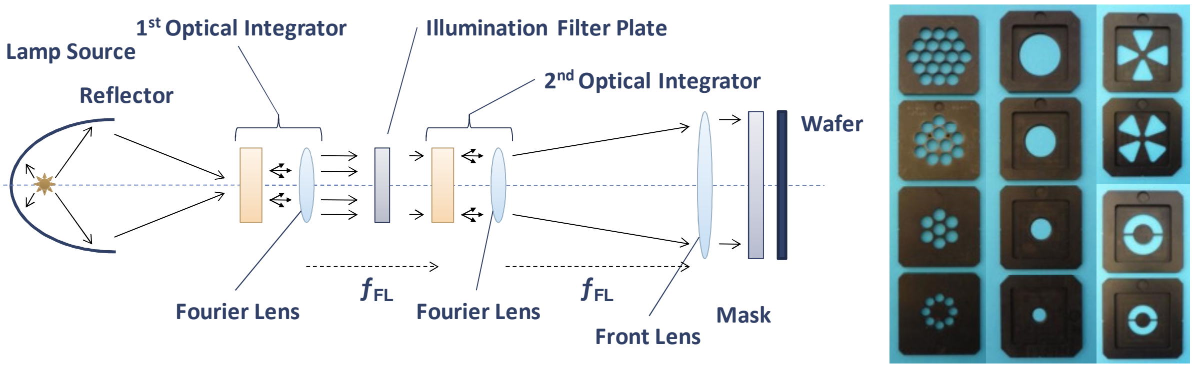

Fig. 2:
Left: Schematics of MO Exposure Optics. Two Köhler Integrators at a Fourier length distance homogenize both, exposure light irradiance and angular spectrum.
Right: A set of exchangeable illumination filter plates allows customized illumination.

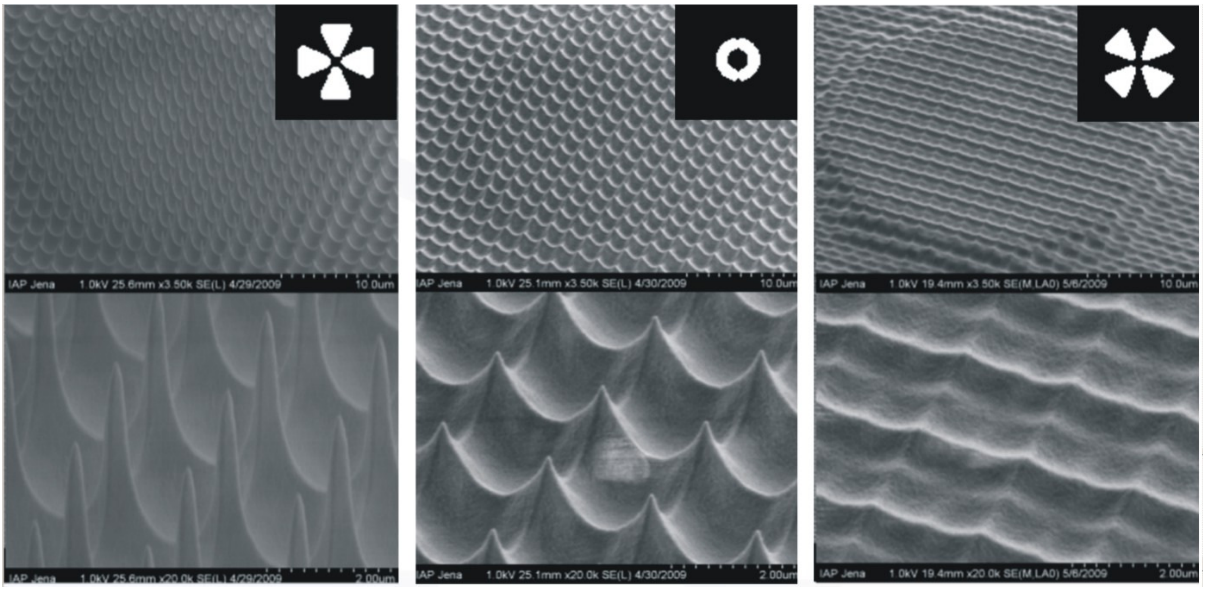

Fig. 3:
Proximity lithography (10µm gap) of grey-level mask on a mask aligner equipped with MO Exposure Optics. The different illumination filter plates (left-to-right) have strong influence on the shape of the printed pattern.
[Experiment and photos by T. Harzendorf and U. Zeitner, Fraunhofer IOF, Jena, Germany]