EUV-LET: Large-area nanopatterning by interference lithography for scientific and industrial research

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The EUV laboratory exposure tool (EUV-LET) is a compact nanostructuring setup that is used for large-area patterning (cm²) of periodic nanostructures with half-pitches below 100 nm. Applications are found in various research fields (e.g. diffractive optical elements, anti-reflective coatings, metamaterials, nanowires) as well as in prototype development and small-batch production. Recently the working wavelength of the tool was changed from 10.9 nm to 13.5 nm in order to also enable industrial photoresist development and resist characterization.

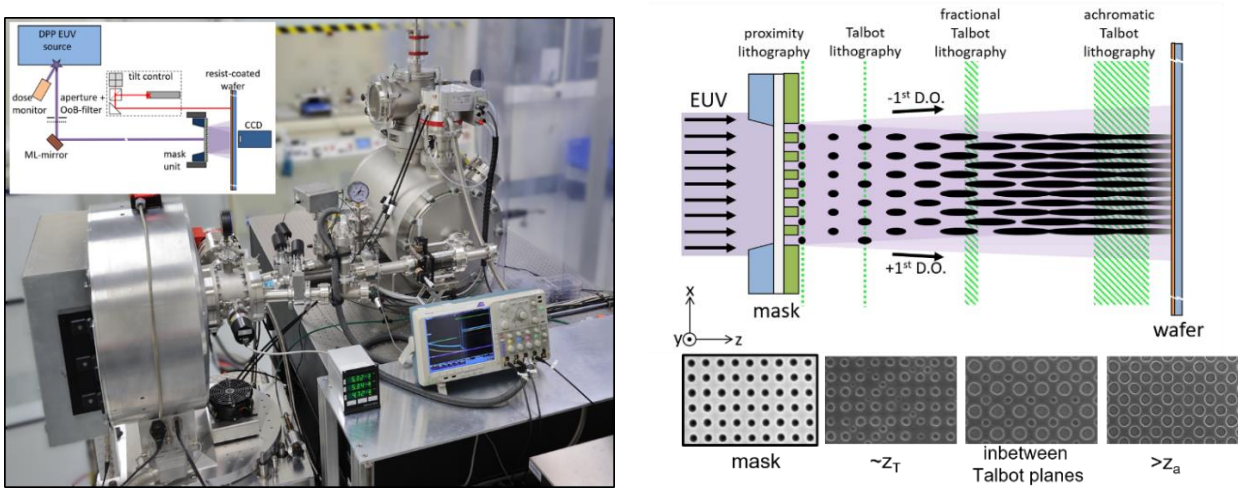

Fig. 1 *Left: Realized EUV-LET for 13.5 nm working wavelength with operation scheme (inset). Right: Talbot scheme with mask structures and exposure results in Talbot and achromatic Talbot distance (z_T and z_a).*

The EUV-LET utilizes partially coherent radiation from a compact discharge-produced plasma EUV source, spectrally filtered by an out-of-band filter and a multilayer mirror to in-band EUV at 13.5 nm with 4 % bandwidth (at FWHM). Phase-shifting transmission masks are positioned precisely in sub-100 µm distance to the resist-coated wafer and define the printed features. For high-resolution patterning of periodic structures the (achromatic) Talbot lithography is used, which is perfectly suited for partially coherent radiation with a defined bandwidth, as provided by a plasma-based radiation source. Since all diffraction orders contribute to the intensity modulation, high throughput is achieved with typical exposure times of several minutes. The system allows for precise mask-to-wafer positioning, semi-automatic exposure series including dose and distance scans and in-tool mask characterization and inspection. Theoretical resolution limit of the achromatic Talbot lithography is in the sub-10 nm regime and practical resolution is only limited by the available photoresists if the required transmission masks can be fabricated. So far we demonstrate with the realized prototypes sub-30 nm resolution with single exposure fields of 1 x 1 mm² that can be stitched together to achieve even larger areas.

In this paper we present the realized exposure tools, the developed mask fabrication process together with the latest exposure results and exemplary applications in large-area pre-patterning (at 10.9 nm) and industrial resist development (at 13.5 nm).