Novel registration error metrology for multiple electron beam lithography

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MAPPER's FLX1200 pre-production platform is a promising low-cost, high throughput (1-10 wph) maskless multiple electron beam lithography system. It is able to address a wide range of market segments from mature to advanced technology nodes.[1] CEA Leti partakes in the IMAGINE consortium, that is founded to ensure industrial take-off by developing integrated manufacturing flows and process control solutions. Special attention is given to the correlation between in-line tool metrology and off-line metrology of features written on the wafer.

Overlay is the misalignment of the current layer with respect to previous layers and is one of the critical process control parameters in lithography. In a standard manufacturing environment, the overlay budget is only 1/4th or even 1/5th of the critical dimension (CD).[2] Part of this budget is allotted to intra-field registration errors, whose distribution strongly depends on the writing strategy of the lithography machine. The MAPPER tool is massively parallel: it writes using up to 13,260 beams, consisting of 49 Gaussian sub-beams each. The wafer is moved while each individual beam writes a 2 µm-wide stripe along the full length of the wafer (fig. 1a,b). Depending on the number of beams, this process may be repeated up to 20 times for each lane until the wafer is fully covered.

Stitching errors (fig. 1c) are pattern misplacements between two stripes. They are caused by misalignments in the system, such as the stage error, thermal drift and beam alignment. There is a strong need to have fast and accurate on-wafer metrology to quantify beam-to-beam stitching, especially for system calibration and requalification after submodule swaps. A short requalification time increases productivity of the cell and reduces costs for the wafer fab.

This paper will present a completely novel approach to optical registration metrology that is especially adapted to stitching error between stripes. This is particularly challenging because of the sub-micrometer dimensions involved. Schematics of the new registration target and measurement system are given in figure 2. The target is illuminated by various source conditions while the optical responses are measured.

Preliminary simulations of the response of a single target as a function of misalignment (Δx, Δy) and illumination conditions have been performed**.** The results show that from these signals it is possible to estimate the stitching errors $\Delta\hat{x}$ and $\Delta\hat{y}$ independently (fig. 3). This work will also discuss the different kinds of process integration required for the implementation of this new registration metrology.

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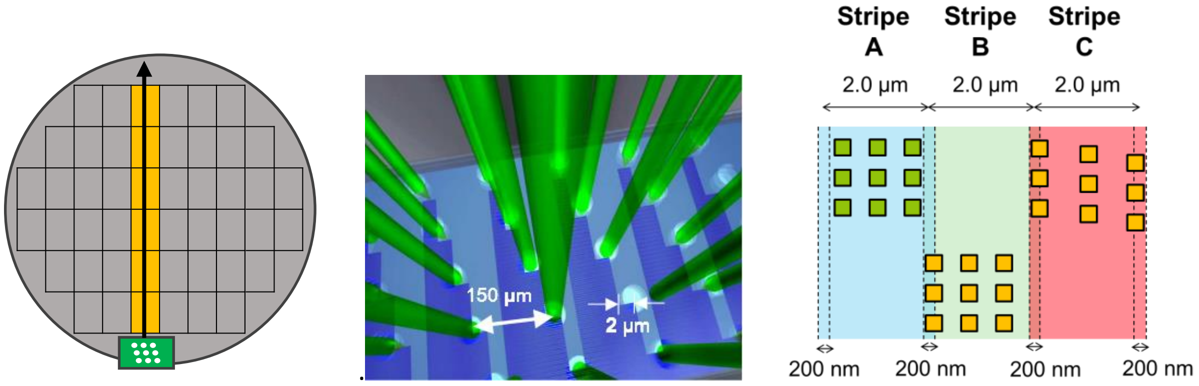
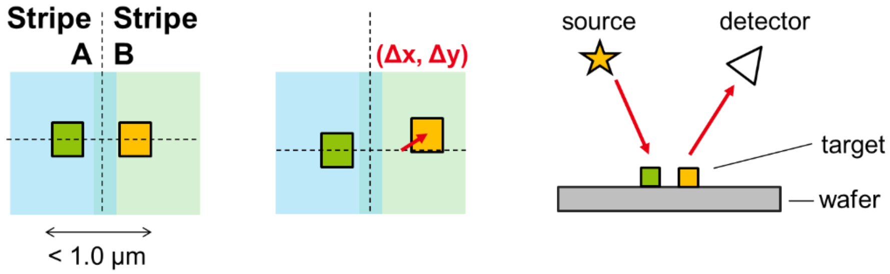
[1] G. de Boer, MAPPER : progress toward a high-volume manufacturing system, *Proc. SPIE,* Vol. 8680, 2013
[2] International Technology Roadmap for Semiconductors 2*, More Moore Lithography tables MM06,* 2015, http://www.itrs2.net



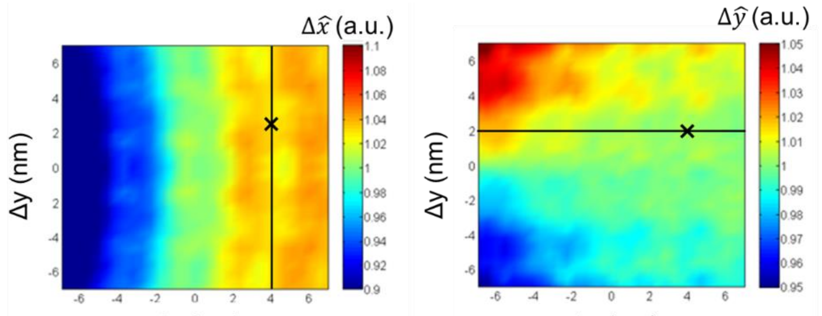
(a) *(b)* *(c)*

Figure 1: (a) Writing strategy of MAPPER's FLX-1200: the wafer is moved with respect to the beams to expose a lane (highlighted) of standard fields, this process is repeated up to 20 times depending on the number of active beams. (b) The beams individually write 2 µm-wide stripes all along the wafer. [1] *Between the stripes there is a 200 nm overlapping stitching region. (c) Schematic of a contact pattern in (A) a well-aligned stripe, (B) a timing error causing a pattern shift and (c) a stripe with incorrect X- and Y-magnification.*



(a) *(b)* *(c)*

Figure 2: (a) Schematic of a perfectly aligned target structure, with left and right parts in stripes A and B respectively. (b) Schematic of a target with stitching error (Δx, Δy). (c) Schematic of the metrological setup: the target is illuminated by the source, its response is measured and processed to estimate the stitching error ($\Delta\hat{x}$,$\Delta\hat{y}$).



(a) Estimation of $\Delta\hat{x}$ *(b) Estimation of* $\Delta\hat{y}$

Figure 3: The optical response of the new target with misalignment (Δx, Δy) (fig. 2b) has been simulated for different illumination settings. From these signals, we independently estimate the stitching errors $\Delta\hat{x}$ (a) and $\Delta\hat{y}$ (b). For example, suppose the stitching error (Δx, Δy) is (4 nm, 2 nm), indicated by the crosses. In (a) we see clearly that the estimation $\Delta\hat{x}$ remains relatively constant independently of error Δy (the black line), reconstructing the 4 nm. (b) The estimation $\Delta\hat{y}$ is not completely independent from error Δx (the black line), still offering an opportunity for improvement.