Real-time focus and overlay measurement by the use of fluorescent markers

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Introduction

Improving overlay (OVL) control including process dependencies below a level of 5 nm is a complex challenge[1]. Felix et al. identified five categories contributing to on-product overlay: scanner, process, reticle, metrology and advanced process control[2].

This poster presents a method to sample OVL real-time, i.e. during expose[3]. It is proposed to use fluorescent material in at-product-pitch markers, e.g. positioned in the scribe line, to generate real-time OVL signals. These signals shall provide insight in expose-beam-induced overlay errors, e.g. as caused by lens heating.

The method is applicable in multiple-patterning production using DUV, EUV and electron beam exposures, when similar pupil illumination is used in consecutive steps.

We foresee an accelerated yield-ramp, enabled by real-time OVL data, since these could characterize correctable OVL errors. The method is expected to be most economical for the production of small series of ICs at latest patterning node, e.g. ASIC.

LELE process flow for in-line OVL control

Fig. 1 shows a modified Litho-Etch-Litho-Etch double-patterning (DP) process[4], enabling real-time metrology. Litho-1 prints both costumer part and (at-pitch) markers. After development and etch, the markers are filled with fluorescent material. During litho-2 the fluorescent signal measures OVL and focus. The real-time metrology data can be related to a-posteriori measured overlay and focus[1,5].

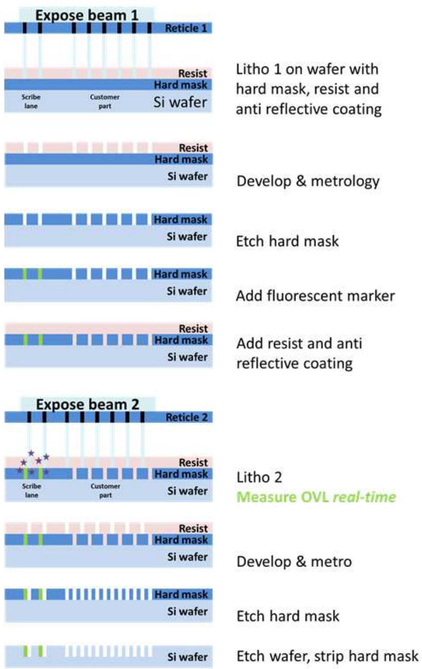

Figure 1 LELE DP process for real-time metrology

Marker design & photon budget

The in-plane geometry of the marker pair is determining the system sensitivity to focus and OVL. Although we also envision focus metrology with an appropriate marker design, we limit the discussion here to the design of a marker for OVL.

The fluorescence strength is predicted by a photon budget model, assuming realistic attributes of the scanner and marker material.

The inset in Fig. 2 shows the signal generation principle: photons are generated when the patterned expose beam overlaps with a marker. For OVL metrology in both the +X and –X direction, a pair of markers is required. The main panel of Fig. 2 shows the difference between the fluorescence signal from such a marker pair.

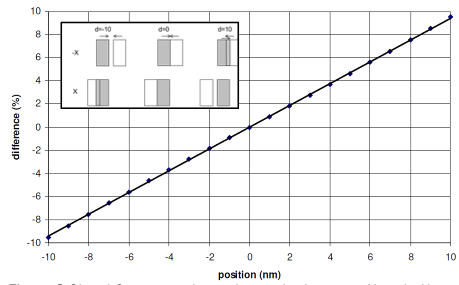

Figure 2 Signal from a marker pair, monitoring e.g. +X and –X as a function of position. Inset: schematic OVL marker pair lay out.

Reticle lay out

Fig. 3 shows an arrangement of a set of marker pairs on the first and second mask, as well as the resulting pattern after both exposures. The slit of the expose beam is a few mm wide. Hence the markers shall be separated by at least the slit width to avoid cross-talk between X- and Y-OVL signals. Consequently, for a field size of 36 mm, the number of marker pairs is limited to about ten.

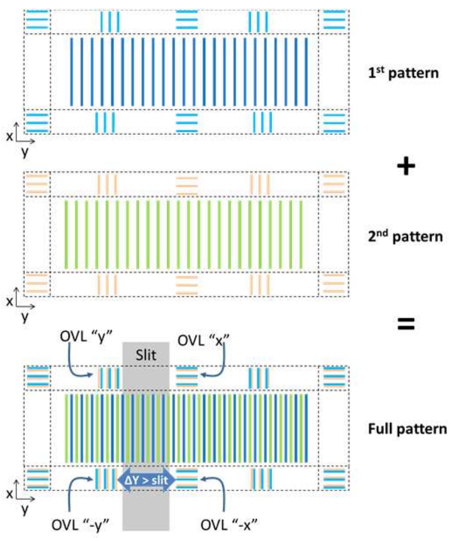

Figure 3 Illustration suggesting a possible arrangement of marker pairs in the scribe lanes. The scan direction of the stages is Y. The alternating marker orientation enables sampled measurements of the X- and Y-OVL.

At-product-pitch marker OVL accuracy estimate

A simple photon budget has been made to estimate the detection sensitivity in the shot noise limit. In a DUV system at expose dose of 20 mJ cm^{-2} the detector records ~10^5 photons from a 5x5 µm marker with 15 nm lines at 40 nm pitch, see Fig. 4. Hence, fluorescent markers enable real-time OVL detection with accuracy of 0.02 nm (1σ) for the best-case of shot-noise-limited detectors in expose systems with NILS = 3.

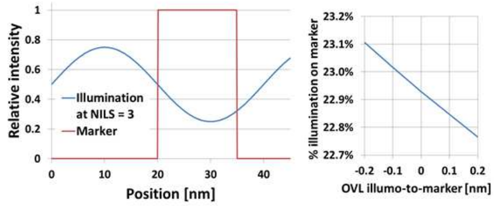

Figure 4 Left panel: Example of one period of both exposure light (blue line) with a NILS of about 3 and the localized scintillating marker material (red line). The marker has the same pitch but a reduced width. Right panel: The fraction of the illumination light with a 40 nm pitch that hits a 15 nm marker as function of misalignment between illumination and marker

Engineering tasks required for implementation

- Realistic marker design, based on photon-budget modeling of the sensitivity for focus and OVL for realistic process conditions
- Selection of optimal fluorescent materials, compliant with further processing
- Process development for the application of fluorescent material on the markers
- Development of a fluorescence detector in the scanner, offering at least two signal read-outs

Conclusions

1. A method for real-time overlay measurement is proposed
2. The predicted accuracy of the method is better than 0.1 nm (3σ)
3. Before practical implementation of the method, quite some engineering effort is still required

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