Measurement of Placement Accuracy and Overlay in E-beam Lithography with 2-D Vernier Arrays

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Electron-Beam Lithography (EBL) was for many years and remains the main tool for writing of advanced photomasks for chip manufacturing. However, direct e-beam writing on wafers has for decades been considered too slow for high volume production. Nevertheless, there are quite a few niche applications where EBL can be a preferable technique for writing critical chip layers on either non-standard size substrates (e.g., III-V semiconductors), or in cases where the volume of production does not justify the use of the costly high-resolution DUV or EUV lithography with a reasonable profit margin. Naturally, the EBL writers used in production need to be well calibrated and their performance monitored, preferably, for every exposed wafer before the next process step. Some of the important EBL tool parameters such as field stitching, placement, and overlay errors must, ideally, be measured with sub-5 nm precision just after resist development.

One dimensional Vernier scales[1,2] have been utilized to measure the abovementioned quality parameters. These methods required post-litho etching steps to obtain reliable measurements with approximately ± 3 nm accuracy. Additionally, automation of the measurements for 1-D verniers proves quite difficult.

In this paper, we present a new method that employs 2-D overlaid Vernier arrays (Fig.1) to measure field stitching, placement, and overlay errors using simple SEM image processing (Fig.2). As compared to the preceding methods, overlaid 2-D Vernier arrays can provide the measurements with sub-1 nm accuracy directly on resist after e-beam lithography step. We also report an automated procedure and describe the process flow for on-wafer e-beam writing qualification for chip production.

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[1] Greibe, T., Anhøj, T. A., Johansen, L., & Han, A. (2016). Quality control of JEOL JBX-9500FSZ e-beam lithography system in a multi-user laboratory. Microelectronic Engineering, 155, 25-28.

[2] S. Thoms, D.S. Macintyre, K.E. Docherty, J.M.R. Weaver, Alignment verification for electron beam lithography, Microelectron. Eng. 123 (2014) 9–12.

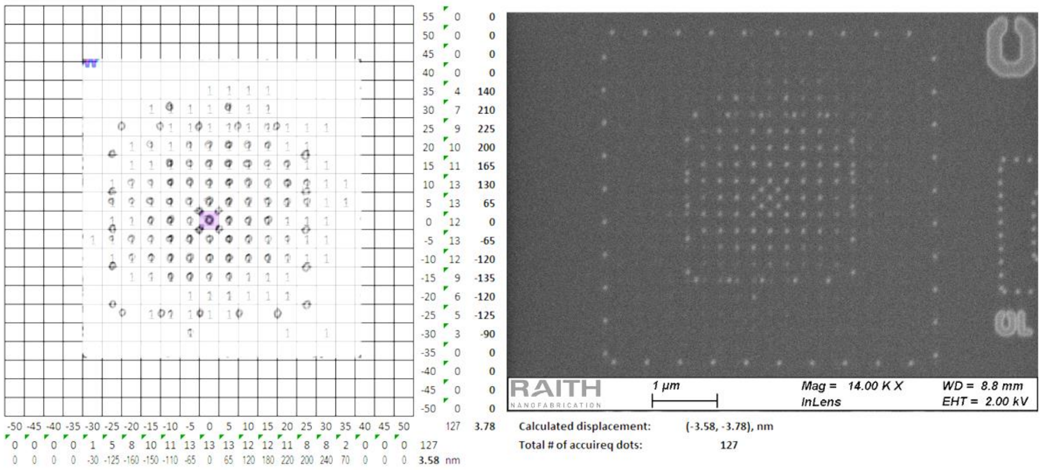

Figure 1: Illustration of displacement error calculation. The original SEM image (right) is processed and overlaid with the measurement matrix (left). Vernier measurement matrix values are set to 1 where image dots fall near the centers of the grid cells. Other cells are assumed to have 0 value. Dots crossed by the cell borders are markers, which are not a part of the calculation. The displacement error is opposite to the shift of the matrix center of gravity from the marked grid center. In this example the SEM image dots pitch is 252.5 nm and the Vernier measurement matrix pitch is 5 nm.

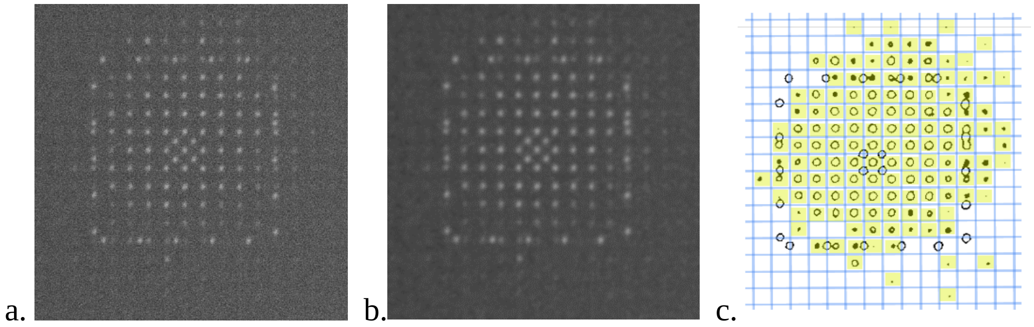

Figure 2: SEM image processing procedure: a. original photograph; b. Gaussian blur applied; c. threshold filter applied and a counting grid constructed aligned to the image. Nonempty cells of the grid, except those containing markers only, are accounted for the calculation of the center of gravity, as in Fig.1. The markers are designated as being crossed by the grid lines.