Write-field alignment optimization using self-developing electron beam resist

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In electron beam lithography (EBL), large area pattern is divided into small write-fields, which are stitched together by stage movement to generate the large area pattern. Precise stage movement is essential to minimize the stitching error, and this can be realized by using laser interferometer controlled stage. In addition, electron beam deflection has to be adjusted to match the stage movement, which is referred as write-field alignment. For EBL using SEM-based system (such as Raith 150^{TWO} or Hitachi SU-70), the write-field is typically on the order of 100 µm in order to achieve sub-50 nm stitching error depending on the stage accuracy. But to write large area nanostructures such as over 10 cm^2, large write-field such as 1 mm^2 has to be used as otherwise the stage movement time would be impractically too long. However, write-field alignment accuracy decreases with large write-field obtained by using small magnification. Here we show that by using self-developing resist as in-situ feedback, one can greatly improve write-field alignment accuracy.

As shown schematically in Figure 1, after standard write-field alignment procedure at low target magnification (e.g. 100×), test pattern is exposed near the write-field boundaries using self-developing resist. Then at high magnification (e.g. 5000×) the exposed pattern is examined and analyzed in order to determine the necessary adjustment of zoom factor and rotation. Next, a new pattern is exposed using the adjusted zoom factor and rotation; and examined and analyzed at high magnification. The procedure will be repeated until stitching error approaches the accuracy of laser interferometer controlled stage movement. Finally, desired pattern will be exposed with regular electron beam resist using the optimized write-field alignment parameters (notably zoom factor and rotation).

Figure 2 shows test pattern exposed on self-developing resist nitrocellulose, which has been previously used as ion beam resist [1]. We found that nitrocellulose is not a useful electron beam resist because of the very thick residual layer even at very high exposure dose [2]. However, such a residual layer wouldn't prevent it from being used as an in-situ feedback for write-field alignment optimization. Figure 2a and 2b show obvious overlap and rotation misalignment, respectively. As shown in Figure 2c, after adjustment of zoom factor and rotation, write-field alignment with accuracy of ~50 nm was achieved for a large write-field size of 1 mm^2 obtained at a low magnification of 100×.

[1] M. W. Geis, J. N. Randall, T. F. Deutsch, N. N. Efremow, J. P. Donnelly and J. D. Woodhouse, J. Vac. Sci. Technol. B, **1**, 1178 (1983).
[2] R. K. Dey and B. Cui, abstract submitted to EIPBN 2013.

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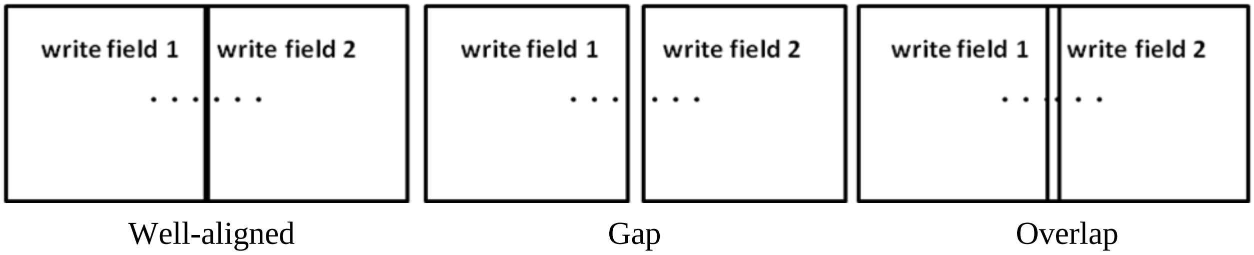
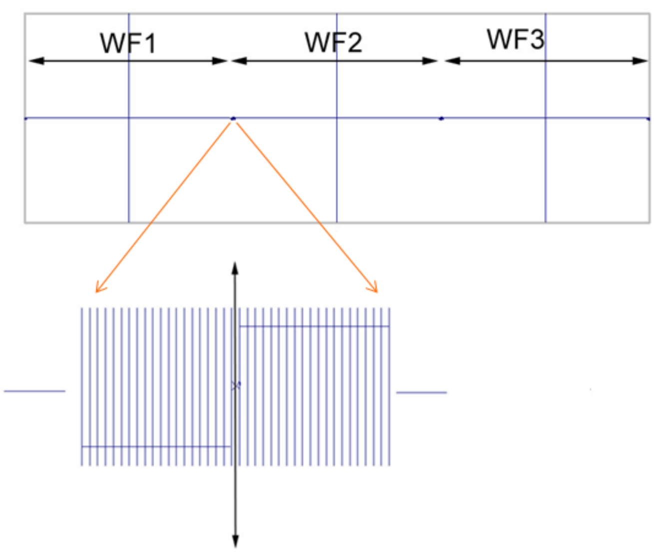


Figure 1. Schematic write-field alignment with test pattern (here periodic dot array) exposed at write-field boundary using a self-developing resist. The relative location of the dot array across two write-field boundaries reveals the alignment accuracy. The misalignment along the horizontal (vertical, not shown) direction determines the adjustment of zoom factor (rotation).



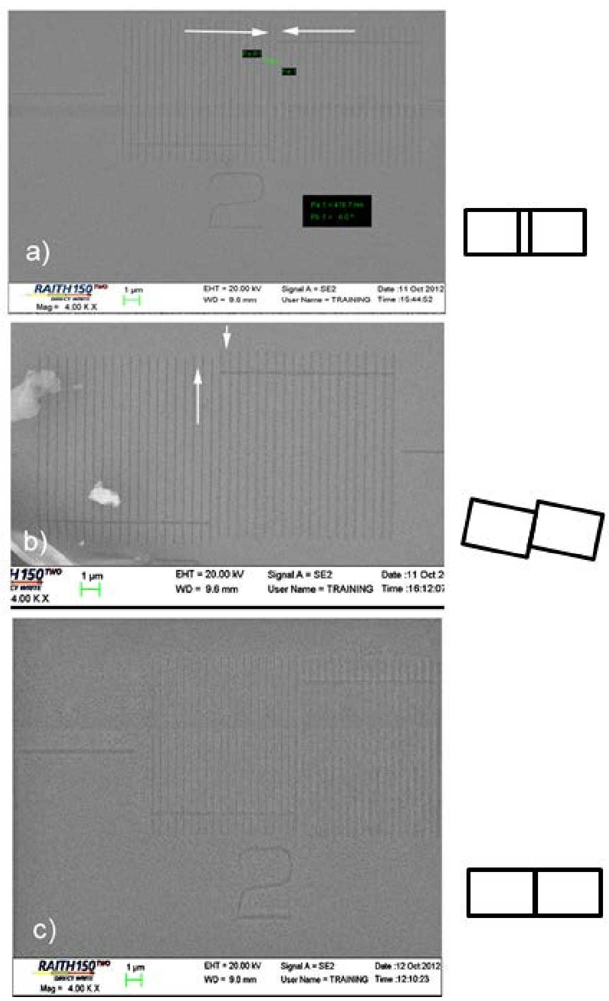


Figure 2. Pattern design (left, 500 nm period line array) and exposed pattern on nitrocellulose resist with large write-field (WF) of 1 mm^2 (right). (a) Overlap misalignment between two adjacent write-fields; (b) Rotation misalignment between two adjacent write-fields; (c) Optimized alignment with ~50 nm accuracy between two adjacent write-fields after adjustment of zoom factor and rotation.