Dot-Matrix Marks for Dynamic Overlay Measurements in Electron Beam Lithography

E. Kratschmer, J.J. Bucchignano, D.P. Klaus, M.A. Guillorn
IBM Research, Yorktown Heights, New York 10598

Due to the serial pattern data transfer in electron beam lithography (EBL) there is a larger spectrum of dynamic overlay (OL) errors as compared to projection optical or EUV lithography. An example of a Si nanowire pattern[1] showing dynamic overlay errors is shown in Figure 1. To capture the full spectrum of dynamic overlay errors in EBL, the overlay mark needs to be of high resolution, i.e. small enough size to capture the details of temporal and spatially local overlay error variations. This is in contrast to the few micrometer or tens of micrometer size marks, which are optimized for measurements in optical inspection tools to provide a global or chip level OL measurement. The highest resolution shape for this application is a single pixel dot exposure. With one dot exposed in level A and one dot exposed in level B, the overlay of level B to level A can be measured using an imaging technique capable of sufficiently high resolution to image the single pixel dots, like secondary electron microscope (SEM) imaging. The small size and short exposure time of the single pixel dot marks provides the highest temporal resolution, and a mark size that is now comparable to the highest resolution shape sizes in device patterning for the 14 nm node and below.

By expanding the single pixel dot OL mark exposures locally into a matrix of dots, the dot-matrix overlay mark gains in robustness from the redundancy of the additional dots. More importantly, the analysis of the OL variations within each dot-matrix mark can provide a time resolved record of OL errors arising from settling effects and vibrations. In addition, it can provide a spatially resolved image of OL errors across deflection field boundaries where shape butting errors can have a deleterious impact on device yield and performance. A sample layout of a dot-matrix OL mark is shown in Fig.2. The size of the single dots, the dot pitch, and the offset between the level A mark and the level B mark can be tailored maximum range of expected OL errors, as well as the desired time resolution and duration. An example of a dot-matrix OL mark exposure in HSQ resist is shown in Fig.3 along with a vector plot of the of individual 12 x 8 OL measurements. The analysis shows a small (-4.7, -6.1) nm average OL error with 3*sigma OL error variations of (11.2, 14.4) nm for the X and Y respectively.

This presentation will give details about the implementation and applications of the dot-matrix OL marks in device patterning.

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[1] Sufi Zafar, Christopher D'Emic, Ali Afzali, Benjamin Fletcher, Y Zhu and Tak Ning, *Nanotechnology* **22** 405501 (2011)

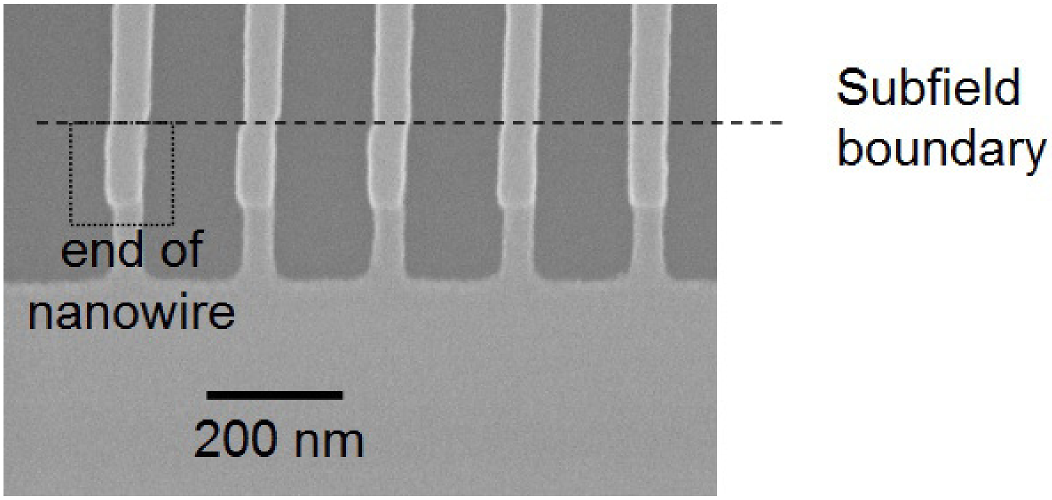

Figure 1. SEM image of nanowires which show an OL error variation in the form of a jog near the ends of the nanowires. The ends of the five nanowires are exposed in a different subfield from the rest of the nanowires causing a jog that becomes progressively smaller as the exposure progresses from left to right.

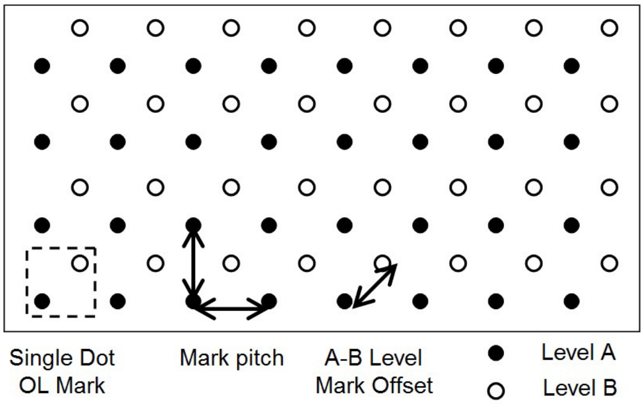

Figure 2. Expansion of single dot OL mark into dot-matrix OL mark

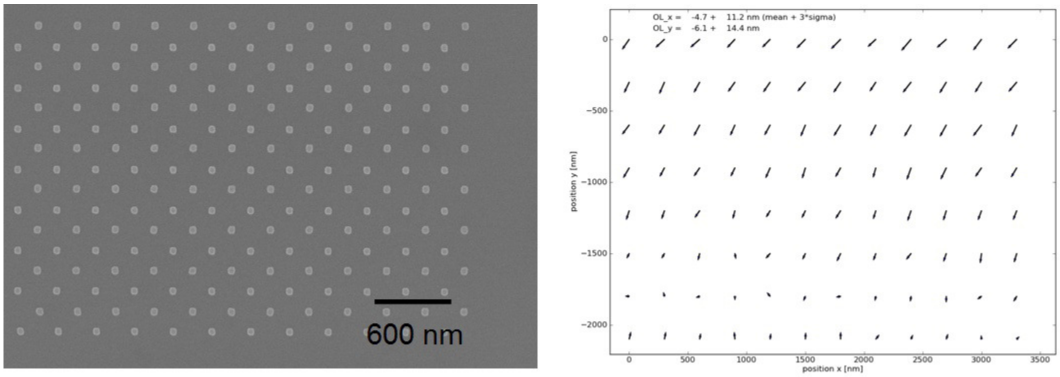

Figure 3. Example of dot-matrix OL mark and vector plot of the individual OL errors.