Sub-Pixel Alignment for Direct Write Electron Beam Lithography

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The ability to perform highly accurate alignment is essential for the fabrication of many types of devices, and will become more critical as novel, nano-scale structures are investigated. In CMOS,[1,2] for example, tight overlay tolerances are necessary not only for achieving high device packing densities but also have an impact on device performance by controlling the device channel length.

In high voltage (100 keV) e-beam direct write systems suitable mark contrast is typically generated using atomic number contrast in a back-scattered electron signal. This typically requires the incorporation of high-atomic number materials into the device process flow, which can be limiting. Ideally, a suitable signal can be generated from materials that are compatible with the entire device process flow.[3] In this paper we report the results of using simple topography to generate adequate contrast for mark detection.

The alignment algorithm employs a cross-correlation process to find the offset of a mark image with respect to the position of a template image. This generates an approximate offset value. To refine the alignment, the autocorrelation of the mark image is fitted to the cross-correlation and the fitted function is moved around using a least squares criterion to determine the alignment position with sub-pixel resolution. We will describe the novel, sub-pixel resolution algorithm in detail.

The effectiveness of the alignment process is strongly influenced by the mark geometry, and we present the results from three different mark types that indicate that the use of a compact mark geometry in the form of a two-dimensional Barker series[4] (Figure 1) provides excellent alignment accuracy (Figure 2), even at very low signal-to-noise values. This type of mark is also relatively robust with respect to the effects of subsequent processing steps.

Finally, we will illustrate the utility of the alignment process with the example of high aspect ratio zone plates created using multiple, aligned e-beam writes (Figure 3).

References

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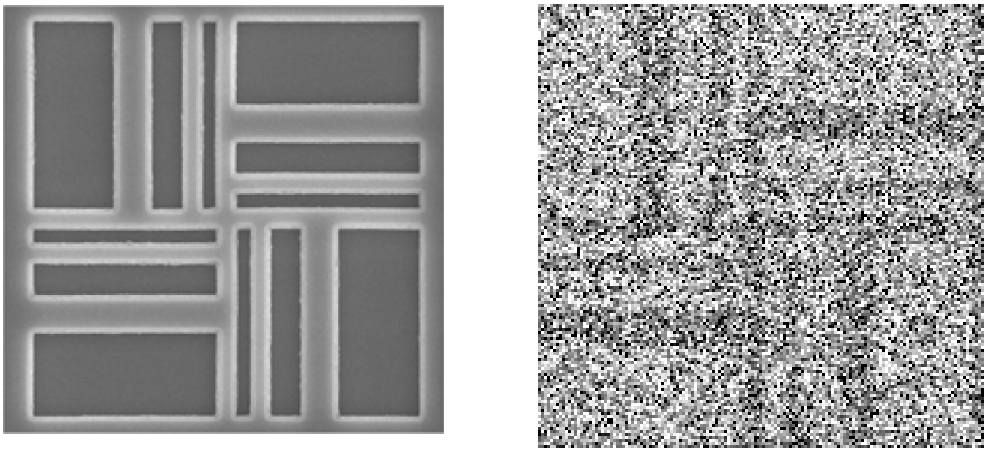

Figure 1. SEM of Barker series topographic marks etched in Si (left) and corresponding mark image acquired in beam writer using 100 keV backscattered electron signal (right). The mark is 2 μm across.

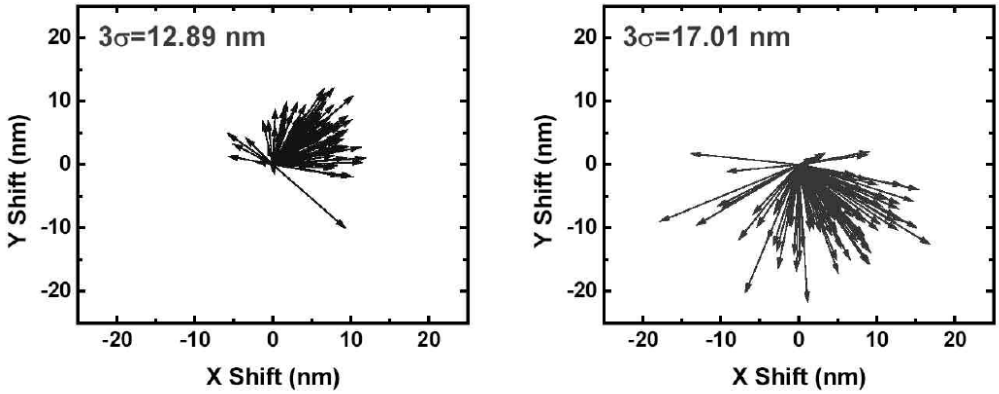

Figure 2. Offset data for 100 alignment mark measurements for marks as fabricated (left) and coated with resist (right).

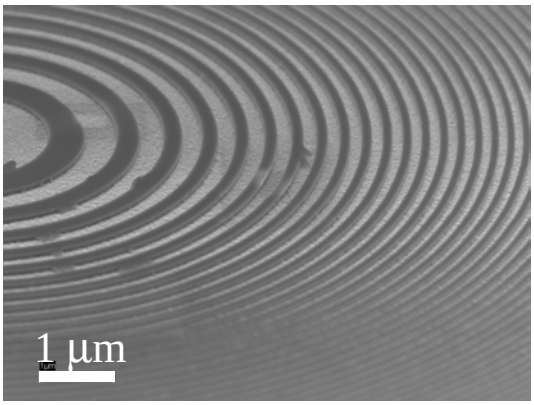

Figure 3. SEM micrograph of a two-step zone plate exposure showing a Ni plated zone plate overwritten with a second exposure in resist.