Assessment of Gaussian Beam Shape in E-beam Lithography with 2-D Vernier Arrays

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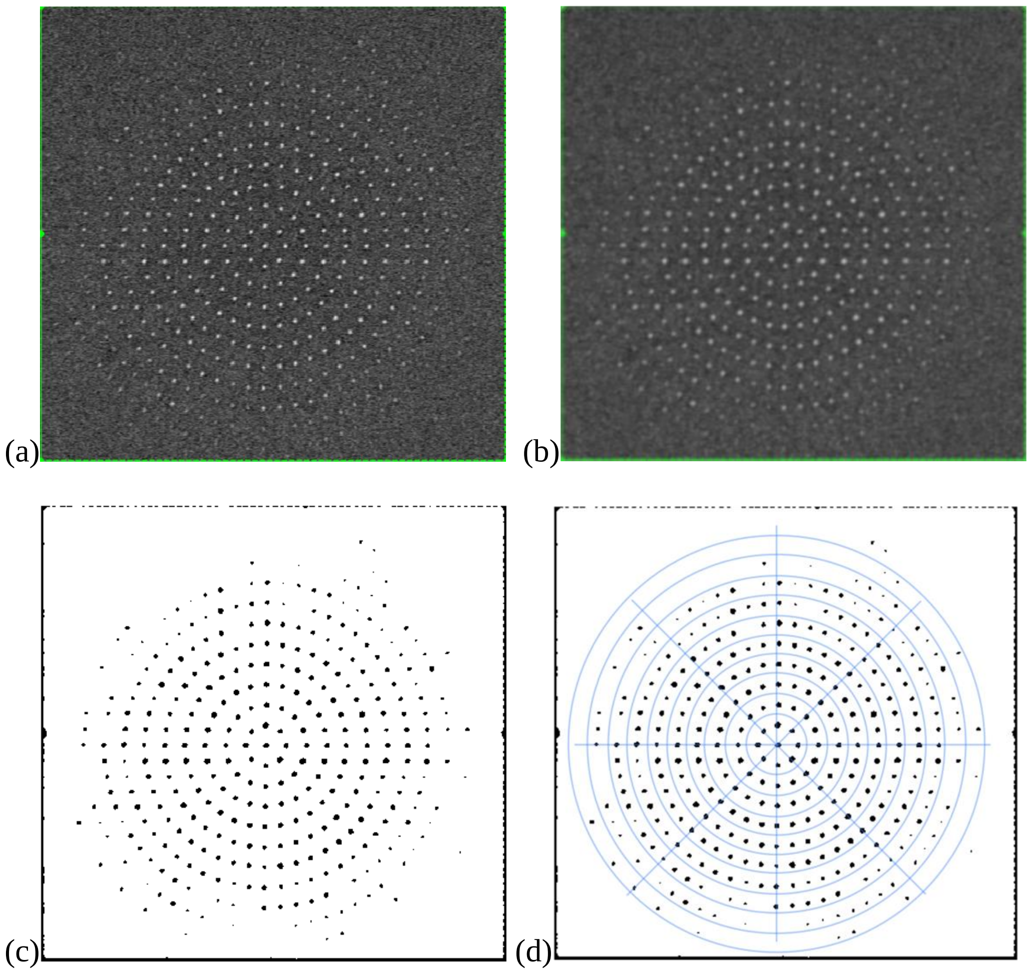
Running Gaussian e-beam writers with a beam spot size roughly equal to the critical dimension (CD) of the written pattern is the way to achieve the highest possible throughput. However, the use of e-beam writers in such a mode requires tight control of the beam spot size and roundness across the scanning field of the tool. Moreover, to obtain a higher production yield it is advisable to look at all the dies exposed on the wafer after resist development and before proceeding to the next fabrication step. The most direct way is to use a CD-SEM. However, it may be very time-consuming and requires taking SEM images at magnifications higher than ^{x}200K to have sufficient accuracy for CDs smaller than 50 nm. This appears to be quite difficult, because the SEM probe itself introduces changes to small e-beam resist features during image acquisition due to resist swelling. Also, the image shape can be distorted by resist charging and the SEM drift, which becomes significant at high magnifications.

Here we present a method to determine the shape and the size of the e-beam spot after exposure, based on two-dimensional Vernier arrays and agnostic of SEM artifacts. The exposed test pattern consists of two centrally symmetric square or circular 2-D overlaid arrays of small dots, typically 2-10 nm in diameter. The pitches of the two arrays are slightly different with the minimum difference equal to the beam step size (machine grid). The offset between the dots of the arrays increases step by step from the arrays center to the periphery. The step size determines the resolution of the method. The nominal exposure dose is chosen such, that only the overlapping dot areas from the two arrays are being sufficiently exposed.
The resulting image developed in resist is the fringe pattern of interference between the two arrays and represents a magnified (^{x}50 to ~ ^{x}200) pixilated image of the beam spot on a measurement lattice either square or polar (Fig.1). The arrays are exposed within a range of doses, which allows for the measurement of the absolute beam spot size under the assumption of the Gaussian beam current density distribution, in addition to the measurement of the beam shape. The ranges of arrays are distributed across the scan field to collect the data at different beam deflection positions. A method of automated analysis of the 2-D Vernier patterns was developed.



(a) (b) (c) (d)

Figure 1: Automated SEM image processing sequence for polar Vernier array with radial pitch 50.5 nm and 1 nm grid resolution (spot magnification ≈ ^{x}50). (a) original SEM photo, (b) Gaussian blur applied, (c) optimized threshold function applied, (d) aligned polar measurement mesh calculated. The population of mesh cells is counted, and the shape roundness is calculated.