Improved Alignment Algorithm for Electron Beam Lithography

S. Thoms , Y. Zhang and J. M. R. Weaver
School of Engineering, University of Glasgow, Glasgow, UK, G12 8LT
stephen.thoms@glasgow.ac.uk

Alignment in electron beam lithography is generally carried out by locating four markers and then mapping the stage coordinate system onto the designed coordinates of the markers. Improvements in alignment have arisen from improved marker fabrication and detection methods. There is however another route to improving the alignment, and that is to consider the mapping algorithm.

The mapping takes 8 parameters, namely the x and y coordinates of four markers, and uses these to adjust 8 correction parameters. These are scale, rotation, offset and keystone, all in x and y. There is therefore a unique solution to the mapping problem which perfectly maps the stage coordinate system onto the design coordinates. There are two drawbacks with this which both arise from inevitable errors in mark location. The first is that an error in any of the mark locates, for instance due to a defective marker, immediately results in an error in the alignment. Secondly, there is no way to detect such errors from the alignment algorithm itself; instead they are detected later in the process which is costly.

The solution to this problem is to use more than four mark locates for the stage mapping algorithm. A least squares fit can then be used to find the correction parameters. This has the advantage that rogue markers can be detected by looking at the residual position errors between the actual marker positions and the positions calculated from the stage mapping. Rogue markers can either be eliminated from the calculation, or replaced by other markers. The averaging inherent in the least squares fit also ensures greater accuracy in the stage mapping.

This was tested on an array of inverted pyramidal markers formed by using KOH etching of silicon. These markers are used for aligning thermal atomic force microscope probes and tolerances of greater than 100 nm have had to be designed into the process because alignment has been poor. Table 1 shows the residual errors after finding 8 markers, and how by eliminating or replacing rogue markers, these can be substantially reduced. Figure 1 shows a good marker and Figure 2 a rogue marker which was identified using this technique. The ability to identify bad markers in this way is a useful first step to fixing the fabrication faults which created them in the first place.

Marker number	Iteration 1		Eliminate marker 6		Eliminate markers 3 and 6		Eliminate marker 6, substitute for marker 3.	
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*
1	-8.2	-8.3	-6.9	-5.5	-1.6	-3.5	-3.7	-3
2	-10.2	-0.2	-9.5	1.4	2.1	5.7	-2.3	6.8
3	40.1	14.9	40.3	15.2			29.8	-7.3
4	-23.8	-10.1	-24.1	-10.9	-0.7	-2	-9.4	0.1
5	-33.8	-60.5	-4.3	4	-4.3	4	-7.1	4.7
6	54.3	118.8						
7	-1.2	-45.1	13.6	-12.8	13.6	-12.7	8.3	-11.4
8	-17.3	-9.5	-9	8.5	-9.1	8.5	-15.7	10.1

Table 1: Residual marker position errors after using 8 markers for the stage mapping algorithm. The residuals for markers 6 and 3 are large, and these markers can be identified as poor and therefore either removed from the calculation, or replaced with adjacent markers.

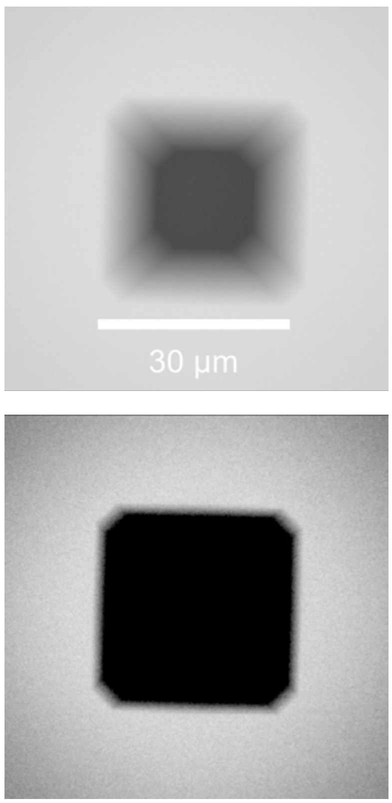

Figure1: A good marker; the lower image is of the same marker but with the contrast enhanced during image collection.

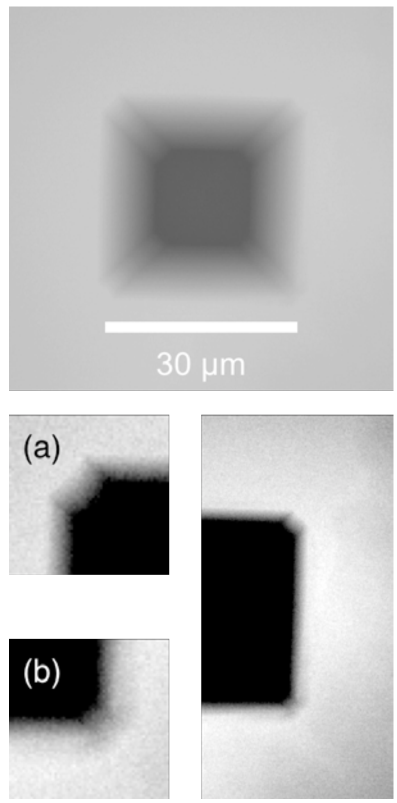

Figure 2: A rogue marker; the lower image is of the same marker but with the contrast enhanced during image collection, so that the defect on the bottom right can be seen more clearly. (a) shows an enlargement of the top left corner, and (b) shows the defective bottom right corner.