Multiple Beam Sub-80 nm Lithography with Miniature Electron Beam Column Arrays

C.S. Silver, J. P. Spallas, and L.P. Muray

Novelx, Inc., 3746 Mt. Diablo Blvd. #202, Lafayette, CA 94549, USA

Miniature electron beam columns are good candidates for high resolution, high throughput maskless lithography applications due to their potential for high density column arrays and inexpensive fabrication. Columns can be manufactured using standard bulk micromachining and IC fabrication methods, enabling reliable and repeatable fabrication using proven processing techniques. Miniature columns with this type of design have previously demonstrated high-resolution imaging and lithography capabilities[1, 2].

A 1x4 electrostatic column array has been developed using monolithically fabricated bonded stacks of silicon and glass. Figure 1 shows a 1x4 array assembled with two thermal field emitters, a microchannel plate detector, and a flex PC cable for column interconnects. The lens stacks are bonded to a ceramic susbtrate that includes embedded interconnects, surface-mount connectors, and passive components for impedence matching. Each column in the array is individually correctable. The monolithic aperture design simplifies the manufacturing of high-density column arrays and enables precise column-to-column registration. The array was designed to allow tiling individual 1x4 arrays into nx4 modules, providing a clear path for scaling up. The column arrays themselves can also be scaled up to larger monolithic arrays (i.e., 4x4 or greater, depending on the substrate design), which in turn can be tiled into larger modules for higher throughput.

This paper presents the first results from simultaneous multiple beam lithography using miniature column arrays. Independent patterns were exposed synchronously using two columns in a 1x4 column array, resulting in 80 nm features written into 45 nm ZEP-520A resist. 70 nm features have been written in asynchronous exposures using individual columns in the array. Figure 2 shows two sets of synchronous exposures produced with two columns in a 1x4 array scanning independently. A raster-scan writing strategy was used with a high-speed blanker at a 5 MHz clock rate for a nominal dose of ~5 uC/cm^2. These lithography results will be presented and discussed.

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[1] J. P. Spallas, C. S. Silver, L. P. Muray, T. Wells, and M. El-Gomati, "A Manufacturable Miniature Electron Beam Column," Microelectron. Eng. 83, 984 (2006).

[2] L. P. Muray, C. S. Silver, J. P. Spallas, "Sub- 100-nm lithography with miniature electron beam columns," JVST B 24 (6), 2950 (2006).

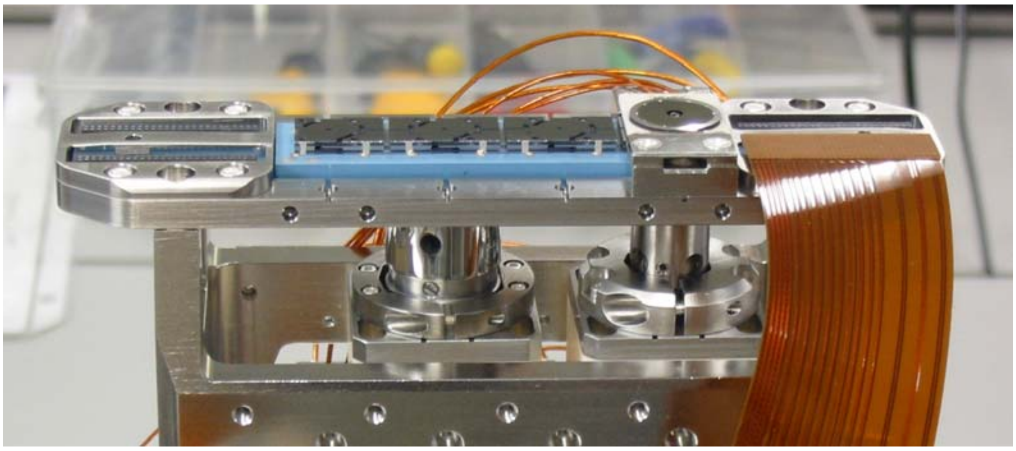

Fig. 1: Photo of 1x4 column array with thermal field emitters mounted to two of the columns, a microchannel plate detector mounted to one of the columns, and a flex PC cable providing interconnects for the rightmost column. The second flex PC cable required for simultaneous lithography is not attached in this photo.

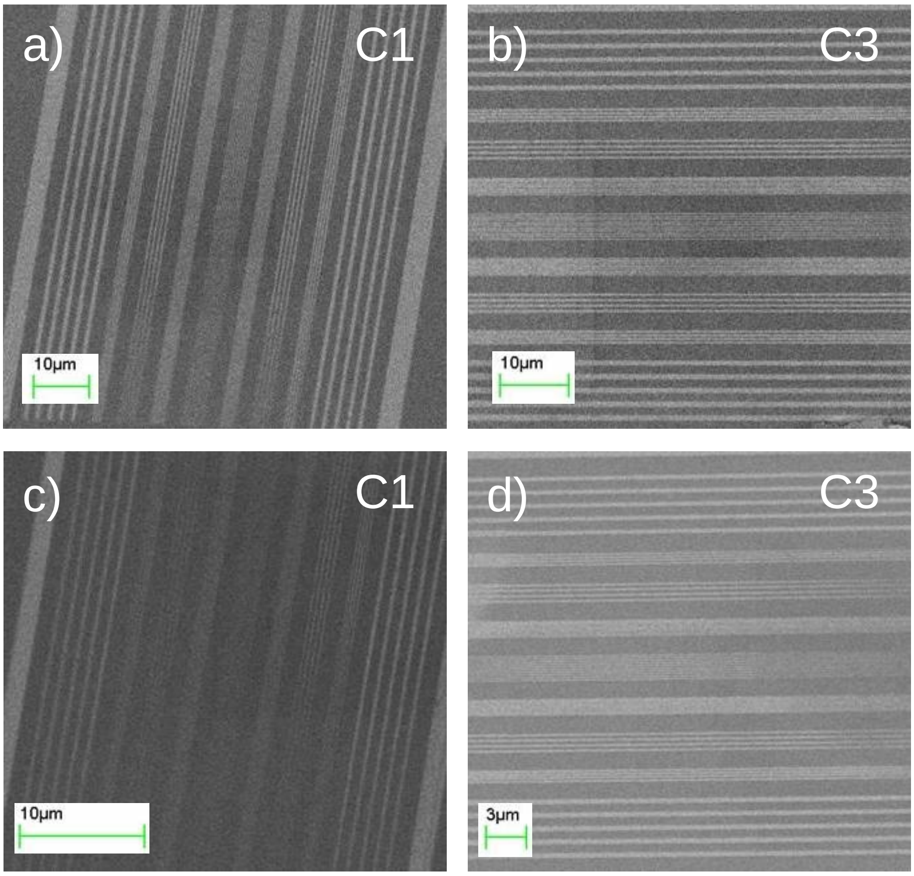

Fig. 2: SEM images of multiple beam lithography using two columns in a 1x4 column array exposing synchronously. Exposures (a) and (b) were written simultaneously by two different columns, as were exposures (c) and (d).