A Simple Technique for Beam Focusing in Electron Beam Lithography on Optically Transparent Substrates

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Electron-beam lithography (EBL) resolution is limited by beam spot size. Generally height measurement routines are performed during EBL to ensure a focused beam at the wafer surface regardless of the wafer height. Substrates such as glass, GaN, and SiC, which are widely used for biomedical and high power electronic applications, are transparent to the laser wavelength used during EBL height measurement, resulting in inaccurate height measurements or preventing measurement totally. Inaccurate sample height measurements result in de-focused beams at the local writing points of the wafer surface, making high-resolution patterning of transparent substrates challenging. A common solution is to coat a thin layer of Al on top of resist to provide reflectivity for height measurements, and then strip the metal before development. Such an approach results in degradation of resolution due to extra electron scattering and chemical interactions, and some resists are not compatible with metal etching chemistries. In this work we have developed an easy technique for focusing an electron beam on the surface of a transparent substrate. Our method is to measure height positions from several points around the perimeter of the wafer where a metal “edge bead” is deposited. Assuming a planar wafer, this data is then used to estimate the height at any point across the sample, using a simple 2-D linear regression routine. Before exposing a given cell in a layout, the column is adjusted to focus at the numerically-estimated height, and no height measurement is attempted during exposure.

We tested this technique on 100 nm-thick ZEP520A resist on glass substrates with thin indium-tin-oxide (ITO) charge-dissipation films, using a Vistec EBPG5000 tool at 50 keV and 100 pA. Figures 1 and 2 (a-e) show arrays of 18 nm nano-pores and gratings of 37 nm lines written with the beam focused at heights estimated from 2-D linear regression. The measured heights from the sample perimeter and the fitted sample plane are shown in Figure 3, where the heights of the imaged sample positions are specified. For the top rows of patterns in Figures 1 and 2, although the sample height varied by as much as 41 μm, consistent pore diameters and line widths were achieved. The resolution realized on transparent substrates using this technique is consistent with the best resolution achieved on Si substrates where automatic height detection and focus adjustment is used during the writing, as shown in Figure 4. To show effects of a defocused beam, the same pores and gratings were written at each position while fixing the focusing height at that of the center cell, i.e. 36 μm, and poor focus resulted away from that position, as expected [See bottom rows of images (f-j)]. The results show that this method is a simple but effective technique for high resolution EBL on transparent substrates.

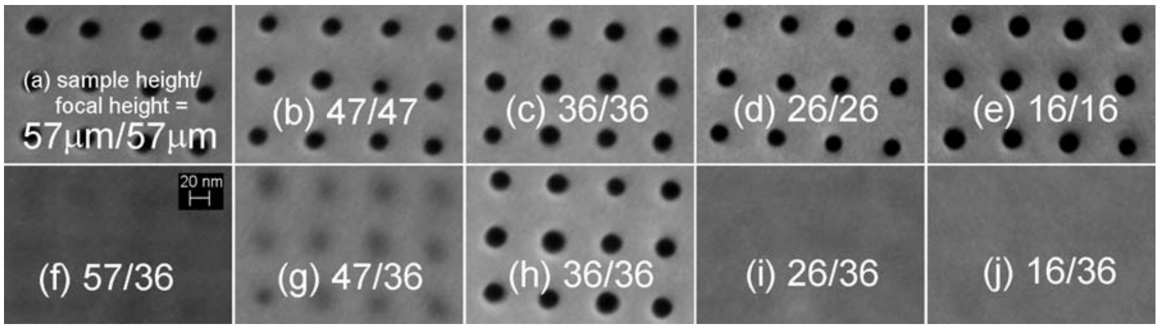

Fig. 1: Nano-pores in ZEP520A on ITO (a-e) focusing at estimated sample heights as noted in Fig. 3 and (f-j) focusing at height of center cell. The first value is the estimated sample height and the second is the focusing height, both in μm. Average pore diameter and pitch are 18 nm and 59 nm.

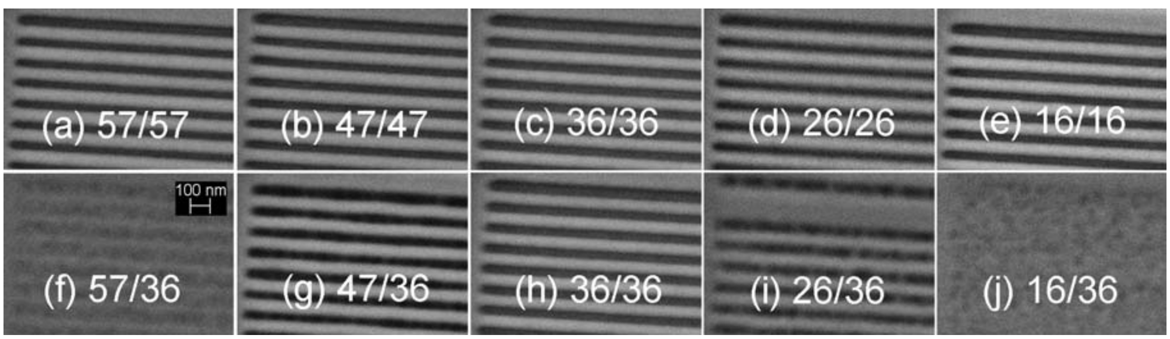

Fig. 2: Gratings in ZEP520A on ITO. Average line width and pitch are 37 nm and 100 nm.

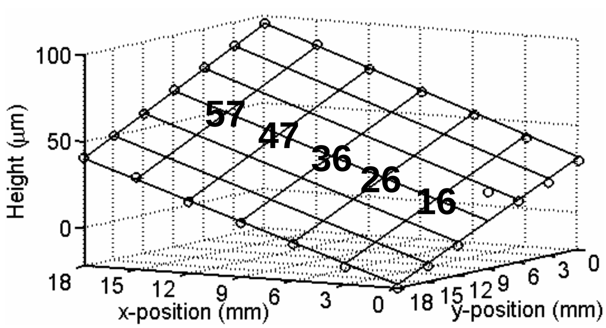

Fig. 3: Measured data from metal edge bead and 2-D linear regression fitted plane. Values on the plane are estimated sample heights at the locations imaged in Figs. 1 and 2.

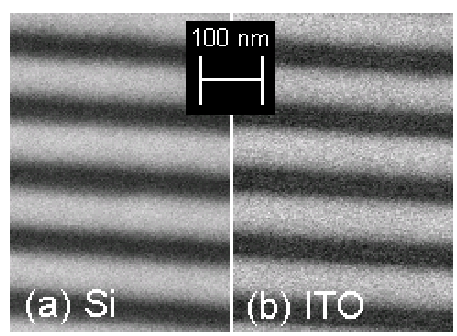

Fig. 4: Most aggressive gratings in ZEP520A on (a) Si, using automatic height compensation and (b) ITO/glass, using our height estimation technique. Line width and pitch are 36 and 100 nm.