Development of a column using permanent magnet lens for a multi-axis maskless E-beam lithography system

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One column with five stage lenses using permanent magnet was developed (Fig.2). The diameters of the lenses are smaller than 27mm so that the column element can be used for multi-axis and multi-beam lithography system presented by PARAM (Fig.1)[1].

Electron beam lithography system can be used in cutting process and hole layer. It is also expected as mask-less lithography.

We are going to develop multi-axis and multi-beam system. One column has 2500 square shape beamlets. Because of Coulomb interaction total beam current in one column is limited within two microamperes for 16nm pattern at acceleration voltage of 50kV. The throughput from 5 to 10 of 300 mm wafers can be accomplished. Multi-beam column requires at least 5 stage magnetic lens. Among those lenses the reduction lens and the objective lens need strong magnetic field. If we use conventional electromagnetic lens, power consumption will be more than 10kW for 90 columns. It will not be practical.

In this system low power consumption lens is important, so neodymium permanent magnet cylindrical rings of which diameter are smaller than 25mm are used. Magnetic field stronger than 4000 gauss for an objective lens could be formed for a fine beam 16nm in proximity to the silicon wafer. And total column length between emitter and objective plane can be 400 mm. These features reduce Coulomb interaction.

As the strength of the permanent magnet lens can be adjusted within ±4% of the expected value, a coil for correction lens field can be used to correct ±4% of the magnetic field. It is possible to reduce the power consumption smaller than 0.16% (several tens Watts) when using the electromagnetic lens.

Figure 3 shows an SEM image obtained by scanning on a heavy metal dot using four beams which is image of aperture in magnification ratio of 1/250. Figure 4 shows the exposed image of the beam.

We have confirmed that the expected characteristics are obtained in the column using permanent magnets.

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[1] Yasuda et al.: Multi-axis and multi-beam technology for high throughput maskless E-beam lithography, J. Vac. Sci. Technol. B 30(6), Nov/Dec 2012

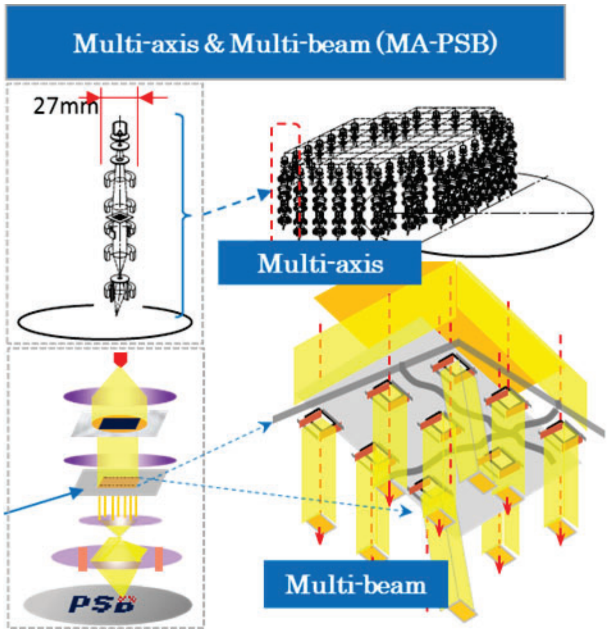

Figure 1: PARAM EB exposure system goal

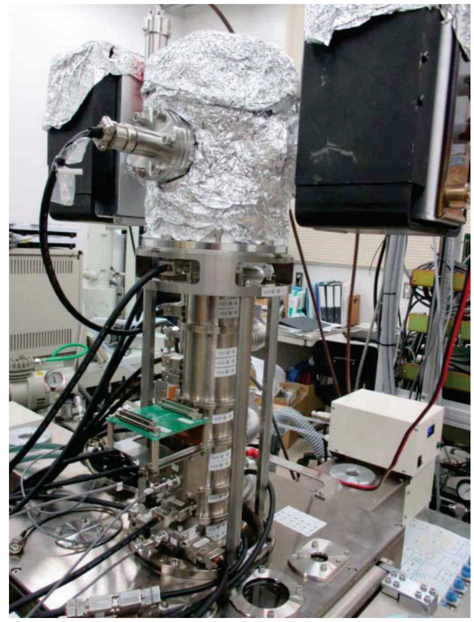

Figure 2: Test column

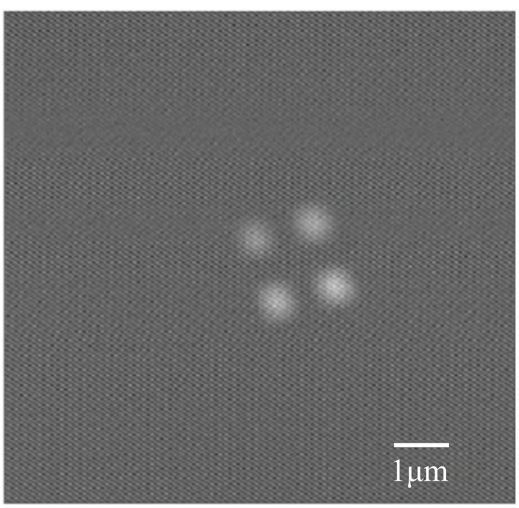

Figure 3: SEM image: SEM image is obtained by scanning on a heavy metal dot using four beams which is image of aperture in magnification ratio of 1/250. Distance between each two beams is 1μm.

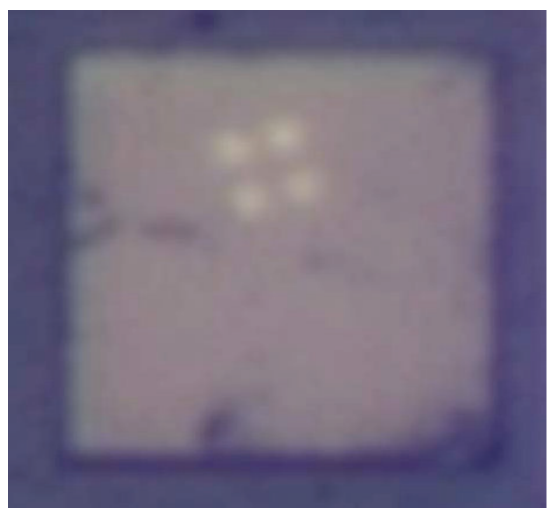

Figure 4: Exposed image of the beam