

## Multi-axis and Multi-beam technology for high throughput maskless E-beam lithography

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We have devised a new maskless E-beam lithography method which can achieve the throughput of 10WPH. The method is called 'Multi-Axis Programmable Shaped Beam' (Multi-Axis PSB). It is a kind of massive parallel electron beam lithography. More than 200,000 beams write a wafer and total beam current reaches dozens of microampere.

It may be difficult to write finer than 10nm patterns with more than 2 $\mu$ A beam current at 50 keV with single column because of beam blurring caused from Coulomb interaction. And it may be difficult to take more than 100,000 uniform beams from one emitter. So Multi-Axis PSB system divides all the beams into 87 groups. Each group has 2,500 - 10,000 beams formed by a small column arrayed in 26mm x 33mm lattice. The small column is called Column Element (CE). Each CE has an emitter, apertures, deflectors and small lenses. The key technology of Multi-Axis system is the lens. It is made smaller than 30mm and consumes very low power using permanent magnets. Multi-Axis systems make it possible to write fine patterns with extremely large current.

In PSB method a beam from an emitter is divided into thousands of beams with PSA device. The size of the beam is the same as the minimum pattern size of the device. For example, the beam size is 16nm square when the minimum feature size of the device is 16nm. The all beams from one emitter are arrayed within a 3.2 $\mu$ m x 3.2 $\mu$ m field. The number of beams within a CE depends on the size of beam. Every beam switched according to the bitmap data. The feature of PSB lithography is the sharpness of pattern edges.

The key technology of Multi-Axis PSB is the emitter. The uniform illumination and high-intensity of long life electron beam irradiation require low power and restricted emission areas. We have developed LaB<sub>6</sub> TFE in a rhenium sheathe.

These technologies are essential for Multi-Axis PSB system

Table.1 Specifications of Muti-Axis PSB

Technology	16nm HP	11nm HP	8nm HP
Acc. Voltage	50 kV		
Number of CEs	87		
Distance between CEs	26mm x 33mm		
beam size	16nm	11nm	8nm
Number of beams	217,500 (50 x 50 x 87)	451,008 (72 x 72 x 87)	870,000 (100 x 100 x 87)
Distance between beams	64 nm	44 nm	32 nm
Current density	400 A/cm <sup>2</sup>		
Max. total current	223 $\mu$ A (2.56 $\mu$ A x 87)		
Throughput	10 WPH		

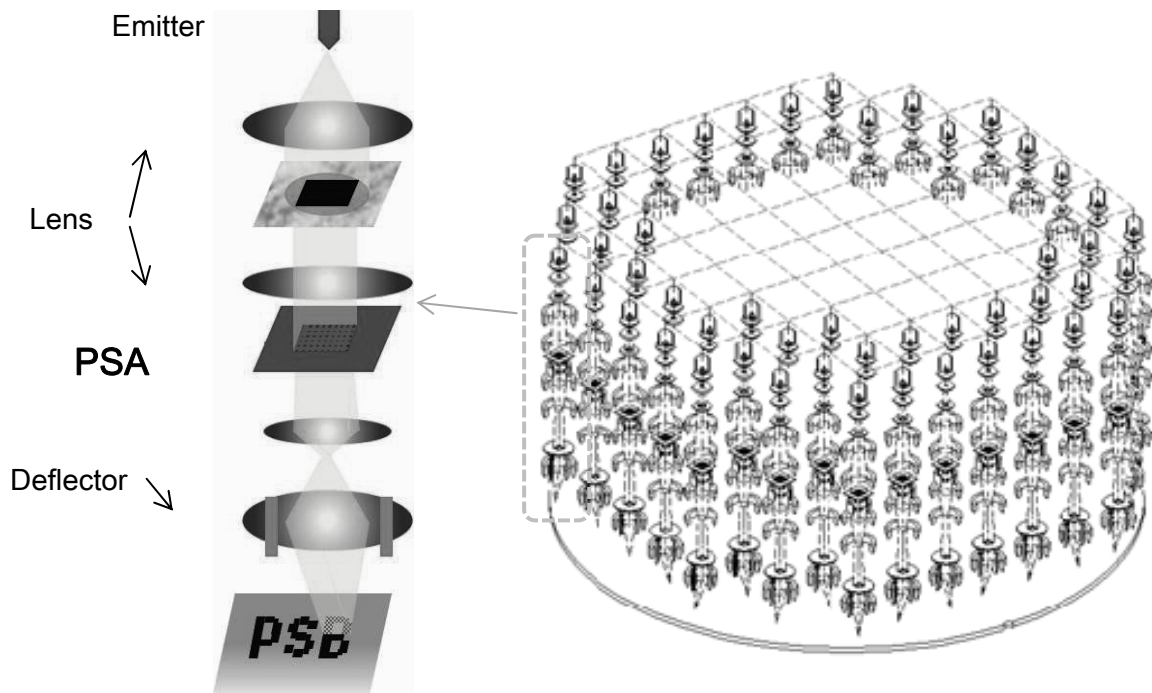


Figure 1. Multi-Axis PSB (87CEs)

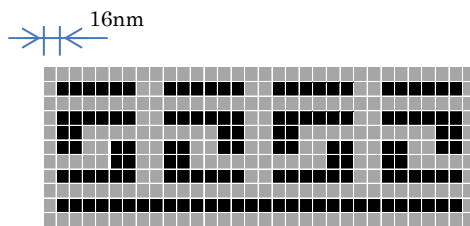


Figure 2. Writing method of PSB.  
Tiling and step by step.

Figure 3. Emitter

LaB<sub>6</sub> tip is embedded in the rhenium sheathe.  
Emission from side surface is suppressed.

