Ultra-Compact Electron Beam Direct Writing Machine: Electron Optical System and Nanometer level Multi-axis Stage

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In order to respond to diversified and deeply developed semiconductors, MEMS, medical, biotechnology research and development, small volume multi-product production field is necessary which is completely different strategy from Mega-Fabs. These market needs are the realization of miniaturization and thinning of the 100 nm node class and verification of principles related to new circuit design, device, integration process, element / material process, reliability, quality etc., and flexible small quantity multi-varieties products, which are supplied to the market through development and production. In order to fulfill this need, it is indispensable to use a small substrate different from the Mega-Fabs, a very small, inexpensive, lightly maintenance load, high robust system.

From this viewpoint, this research proposes an exposure apparatus for ultra-small substrate specialized for electron beam exposure (hereinafter abbreviated as EBDW). Many developments of EBDW for Mega-Fabs have been carried out in the past, but the point that the throughput becomes extremely slow because it targets large-diameter substrates was a weak point. However, when an ultra-small substrate is to be exposed, the drawing area is small, and it does not become a substantial obstacle. In the case of semiconductors, the fine process layers which are the main object of the EBDW is gate layer, contact layer, metal-1 layer, and other rough layers can be coped with optical exposure.

In this research, "Point beam vector / raster scan writing method" was taken into consideration of high-speed writing control system of the writing machine, maintenance free, robustness and the like.

In this method, it is possible to cope with the need for ultrafine lines from 10nm to 50 nm node by selecting / optimizing writing conditions. In order to achieve this objective, we studied a very small electron optical system [Figure 1]. In this method, by mounting a small electrostatic lens directly under the electron gun and controlling the radiation angle of the electron beam, the same function as the condenser lens can be achieved.

In the present electron optical system, the electrostatic electrode for electron beam alignment control placed just under the lens is used together with the blanking electrode function for turning on / off the electron beam at high speed, and the vector / raster hybrid scan type writing is performed.

As a result, miniaturization and high resolution of the writing apparatus can be realized at the same time. The basic resolution performance is about 80 nm (single L / S) and about 100 nm (multiple L / S: depending on the substrate / writing condition) when the acceleration voltage is 15 kV.

In addition, we studied the X - Y - Z - Θ multiaxial stage [Figure 2] with nanometer level resolution capable of high speed writing under ultrahigh vacuum. In this method, the inverse piezoelectric effect and the solid natural resonance with respect to the applied voltage of the piezoelectric element are simultaneously synthesized, local displacement is generated as a standing wave, and propagates to the stage to drive the drawing stage with high accuracy.

As a result, it is possible to realize a nonmagnetic, nanometer level driven ultra-small multi-axis EBDW (position resolution <10 nm).

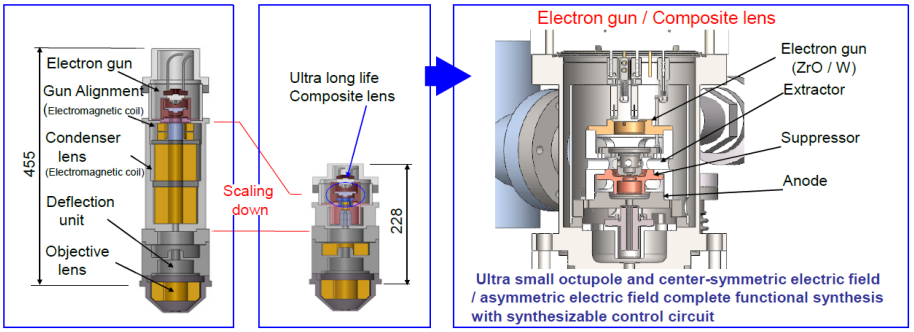

Figure 1, Electronic Optical System

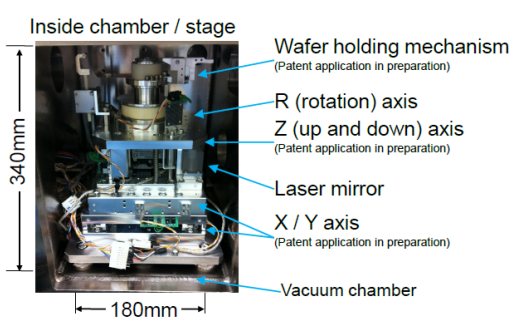

Figure 2, X - Y - Z - Θ Multi - axis Stage

References: Japanese Patent Application Laid-open No. 2016-110864, No. 2016-110865, No. 2016-110868