Surface electron emission lithography with electron source of high emission efficiency

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We have developed Surface Electron emission Lithography (SEL) to improve the throughput of electron beam lithography. In this study, SEL that is 1:1 electron projection lithography using a planar type silicon nanowire array ballistic electron emitter (PBE) with high emission efficiency is demonstrated. It was confirmed that a test bench of SEL resolved patterns of 30 nm in width over 0.2 um square area in first report[1]. After that, the prototype SEL system (Figure 1) exposed sub-micron patterns distributed over 3 mm square area.

The surface electron emitter projects a patterned electron image on the target wafer since the patterned mask was formed on the surface electrode of the electron emitter. The electrons are emitted from openings of the mask. When a pulsed voltage is applied to the electron emitter, the patterned electron beam strikes the resist film coated on the target wafer and make replica of the pattern. An advantage of SEL is high resolution based on the small chromatic aberration and the small coulomb blur without any crossover in the electron optics. Another advantage is potentially high throughput due to surface electron emission lithography. When we get sufficient current from the electron source the throughput can be more than 100 wafers/hour for mass production.

Emission efficiency of the electron emitter has been improved in order to achieve the high throughput. Because the structure of surface electrode intensely affects the emission efficiency, we examined the properties of the surface electrode. When the hot electrons are injected into the metal electrode, the energy of electron is quickly distributed to a large quantity of electrons in metal. Although the electrode should be made as thin as possible, film structure changes depending on the thickness. We succeeded in forming the extremely thin electrode with small sheet resistance by making the electrode into a composite material. According to some newly developed processes for forming electron emitter, the emission current increases by ten times. In this study, SEL with improved throughput is demonstrated (Figure 2).

REFERENCES:

1. A. Kojima, H. Ohyi and N. Koshida, Journal of Vacuum Science and Technology **B26** 2064 (2008).

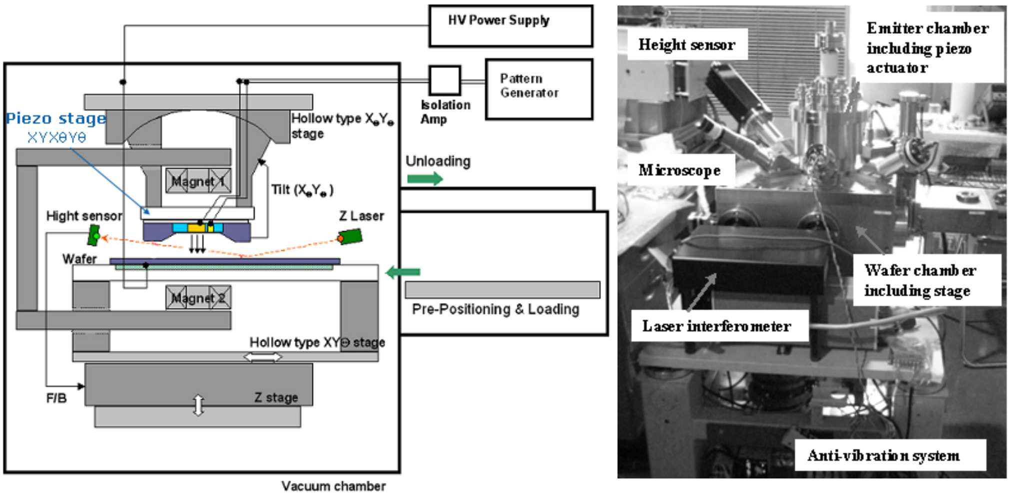

Figure 1: Schematic parallel EB lithography using PBE as a patterned surface electron emission source (left), and prototype EB stepper (right).

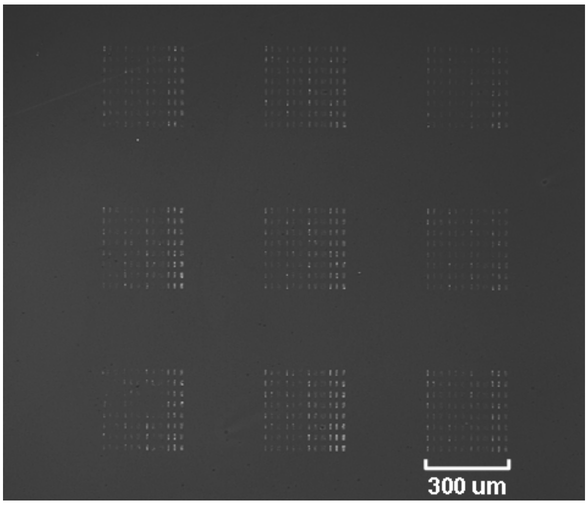

Figure 2: The exposed pattern transferred from the PBE. Electron dose amount is 30 $\mu C/cm^2$. The patterns are composed of repetitions of line and space pattern. The width of line is 0.2 μm and space is from 0.4μm to 1.8μm .