Fabrication of sub-10 nanometer half-pitch dense line and space structure by using electron beam lithography

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Nanotechnology is one of the most promising technologies that generates industrial revolutions in many fields such as semiconductor, ICT, biotechnology, energy, ecology and so on. Recently sub-10 nanometer scale structures are widely fabricated and investigated. Electron beam lithography with energy of more than 100 keV is one of the best methods to fabricate them by virtue of its small beam spot size and controllability.

An electron beam lithography system of 130 keV beam energy (CABL-UH130, CRESTEC) was utilized for this research. CABL-UH series were developed to realize the high-resolution writing, high stability and high reliability. To achieve the high-resolution fabrication, the acceleration voltage of up to 130 kilovolts was adopted and a beam spot size is minimized by the single-stage acceleration electron gun which suppresses Coulomb blur.[1] On the other hand, to achieve high stability and reliability, micro-discharge is the main problem for the electron gun. In principle, a micro-discharge happens more often in a single-stage acceleration electron gun than in a multi-stage electron gun. But CABL-UH's electron gun is made with high-work-function materials and is free from micro-discharge. In addition, a stray magnetic field, temperature variation and vibration are controlled without a dedicated shielding room because these disturbances sometimes affect writing performance.

To achieve single nanoscale pattern formation, several conditions for lithography were investigated. The negative tone resist, hydrogen silsesquioxane (HSQ) was selected and sodium hydroxide (NaOH) with 4% wt. sodium chloride (NaCl) was used as developer. Development time was optimized. Line and space patterns with half-pitch of 6, 7, 8 and 9 nanometers were fabricated on the area of 50 x 50 micrometer square. Magnified pattern images are shown in figure 1. Several applications are expected from this result. For example, development of pattern inspection for mask and wafer fabrication process.[2]

[1] T. Okino et al., Jpn. J. Appl. Phys. **52**, 06GB01 (2013)
[2] S. Iida and T. Uchiyama, in 31st International Microprocesses and Nanotechnology Conference Sapporo Park Hotel, Sapporo, Japan

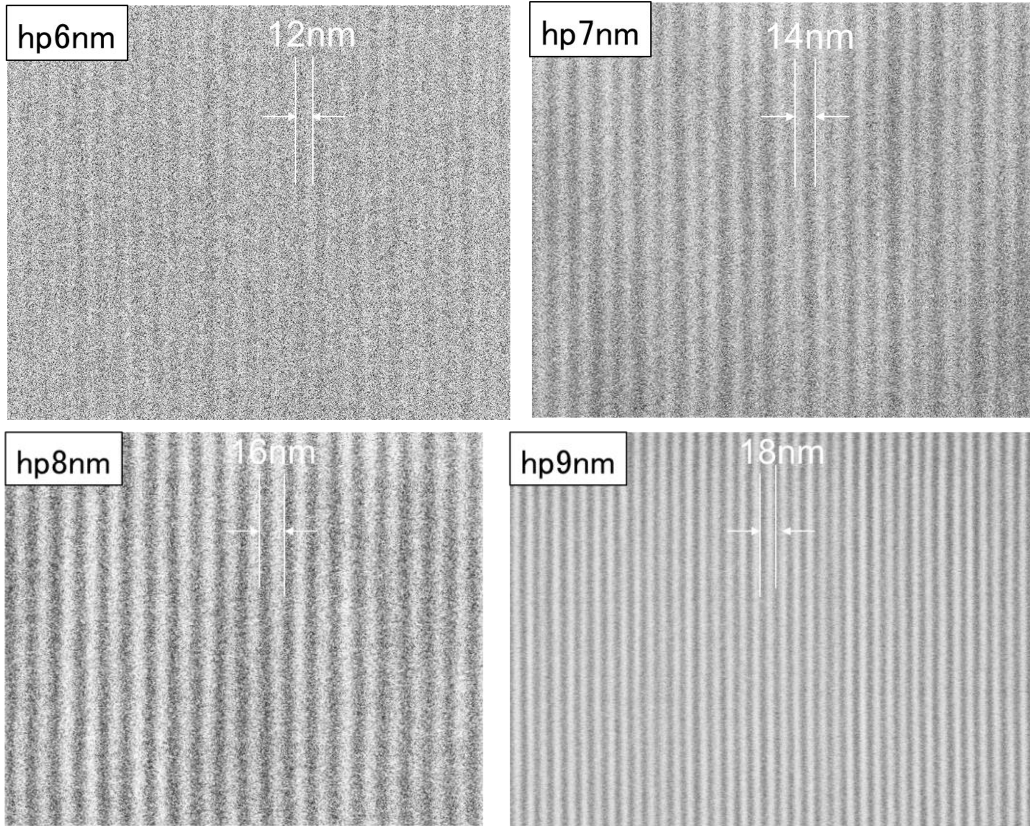

Figure 1: SEM image of the fabricated dense line and space structure with half-pitch of 6, 7, 8 and 9 nanometers.