ELECTRON BEAM PROJECTION NANOPATTERNING USING CRYSTALLINE LATTICE IMAGE

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ABSTRACT

Two different paradigms exist in the development of nanofabrication process. One is top-down method to define small feature from large scale material by lithography process, the other is bottom-up method to collect atoms or molecules to build nanoscale feature. We suggested Atomic Image Projection Electron-beam Lithography (AIPEL) as one of top-down nanofabrication technologies[1]. AIPEL is a nanolithography process using the phase contrast generating a high-resolution image of crystal material in a transmission electron microscopy (TEM). Nano-scale patterns which angstrom-level atomic image is magnified by AIPEL process can be transferred on an electron sensitive material, such as resist and self-assembled monolayer.

AIPEL can reduce the effect of image blurring by columbic repulsion on the electron sensitive material because the magnification of atomic image makes distance between electrons away. Various patterns are obtained from tremendous atomic images of crystals in nature. Indeed, AIPEL, a kind of projection e-beam lithography technologies, has higher throughput than conventional e-beam lithography. We have developed the equipment for AIPEL with JEOL Ltd., Japan by modification of 200 kV field emission TEM. This equipment exposes atomic image magnified from 20 to 300 times on the substrate (4 mm × 17 mm) with an electron sensitive material.

(110) projection atomic image of silicon with diamond structure($Fd\bar{3}m$) transferred on a positive e-beam resist of ZEP520A from Nippon Zeon, Japan and a negative e-beam resist of hydrogen silsequioxane (HSQ, FOX-12) from Dow corning, USA with changing patterning magnifications. In (110) projection atomic image of silicon, distance between dots is 3.14 Å. Minimum dot and spacing was measured about 70 nm on ZEP520A at 200 times patterning magnification, about 40 nm on HSQ at 120 times by Atomic Force Microscope (AFM), respectively. Line patterns were acquired by selecting a different projection direction of silicon atomic image on both ZEP520A and HSQ resist. In addition, the result of AIPEL process using β-Si_3N_4 with hexagonal crystal system ($P6_3/m$) shows different patterns except dot and line can be generated by changing atomic image.