Atomic Layer Defect-free Top-down Processes for Future Nano-devices

Seiji Samukawa [1]

[1]*Tohoku Univ., Japan*

In the fabrication of semiconductor devices, reactiveplasmas are widely used in key processes such as?etching, surfacemodification and film deposition. Thereis now demand for atomic level processing?precision and fordeposition accuracy that allows the control of structures at the molecularlevel. However, in ultra-miniature nanoscale devices that will become themainstream in the future, the use of plasma processes can cause seriousproblems such as abnormal etching, sub-surface material damage, and breakdownof insulation films by the accumulation of ions or electrons emitted from theplasma. Also, surface defects (danglingbonds) of over a few tens nm in depth can form by exposure to ultraviolet (UV)emissions from the plasma. Process induced defectsduring plasma processing can have a large influence on the electrical andoptical properties of devices as nano-scale devices have a larger surface areacompared with the bulk material. Furthermore, since future nano-devices will require size control ofthree-dimensional structures with atomic precision, it will be absolutelyessential to control surface chemical reactions with high accuracy andselectivity at the atomic layer level. For this purpose, atomic layer defect-free deposition (ALD) and atomiclayer defect-free etching (ALE) processes are very important for the futurenano-devices.

Neutral beam process technology has attracted attention as a wayof solving these issues. The neutral beam suppresses the incidence of chargedparticles and UV photon radiation onto the substrate, and is able to expose thesubstrate only to energy controlled neutral beam enabled by preciselycontrolling ion acceleration energy with the applied electric field beforeneutralization. These attributes allow ultra-precise nano-processing whichsuppresses the formation of defects at the atomic layer level and controlssurface chemical reactions with high precision. Thisis certainly true atomic layer etching (ALE) and deposition (ALD). Usingneutral beam processing, now, atomic layer defect-free and roughness-free Si(or Ge) channel etching for sub-10 nm fin-FETs, ultra-thin gate dielectric filmformation for sub-22 nm fin-FETs, transition metal oxidation for ReRAM, atomiclayer super-low dielectric film deposition for sub-22 nm FETs, atomic layerdamage-free etching of magnetic materials by complexing reactions andlow-damage surface modification of carbon materials for future nano-deviceshave been successfully demonstrated.