GEC18-2018-000368

Abstract for an Invited Paper
for the GEC18 Meeting of
the American Physical Society

Atomic Layer Defect-free Etching and Deposition Processes for future sub-10-nm devices.

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In the fabrication of semiconductor devices, reactive plasmas are widely used in key processes such as etching and film deposition. There is now demand for atomic level processing precision and for deposition accuracy that allows the control of structures at the molecular level. However, in ultra-miniature nanoscale devices that will become the mainstream in the future, the use of plasma processes can cause serious problems such as abnormal etching, sub-surface material damage, and breakdown of insulation films by the accumulation of ions or electrons emitted from the plasma. Also, surface defects (dangling bonds) of over a few tens nm in depth can form by exposure to ultraviolet (UV)emissions from the plasma. Process induced defects during plasma processing can have a large influence on the electrical and optical properties of devices as nano-scale devices have a larger surface area compared with the bulk material. Furthermore, since future nano-devices will require size control of three-dimensional structures with atomic precision, it will be absolutely essential to control surface chemical reactions with high accuracy and selectivity at the atomic layer level. Neutral beam process technology has attracted attention as a way of realizing these requirments. The neutral beam suppresses the incidence of charged particles and UV photon radiation onto the substrate, and is able to expose the substrate only to energy controlled neutral beam enabled by precisely controlling ion acceleration energy with the applied electric field before neutralization. This is certainly true atomic layer etching (ALE) and deposition (ALD).