GEC18-2018-000102

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

Surface reaction control of plasma etch for atomic level accuracy in ULSI devices fabrication

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The structures of LSI devices are becoming increasingly three-dimensional and the process flows are becoming more complex to increase circuit density, e.g. adoption of design-technology of co-optimization (DTCO), and gate-all-around (GAA) transistors. In plasma etching processes of the future LSI device fabrication, not only the profile control with atomic-level accuracy, but also conformal etching of a high aspect pattern are required, To meet these requirements, Atomic Layer Etching (ALE) technologies have been investigated. In the ALE, each surface reactions, adsorption, protection, and desorption are controlled separately and accurately to improve etch profile and selectivity. We have investigated a cyclic ALE of a microwave ECR plasma etching tool based on the triple time modulation (Tri-TM) technology which is a combination of plasma, RF, and gas pulsing modulation. The Tri-TM has been applied to high selective various thin films etching, e.g. Si, SiN, HfO. We have also investigated rapid thermal cyclic ALE technology by using IR lamp and plasma source for accurate conformal etching. High selective SiN, TiN, and W conformal etching have been achieved. Etching mechanism, modification layer formation and desorption were investigated in the both etching technologies.