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PLASMA-SURFACE INTERACTIONS OF ATOMIC LAYER PROCESSING TOWARD SUB-NM-NODE SEMICONDUCTOR DEVICES

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The most advanced generation of semiconductor devices that are already in mass production (as of early 2023) is said to be 3nm technology node devices. The actual sizes of the smallest transistors used in such devices may vary among the chip producers and can be larger than 3nm, but they are still smaller than the smallest pattern sizes that the lithography processes can create. Such structures are typically formed by self-aligned double and quadruple patterning (SADP/SAQP) processes, where atomic-layer deposition (ALD) and plasma etching are used. For ALD, as the surface temperature during the processes is often required to be sufficiently low, plasma-enhanced ALD (PE-ALD) is also widely used. In this way, plasma technologies are the driving force for the most advanced semiconductor manufacturing processes. As the mass production of the next generation of semiconductor devices, i.e., 2nm node devices, is already in sight and new and complex device structures such as those for gate-all-around field effect transistors (GAA-FETs) need to be mass-produced, highly innovative plasma processing techniques with atomic-scale accuracy must be developed expeditiously and cost-effectively. For this purpose, a large part of the conventional try-and-error approach for process development must be replaced with more logical approaches based on a better understanding of the fundamental mechanisms of surface processing. In this presentation, recent analyses of plasma-material interactions based on atomic-scale numerical simulations and surface reaction experiments will be presented with plasma-enhance atomic-layer etching (PE-ALE) of Si and SiN with halogen and hydrofluorocarbon surface modification,[1,2] thermal ALE of Ni by oxidation and formation of metal complexes,[3] and PE-ALD of SiN with chlorosilane precursors and nitrogen/hydrogen plasmas[4], as examples of the most challenging atomic-layer processes.[5] The need for a process-oriented database of surface reactions will be also emphasized.

References

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