Evaluating Atomic Layer Etching: Analytical Approaches to Ion Energy Control for semiconductor devices

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Atomic layer etching (ALE) has emerged as a promising alternative to reactive-ion etching (RIE) for fabricating advanced semiconductor devices. ALE involves two main steps: surface modification and etch. ALE exhibits self-limiting characteristics, which ensure that the etching process terminates after removing a single atomic layer. However, ion energies exceeding material-specific thresholds can cause excessive sputtering and surface damage, leading to suboptimal device performance or outright failure. Therefore, maintaining ion energies within an optimal range is crucial to preserve surface quality and ensure device reliability and efficiency.

In this study, we explore ALE processes within Inductively Coupled Plasma Reactive Ion Etching (ICP RIE) systems, focusing on the precise control of plasma parameters to change the energy of ions impacting the etched surfaces. Recognizing the material-specific nature of ALE regimes, such as 40-60 eV for Si and 50-90 eV for GaN, we employed a Retarding Field Energy Analyzer (RFEA) to measure ion energies within the ICP RIE tool. Our investigation delves into the effects of various carriers, clamp sizes, power settings, and pressures on ion energy, aiming to identify optimal combinations of these parameters to achieve the desired ion energies for ALE. Upon determining the appropriate settings, we assess the impact of these ion energy parameters on etch per cycle (EPC) and surface morphology post-ALE. Finally, we discuss the implications of ALE in enhancing the performance of GaN High Electron Mobility Transistors (HEMTs), highlighting its potential benefits in power electronics applications.