Enabling 3D and High-Aspect Ratio Etch Technologies Through on-Chamber Process Vacuum

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As device lateral dimensions shrink with each successive technology node, there is an overall trend for growth in the vertical direction – first seen with finFETs, now with 3D NAND and capacitor structures for DRAM. For plasma etch, this vertical trend has led to the expansion of high aspect ratio applications, which generally require higher gas flow rates to improve selectivity and profile control. Higher process gas flow rates will result in higher etch rates, creating higher rates of removal for etch by-products which then need to be effectively managed by the supporting vacuum system for the process chamber. In addition, next-generation memory technologies, for example MRAM or FeRAM, typically require etch of non-volatile materials, also posing a significant challenge to the robustness and cleanliness of the process chamber vacuum system.

Historically, the chamber vacuum system was relied upon to deliver a low pressure and low particle environment using turbomolecular pumps (TMPs). These pumps operate spinning rotors at very high speeds to propel gases down and out of the pump. Condensable etch by-products can be managed by controlling the internal pump temperature profile to ensure that surfaces in the gas path are hot enough to keep the by-product in the vapour phase. In general, the higher the gas flow rate, the more heat that is imparted to the TMP rotor and the higher the rotor temperature. However, a hot rotor poses two challenges: creep and corrosion, the rates of both are increased at higher temperatures. Rotor creep is deformation due to sustained stress and temperature and increases exponentially with temperature. Etch process gases, such as BCl3 and Cl2, are corrosive and can attack the TMP at higher temperatures. These challenges clearly highlight what is typically perceived to be the most critical aspect of TMPs on harsh processes – thermal control.

Atomic layer etch (ALE) is another application that poses new vacuum system challenges. Similar to atomic layer deposition (ALD), ALE is a cyclic process, consisting of alternating “activation” and “removal” steps. The ability to quickly switch pressure and flow regimes for each of these steps is critical for maintaining high wafer throughputs.

This paper will not only discuss traditional pumping challenges and proven solutions, but also the novel application challenges which could potentially gate more complex 3D NAND, PRAM and other device structures.