Applied Centura® DPN HD System

The Centura DPN HD system complements Applied's long-standing leadership in DPN technology for logic to enable scaling of dynamic random access memory (DRAM) peripheral gates to the 3x/2x nodes. Scaling these gates is key to advanced high-performance, low-power devices, but current nitridation processes have difficulty achieving optimal leakage and threshold voltage. Capitalizing on the pulsed-RF plasma technology and integrated post-nitridation anneal (PNA) developed in Applied's pioneering work in decoupled plasma nitridation (DPN) technology, high-temperature, high-power DPN HD processing achieves the highest nitrogen doses as well as superior leakage and threshold voltage performance.

Nitridation is a process whereby nitrogen is driven into silicon oxide (dielectric) to increase the capacitance of the film, allowing for effective oxide thickness scaling. Besides raising the dielectric constant, the nitrogen content improves resistance against dopant diffusion through the gate dielectric.

As transistors have scaled down, the capacitance of the gate dielectric has had to increase to control short-channel effects (i.e., undesired physical phenomena in the scaled down channel). Initially, this higher capacitance was achieved by reducing silicon dioxide thickness. However, when gate oxide thicknesses dropped below 30Å, leakage from silicon dioxide was unacceptably high.

Over the past decade, nitridation has been used to incorporate nitrogen into a previously grown silicon dioxide film to form SiON (oxynitride). Besides raising the gate dielectric constant, thus reducing the equivalent oxide thickness (EOT), this technique produces a ten-fold reduction in gate leakage. During this time, operating powers have scaled rapidly from 2.5V to operating voltages approaching 1.0V while transfer rates have increased from 1.0GB/s to more than 20GB/s. Scaling the DRAM peripheral gate is the heart of this aggressive performance improvement.

The new DPN HD system comprises plasma nitridation and PNA chambers integrated on the Centura mainframe. In the former, silicon oxide dielectric is infused with nitrogen, creating the desired high nitrogen concentration at the oxynitride/poly interface and low concentration at the silicon/oxynitride interface of the gate stack to maintain high channel mobility.

Conventional nitrogen plasma nitridation approaches a limit when scaling the dielectric gate to approximately 20Å. Attempts to increase nitrogen content can enable further EOT scaling, but leakage and threshold voltage requirements can no longer be met. Using new plasma chemistry with high-temperature, high-power enhancements instead, the DPN HD system satisfies all three demands by altering the tradeoff among them. Direct wafer heating ensures stable temperature throughout the process; high power compensates for lower nitridation rates from the new chemistry.

Nitrogen concentration in the oxynitride decreases after nitridation. A high-temperature PNA immediately following nitridation counteracts this. Integrating nitridation and PNA chambers on one platform removes time-dependent variability, producing a stable and robust manufacturing process. The PNA also eliminates an unstable bonding phase from the nitridation process that causes fluctuation in electrical characteristics and, hence, in threshold voltage. By removing this phase, the PNA helps to optimize device performance.