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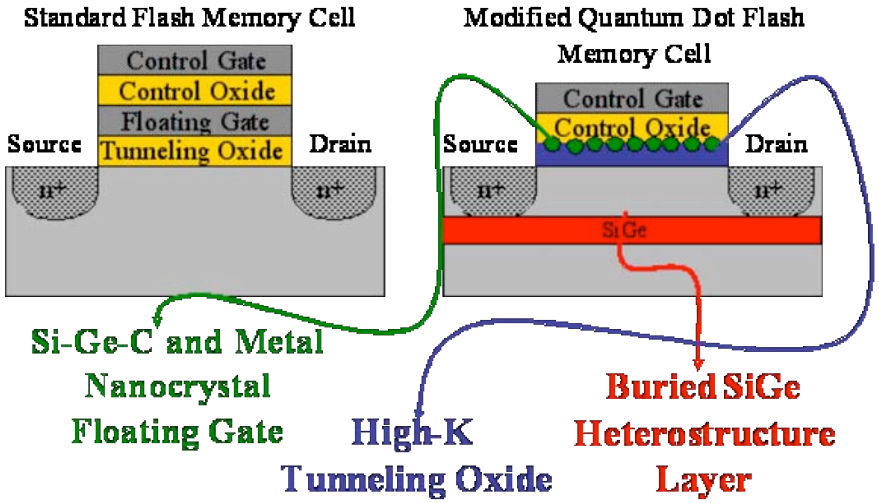
Spatially Ordered Self-assembled Quantum Dot Gate Low voltage/power, High Speed Nanoscale Flash Memories

Conventional flash memories have several serious drawbacks in terms of their scalability because a single defect in an ultra-thin tunnel oxide would discharge a continuous floating gate. This NIRT research program investigates new nanoscale memory cell structures with the goal of providing a compact, low-power, high-speed (programming, erase and read operation) semiconductor non-volatile memory technology. The research explores Si, Si-Ge-C and metal self-assembled quantum dot (SAQD) floating gates on various dielectrics such as silicon dioxide, and high-k hafnia and zirconia. SAQDs enhance charge retention and V_T stability, as well as possibly allow multi-level storage. We have demonstrated that SiGe SAQDs, which have lower bandgap than Si, provide improved charged retention by using such deeper quantum wells. We are in the process of using bio-mimetic schemes involving chaperonin proteins, as well as diblock co-polymers to guide the assembly of nanoparticles. The use of high-k tunnel and control dielectrics have also been shown to provide dramatic advantages over conventional silicon dioxide or oxy-nitride. High-k gate dielectrics allow for physically thicker, but electrically thinner "equivalent" oxides than silicon dioxide. High-k-based dielectrics provide high capacitive coupling, without sacrificing non-volatility, and allow for lower-voltage and/or higher-speed operation through the reduction in barrier height to channel hot electron (CHE) injection and tunneling, and increased device lifetime.

On the theoretical front, we have developed a multiscale model to describe the growth of silicon nanoparticles in silicon sub-oxide. This computational approach integrates i) first principles quantum mechanics to calculate the behavior of silicon and oxygen atoms in an oxide matrix, ii) continuous random network modeling to simulate amorphous silicon and oxide structures as well as their interfaces, and iii) kinetic Monte Carlo to describe long-time scale silicon nanoparticle nucleation and growth.



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