Silicon nanocrystals: Physics and memory technology

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Silicon nanocrystals are being increasingly considered for memory applications. This paper, discusses the physics of charge storage and confinement in nanocrystals as well as the methods of injecting charges into them. Two potential applications of nanocrystal based memory devices are reviewed with emphasis on impact of nanocrystals size and density. First, silicon nanocrystals provide an opportunity to scale conventional floating gate NOR Flash by mitigating the vulnerability to isolated tunnel oxide defects, which in turn enables one to scale oxide thicknesses and reduce operating voltages. For 1T DRAM (one-transistor dynamic random access memory) applications that use tunneling transport with thin tunnel oxides, both silicon oxide nitride oxide silicon (SONOS) and nanocrystal memories have limitations in that the former needs higher operating voltages for modified Fowler-Nordheim (FN) tunneling into nitride whereas the latter has limited threshold voltage shift and data retention. A hybrid silicon nanocrystal SONOS architecture that employs nanocrystals as intermediate states to accelerate tunneling into the nitride layer is shown to improve programming speed by orders of magnitude (about 106 times) compared to SONOS at lower voltages and also offer good threshold voltage shifts and refresh time. Key to these memory technologies is the ability to form silicon nanocrystals of required size and densities and preserving them during subsequent processing. This paper reviews chemical vapor deposition (CVD) physics of nanocrystals atomistic nucleation and their passivation by nitridation. Nanocrystal non-volatile memory (NVM) and hybrid DRAM may provide an opportunity to alleviate the challenges of embedding capacitor based DRAM and floating gate NVM on the same chip.

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