Abstract

Catalyst-free growth of InAs quantum dots (QDs) with different size and density was undertaken by metal organic chemical vapor deposition technique in this work to investigate its capability on charge storage in GaAs metal-oxide-semiconductor (MOS) based non-volatile flash memory application. The QDs were grown both on p-type GaAs (100) substrates and high-k ZrO_2 dielectric layer, the later was deposited onto ultrathin GaP layer passivated GaAs substrates. QDs were grown on GaAs substrates under normal atmospheric pressure in the temperature range 380 – 450 ^{0}C. This temperature window is found to be lower than the existing data available in the literature which is 500 – 600 ^{0}C, and under reduced pressure. At 380 ^{0}C, uniform QDs with diameter 5 – 30 nm and height 5 – 10 nm were obtained, whereas at a temperature of 530 ^{0}C, InAs nanoislands with wetting layers were formed instead of QDs. The densities of the QDs were found to be 2×10^{11} – 5×10^{10} cm^{-2}; lower one being at higher growth temperature. The QDs were found to be round shaped, single crystalline, well distributed with diameter around 24 nm. The size and density of the InAs QDs on high-k dielectric (ZrO_2) were controlled by varying the growth temperature. To demonstrate the efficacy of QDs as charge storing nodes and the effect of QD size on charge storage behavior, GaAs MOS based memory devices with structure Al/ZrO_2/InAs QDs/ZrO_2/(GaP)GaAs were fabricated. The devices exhibit maximum memory window of 6.83 V, low leakage current density (~10^{-6} A/cm^2) and reasonably good charge retention of 86.2% after 10^5 s. The hysteresis width increases with decrease in size of the QDs, whereas charge retention is found to increase with increasing the dot size. Suitable electronic band diagrams corresponding to programming and erasing operations are proposed to explain the operation. While analyzing leakage current characteristics in different GaAs MOS devices, viz. GaP passivated, unpassivated, and QDs enabled devices, it is found that in unpassivated devices the carrier transport is due to Poole-Frenkel emission, whereas Fowler-Nordheim tunneling is the dominant conduction mechanism in both the passivated and QDs enabled devices.

Keywords: Quantum dots, metal-oxide-semiconductor, memory, charge storage, carrier transport.