Charge retention characteristics of charge trapping nonvolatile memories with silicon carbonitride (SiCN) dielectrics

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Introduction Nonvolatile memories (NVMs) have become essential components in the data storages for communication and multimedia applications. The MONOS (Metal-Oxide-Nitride-Oxide-Silicon) structure with a charge trapping silicon nitride layer has received considerable attention as a possible replacement for the floating-gate type NVMs. However, it is a critical challenge for MONOS-type NVMs to achieve fast programming and erasing speeds and long retention time simultaneously. Recently, we have proposed the application of silicon carbonitride (SiCN) films with a low-dielectric constant (low-k) and a narrow band gap to the charge trapping layers. [1-5] Higher programming and erasing speeds and reduced power consumption can be achieved by using the low-k (ε=4.8-4.9) and narrow-band gap (3 to 4 eV) SiCN charge trapping films as compared with the silicon nitride films. In the present study, we investigated the charge retention behavior of memory capacitors with the SiCN charge trapping layers.

Experimental procedures A tunnel oxide film of 2.4 nm in thickness was first formed on p-type (100) silicon substrates using a rapid thermal oxidation technique. A 31.5-nm-thick SiCN film with a relative dielectric constant of 4.8-4.9 was grown at 400 °C using a PECVD technique. A 17.3-nm-thick blocking oxide film was grown using a PECVD technique. Finally, an aluminum film was deposited to form the gate electrode on the SiO_X-SiCN-SiO_2 stacked films. Programming and erasing voltages of +14.3 V and -15.1 V were applied to the gate electrode to inject electrons and holes into the SiCN layer through the tunnel oxide film. Charge retention characteristics of the SiCN memory capacitors were measured at temperatures ranging from 85 °C to 240 °C.

Results and Discussion Figure 1 shows the charge retention characteristics of the SiO_X-SiCN-SiO_2 structure at temperatures of 85 °C, 160 °C and 236 °C after programming and erasing operations. From these results, we can see that both the rates of electron and hole charge loss in the structure increased as the temperature increased. The testing temperature of 85 °C equaled the maximum operating temperature typically required for micro computing units. In the charge retention test at 86 °C, the remaining memory window of the SiCN capacitors after ten years was estimated to be 27 % of the initial window. The SiCN film can be employed as the charge trapping layer of the nonvolatile memories. The time-to-failure (t_F) at each testing temperature versus 1000/T is shown in Fig. 2. Here, the time-to-failure is defined as the time required for the flat-band voltage shift (ΔV_{FB}) to reach ±1.6 V. The thermal activation energies (E_A's) for electron and hole charge loss were 0.9 eV and 0.4 eV, respectively.

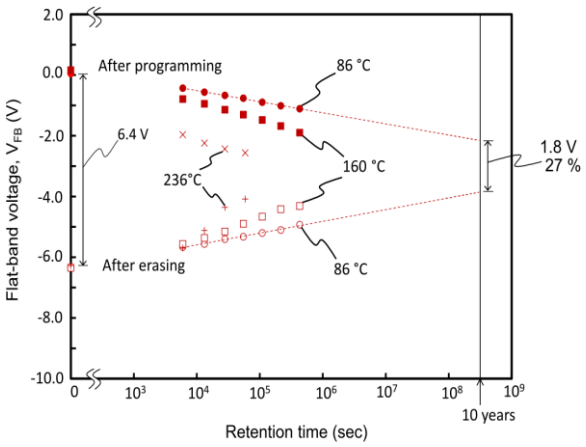

Fig. 1. Charge retention characteristics of the SiO_X-SiCN-SiO_2 test capacitors at 86, 160 and 236 °C.

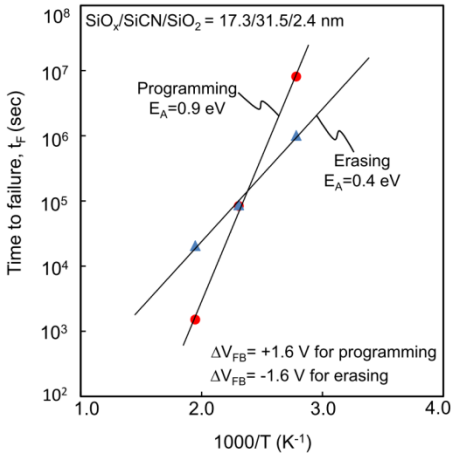

Fig. 2. Time-to-failure (t_F) versus 1000/T.

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