Spatial Distribution of Injected Charge Carriers in SONOS Memory Cells

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ABSTRACT

Spatial distribution of injected electrons and holes is evaluated by using single-junction charge pumping technique in SONOS(Poly-silicon/Oxide/Nitride/Oxide/Silicon) memory cells. Injected electrons are limited to length of ONO(Oxide/Nitride/Oxide) region in locally ONO stacked cell, while are spread widely along with channel in fully ONO stacked cell. Hot-holes are trapped into the oxide as well as the ONO stack in locally ONO stacked cell.

KEYWORDS

SONOS Memory, Locally ONO stacked Cell, Single-Junction Charge Pumping Technique, Spatial Distribution

Ⅰ. INTRODUCTION

SONOS (Poly-silicon/oxide/nitride/oxide/silicon) non-volatile memory is considered as the most promising flash memory technology in the near future. The reasons are as follows; high-density, low power consumption and simple& logic compatible process [1-4]. Out of them, the most attractive is realization of two-bit per cell for high volume capacity [5,6]. It can be achieved by storing charges locally in the nitride discrete traps above junction edges. In order to guarantees reliable two-bit operation in localized charge-trapping SONOS memory, lateral charge distribution in a nitride layer must be controlled as small as possible after programming and erase. In this paper, we directly show the spatial distributions of locally trapped charges in a nitride layer by using single junction charge pumping technique.

Ⅱ. MEMORY CELL STRUCTURES

Figure 1 shows schematic cross sections of (a) locally ONO(Oxide/Nitride/Oxide) stacked cell and (b) fully ONO stacked cell. In the locally ONO stacked cell, the ONO dielectrics are only stacked at drain side. They are fabricated using 0.13 um technology with shallow trench isolation. Locally ONO stacked cell has channel length of 0.15 um in the thin oxide region and 0.1 um in the ONO stacked region. Channel length of fully ONO stacked cell is 0.25 um. The thicknesses of the stacked ONO are 3.5~4.0 nm for the bottom oxide, 4.7~5.0 nm for the nitride, and 7.0~8.0 nm for the top oxide.

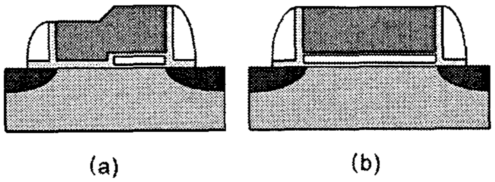

Fig. 1 Schematic cross sections of (a) locally ONO stacked cell and (b) fully ONO stacked cell.

III. EXPERIMENTAL SET-UP

For single junction charge pumping measurement, continuous square pulses are applied to the gate while the substrate is grounded. HP4156C parametric analyzer is used to measure the charge pumping currents from one junction while the other junction is left floating. The gate pulse has a frequency of 10 MHz, 50% duty cycle, rise/fall times of 10 ns and a fixed base voltage (V_b) of -3 V by a pulse generator (HP8110A).

IV. RESULTS AND DISCUSSION

The single-junction charge pumping curves measured separately from the abrupt drain and graded source junctions of the fully ONO stacked cell and the locally ONO stacked cell are shown in Fig. 2.

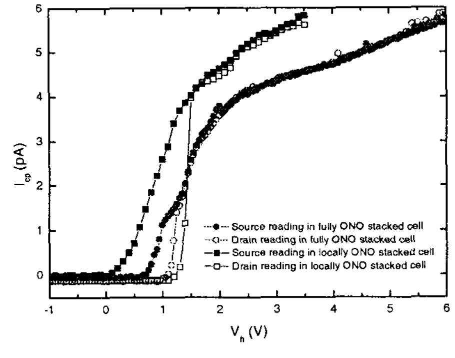

Fig. 2 Single-junction charge pumping currents measured separately from the graded source junction and the abrupt drain junction of the fully ONO stacked cell and the locally ONO stacked cell at initial state.

The charge pumping currents (I_{cp}) from the drain junction for both cells are measured at nearly same pulse height (V_h). However, I_{cp} read from the source junction for locally ONO stacked cell occur at less V_h of a charge pumping pulse than one for fully ONO stacked cell. This means that local threshold voltage (V_t) of the locally ONO stacked cell is low at source region because the locally ONO stacked cell has only thin oxide at source side.

Figure 3 shows the single-junction charge pumping curves after channel hot electron programming.

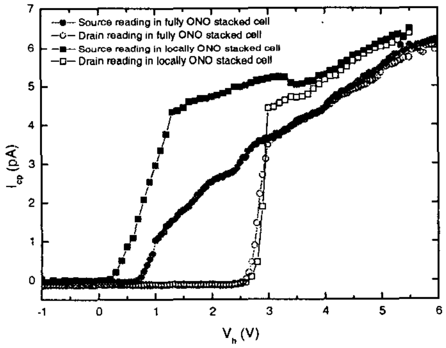

Fig. 3 Single-junction charge pumping currents measured separately from the graded source junction and the abrupt drain junction of the fully ONO stacked cell and locally ONO stacked cell after channel hot electron programming at the drain junction. The programming is performed by applying 3.5 V to the gate, 1 V to the drain, and 4.5 V to the source for 20 us.

After drain programming, I_{cp} measured from the drain junction begin to flow at same V_h, and has same appearances in both cells. But, it can be seen that I_{cp} read from the source junction is quite different in both cells.

Figure 4 shows the single-junction charge pumping curves after band-to-band hot-hole drain erasing.

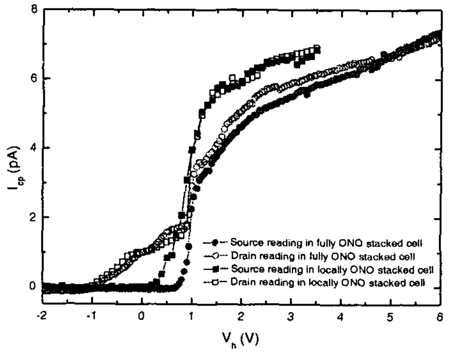

Fig. 4 Single-junction charge pumping currents measured separately from the graded source junction and the abrupt drain junction of the fully ONO stacked cell and the locally ONO stacked cell after band-to-band hot hole erasing at the drain junction. The erase is performed by applying -6.5 V to the gate and 5 V to the drain for 20 us.

I_{cp} from the source junction for locally ONO stacked cell are measured at less V_h of a charge pumping pulse than one for fully ONO stacked cell. Compared Fig. 2 with Fig. 4, I_{cp} measured from the source junction at initial state are the same as one after drain erase for locally ONO stacked cell. However, I_{cp} from the drain junction are measured at same V_h for both cells.

The interface and bulk charges from the obtained charge pumping data are firstly separated with the assumption that the interface-trap density is spatially uniform along the channel. Also, the obtained charge pumping data can be transformed into the lateral distribution of its local threshold voltage and the trapped charge density.

Figure 5 shows local V_t distribution of the locally ONO stacked cell and the fully ONO stacked cell at initial, programming, and erase state.

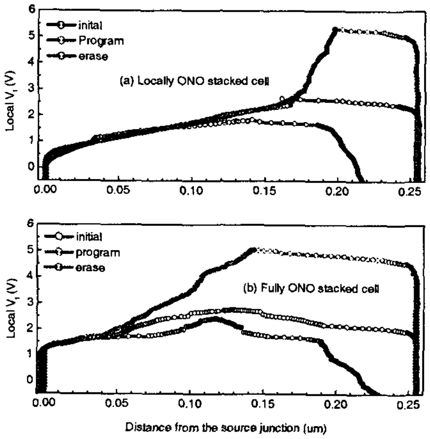

Fig. 5 Lateral profiles of local V_t with distance from source junction at initial, programming, and erase state for the locally ONO stacked cell and the fully ONO stacked cell.

Nitride trapped electron distributions of the locally ONO stacked cell and the fully ONO stacked cell after programming are shown in Fig. 6.

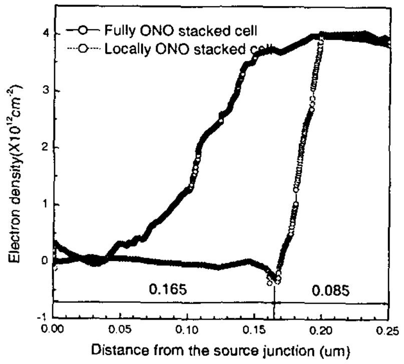

Fig. 6 Electron distributions of the locally ONO stacked cell and the fully ONO stacked cell after programming.

It can be seen that lateral distribution width of injected electrons is limited to length of

ONO region in the locally ONO stacked cell, while electrons are spread widely along with channel in the fully ONO stacked cell. The trapped electron charges in the nitride layer are 4×10^{12} cm^{-2}, lateral charge centroid of injected electrons is 0.177 um for the fully ONO stacked cell and 0.217 um for the locally ONO stacked cell.

Figure 7 shows nitride trapped hole distributions of the locally ONO stacked cell and the fully ONO stacked cell after erasing.

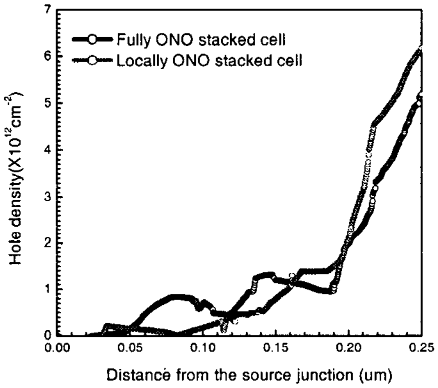

Fig. 7 Nitride trapped hole distributions of the locally ONO stacked cell and the fully ONO stacked cell after erasing.

It can be seen that hot-holes are injected into not only the ONO stack but also the oxide in the locally ONO stacked cell. Lateral charge centroid of injected holes is 0.194 um for the fully ONO stacked cell and 0.22 um for the locally ONO stacked cell.

V. CONCLUSIONS

We have directly showed the spatial distributions of locally trapped charges in a nitride layer by using single junction charge pumping technique. Injected electrons are limited to length of ONO region in locally ONO stacked cell, while are spread widely along with channel in fully ONO stacked cell. Hot-holes are trapped into the oxide as well as the ONO stack in locally ONO stacked cell.

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