Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.630-631

P4-4

Characteristics of Band-to-Band Hot Hole Injection for Erasing Operation in Charge Trapping Memory

Lei Sun[1], Liyang Pan[1], Huiqing Pang[1], Ying Zeng[1], Zhaojian Zhang[1], John Chen[2] and Jun Zhu[1]

[1]Institute of Microelectronics, Tsinghua University, Beijing 100084, P.R.China
Phone: +86-10-62791272, Fax: +86-10-62771130, E-mail: sunlei@tsinghua.org.cn
[2]Semiconductor Manufacturing International Corporation, Shanghai 201203, P.R.China

1. Introduction

In the charge trapping memory, such as the SONOS memory, injected charges are stored in a localized region along the channel. These localized charges will have impacts to the cell's read characteristics, as well as the programming/erasing and reliability [1][2]. A SONOS memory is usually programmed by channel hot electron (CHE) or channel initialed secondary electron (CHISEL) injection [3], by which means electron are trapped in a narrow region as illustrated in Fig.1. To erase these electrons, band-to-band hot hole (BBHH) injection is usually introduced [4], which has lower voltage bias and faster erase speed compared to F-N tunneling. However, the injected holes may have different distribution position and range, which will bring problems to the cell's performance. Using a charge pumping method, we obtain the precise distribution of injected electrons and holes in SONOS memory, and study the characteristics of different erase conditions and effects to the performance of charge trapping memory.

2. Testing Method

To get the accurate electron distribution, we combine the constant gate low voltage method and constant gate high voltage one during the charge pumping measurement [5]. Fig. 2a and Fig. 2b give the charge pumping current (I_{cp}) data of these two methods respectively. I_{cp} is measured from source and drain separately with the opposite side floating. The positive shift of I_{cp} presents electrons injection, and the difference between curves of source and drain indicates the electron distribution along the channel. We use the SONOS sample for measurement with the W/L 20 μm/0.8 μm. Electrons distribution after CHE program (V_d = 6.5 V, V_g = 7 V) is shown in Fig.3. A narrow peak distribution of trapped electrons can be observed near the drain junction, with a width about 50 nm. Another peak at the edge of the gate does not contribute to the increase of V_T because it is located within the drain junction.

Constant gate low voltage method is also used to profile the holes distribution induced by BBHH injection. Fig.4 is the I_{cp} data after hot holes injection to a virgin cell. The negative shift indicates the trapped holes' distribution position and range, which is at the edge of gate and has quite a narrow range.

3. Experimental Results and Discussion

Fig.5 shows the charge pumping measurement results of BBHH injection erase to the CHE programmed cell. Condition for erasing is V_d = 6 V, V_s = 0 V and V_g = -6 V. Fig. 6 is the calculated charge distribution, and the I_d-V_g curves during the erasing operation are shown in the inset. After 10 μs hot hole injection, trapped holes near the edge of gate at the drain side can be observed, which indicates that holes have neutralized local trapped electrons. At the same time, electrons near the drain junction are partly neutralized, and still a certain number of electrons left even after 10 ms BBHH erasing operation. These electrons make the I_d-V_g curve unable to be erased to the virgin state, resulting in the increasing of the V_T after P/E cycles and degrading the device's reliability.

This problem is severer when CHISEL program operation is used. As Fig. 7 shown, BBHH injection cannot neutralize the trapped electrons because their distribution is wider and farther from the drain junction.

One way to solve this problem is the optimization of erase condition. Fig. 8 illustrates the effect of different drain bias to the holes' distribution. The charge pumping current shows that higher V_d produces higher lateral electric field, resulting in wider hole distribution. Therefore, by changing the voltage condition of erase operation, we can make the BBHH injection point overlap with the trapped electrons.

In the charge trapping memory, this localized distribution of electrons and holes will also have impacts to the reliability, such as the programming/erasing cycling endurance. As shown in Fig. 9, the V_T after erasing operation will increase gradually with the increase of programming/erasing cycles due to the accumulation of un-neutralized electrons in the nitride layer. If higher drain voltage is used during the BBHH erasing operation, the V_T shift can be reduced effectively.

4. Conclusions

In this paper we study the characteristics of BBHH injection for erasing in charge trapping memory. The injected holes are trapped in the region of drain side and can partly neutralize the electrons induced by CHE or CHISEL operation. By optimizing the erase voltage condition, the erasing ability of BBHH injection can be enhanced and endurance can be improved consequently.

Acknowledgements

This paper is supported by Chinese National Natural Science Foundation (Project ID: 60306007) and Chinese Hi-Tech Plan (Project ID: 2003AA1Z1420).

References

[1] Lei S. et al., *Jpn. J. Appl. Phys.* **44** (2005) 2710.
[2] Luca L. et al., *IEEE Trans. Electron Devices* **49** (2002) 1939.
[3] J.D. Bude et al., *IEDM*, 1997, p.279.
[4] Chih-Chieh Y. et al., *IEEE Electron Device Lett.* **25** (2004) 643.
[5] Chun C. et al., *IEEE Trans. Electron Devices* **45** (1998) 512.

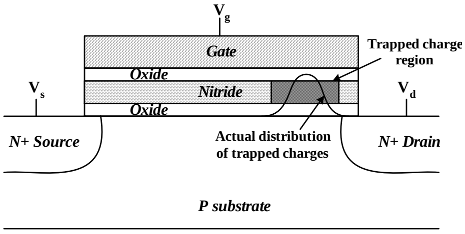

Fig.1. Demonstration of localized trapped charges in SONOS memory.

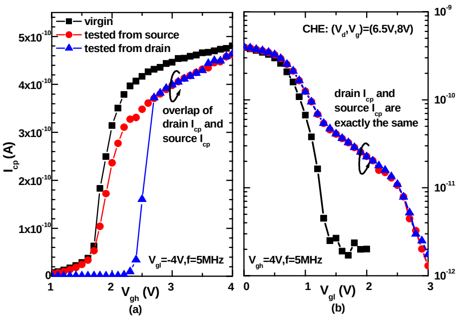

Fig.2. (a) Constant gate low voltage charge pumping curves after CHE programming, and (b) constant gate high voltage charge pumping curves. I_{cp} are measured from source side and drain side separately.

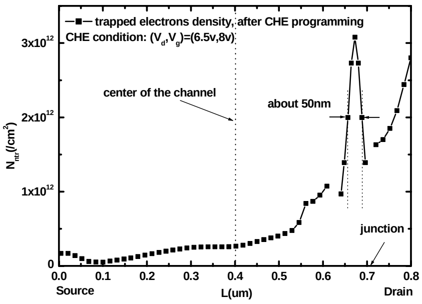

Fig.3. The trapped electrons distribution after CHE programming.

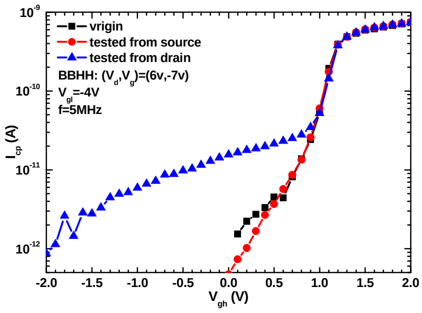

Fig.4. Charge pumping current after BBHH injection to a virgin cell, using constant gate low voltage charge pumping method.

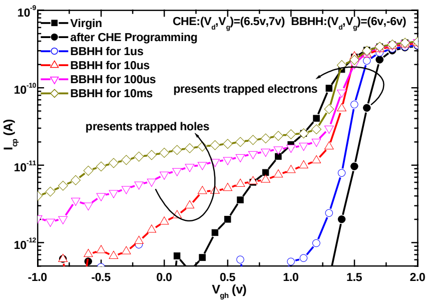

Fig.5. Transient characteristics of BBHH injection to a CHE programmed cell, tested by constant gate low voltage method.

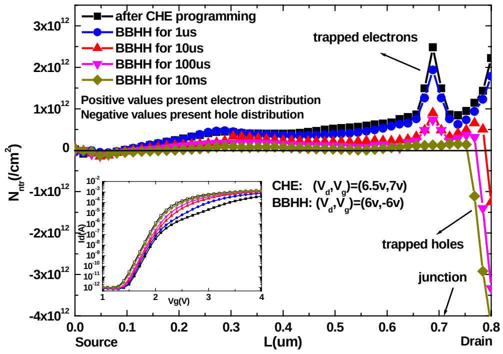

Fig.6. Actual electrons and holes distribution along the channel after CHE programming and BBHH erasing. Inset shows the I_d-V_g curves during the erasing operation.

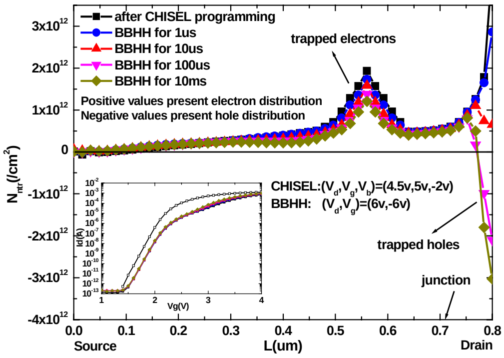

Fig.7. Electrons and holes distribution after CHISEL programming and BBHH erasing. Inset shows the I_d-V_g curves during the erasing operation.

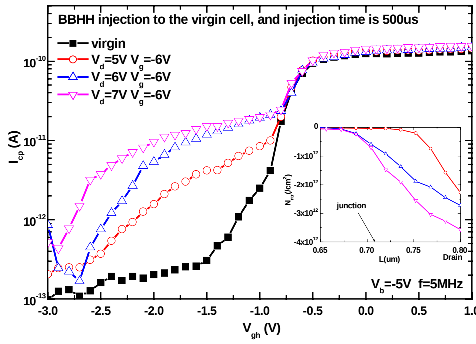

Fig.8. I_{cp} measurement of different drain voltage bias in the BBHH injection (V_d = 5 V, 6 V, 7V, and V_g = -6 V). Inset is the distribution of trapped holes.

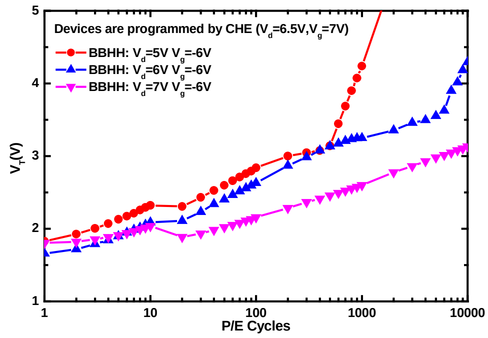

Fig.9. Comparison of V_T characteristics after BBHH erasing operation under different V_d conditions.