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Low Power 0.13um Single Poly Embedded P-channel SONOS Flash Using Band-to-Band Programming

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I. Abstract -An embedded single poly P-channel flash with the **B**and-to-**B**and tunneling induced **H**ot **E**lectron(BBHE) programming, has advantages of fast programming and low power is demonstrated in this paper. With only 3 additional non-critical masks, the SONOS base technology is embedded into 0.13um logic technology successfully. The BBHE injection scheme has been utilized to achieve fast programming, low power consumption and page program.

II. Introduction

SONOS has been considered as the best substitution for conventional floating gate Flash memory in embedded application [1]. Because of its high compatibility to logic process, and less over-erase compare to floating gate memory.

There are three popular mechanisms to inject electron into nitride including **C**hannel-**H**ot-**E**lectron(CHE) injection, Fowler-Nordheim(FN) tunneling injection, and **B**and-to-**B**and tunneling induced **H**ot **E**lectron(BBHE) injection. However CHE scheme need large programming current to keep the programming speed in acceptable level, and FN tunneling programming need long programming time[2]. That makes these two mechanisms do not so favor to use on advance embedded flash. To overcome these problems, we developed a 2T p-channel embedded SONOS flash programmed by BBHE. Two major advantages of BBHE are low power consumption and high programming efficiency(10^{-3}~10^{-2})[3].

III. Cell Structure and Process

Fig. 1 (a) illustrates the cross-sectional diagram of the 2T device in which consists of two p-type transistors. One is the SONOS transistor for storage data, and the other is the transistor with gate oxide for read/ programming selection. Fig. 2 shows the process flow of the device. Only three noncritical additional masks are required to embed the device into 0.13um logic technology. The first additional mask is used to form deep n-well for programming and erasing high voltage operations of the device. The second additional mask is employed to define and form ONO stack, whereas the third additional mask is to define select transistor and SONOS cell. The operation conditions of the device are listed in Table I. In programming operation, a positive voltage is applied on **c**ontrol-**g**ate(CG) and a negative voltage is supplied on **b**it-**l**ine(BL) to perform the BBHE injection. The device at program state has high conductivity and drives large current under read operation. In erasing operation, a negative voltage applied on CG and a positive high voltage applied on BL/**n**-**w**ell(NW)/**s**ource-**l**ine(SL) are supplied to result in electron tunneling out of the nitride storage layer.

IV. Result and Discussion

The BBHE mechanism is illustrated in Fig. 1 (b). The high vertical electrical field across deep-depletion region of PLDD underneath the CG/BL overlap region generates electron-hole pairs. Some generated electrons are accelerated by the lateral electrical field across the P+/NW junction, gain sufficient energy to surmount the energy barrier of bottom oxide and then are trapped in nitride layer. Fig. 3 shows programming characteristic of BBHE programming mechanism. The current level increases over 45uA within 1us while BL voltage at -6V. Programming speed comparison is demonstrated in Fig. 4. BBHE has faster programming speed against CHE with more than 3 orders improvement in programming speed. Fig. 5 shows the BBHE programming current prediction and programming current is about 0.2uA. Comparing with the current of CHE injection scheme, BBHE injection performs up to 2 orders power saving in programming operation. Therefore, page program with 1Kbits can be realized by using BBHE programming. Channel FN tunneling erasing characteristic are demonstrated in Fig. 6, the current level can be erased successfully within 600ms with CL=-6.5V. Fig.7 demonstrates the data retention characteristic at 150^{o}C. The window of programming/erasing state can be kept with 35uA and above after 1000 hours baking. Charge retention capability of the cell operated with BBHE injection, as demonstrated in Fig. 8, meets the requirements of 10-years at 85°C. Programming disturbance characteristic of the device is demonstrated in Fig. 9. The current window can keep over 45uA by supplied -2V on CG. The comparison of endurance characteristic of BBHE and CHE injection scheme is shown in Fig. 10. Programming with CHE scheme performs worse endurance characteristic, which is probably caused by the hole bombardment onto oxide layer. Distribution of memory cells at erase and programming states of a test array with 2k bytes memory cells is shown in Fig. 11. Table II tabulates the key summary of the cell with BBHE and CHE operation schemes. It is clear that BBHE scheme has faster programming speed, lower power consumption, and lower degradation for flash memory.

V. Conclusion

In this paper, a low cost and simple logic based single poly embedded flash with BBHE programming scheme is proposed. By using BBHE scheme can achieve high speed, low power, low degradation, and page programming target. Compare with the traditional floating gate embedded flash memory, the device is very promising due to its low operation bias, low power consumption, high speed by page program, and easily embedded into logic process.

Reference

[1] C. Swift et al, *IEDM Tech. Dig*., p.927, 2002.
[2]Soo. Doo. Chae et al SSDM pp206-207, 2003.
[3]T.Ohnakado et al IEDM Tech. pp279-282, 1995.
[4]H.M.Lee et al IEEE NVSMW 21st, 2006.

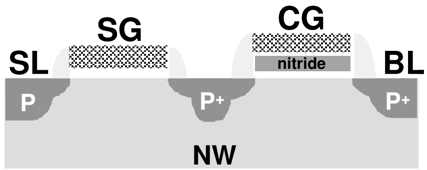

Fig.1(a) 2T device cell structure

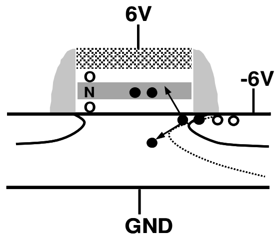

Fig. 1(b) BBHE programming mechanism

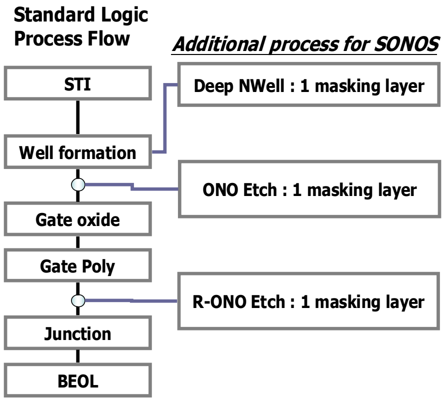

Fig. 2 Embedded Flash Process flow

Unit:V

Schemes	SL	SG	CG	BL	NW
BBHE PGM	Float	0	6	-6	0
CHE PGM	0	-4.4	-0.5	-6	0
Erase	6	3	-6.5	6	6
Read	0	-3	0	-1.5	0

Table I. Operation condition table.

Schemes	BBHE	CHE
PGM current	0.1~1uA	>150uA
PGM Efficiency	10^{-2}~10^{-3}	10^{-6}~10^{-4}
PGM Type	Page(32 bit)	Byte(8 bit)
PGM time(>40uA)	1usec	100usec
Hole Injection	Low	High
Interface Degrade	Low	High

TableII. Characteristic comparison between BBHE and CHE.

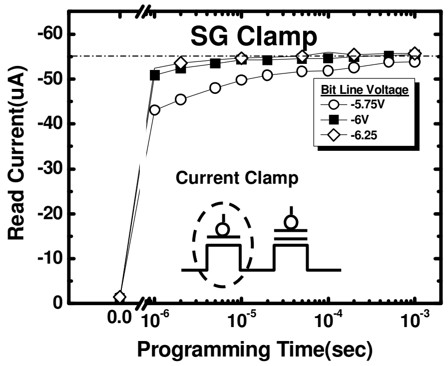

Fig. 3 BBHE programming trend of different BL voltage

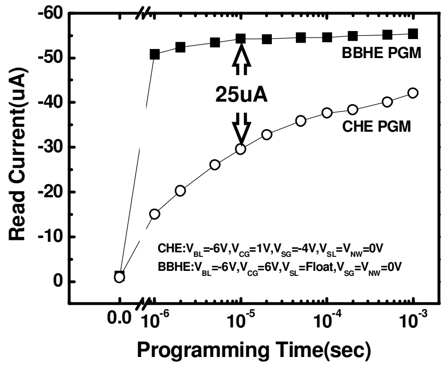

Fig. 4 Programming speed comparison between BBHE and CHE

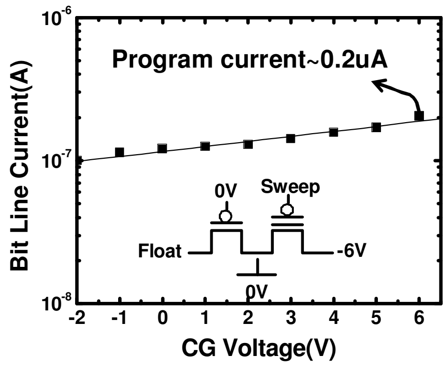

Fig.5 Programming current of BBHE.

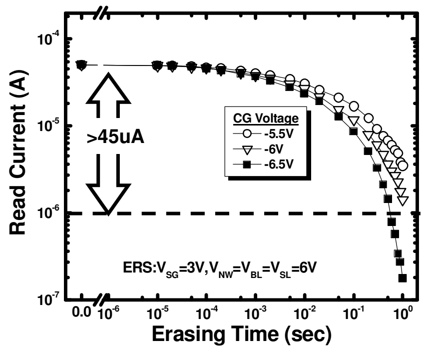

Fig. 6 Erasing trend with channel FN scheme

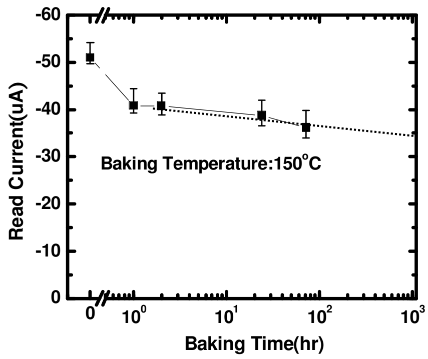

Fig. 7 Retention behaviors of the cell with BBHE injection scheme

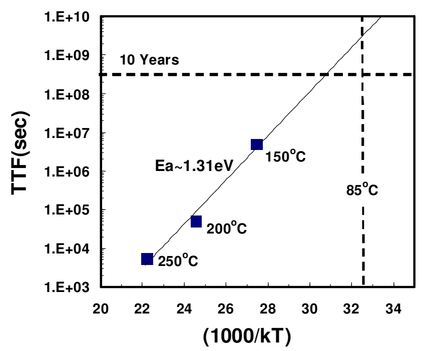

Fig. 8 Arrhinus plot for activation energy extraction.

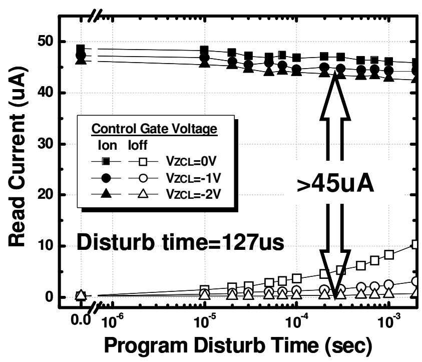

Fig. 9 BBHE program disturbance characteristic

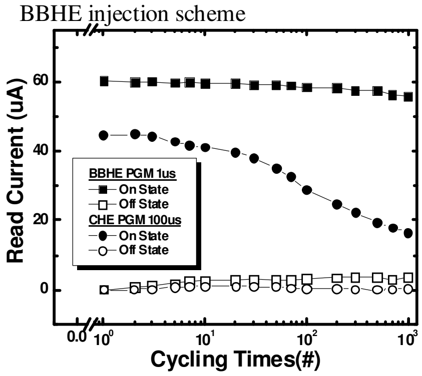

Fig. 10 Endurance characteristic of BBHE programming and FN erasing

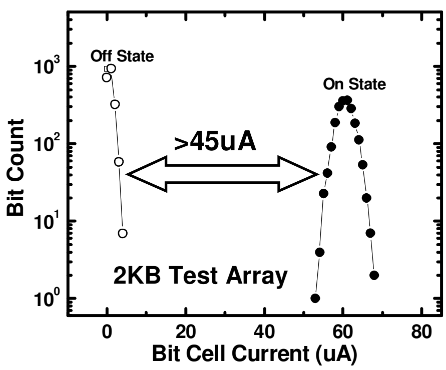

Fig. 11 Cell current distribution of 2K bytes array after programming and erase