Phase Change Memory Device with U-shaped Heater (PCM-U)

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ABSTRACT

We have focused on the structural modification of heater and recently invented phase change memory device with U-shaped heater (PCM-U) device, to reduce the writing current. It is experimentally obtained that the PCM-U device has noticeably shorter SET operation time, shows 50% reduction of RESET current and shows 44% reduction of SET current, compared with the conventional device. This improvement is suggested to be due to the overlap of programmable volume.

Key words: phase change memory, writing current, heater

1. INTRODUCTION

As a next generation memory, phase change memory (PCM) has attracted a lot of attention, because PCM combines all the desirable characteristics including non-volatility, high speed and high density [1,2]. The basic phase change material is $Ge_2Sb_2Te_5$ alloy (GST), which is the same family of material used in optical rewritable disks [3].

Writing operations of PCM are based on two reversible phase transition by Joule heating. One is SET operation which is phase transition from resistive amorphous to conductive crystalline. The other is RESET operation which represents vice versa [4,5]. To obtain the two SET and RESET operations, respectively, the temperature of GST reaches over its crystallization temperature (T_c) and melting temperature (T_m), respectively. These two writing operations inevitably require high power consumption. Therefore, researchers have scaled down TiN/GST contact size [4,6], introduced GST-confined structure [4,6], changed phase change material [7] and applied new heater material [8], to reduce the writing current.

However, there has been little research interest on the structural improvement of heater. We firstly proposed [9] and successfully manufactured PCM-U device, in which TiN heater surrounds GST.

2. EXPERIMENTS

We fabricated the PCM-U devices together with the conventional device, and compared their writing behaviors, to confirm the feasibility of the PCM-U device. Figure 1 shows the fabrication procedures of the two devices. $Ge_2Sb_2Te_5$ thin film was deposited by co-sputtering system with $Ge_2Sb_2Te_5$ target. The same cell pore size of 500nm was initially designed. The fabrication difference of the two devices is only the formation sequence of TiN heater. TiN was formed after TiW formation in the conventional device, while TiN was formed after cell active pore formation in the PCM-U device. Figure 2 presents the final cross sectional views of the two devices.

The operation behaviors were characterized by the electrical measurement system. To obtain writing current, programming curves (R-I) for SET/RESET operations of fabricated devices were obtained. Current pulses were obtained by HP 8110A. The current pulses with various amplitudes were applied for data programming, in which the pulse width was fixed at 1us. Resistance across the phase change material was measured by HP 4145B, via steady-state I-V tests in sampling mode.

3. RESULTS & DISCUSSION

Figure 3 shows that, compared with the conventional device, the PCM-U device has 0.7V smaller threshold switching voltage, which indicates that SET operation occurs in a lower value of the applied voltage in the PCM-U device. This also implies that SET operation time of the PCM-U device is shorter in the same value of applied voltage.

Writing current of the two devices was also compared as shown in Fig. 4. It is observed in the PCM-U device that RESET current decreases from 14mA to 7mA, and SET current decreases from 3.2mA to 1.8mA, compared with the conventional device. The reasons for the lower writing current in the PCM-U device are discussed as follows.

It is well known that phase change occurs only in programmable volume, where thermal heat is mostly concentrated, and that the programmable volume is known to be generated at the TiN/GST contact [10-13]. It is suggested that, in the PCM-U device, the programmable volumes generated at the Bottom-TiN/GST contact, at the two Side-TiN/GST contacts and at the Top-TiN/GST contacts are overlapped. The concentration of thermal heat is thought to be more remarkable in the overlapped area, compared with non-overlapped area. This suggests that the PCM-U device with the overlap has shorter operation time and lower writing current, compared with the conventional device without the overlap. Therefore, it is obtained that the overlap of the programmable volume causes the PCM-U device to have the improved electrical properties.

4. CONCLUSION

To reduce the writing current, we firstly report the structural modification of the heater and successfully manufactured PCM-U device, where TiN heater surrounds GST.

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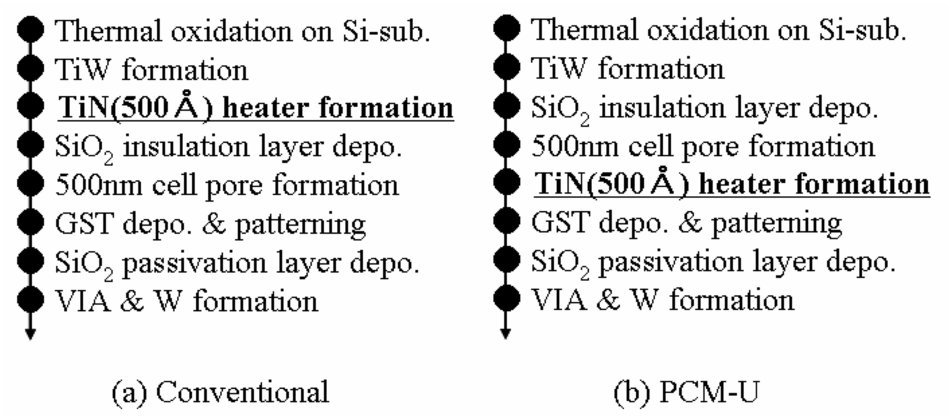
Biographies

Dr. Young Sam Park was born in Korea, in 1972. He received the B.S., M.S., and Ph.D. degrees in materials science and engineering from Korea Advanced Institute of Science and Technology (KAIST), Korea, in 1994, 1997 and 2002, respectively. From 2002 to 2004, he joined Samsung Electronics Company, Ltd., Korea, where he involved in the development of Flash and SONOS memories for Smart Card Integrated Circuits applications.

Since 2004, he has been with Functional Electronic Device Team, IT Convergence & Components Lab., Electronics & Telecommunications Research Institute (ETRI), Korea, where he has been involved in the development of Phase change Random Access Memory (PRAM). He has published more than 15 technical papers in the field of memory technology. He holds more than 25 patents related to memory technology.



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- TiW formation
- **TiN(500 Å) heater formation**
- SiO_2 insulation layer depo.
- 500nm cell pore formation
- GST depo. & patterning
- SiO_2 passivation layer depo.
- VIA & W formation

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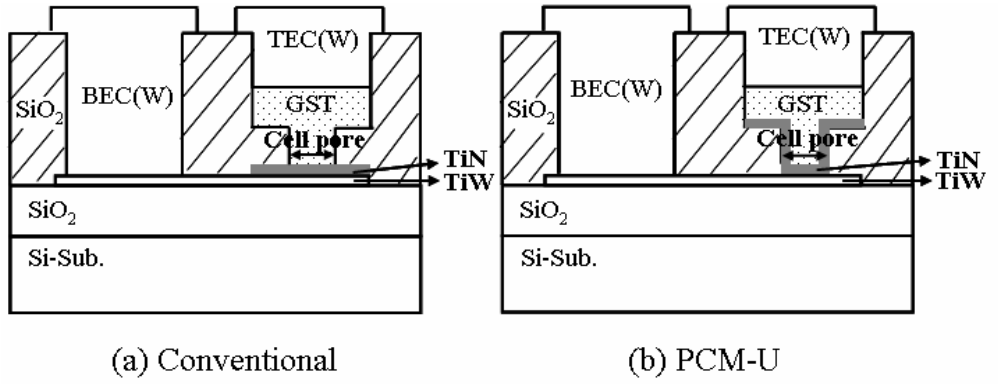
(b) PCM-U

Figure 1. Process sequences of the two devices.



(a) Conventional (b) PCM-U

Figure 2. Schematic views of the two devices.

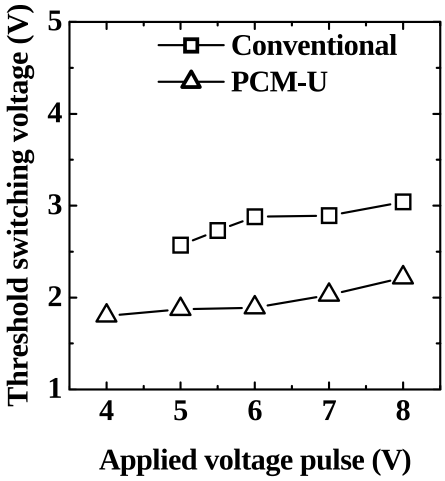


Figure 3. Threshold switching voltages.

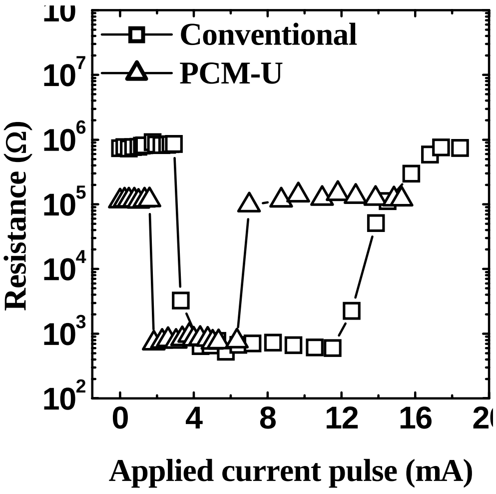


Figure 4. Writing current (I_{RESET} and I_{SET}) of the two devices.