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Elevated-Confined Phase Change RAM Cells

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1. Introduction

Among the emerging nonvolatile memory technologies, Phase Change RAM (PCRAM) has the most potential to replace FLASH due to its many ideal memory properties such as fast access time, low power consumption, high endurance, good data retention, high scalability [1]. One of the challenges for PCRAM is to reduce its power consumption so that it is compatible with minimum MOS transistor drive current/voltage for high density integration. Different methods of reducing the programming current/voltage have been proposed previously such as using downscaling the contact area [2], doping the phase change material [3] and using new cell structure [4]. In this paper, we proposed a new PCRAM cell structure, which is based on the improvement in thermal confinement, for lowering the power consumption.

2. Design

Conventional PCRAM cell has a confined structure as shown in Fig. 1(a). Due to its good thermal confinement, the programming current is lower when compared to a lance structure [1]. However, in this paper, a new elevated-confined PCRAM cell structure was proposed as shown in Fig. 1(b) to further improve the thermal confinement by enclosing the active region with more dielectric. This is done by reducing the bottom metal electrode of a conventional confined structure into a column and elevating the active region above it.

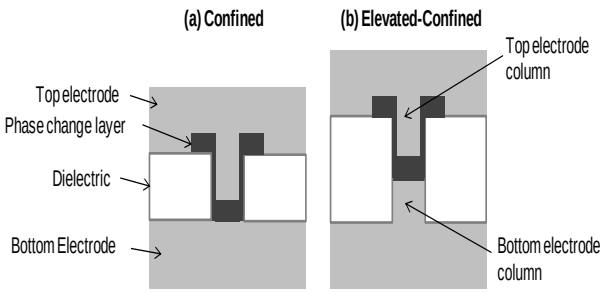

Fig. 1: Cross section schematics of a) confined and b) new Elevated-confined PCRAM cell structure

3. Simulation Results

Simulations of both conventional confined and new elevated-confined PCRAM structures were performed using Ansys thermal simulation software. Fig. 2 shows the temperature profile at the vicinity of both active regions. For the elevated-confined structure in Fig. 2b, the temperature profile is more evenly distributed at the active region and thus enabling a faster rise in temperature from all directions. Moreover, Fig 2b shows that the more heat is able to being sustained underneath the active region of an elevated-confined structure. This is due to the better thermal confinement provided by the surrounding dielectric. In addition, with the application of a 50 ns of 1.2 V, the simulated peak temperature of a conventional confined structure was 620°C whereas that of an elevated-confined structure was higher at 658°C.

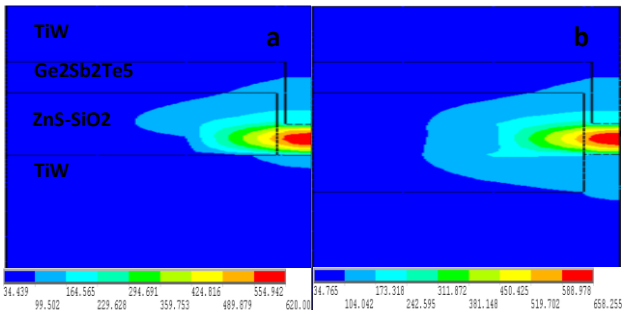

Fig. 2: Simulated temperature profile of a) conventional and b) elevated-confined PCRAM structure

4. Fabrication Process

The elevated-confined PCRAM cells were fabricated using process steps as shown in Fig. 3. First, 250 nm TiW was deposited as the bottom electrode followed by the patterning of resist pillars (diameter ranged from 350 nm to 1 um). TiW columns of 60 nm in height were fabricated by etching the samples in a reactive ion etcher. The etch gas was CF4:O2 of 30:2 sccm which provided an etch rate of 14.8 nm/min at the RF power of 80 mW. 150 nm of dielectric (ZnS-SiO2) was then deposited using an ion beam deposition system. The resist pillar was lifted off using ultrasonic bath and pores of 90 nm in height were formed. 50 nm of phase change material layer followed by a 10 nm protection TiW layer were then sputtered into the pores. Finally, 200 nm TiW was deposited as the top electrode.

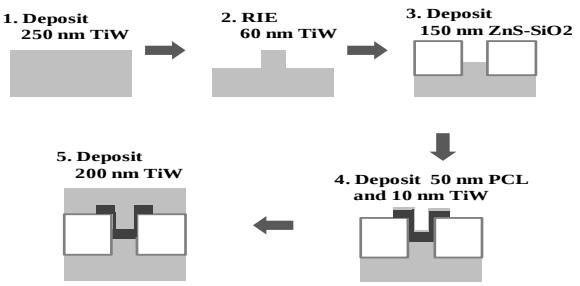

Fig. 3: Fabrication steps of elevated-confined PCRAM cell

5. Experimental Results

The fabricated PCRAM cells were tested and the results were compared with those of conventional confined structures. Both the current and voltage values of SET (polycrystalline) to RESET (amorphous) states were recorded with SET states having resistance < 50 kΩ and RESET states having resistance >1 MΩ. Fig. 4 shows the RESET power comparison of PCRAM cells having (a) conventional confined and (b) elevated-confined structures. It clearly shows that that the elevated confined PCRAM cells require lower RESET power than that of conventional ones when the contact size was ranged from 350 nm to 1 um and the voltage pulse width was varied from 5 ns to 40 ns. Fig. 5 shows that the 1um elevated confined PCRAM cells provides a reduction of 20 % in RESET power when compared to that of conventional confined PCRAM cells. This power reduction increases to 65 % when the contact size is reduced 350 nm, thus showing its excellent scalability apart from having a lower power consumption. The endurance of the elevated PCRAM cells were tested to above 1E6 as shown in Fig. 6. The IV curves (DC measurements) showing the PCRAM characteristics using were plotted in Fig.7.

6. Conclusion

Elevated-confined PCRAM cell structure was proposed and investigated. Besides having lower power consumption, it has an excellent scalability. With further tuning of the structure dimensions such as the height of the top/ bottom electrode column, the performance could be optimized and this shall be investigated.

References

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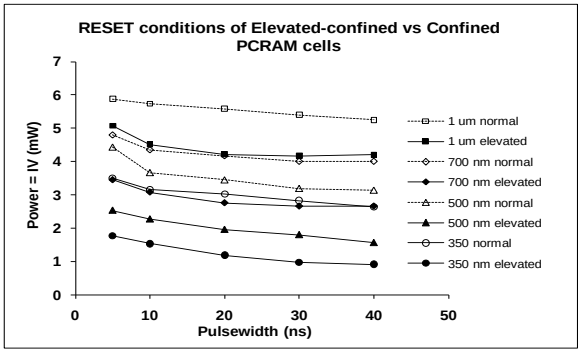

Fig. 4: RESET conditions of elevated-confined and conventional confined PCRAM cells

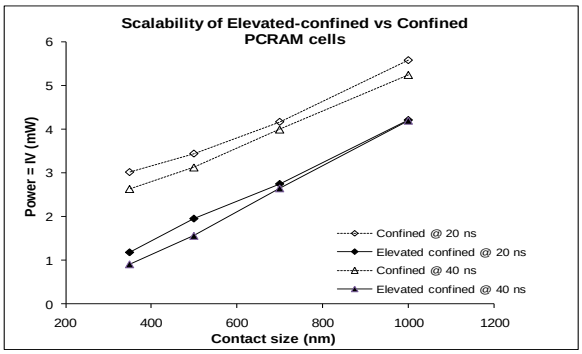

Fig. 5: Scalability of elevated-confined and conventional confined PCRAM cells

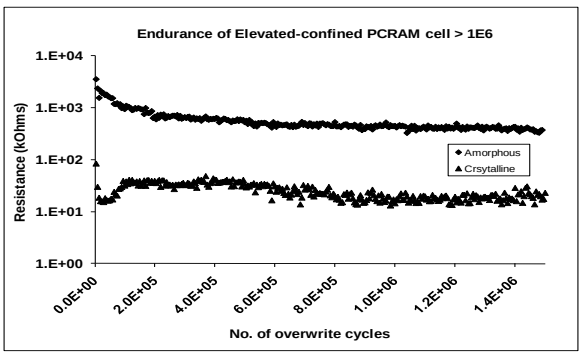

Fig. 6: Endurance of elevated-confined tested > 1E6

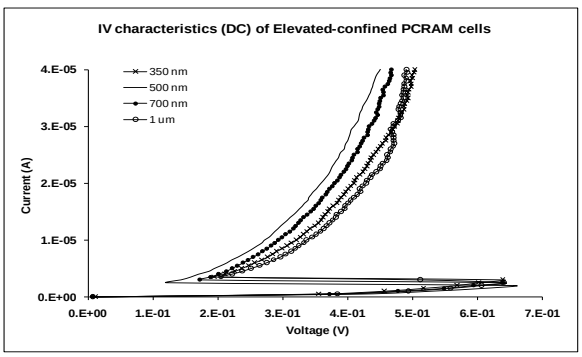

Fig. 7: IV curves (DC measurements) of elevated-confined PCRAM cells