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Highly Reliable Ring Type Contact Scheme for High Density PRAM

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Abstract

High density PRAM(Phase Change Memory) was successfully demonstrated by using advanced ring type contact scheme. This novel contact scheme generates the reduction of reset current with low set resistance and uniform cell distribution. This approach exhibits strong feasibility of high density PRAM beyond 256Mb.

Introduction

Chalcogenide based PRAM is one of the promising candidates for future memories because of its non-volatility, good scalability, fast read and write time, strong cycling performance, and excellent compatibility with current CMOS logic process [1]. PRAM uses reversible phase change of chalcogenide material ($Ge_2Sb_2Te_5$- GST), which shows two different phases such as crystalline one for a set state with low resistance and amorphous one for a reset state with high resistance. In order to perform reversible switching between two different states, we applied current pulses of different widths and heights suitable for each state. Figure 1 shows a typical I-V curve for a PRAM device in which two different TEM pictures are illustrated for the high resistive reset state and the low resistive set state, respectively. It was observed in the TEM picture for the reset state that amorphous GST fully covers the contact area, which prevents the current flow, resulting in the high resistance.

Typically, the reset writing process in PRAM device is carried out by melting down the GST films on the bottom electrode contact (BEC). Since a large cell current is required to melt down the GST, it is very important to reduce the reset current for high density PRAM device whose cell current is inversely proportional to the PRAM density. Therefore, in order to satisfy the low reset current in high density PRAM, there have been several structural and compositional efforts in the storage module [1,2]. Figure 2 shows that the reset current as small as at least 0.6mA is required for reliable operation of 256 Mb. Another critical factor for high density PRAM is the BEC area uniformity, because the reset current is directly determined by the BEC area. Thus, it is very crucial to maintain sharp contact area uniformity. Figure 3 shows the distribution of contact size for conventional pillar type BEC structure. It was found that the contact size was widely distributed over several nm ranges, resulting in functional failures, as manifested in TEM pictures. Since almost all of data can be fitted by a Gaussian distribution, the functional failure might be attributed to the accidental BEC process variation. Therefore, it is strongly desired to reduce low reset current with maintaining uniform cell distribution for high density PRAM. In this paper, ring type bottom electrode contact was proposed for achieving low reset current and uniform contact area in high density PRAM.

Ring Type Bottom Electrode Scheme

Among the approaches to be taken for scaling the reset current, the decrease of the BEC area has strong and direct influence on the reduction of reset current. As the BEC size is decreased below 40 nm in the pillar type BEC structure, the reset current was typically reduced around 0.6 mA, while the contact resistance and set resistance is greatly increased and widely distributed, as illustrated in Figure 9 and 10. Therefore, we modified the BEC structure from conventional pillar type to advanced ring type contact whose schematic view was described in Figure 4. Figure 5 shows the TEM picture of GST module after fully integration. It was observed that the ring type scheme was successfully integrated in 256 Mb PRAM device without any other process issues. Figure 6 shows the contact area variation of given contact size for two different BEC schemes. Ring type scheme shows almost a half of conventional BEC area at a given contact size and less dependency on the contact size, resulting in strong immunity to process variation.

Figure 7 shows the numerical simulations in which the reset current can be reduced to 0.57 mA for the ring type BEC scheme. This low reset current was in close agreement with the measured results of resistance-writing current (R-I) curve as shown in Figure 8. In addition, the ring type BEC scheme maintains relatively low set resistance. Figure 9 shows the distribution of set resistance in which the ring type scheme has sharper contact resistance distribution than the conventional BEC at a reset current of below 0.6mA. Figure 10 shows the correlation of reset current with set resistance. It was found that the ring type BEC scheme was less dependence of set resistance on reset current than the conventional scheme, which means the strong scalability of BEC scheme. Figure 11 shows the distribution of set and reset resistances for ring type BEC scheme. It was clearly demonstrated that ring type BEC scheme show sharper distribution, which is due to the stable BEC process variation.

Summary

Advanced ring type contact technology was developed for high density PRAM. It was clearly demonstrated that the ring type BEC scheme shows reliable cell distribution and reduces the reset current with maintaining low set resistance. Thus, the ring type BEC technology can provides reliable storage module process for high density PRAM beyond 256 Mb.

References

[1] Y.N. Hwang et al., “Writing Current Reduction for High-density Phase-change RAM,” Proceedings of IEDM, 2003

[2] C.W. Jeong et al.,“Switching Current Scaling and Reliability Evaluation in PRAM,” Proceedings of NVSMW, 2004.

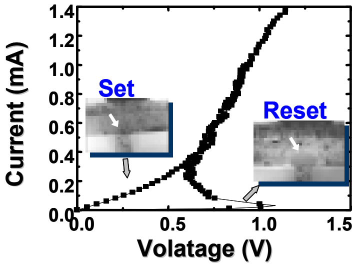

Figure1. Typical I-V curve for an PRAM device

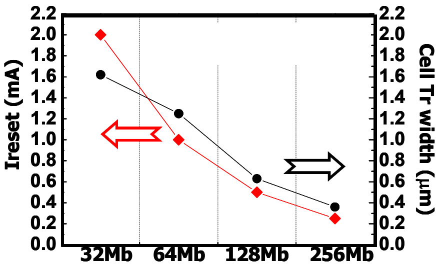

Figure 2. Ireset and cell Tr width as a function of PRAM density.

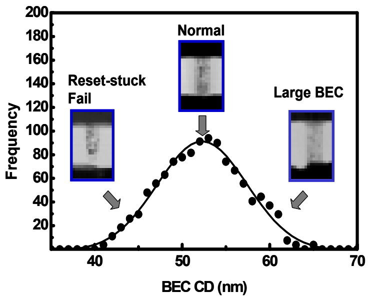

Figure 3. BEC CD variation. of conventional type BEC

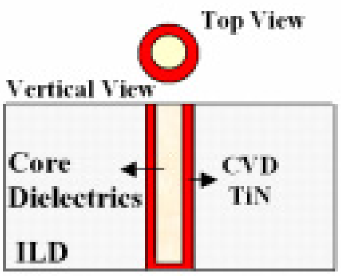

Figure 4. Schematic view of ring type BEC.

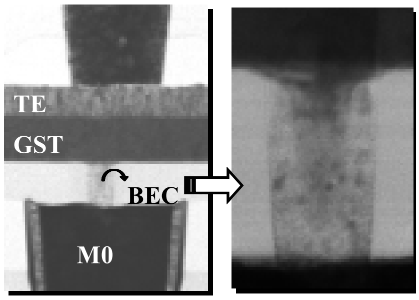

Figure 5. Final TEM picture of fully integrated 256 Mb PRAM with a ring type BEC scheme.

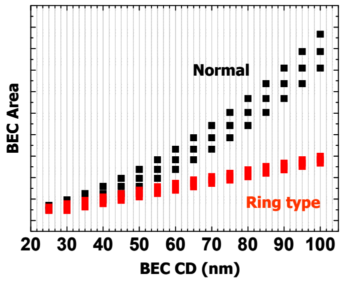

Figure 6. Variation of BEC area for conventional and ring type BEC.

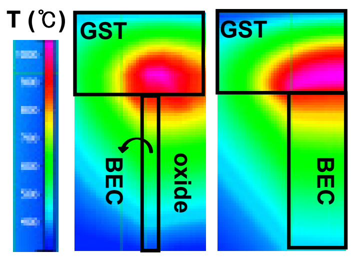

Figure 7. Simulation results of conventional and ring type BEC.

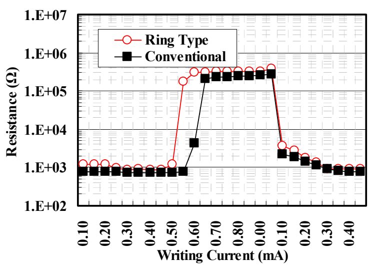

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Figure 8. R-I curve for conventional and ring type contact

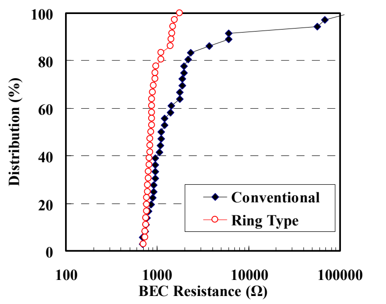

Figure 9. BEC resistance distribution for Ireset of 0.6mA

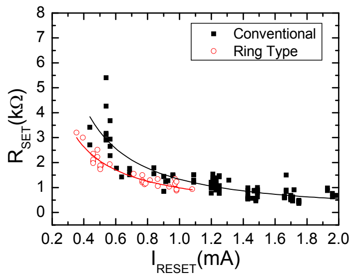

Figure 10. Rset-Ireset curve for conventional and ring type BEC

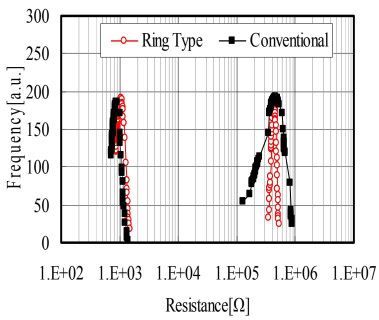

Figure 11. Fail bit distribution of 16 Mb sample cell array