Characteristics of SbTe and GeTe based Phase Change Materials in Various Confined Cell Structure

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Recently phase change random access memory (PRAM) has been extensively investigated as not only non-volatile memory field but also storage class memory which is required higher performance than the former one. The key issues for extending the application field of PRAM such as wireless system, XIP application, or computing platform are increasing the write speed and life cycle. These two features are closely related to the phase change materials and cell structure which carry it. And also phase transition characteristics of the materials are sensitively affected by cell structure. Write speed of PRAM is mostly dependent on the crystallization time of phase change materials. Accordingly, many studies have been made on fast crystallization materials. GST based materials such as $Ge_2Sb_2Te_5$, $Ge_1Sb_2Te_4$ and $Ge_1Sb_4Te_7$ shows slow crystallization above hundred of nano second so these materials are suitable for NVM applications. On the contrary, SbTe based materials (Sb_2Te_3, Sb_7Te_3) and doped GeTe based one shows fast crystallization under several tenths of nano second so these materials are promising for high speed applications [Fig. 1]. In this study, write speed and life cycles of GST, Bi doped GeTe and delta phase SbTe are compared in various PRAM cell as given in Table 1. As mentioned above, PRAM cell with Bi doped GeTe and delta phase SbTe exhibited improved SET speed up to 6 times in comparison with Ge2Sb2Te5 as shown in Fig. 2. Reset and SET margin is also two orders of magnitude except PCM#1(high Bi doped GeTe) which is reduced sensing margin with increased conductivity along with increased Bi concentration. Meanwhile, life cycle of PRAM is also important parameter to enhance the system performance. Published endurance cycle is $10^5 \sim 10^8$ and ITRS expect the higher endurance level of 10^{12} cycles after 4x nanometer technology node. Endurance cycle is degraded due to the phase segregation of phase change materials and void formation in the programming volume [Fig. 3(a)][1]. Therefore it is hard to reach the over 10^9 cycles without reset and set degradation. However, life cycle is significantly improved in confined cell structure such as dash type cell [Fig. 3 (b)][2], self aligned plug (SAP) cell [Fig. 3(c)][3] and conventional plug cell [Fig. 3(d)][4]. Especially reset/set operation for dash type cell is maintained cycle of $2x10^{11}$ [Fig. 3(a)]. This means that phase segregation and/or voiding by electro migration and/or incongruent melting[5][6] can be avoided by full melted isolated cell structure which have low heating temperature gradient and voiding and segregation source.

In conclusion, improvement of SET speed and endurance cycle in a confined cell structure with high speed materials can be accelerated the use of PRAM for DRAM-like or the storage class memory applications.

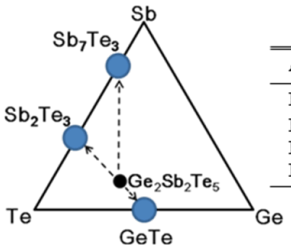

Table 1

PCM	*Composition*	*Cell Structure*
PCM#1	high Bi doped GeTe	Plug cell
PCM#2	low Bi doped GeTe	Plug cell
PCM#3	Ge2Sb2Te5	Planar / SAP cell
PCM#4	Delta phase SbTe	Dash Confined cell

FIG.1 Spread out of phase change materials from non volatile GST based chalcogenide materials

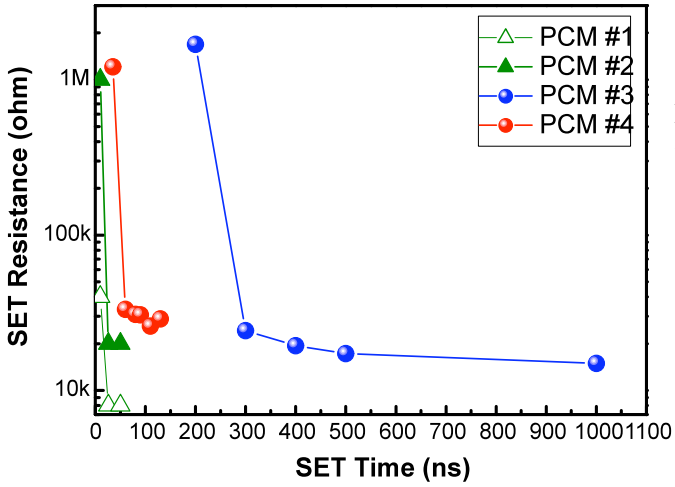

FIG.2 (a) SET speed of various phase change materials. Bi doped GeTe (PCM #1, 2) and delta phase SbTe (PCM #4) shows shorter write time than GST (PCM #3).

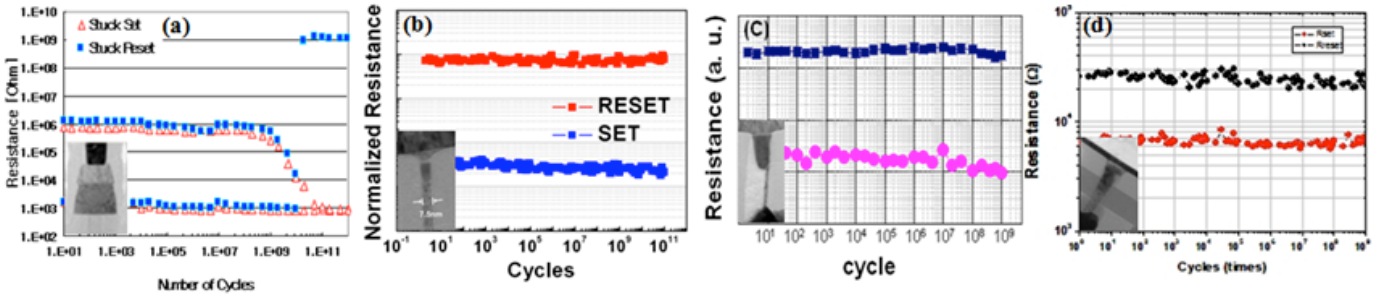

FIG.3 Cycling endurance characteristics of (a) conventional planar type cell[1], (b) dash confined cell[2], (c) self-aligned plug type cell[3] and (d) conventional plug cell[4].

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Biographies

Dongho Ahn was born in 1968. He received a B.E and M.E in electronics from Konkuk and Kyung-Hee University, Seoul, Korea, respectively. And he received a Ph.D. degree in Materials Science and Engineering with a thesis on phase change material and devices from Seoul National University, Seoul, Korea. He has been a principal engineer at Samsung Electronics since 1992. His research area has been thin film technology including chalcogenide materials for phase change memory.