Characteristics of SnSbTe (SST) Thin Films Grown by Atomic Layer Deposition for High Performance Phase Change Random Access Memory (PCRAM)

Keun Lee, Sehun Kang, Jachun Ku, Kwon Hong, and Sungki Park

NM Material Research Team, R&D Division,
SK Hynix Semiconductor Inc.,
San136-1, Ami-ri, Bubal-eub, Icheon-si, Gyeonggi-do, 467-701, Korea, e-mail) keun.lee@sk.com

Phase change random access memory (PCRAM) has attracted great interest as a candidate for next generation non-volatile devices with the meet of increasing need for high density, fast switching speed, good endurance, and compatibility with CMOS logic process. As a storage element for high performance device, low Ireset and fast phase transition speed of phase change material (PCM) are required.[1][2] In this work, physical characteristics and gap-filling performance of ALD SnSbTe (SST) films were investigated.

SST thin films were grown by thermal atomic layer deposition (ALD) using metal-organic precursors on SiN(50nm)/Si substrate. Figure 1. shows ALD SST pulse sequence which consist of [SbTe] binary and [Sn] single sub-cycle. SST film composition was controlled by the sub-cycle ratio of [SbTe, n-cycle] and [Sn, m-cycle]. SEM result (Figure 2.) shows the growth behavior of single Sn phase and the growth mode control was possible using in-situ treatment. Without in-situ treatment, island growth was shown due to heterogeneous reaction of Sn. However, continuous Sn film deposition was possible through in-situ treatment. Figure 3(a). shows the self-terminated growth behavior of ALD SbTe binary phase. Layer density and film thickness was confirmed by increasing Sb incorporation at a fixed Te exposure. The growth rate of SbTe was saturated by 0.3nm/cycle after 2.0 of Sb/Te exposure ratio. In addition, composition control of SbTe binary film was possible from 14 to 62 at% of Te by controlling Sb/Te exposure ratio. Stoichiometric Sb_2Te_3 composition window was shown in Figure 3(b) inset, from 0.2 to 0.4 Sb/Te exposure ratios. In case of Sb-rich SbTe, Sb increases and Te decreases with increasing Sb/Te exposure ratio. In Sb-Te binary system, stoichiometric Sb_2Te_3 is intermetallic compound and Sb-rich SbTe is single δ-phase from 16.4 to 36.7 at% of Te.[3]

Figure 4. shows TEM cross-section image of ALD SST films with increasing Sn composition at a fixed Sb/Te composition ratio. Figure 4(a) Sn~33at% and figure 4(b) Sn~40at% SST films show nano-mixed phase and as-deposited amorphous phase was confirmed by XRD. (XRD data is not shown here.) However, phase segregation was shown in case of Sn~49at% (figure 4.(c)) and the segregated phase size was increased with increasing Sn composition. (Figure 4(d) and 4(e)) This phenomenon is due to the agglomeration of single Sn as shown in Figure 1(a) and Sn composition optimization is required for hole-filling of SST film.

Figure 5. shows the cross-sectional TEM image of confined cell structure and the cell dimension is 15nm. (Aspect ratio~6.7:1) Confined cell was completely filled with ALD SST film and it shows good gap-filling performance without physical void or seam.

Electrical and physical phase transition properties of ALD SST will be discussed.

Reference

[1] C.M. Lee et al., VLSI Tech. (2007)
[2] T.J. Park et al., Thin Solid Films 515 (2007) 5049
[3] G. Ghosh, J. Phase Equilibria, 15 (1994) 349

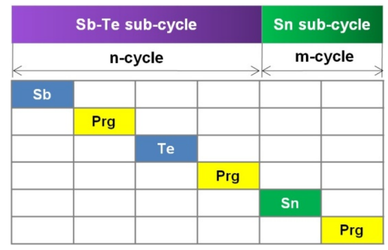

Figure 1. ALD SST pulse sequence consist of [SbTe]-[Sn] super-cycle. Composition was controlled by ratio of n-cycle and m-cycle. (n/(n+m) or m(n+m))

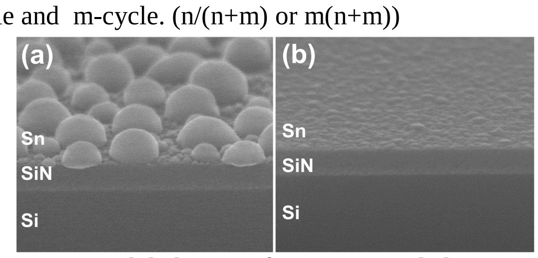

Figure 2. Growth behavior of ALD Sn single by SEM (a) without *in-situ* treatment, (b) with *in-situ* treatment

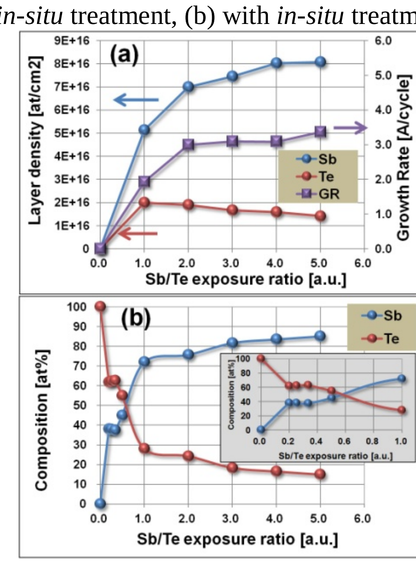

Figure 3. Growth behavior of ALD SbTe binary (a) Self-terminated reaction, GR~0.3nm/cycle, (b) Composition control by Sb/Te exposure ratio (inset: ratio from 0 to 1.0)

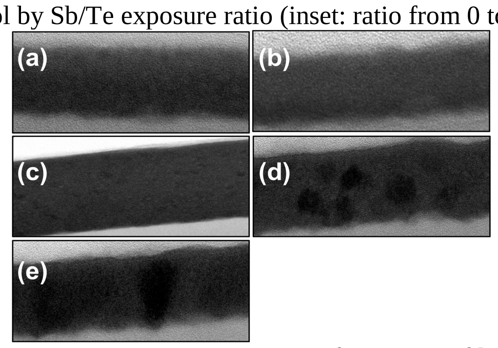

Figure 4. TEM cross-section image of ALD SST films (a) Sn~33at%, (b) Sn~40at%, (c) Sn~49at%, (d) Sn~62at%, (e) Sn~68at%, Sb/Te composition ratio was fixed.

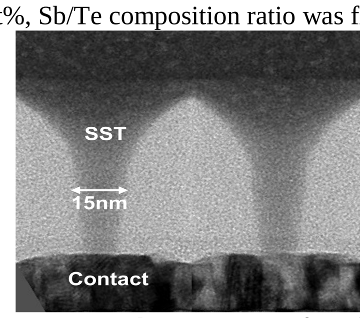

Figure 5. Cross-sectional TEM image of confined cell structure filled with ALD SST film