Journal of Alloys and Compounds 664 (2016) 591–594

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

Uniform silicon carbide doped Sb_2Te nanomaterial for high temperature and high speed PCM applications

Yun Meng [a, b], Qiuming She [c], Liangliang Cao [b], Yan Chen [c], Peigao Han [a, *], Zhitang Song [b], Bo Liu [b], Liangcai Wu [b, **], Lianke Song [a]

[a] Shandong Province Key Laboratory of Laser Polarization and Information Technology, School of Physics and Engineering, Qufu Normal University, Qufu, 273165, PR China
[b] State Key Laboratory of Functional Materials for Informatics, Laboratory of Nanotechnology, Shanghai Institute of Micro-system and Information Technology, Chinese Academy of Sciences, Shanghai, 200050, PR China
[c] School of Environmental Science and Engineering, Donghua University, Shanghai, 201620, PR China

ARTICLE INFO

Article history:
Received 30 October 2015
Received in revised form
29 December 2015
Accepted 5 January 2016
Available online 6 January 2016

Keywords:
Uniform nanomaterial
Thin film
Rapid transition
Thermal stability

ABSTRACT

Sb–Te alloy is widely considered as one of the important materials for phase change memory (PCM) with fast operation speed. However, the poor amorphous phase stability limits its wide application. In this work, silicon carbide (SiC) doped Sb_2Te (Sb_2Te-SiC) nanomaterial was proposed to improve the thermal stability of Sb_2Te. It was found that the crystallization temperature of Sb_2Te was remarkably improved from 149 °C to 251 °C. Accordingly, the temperature for 10-year data retention increases from 56.5 °C to 156.4 °C. X-ray diffraction and transmission electron microscope results indicate that the grain size of Sb_2Te-SiC film was largely reduced with SiC doping. Besides, experimental results show the Sb_2Te-SiC nanomaterial is very uniform and no phase separation was observed even after 300 °C annealing. Furthermore, the Sb_2Te-SiC nanomaterial based PCM cells show fast operation speed of 7 ns and good endurance ability of 2.1×10^4 cycles.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Among the emerging nonvolatile memories, phase change memory (PCM), as the most promising one, is attracting more and more attention. Compared with the other nonvolatile memories, PCM has high scalability, high density and high switching speed [1–3]. In a PCM cell, data storage is achieved by exploiting a reversible phase change between RESET state (high-resistive amorphous state) and SET state (low-resistive crystalline). $Ge_2Sb_2Te_5$ (GST) is the most popular compound for PCM applications, but low crystallization temperature and inferior crystallization speed prevent its application in high thermal stability and high speed PCM [4,5].

As its growth-dominated crystallization mechanism, Sb_2Te show high speed for PCM applications [6,7]. However, the low crystallization temperature (<100 °C) leads unstable amorphous state, which limits its wide application in PCM [8]. Intense research efforts have been made to address the poor amorphous stability, such as doping Ti [9], Al [10], Ga [11] Cu [12] and W [13], into Sb–Te alloys materials, which effectively improve the amorphous thermal stability. Besides various element doping, compound doping is also an effective method to improve the properties of Sb–Te alloy. In our previous work, we have studied SiO_2 doped Sb_2Te material, which increases the thermal stability of Sb_2Te material [14]. However the oxygen elements will oxidize the Sb and Te elements inevitably, deteriorating the reversible phase change ability. For those reason, non-oxygenated compounds should be selected as dopant. In this work, silicon carbide (SiC) doped Sb_2Te (Sb_2Te-SiC) nanomaterial was proposed to improve the thermal stability of Sb_2Te. With SiC doping, the crystallization temperature could be 251 °C and the temperature for 10-year data retention is 156.4 °C, which show the excellent amorphous phase stability of Sb_2Te-SiC nanomaterial. No new phase except Sb_2Te was observed in X-ray diffraction (XRD) result, indicating Sb_2Te-SiC nanomaterial is a uniform structure. Transmission electron microscope (TEM) results also show the SiC doped Sb_2Te nanomaterial is very uniform and the grain size are obviously reduced. What's more, the 7 ns operation speed proves

* Corresponding author.
** Corresponding author.
E-mail addresses: hanpeigao@126.com (P. Han), wuliangcai@mail.sim.ac.cn (L. Wu).

http://dx.doi.org/10.1016/j.jallcom.2016.01.036
0925-8388/© 2016 Elsevier B.V. All rights reserved.

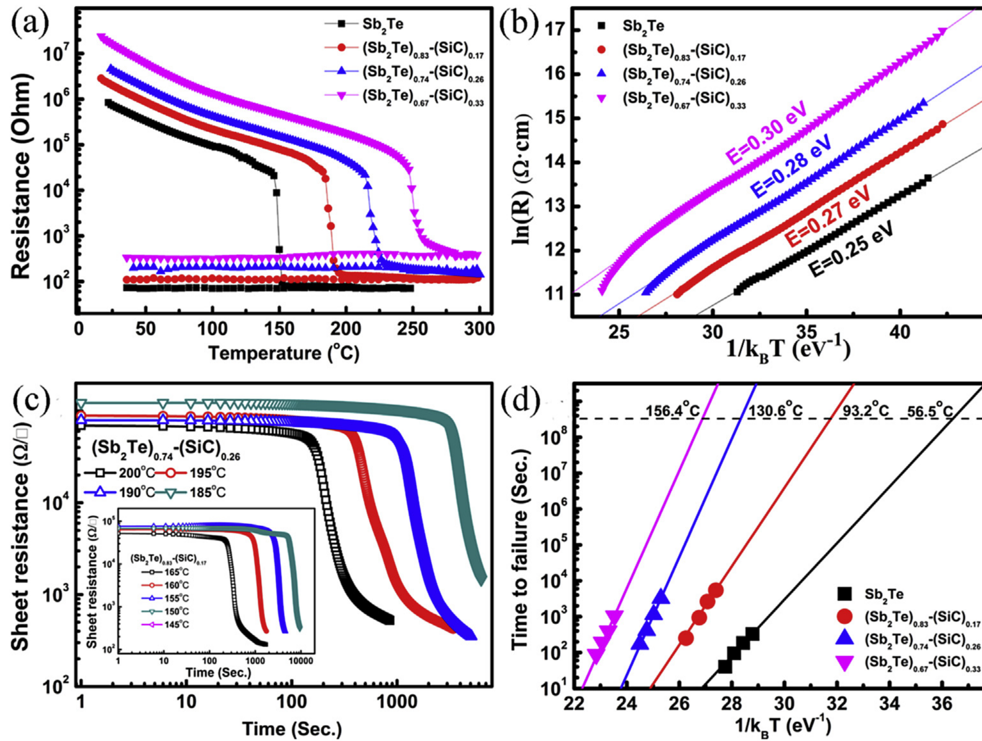

Fig. 1. (a) Sheet resistance of Sb_2Te and Sb_2Te-SiC films with the heating rate of 20 °C/min as a function of the temperature; (b) the linear fitted curves based on logarithmic resistivity versus reciprocal temperature in amorphous state; (c) the isothermal plots with the change of resistance as the time for $(Sb_2Te)_{0.74}$-$(SiC)_{0.26}$ films and insert is that for $(Sb_2Te)_{0.83}$-$(SiC)_{0.17}$; (d) plot of the failure time for 10-year data retention.

the fast operation ability of Sb_2Te is not affected by SiC doping.

2. Experiment

~150 nm thick thin films were deposited on Si/SiO_2 substrate and carbon membrane substrates by co-sputtering Sb_2Te target and SiC target at room temperature. The sputtering power applied to Sb_2Te target was fixed at 20 W, while that to SiC target was 0 W, 15 W, 30 W and 50 W. The compositions of the deposited films were determined using energy dispersive X-ray spectroscopy (EDS). We marked those four different compositions films as Sb_2Te, $(Sb_2Te)_{0.83}$-$(SiC)_{0.17}$, $(Sb_2Te)_{0.74}$-$(SiC)_{0.26}$ and $(Sb_2Te)_{0.67}$-$(SiC)_{0.33}$. Sheet resistivity depending on temperature measurements was measured in a vacuum chamber at a heating rate of 20 °C/min. The crystalline structure were measured by X-ray diffraction (XRD) using Cu Ka radiation in the 2θ range of 20°–60°. Different composition films annealed at 300 °C in N_2 atmosphere for 5 min was used to demonstrate the microstructure by TEM in bright field, high-resolution transmission electron microscope (HRTEM) and selected area electron diffraction (SAED). In order to perform device testing, T-shaped PCM devices were fabricated by a 0.13 μm CMOS technology. Then, 50 nm thick PCM layer was deposited on the W bottom electrode with 190 nm in diameter. Finally, 20-nm-thick TiN and 300-nm-thick Al were deposited as adhesion layer and top electrode, respectively. Resistance–voltage (R–V) measurements and current–voltage (I–V) curves were carried out by Tektronicx (AWG-5002B) and Keithley 2600 m.

3. Results and discussions

Fig. 1(a) shows the sheet resistivity (R_S) of Sb_2Te and Sb_2Te-SiC films as a function of temperature at a heating rate of 20 °C/min. The initial states of those films are as-deposited amorphous phases. With the temperature arising, the resistance of the films decreases. The crystallization temperature (T_c) is determined by the minimum of first derivative of dR/dT. The T_c goes up from 149 °C to 251 °C with SiC centration increasing. The higher T_c will greatly enhance the amorphous thermal stability. Activation energy (E_σ) is an important factor showing the thermally activated transport behavior. Based on the equation: $\sigma = \sigma_0 \exp(-E_\sigma/k_BT)$ (where σ_0 is a pre-exponential factor and E_σ is the activation energy), the value of E_σ could be calculated. As shown in Fig. 1(b), with the SiC concentration increasing, E_σ increases from 0.25 eV to 0.30 eV.

Thermal stability can also be evaluated by data retention. It can

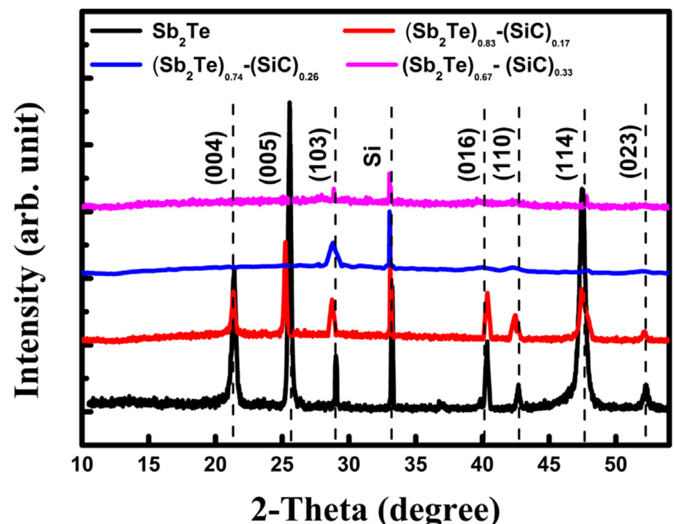

Fig. 2. XRD patterns of Sb_2Te and different composition Sb_2Te-SiC films.

Download English Version:

https://daneshyari.com/en/article/1607181

Download Persian Version:

https://daneshyari.com/article/1607181

Daneshyari.com