GST, GeTe and C-doped GeTe materials for Phase Change Memory cells

V. Sousa, L. Perniola, A. Fantini, G. Betti Beneventi, E. Gourvest*, S. Loubriat, A. Bastard*, A. Roule, A. Persico, H. Feldis*, A. Toffoli, D. Blachier, S. Maitrejean, B. Hyot, J. F. Nodin, C. Jahan, G. Reimbold, T. Billon, B. André, B. De Salvo, F. Boulanger, S. Lhostis*, P. Mazoyer*, D. Bensahel*, P. Zuliani*, R. Annunziata*

CEA, LETI, MINATEC, F38054 Grenoble, France
* STMicroelectronics, Central R&D, 850 rue Jean Monnet, F-38926 Crolles Cedex, France
Mail to: veronique.sousa@cea.fr

ABSTRACT

In this paper, we report on the properties of various phase change materials, namely GST, GeTe and GeTeC, for non volatile memory applications. As expected from thin films characterization, the high temperature data retention properties of the memory cells are improved when going from GST, to GeTe and hereafter GeTeC. The higher set speed of GeTe and the lower reset current of GeTeC are also highlighted.

Key words: Phase Change Memories (PCM), data retention, GST, GeTe

1. INTRODUCTION

Phase Change Memories (PCM) are one of the most promising concepts for the future generations of Non Volatile Memories. Several decades focused on technological developments have led to the set-up of highly competitive PCM demonstrators [1, 2]. Extensive work is nowadays performed on the Phase Change Materials to optimize the cell properties for specific applications. In particular, for the embedded memory market, it is desirable to reduce the writing current while automotive applications require enhancing the high temperature data retention. With the phase change material commonly used for PCM memories (namely $Ge_2Sb_2Te_5$ referred to below as GST), a 10 years data retention cannot be ensured above 85°C [1, 2]. In this paper, we propose a comparative assessment of GST, GeTe and C-doped GeTe phase change materials and memory cells, based on results previously reported [3, 4, 5, 6]. The crystallization temperature and activation energy for crystallization of the materials have been evaluated from optical reflectivity or electrical resistivity measurements on thin films deposited by RF sputtering. For the memory cell characterization, the reset current, set speed, or data retention properties have been evaluated on simple pillar type-resistor.

2. GeTe versus GST

The first part of our study is devoted to the characterization of GST and GeTe materials and memory cells. As seen on the optical reflectivity and electrical resistivity measurements versus temperature, GeTe clearly exhibits a higher crystallization temperature than GST, together with a higher resistivity contrast between the amorphous and the crystalline phase. The activation energy for crystallization being unchanged, the extrapolated temperature for a 10 years fail time, as evaluated on thin films, is hereafter increased by about 30°C (Fig. 1). As for basic memory cell properties, the R(I) curves (Fig. 2) confirm that GeTe based cells have a higher contrast than GST cells, resulting from the lower SET resistance. While the reset currents are in the same range, an other interesting feature of GeTe-based cells is the higher SET speed as compared to the one of GST-based cells. Finally, the achievement of a given fail time is performed at higher temperature with GeTe than with GST (Fig. 3), thus forecasting better high temperature retention properties.

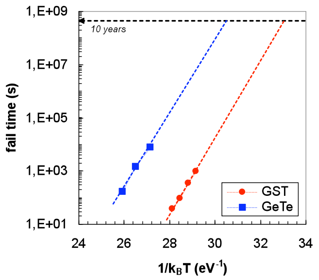

Figure 1: Fail time versus $1/k_BT$ for GST and GeTe thin films.

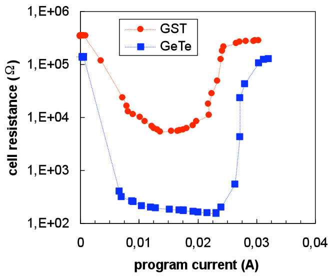

Figure 2: Resistance versus program current for GST and GeTe cells.

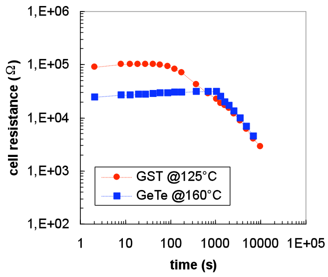

Figure 3: Resistance versus time for GST @125°C and GeTe cells @160°C.

3. GeTeC versus GeTe

The second part of our study is devoted to the comparative assessment of GeTeC versus GeTe materials and memory cells. Thin films characterization shows that C-doping into GeTe leads to increased crystallization temperatures, together with increased activation energies for crystallization (Fig. 4). We hereafter can expect a pronounced increase of the maximum allowed temperature for a 10 years fail time. As for the performances of simple resistor devices, the R(I) curve shows that C-doping induces a pronounced reset current reduction (Fig. 5), whereas better retention properties have been confirmed at 170°C (Fig. 6). However, C-doping also leads to a decreased contrast and to a lower set speed with respect to GeTe, the set speed of GeTeC being hereafter comparable to the one of GST.

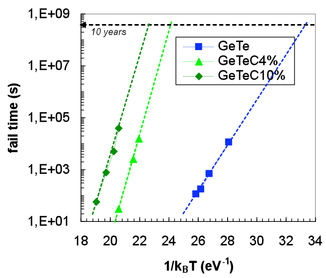

Figure 4: Fail time versus $1/k_BT$ for GeTe, GeTeC4% and GeTeC10% films.

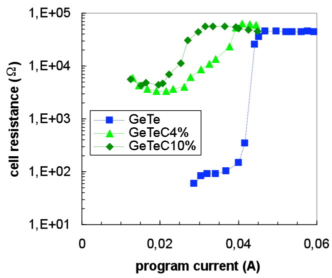

Figure 5: Resistance versus program current for GeTe, GeTeC4% and GeTeC10% memory cells.

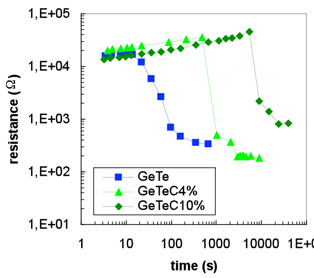

Figure 6: Resistance versus time for GeTe, GeTeC4% and GeTeC10% cells @170°C.

4. CONCLUSION

We have shown how it is possible to improve the data retention properties at high T thanks to phase change materials variations and we believe there is still some margin to achieve aggressive specifications, for example the 10 years data retention at 150°C as driven by automotive applications. Meanwhile, we have highlighted that materials variations also impact other memory cell performances, e.g. the set speed or the reset current, so that compromises between several targeted specifications might be necessary.

REFERENCES

1. J.H. Oh et al., « Full Integration of Highly Manufacturable 512Mb PRAM based on 90nm Technology », IEDM (2006)
2. G. Servalli, « A 45nm Generation Phase Change Memory Technology », presented at IEDM (2009)
3. A. Fantini et al., « Comparative assessment of GST and GeTe Materials for application to embedded Phase Change Memory devices », presented at IMW (2009)
4. L. Perniola et al., « Electrical behavior of Phase Change Memory cells based on GeTe », IEEE Electron Devices Lett., Vol. 31, No. 5, pp. 488-490 (2010)
5. G. Betti Beneventi et al., « On carbon doping to improve GeTe-based Phase Change Memory data retention at high temperature », IEEE International Memory Workshop, pp. 21-24 (2010)
6. G. Betti Beneventi et al., « Carbon doped GeTe Phase Change Memory featuring remarkable reset current reduction », accepted for presentation at ESSDERC (2010)

BIOGRAPHY

Véronique Sousa graduated in 1994 from the Institut National Polytechnique de Grenoble (INPG) in the field of Materials Science and Engineering. During her PhD, which she received in 1997 from the INPG, she worked on the experimental and fundamental aspects of magnetic thin films with perpendicular anisotropy and spent a 3 months stay at the Electrotechnical Laboratory, in the group of Prof. Katayama, to work on magneto-optics. Afterwards, she took a one-year post-doctoral position at INESC in the group of Prof. P. Freitas, and worked on various thin film materials used for magnetic data storage devices such as permanent magnets, spin valves or tunneling junctions. Since October 1998, she is working at CEA-LETI-MINATEC where she first focused on the development of advanced magneto-optical and phase change materials for optical data storage. Hereafter, she managed several projects aiming at the optimization of chalcogenide materials for various solid state memory technologies, namely CBRAM and PCRAM.