PhD subject in Material Science

CEA LETI / LMGP **Grenoble (France)**

"Dimensional effect on phase transition in materials for phase change memories"

PhD Topic:

The general context

As stated in various technological review papers [i] [ii] [iii], new concepts will be needed to fulfill the requirement of memory devices architectures in the near and long terms. The limitation of electronic charging with scaling request to research on new storage concepts: storing information via different resistive states is a very promising approach. Phase Change Random Access Memory (PCRAM) attracts great interest as illustrated by (i) the increasing number of technological papers published in major microelectronics conferences in recent years, and (ii) major industrial memory players announcements of PCRAM prototyping[iv] [v].

The concept of PCRAM was first proposed in the late 60's [vi]. It uses the reversible phase change between the crystalline and the amorphous state of specific materials, such as $Ge_2Sb_2Te_5$ (GST) [vii]. The crystalline GST has a low resistivity and the amorphous GST has a high resistivity, which correspond to the data "0" (crystalline) and data "1" (amorphous). In PCRAM cells, the reversible switching between these two states can be achieved by applying a short and high current pulse for the transition from the crystalline to the amorphous state (reset process) and a relatively long and low current pulse for switching from the amorphous to the crystalline state (set process). During the reset process, there is a phase transition between crystalline and liquid phases. Then the liquid is vitrified in an amorphous state. During the set process, fast crystallization of the amorphous phase occurs. The fast crystallization speed is an important property of phase change materials.

Due to their applications in optical recording since the early 70s, phase change materials, mainly chalcogenides compound from the $GeTe$-Sb_2Te_3 pseudo binary phase diagram, have been the subject of extensive studies (see for example the review by Wuttig et al. [viii]). Nowadays, the principles of high speed phase transformation are still subject to research[ix] [x] [xi]. Moreover, specific phase change materials and nano-dimensional phase change switching [xii] [xiii] are needed to fulfill the requirements of PCRAM. As stated in a recent publication: "More research is required to fully understand the complex crystallization mechanisms of GST thin films and nanostructures" [xiv].

This is the general context of the proposed work.

The local context

LETI is involved in industrial programs to focus on the development of phase change memories. The final goal is the transfer of these technologies to industrial partners.

LMGP has a long experience in the study of phase transition in various systems.

LETI and LMGP are leader and key partners of a local research network which includes 5 laboratories: PERCEVALL (Phase changE Ramdom aCcess mEmory : Validation of material smALl scaLe effect). The study of phase structure and transformation at nano-scale in PCRAM materials is the subject of this project. Through the local laboratory cooperation, the network covers areas from sample preparation to physical analysis through characterizations and modeling.

The program is sponsored by the Nanosciences Foundation (http://www.fondation-nanosciences.fr).

The PhD objectives and tasks

Within this context, the main objectives of the PhD student will be:

(i) the determination and the understanding of local structure of amorphous and crystalline materials used in PCRAM

(ii) The study of dimensional effect on local structure and phase transition.

To achieve these objectives several tasks must be completed. From an experimental point of view, they mainly consist on the definition and on the advanced characterization of nano-sized samples. The major part of the elaboration will be performed by various partners of PERCEVALL project:

- Extensive physico-chemical characterizations will be completed (ie X-ray diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), x-ray photoelectron spectroscopy (XPS), Raman spectroscopy …). Various in situ characterizations are available (XRD, reflectivity…).
- When required, characterizations using large scale facilities will be performed (Synchrotron radiation, Neutron scattering…).
- Additionnally, electrical characterization of nano-devices will be performed and analyzed, in close collaboration with the Electrical Characterization and Modeling Group of CEA-LETI
- Using these results, the candidate shall obtain a good physical understanding of chalcogenide behavior. This understanding will be useful for physical modelling of the phase-change memory electrical behaviour.

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Applicant:

Candidates with strong background in materials science with an interest for advanced characterization techniques. Ability to interact with a diverse group of people is required.
The applicants Master's degree must have been completed outside of France.
The position is for 3 years. The successful applicant will be granted a salary by the Nanosciences Foundation.
The applicant should send CV and contact details for references preferably by e-mail to:

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General informations:

The two laboratories, LETI and LMGP, are located within MINATEC campus (Grenoble, France). The MINATEC innovation campus is is located at the crossroads of three mountain ranges in the heart of the French Alps. It is the home to 2,400 researchers, 1,200 students, and 600 technology transfer experts on a state-of-the-art 20-hectare campus offering 10,000 square meters of clean room space, at foot distance from large scale facilities (X-ray synchrotron at ESRF or neutron scattering at ILL or LLB). An international center for micro and nanotechnologies, the MINATEC campus is unlike any other research facility in Europe.
http://www.minatec.com

LETI is a CEA laboratory. It is one of the main European applied research centers in electronics. More than 85% of its activity is devoted to research that is conducted with outside partners. The main areas of activity are micro/nano-technologies and design for microelectronics, microsystems, biology and health, communication technologies and nomad objects. LETI is endowed with an annual budget of 174 M€ and employs 1,000 people with, in addition, more than 500 external collaborators (postgraduates, research partners and industrialists). The production of new materials and the implementation of these materials in production processes are among the LETI's major innovation activities. State-of-the-art 200 and 300 mm wafer technologies contribute towards our research activities. The LETI nanocharacterisation platform has a large range of advanced characterization tools.
http://www-leti.cea.fr/

The « Laboratoire des Matériaux et du Génie Physique » (LMGP) is an academic laboratory belonging to the « Centre National de la Recherche Scientifique » (CNRS) and to Grenoble Institut Polytechnique (Grenoble INP). The staff consists of 80 persons. Research currently carried out at LMGP concerns many aspects of material science including elaboration, structure and properties of many kinds of functional materials with applications in micro and nanotechnologies, energy, optics and biotechnology. Many different characterization techniques (X-ray diffraction, Raman spectroscopy, transmission electron microscopy.....) are mastered by LMGP staff. Researchers from LMGP are also regular users of large scale facilities.
http://www.lmgp.inpg.fr/

References:

[i] Goronkin, H. and Y. Yang (2004). "High-performance emerging solid-state memory technologies." MRS Bulletin 29(11): 805-808.
[ii] Bez, R. and A. Pirovano (2004). "Non-volatile memory technologies: emerging concepts and new materials." Materials Science in Semiconductor Processing 7(4-6): 349-355.
[iii] Burr, G. W., B. N. Kurdi, et al. (2008). "Overview of candidate device technologies for storage-class memory." Ibm Journal of Research and Development 52(4-5): 449-464.
[iv] Oh, J. H., J. H. Park, et al. (2006). Full Integration of Highly Manufacturable 512Mb PRAM based on 90nm Technology. IEEE International Electron Devices Meeting, 2006. IEDM '06
[v] "Numonyx begins commercial supply of phase-change memory" EETimes, 12/19/08
[vi] Ovshinsky, S. R. (1968). "Reversible Electrical Switching Phenomena in Disordered Structures." Physical Review Letters 21(20): 1450.
[vii] Lankhorst, M. H. R., B. Ketelaars, et al. (2005). "Low-cost and nanoscale non-volatile memory concept for future silicon chips." Nature Materials 4(4): 347-352.
[viii] Wuttig, M. and N. Yamada (2007). "Phase-change materials for rewriteable data storage." Nature Materials 6(11): 824-832.
[ix] Kolobov, A. V., P. Fons, et al. (2004). "Understanding the phase-change mechanism of rewritable optical media." Nature Materials 3(10): 703-708.
[x] Privitera, S., S. Lombardo, et al. (2007). "Phase change mechanisms in Ge2Sb2Te5." Journal of Applied Physics 102(1).
[xi] Hegedus, J. and S. R. Elliott (2008). "Microscopic origin of the fast crystallization ability of Ge-Sb-Te phase-change memory materials." Nat Mater 7(5): 399-405.
[xii] Chen, Y. C., C. T. Rettner, et al. (2006). Ultra-Thin Phase-Change Bridge Memory Device Using GeSb. IEEE International Electron Devices Meeting, 2006. IEDM '06. .
[xiii] Im, D. H., J. I. Lee, et al. (2008). A unified 7.5nm dash-type confined cell for high performance PRAM device. IEEE International Electron Devices Meeting, 2008. IEDM 2008. .
[xiv] Raoux, S., J. L. Jordan-Sweet, et al. (2008). "Crystallization properties of ultrathin phase change films." Journal of Applied Physics 103(11): 114310-7.