I. Physikalisches Institut (IA)
Physik neuer Materialien

I. Physikalisches Institut (IA)
Phasenwechselmaterialien
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Topic for a Master Thesis

Thermodynamics and kinetics of Phase-change Materials

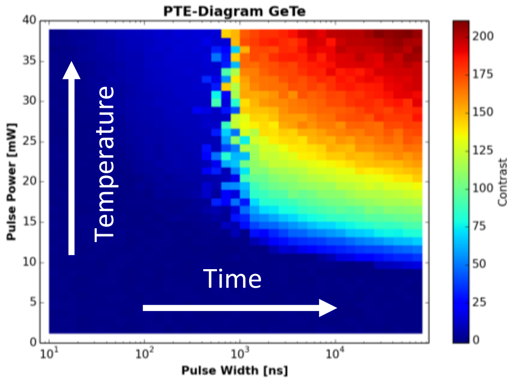

Fig.1 “Effective TTT” diagram determined using laser-measurements for a PCM alloy.

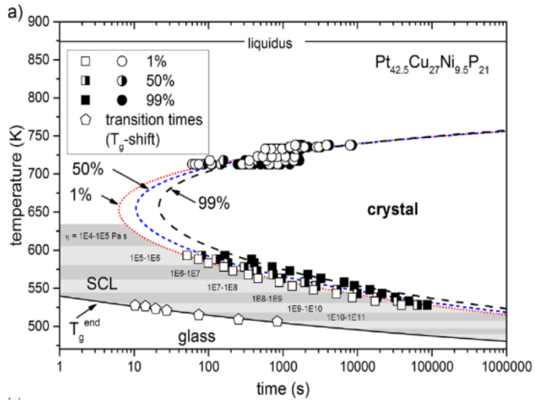

Fig.2 The TTT diagram determined using calorimetry for a bulk metallic glass (ref.2).

Background

Phase-change materials (PCMs) are at the cutting edge of electronic material research for computer memory technology as PCMs can be reversibly switched between the amorphous and crystalline states [1]. The concept of using the strong optical/electrical contrast between these two states in combination with the ultrafast switching in PCMs for data storage has long been pursued by researchers. The fundamental, physical understanding of PCMs is driving technological innovations in information technology. One striking example for commercial use of PCMs is the Intel OPTANE memory, based on PCMs and launched in 2017. This study will focus on the thermodynamics and kinetics of PCMs for a better understanding of the phase switching phenomena.

Goals

We aim to establish the time-temperature-transformation (TTT) diagram for PCMs. From the TTT diagram, we can gain the knowledge of crystallization processes at a given temperature and a given timescale. By analyzing the TTT-diagram, the interfacial energy between the amorphous and the crystalline phases can be extracted, which is a key parameter for modeling the crystallization processes [2]. Gaining this knowledge represents a significant advance for the field. These results could be published in peer-reviewed scientific journals.

Methods

The project involves mainly around two experimental techniques. The applicant will prepare the PCM samples via Magnetron-Sputter-Deposition and perform conventional (and ultrafast) differential scanning calorimetry measurements to study the crystallization processes at different temperatures and timescales. The obtained information will be compared to the results obtained from the second technique, using a laser-melt-quench setup. Combining those two techniques, one can obtain the TTT diagram even for those PCMs which crystallize on a nanosecond timescale.

Expected results & Scientific impact

The TTT diagram has been a well-established thermodynamic approach to the understanding of phase transformations and crystallization. For instance, it has been determined for various amorphous metals (i.e. bulk metallic glasses) to understand their glass forming abilities (crystallization propensity) [2]. However, few has been done for PCMs so far, because the well-established techniques are not sufficiently fast to capture the information of fast crystallization of PCMs. Now, taking the new approach, combining laser and novel calorimetry techniques, we expect to establish the first TTT diagram for PCMs and extract the interfacial energy for these materials. The results would be of potentially large impact on the understanding of PCM thermodynamics, which may lead to one or two publications on this study.

References

[1] M. Wuttig and N. Yamada, Nat Mater **6**, 824 (2007).
[2] O. Gross, S. S. Riegler, M. Stolpe, B. Bochtler, A. Kuball, S. Hechler, R. Busch, and I. Gallino, Acta Mater. (2017).

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