Study of GeTe and Sb_2Te_3-GeTe alloys by time resolved XANES

R.-N. Wang,1 J. E. Boschker,1 V. Bragaglia,1 A. Giussani,1 R. Calarco,1
1 Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany
L. Le Guyader,2 M. Beye,2 I. Radu,2 K. Holldack,2
2 Helmholtz-Zentrum Berlin für Materialien und Energie GmbH
Hahn-Meitner-Platz 1 D-14109 Berlin
P. Fons,3 A. V. Kolobov3
3 Nanoelectronics Research Institute, AIST, Tsukuba Central 4, Higashi 1-1-1 Tsukuba, Ibaraki 305-8562, Japan

ABSTRACT

Time-resolved pump-probe x-ray absorption near edge structure (XANES) was performed on crystalline GeTe and Sb_2Te_3-GeTe alloy (GST) samples with an excitation slightly below the amorphization threshold to study the dynamics behind the optical switching. Although a clear difference in the absorption spectra could be measured by static XANES between the crystalline and optically-amorphized phases, no noticeable trend could be observed with the pump-probe experiments. In the case of the GeTe sample, it was concluded that the sample was deteriorated or amorphized by the repeated laser pulses during measurement. With GST, the sample remained stable under femtosecond excitation, but with the chosen excitation power, the changes induced in the electronic structure most probably happened at a shorter time scale.

Key words: GeTe, GST, XAS, XANES, pump-probe, time-resolved

Quasi-binary Sb_2Te_3-GeTe alloys (GST) are considered to be the most promising materials for phase-change electrical data storage applications. Despite the widespread usage of these materials as optical data storage, the fundamental physical mechanism underlying the switching process is not fully understood yet, and several models are currently discussed and debated. These models need to be verified experimentally by the precise determination of the bond coordination during phase transformation. Statically, by XANES on GeTe near the Ge-L3 edge, tetrahedrally coordinated Ge sites of the amorphous phase can be discriminated from the octahedral sites in the crystalline phase by a difference in the absorption spectrum.[1] The aim of the present study is to exploit dynamical changes of the absorption signal by time-resolved experiments.

In the present study, crystalline GeTe and GST226 were deposited epitaxially by molecular beam epitaxy (MBE) on 5µm thick Si(111) membranes. Static XANES was measured on both materials to find the most suitable probing energy; where the crystalline and the optically-amorphized phases show the largest contrast in absorption. Then, the optimal pumping laser power was determined by a constant delay and probing energy measurement. The goal was to choose an excitation power as close as possible to the amorphization threshold, but still low enough so that the structure fully recovers between each pulse. Finally time-resolved pump-probe XANES measurements in transmission were performed with the parameters determined above.

Figure 1 shows the normalized ratio between the x-ray transmission spectra of the amorphous and crystalline GeTe near the Ge-L edge. Same experiments for GST near the Ge and Sb/Te edges were performed. These measurements show that static XANES can be measured in transmission on such samples grown by MBE on Si(111) membranes.

In the pump-probe experiments on the GeTe sample, it has been noticed that after 20 scans, a change in contrast could be seen by eye at the position of the laser spot. More so, Figure 2 shows the averaged ratio between the pumped and unpumped signals as a function of the number of scans. There is clearly an increase of the average pumped signal over time. The same experiment was reproduced again on a fresh area of the sample at a lower pumping power and a similar effect was observed. Therefore it was concluded that the GeTe sample grown on the Si(111) membrane was getting degraded or amorphized during these measurements. This phenomenon was only observed on the GeTe sample and not for the GST sample, making GST a better candidate for further investigations.

In the pump-probe experiment on the GST sample, no clear difference could be measured between the pumped and unpumped signal in time-resolved measurements, suggesting that with the chosen excitation power, the changes induced in the electronic structure happened before the measured delay ranges or within a shorter timescale.

In conclusion, epitaxial crystalline GeTe and GST grown on Si(111) membranes were found the be suitable for static XANES measurements in transmission. And for pump-probe experiments, epitaxial GST is a better candidate than epitaxial GeTe because of its higher stability under exposure to the repeated laser pulses. For future measurements, wider delay ranges and shorter timescales should be investigated.

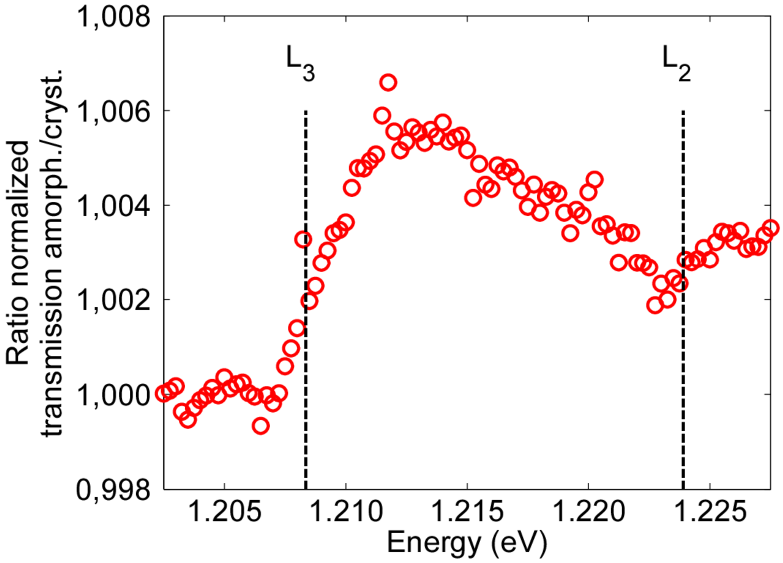

Fig.1: Ratio between the normalized x-ray transmission spectra of amorphous and crystalline GeTe. The vertical dashed lines indicate the positions of the Ge-L3 and Ge-L2 edge, respectively.

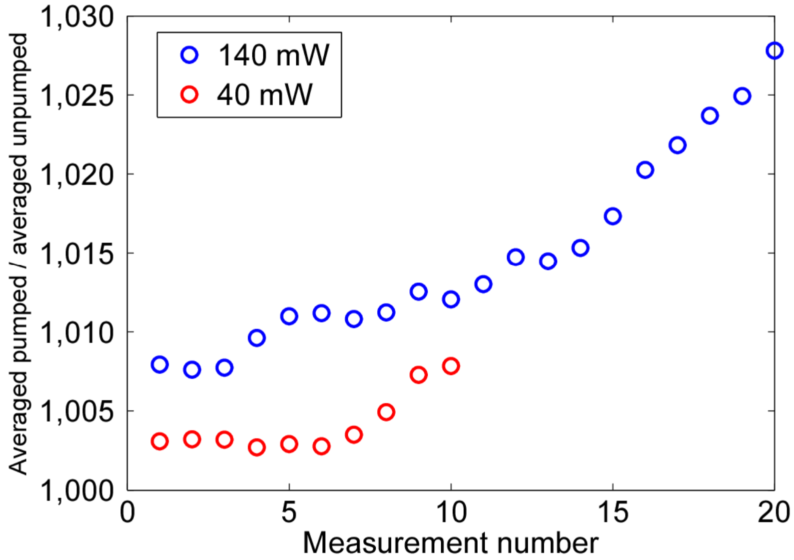

Fig.2: Ratio between the pumped and unpumped signals averaged across the scanned delay range as a function of the number of scans. Blue (red) circles show the measurements with a laser power of 140 mW (35 mW).

REFERENCES

[1] M. Krbal, a. V. Kolobov, P. Fons, K. V. Mitrofanov, Y. Tamenori, J. Hegedu s, S.R. Elliott, and J. Tominaga, Applied Physics Letters **102**, 111904 1–3 (2013).