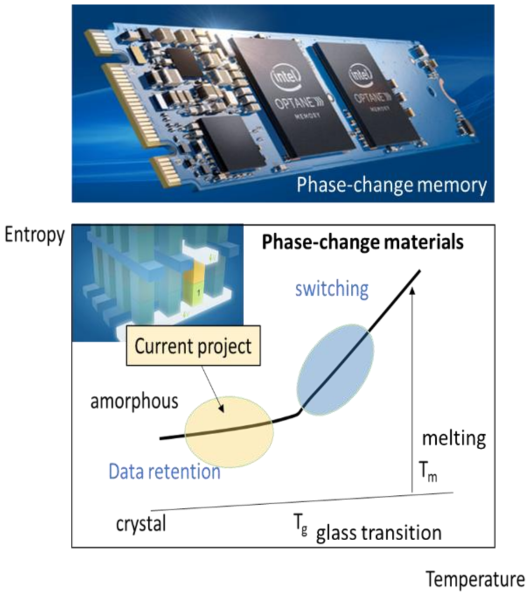
I. Physikalisches Institut (IA) Physik neuer Materialien | RWTH AACHEN UNIVERSITY

Topic for Master Thesis

Energy, resistance, and structural evolutions in amorphous $Ge_{15}Sb_{85}$ for data retention problem in memory technologies

Background and Scientific questions

Enthalpy and structural relaxations occur in amorphous phase-change materials, which change most of the properties of the material. For phase-memory technology (see figure), these property changes during relaxation process are crucial for the data retention ability of the memory devices. It has not been fully understood how the energy, resistance, and structural evolutions are related to each other. Identifying the key factors are important for applying phase-change materials to memory technologies.



Goals and approaches

We aim to make a systematic study of enthalpy and structural relaxations in an amorphous phase-change material $Ge_{15}Sb_{85}$ system and link these energetic and structural changes to the resistance drift in these materials. A recent discovery of a so-called β-relaxation process (local fast atomic motion) in amorphous phase-change materials raises the question how the enthalpy and resistivity drifts are affected by the β relaxation in specific temperature-domains.

First, differential scanning calorimetry (DSC) measurements will be performed to study the energy (enthalpy) changes with time and temperature. After each thermal annealing, a re-scan will be performed to obtain the enthalpy change during the annealing. As such the enthalpy changes as a function of temperature and time can be obtained, which can be directly compared to the resistivity changes induced by annealing.

As for sheet resistance measurements, the resistivity drift as a function of temperature and time will be studied in a Van der Pauw set up. The temperature range of interest is from 50 C until it crystallizes. The measurement will be performed with the same thermal protocol as the DSC measurements. The annealing time will be hours until the drift reaches an equilibrium or steady state.

Finally, the synchrotron x-ray scattering data will be collected following the same thermal protocol that was used for DSC and resistance measurements at DESY Hamburg. This allows a comparison of the existing data of structural relaxation with the enthalpy (DSC) and resistivity changes.

Expected results & Scientific impact

The results are expected to answer the questions how enthalpy, resistivity drift, and structural relaxations are correlated with each other. Does the correlation hold for certain temperature ranges, specific time and length scales? Does the resistivity reach an equilibrium while the enthalpy relaxation is still going on? Does the change in resistivity proceed faster in the β-relaxation temperature-range? From preliminary results, a pronounced decoupling is observed between the enthalpy relaxation and resistivity change after long time annealing. To understand the origin of the decoupling, the data of synchrotron X-ray will be compared with the enthalpy and resistance. We expect a medium-range-order structural domination for enthalpy changes, and a different length scale dependency of the resistivity relaxation process. If proven, the resistance change, associated with band gap widening, results from the interaction or bonding changes between nearest neighbors (i.e. short-range-order), while enthalpy relaxations are dominated by medium-range structural ordering. This study may lead to a publication on this topic.

Dr. Shuai Wei
✉ shuai.wei@physik.rwth-aachen.de
28 C-508 0241 / 80-27169