DS 12: Thermoelectric and Phase Change Materials

Time: Monday 16:30–17:45 Location: CHE 91

DS 12.1 Mon 16:30 CHE 91

Atom Probe Investigation of Intermixing and Thermal stability in GeTe-Sb_2Te_3 Superlattices for Memory Applications — •Nikita Polin, Oana Cojocaru-Mirédin, Henning Hollerman, Alexander Meledin, and Matthias Wuttig — I. Physikalisches Institut (IA), RWTH Aachen University, Aachen, Germany

A chalcogenide superlattice is a periodic structure of layers of two (or more) chalcogenide materials with typical layer thickness of several nanometers. Devices based on GeTe-Sb_2Te_3-superlattices were found to switch with one order of magnitude lower power consumption compared to conventional bulk based $Ge_2Sb_2Te_5$ devices. However, the layers were found to be prone to intermix during deposition at elevated temperatures. Investigation of the thermal stability of the superlattices is thus of applicational and scientific interest.

For this purpose sputtered and annealed GeTe-Sb_2Te_3-superlattices are studied by Atom Probe Tomography (APT), Transmission Electron Microscopy and X-Ray-Diffraction in a correlative manner. Due to the 3D chemical information of the specimens arising from the APT some unexpected findings on the nanoscale could be made: Besides the conventional defects as grain boundaries more exotic nanostructural defects, such as layer splitting, layer dissolving and layer gluing, were found. Additionally heterointerfaces between Ge-rich phases and the surrounding $Ge_2Sb_2Te_5$ were found even at high annealing temperatures of 350°C. Such interfaces might be decisive for the electrical, magnetic, thermoelectric and optical properties of the superlattices.

DS 12.2 Mon 16:45 CHE 91

Impact of interfaces on bipolar resistive switching behavior in amorphous $Ge_2Sb_2Te_5$ thin films — •Hagen Bryja, Christoph Grüner, Jürgen W. Gerlach, Mario Behrens, Martin Ehrhardt, Bernd Rauschenbach, and Andriy Lotnyk — Leibniz Institute of Surface Engineering (IOM), Permoserstraße 15, 04318 Leipzig, Germany

Electrochemical metallization (ECM) memories have attracted much attention as candidates for next generation non-volatile memory applications due to their fast switching, simple structure, high scalability and low energy consumption. Chalcogenide compounds like Ge-Sb-Te-based materials are extensively studied solid electrolytes for such devices and considered within the most promising candidates. However, besides Cu, Ag and Te, the influence of different electrode materials in chalcogenide-based ECM cells has not been investigated and the origin of analog resistive switching, observed in some devices, is still under debate. To shed light on these questions, ECM cells were fabricated using various electrode materials (Al, Ti, Cr, Ta, Co, Cu, Ag, Au, Pt and Cr-CrO_x), a pulsed laser deposited amorphous $Ge_2Sb_2Te_5$ solid electrolyte and a Pt counter electrode. The devices were studied by electrical measurements, secondary ion mass spectrometry and transmission electron microscopy in conjunction with energy-dispersive X-ray spectroscopy. Depending on the utilized electrode material, analog switching, digital switching or no switching occurs. It is observed that the switching behavior is strongly affected by the GST/electrode interfacial interactions, i.e. diffusion and reaction layer formation.

DS 12.3 Mon 17:00 CHE 91

Nanoscale characterization of laser-switched $Ge_3Sb_2Te_6$ with scattering-type Scanning Near-field Optical Microscopy (s-SNOM) and Kelvin Probe Force Microscopy (KPFM) — •Julian Barnett[1], Lukas Wehmeier[2], Andreas Hessler[1], Konstantin Wirth[1], Susanne Kehr[2], Lukas Eng[2], and Thomas Taubner[1] — [1]Institute of Physics (IA), RWTH Aachen — [2]Institute of Applied Physics, TU Dresden

Laser-switching of phase-change materials (PCMs) has gathered renewed interest for (re-)writable nanophotonic applications, such as all-optical memory or metasurfaces [1], because their non-volatile transition between two states with distinctly different optical properties allows for local encoding of information. This application-oriented research is based on the development of PCMs with new optical functionalities, requiring a fundamental understanding of physical processes during local switching to optimize speed, cyclability and control over intermediate states.

Scattering-type Scanning Near-field Optical Microscopy (s-SNOM) is capable of non-destructive, nanoscale characterization of laser-switched PCM devices [2]. We use s-SNOM in combination with Kelvin Probe Force Microscopy (KPFM) to investigate the local electronic properties of laser-switched $Ge_3Sb_2Te_6$, where a single measurement clearly shows four distinctive states: as-deposited amorphous, crystallized, melt-quenched reamorphized, and recrystallized.

[1] M. Wuttig et al. (2017), Nat. Photon. 11, 465.
[2] M. Lewin et al. (2015), Appl. Phys. Lett. 107, 151902.

DS 12.4 Mon 17:15 CHE 91

Thermoelectricity of molecular junctions and their near-Carnot efficiency — •Matthias A. Popp and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Staudtstraße 7, 91058 Erlangen, Germany

We report on thermoelectric transport in molecular junctions, measured with the recently developed squeezable nanojunction technique [1]. A broad ensemble of resonant tunnel junctions with metallic electrodes is investigated. We find correlations between the electric conductance G and the Seebeck coefficient S with unexpected, rigid boundaries. A comparison with the resonant tunneling model shows excellent agreement with experimental data and exposes the generality of the findings. In this framework, measuring $I(V)$ and S for a given junction provides access to the full thermoelectric characterization of the electronic system. A rather unspecific resonant molecular junction displays significant thermoelectric conversion efficiencies. Design rules for optimized efficiency are given.

[1] M. A. Popp and H. B. Weber, Applied Physics Letters 115, 083108 (2019)

DS 12.5 Mon 17:30 CHE 91

Phonons and thermal conductivity in Si/SiO_2 rolled-up nanostructures — •Igor Bogush[1,2] and Vladimir Fomin[3,4] — [1]Scoala Doctorala de Stiinte Fizice si Ingineresti, Institutul de Cercetare si Inovare, Moldova State University, Chisinau MD-2009, Republic of Moldova — [2]Department of Theoretical Physics, Faculty of Physics, Moscow State University, 119899, Moscow, Russia — [3]Department of Theoretical Physics, Moldova State University, Chisinau MD-2009, Republic of Moldova — [4]Institute for Integrative Nanosciences, Leibniz IFW Dresden, Dresden D-01069, Germany

We have developed a differential-geometry formalism for elastodynamic equations applicable for analytical and numerical simulations of phonons in nanowires with arbitrary cross-section geometry and applied it for rolled-up nanostructures. Phonon spectrum for rolled-up Si/SiO_2 bilayer nano-structures with free boundaries is shown to have a similar form as that for unrolled flat nanostructures. Analytical calculations lead to the energy corrections proportional to the ratio of the bilayer width to the structure radius. Geometrical effects for rolled-up structures with small width/radius ratio are neglectable. Therefore realistic rolled-up structures with contacting boundaries can be simulated as flat structures preserving contacting boundary conditions in geometrically non-local sense. Phonon modes are denser for structures with more windings. On this basis we explain the experimentally observed thermal conductivity decrease with increasing number of windings. The present work is supported by the DFG grant no. FO 956/4-1.