DS 15: Thermoelectric and Phase Change Materials

Time: Thursday 10:30–12:00 Location: A 060

DS 15.1 Thu 10:30 A 060

Force constants and bond strength in elemental electron rich Sb — •Franziska Zahn[1], Christopher Benndorf[2], Hans H. Falk[1], Konrad Ritter[1], Eva M. Zollner[1], Sergiu Levcenko[1], Edmund Welter[3], Oliver Oeckler[2], and Claudia S. Schnohr[1] — [1]Felix Bloch Institute for Solid State Physics, Leipzig University, Germany — [2]Institute of Mineralogy, Crystallography and Materials Science, Leipzig University, Germany — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

The valence-electron count of the group V metalloid Sb is 5, corresponding to an electron rich system similar to many thermoelectric and phase change materials such as GeTe and PbTe. Elemental Sb exhibits a layered structure, where each Sb atom has three short and three slightly longer first neighbor bonds. To study the structural and vibrational properties of Sb in more detail, extended X-ray absorption fine structure spectroscopy (EXAFS) was performed at the Sb K-edge at ten different temperatures ranging from 20 K to 295 K. The temperature dependence of the bond length variation σ^2 (mean square relative displacement) was evaluated using a correlated Einstein model, providing static disorder and bond-stretching force constants. Interestingly, the force constant of the long first neighbor bond is ~ 2.5 times lower than that of the short first neighbor bond, but similar to the force constants of the second neighbor bonds. These results are compared to those of first and higher neighbor bonds in metallic Cu, Ge with a classical covalent bonding and GeTe, thus contributing to the understanding of bonding in Sb as an elemental electron rich system.

DS 15.2 Thu 10:45 A 060

Atomic-scale characterization of Cu-Te phases prepared using focused ion beam and thermal heating — •Nils Braun[1], Vladimir Roddatis[2], Sonja Cremer[1], Hagen Bryja[1], Lennart Voss[3], Lorenz Kienle[3], and Andriy Lotnyk[1] — [1]Leibniz Institute of Surface Engineering e.V. (IOM) — [2]GFZ German Research Centre for Geosciences — [3]Institute for Materials Science, Faculty of Engineering, University of Kiel

Cu-Te phases are interesting for thermoelectric applications. However, their crystal structure is still under debate. In this work, we prepared different nanoscale Cu-Te phases from the Cu - Sb_2Te_3 system using FIB and thermal treatment. Epitaxial or polycrystalline Sb_2Te_3 thin films are grown on p-type Si (111) and SiO_2 coated wafers, respectively, by pulsed laser deposition. A standard cross-section FIB preparation method is employed and the lamellae are investigated using advanced TEM methods and XRD.

The formation of van der Waals bonded Cu-Te phases consisting of bi- and tri-layers of Te is observed in epitaxial and polycrystalline samples. The lattice parameters and position of Cu and Te atoms in the resulting phases are determined from atomic-resolution STEM and HREELS images. The crystal structure of the bilayered phase was identified as trigonal Cu_7Te_4 and orthorhombic/tetragonal Cu_3-xTe_2. Moreover, crystal defects such as dislocations were observed in the thin films.

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DS 15.3 Thu 11:00 A 060

Switching of GeTe-Sb_2Te_3 multilayers by infrared femtosecond laser pulses — •Sonja Cremer[1], Martin Ehrhardt[1], Pierre Lorenz[1], and Andriy Lotnyk[1,2] — [1]Leibniz Institute of Surface Engineering, Leipzig, Germany — [2]Laboratory of Infrared Materials and Devices, Ningbo University, China

By phase change material multilayers (MLs) current drawbacks as resistance drift of Ge-Sb-Te thin films for neuromorphic computing may be tackled. This way MLs can help to unleash the full potential of the technologys advantageous characteristics like multilevel cell (MLC) operation. Switching is performed by electric or optical pulses, significantly changing the resistance and reflectivity of the thin film.

Here, we switched PLD grown 30 nm periodic GeTe-Sb_2Te_3-MLs using a 1030 nm laser with 260 fs pulse duration. The laser was part of an optical pump-probe setup to directly monitor reflectivity changes. Successful multiple switching was checked by light microscopy. Follow up SEM and TEM analysis were used to characterize the microstructure evolution. Switching between amorphous and fully crystalline state was found to go along with significant change in reflectivity (~20%). Besides, multilevel crystallization states with nonlinear reflectivity evolution were observed.

Thus, GeTe-Sb_2Te_3-MLs are a potential candidate for MLC operation with a fixed laser wavelength and pulse duration.

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DS 15.4 Thu 11:15 A 060

An on-chip micro-thermoelectric temperature-controller — •Qun Jin, Kornelius Nielsch, and Heiko Reith — Institute for Metallic Materials, IFW Dresden, Dresden, Germany

To extend Moore's law in modern microelectronics, multidimensional nanoelectronic integration and multifunctional component assembly have been greatly explored in recent years. However, these approaches will inevitably make precise temperature control for temperature-sensitive electronic components a major challenge. Therefore, it is important to integrate thermoelectric (TE) films [1-2] into high-performance micro-on-chip temperature controllers.

Here, we report an approach to integrating our freestanding TE films into an on-chip micro-temperature controller for thermal energy management in power electronics [3]. It can achieve more energy-efficient temperature control than our previous TE coolers [4-5]. A cooling temperature exceeding 44.5 K can be achieved using only 445 μW, which is two orders of magnitude lower than that required in microheaters. In addition, our on-chip TE temperature controller shows an ultra-fast cooling rate exceeding 2,000 K/s and excellent reliability of up to 1 million cycles. Our micro temperature controller opens new avenues in developing modern electronics with numerous promising applications.

References: [1] Q. Jin, et al. Nature Materials, 18, 62-68 (2019). [2] Q. Jin, et al. Advanced Materials, 35, 2304751 (2023). [3] Q. Jin, et al. under revision in Nano-Micro Letters. [4] G. Li, et al. Nature Electronics. 1, 555-561 (2018). [5] Q. Zhang, et al. Nature Electronics. 5, 333-347 (2022).

DS 15.5 Thu 11:30 A 060

Field Effect Control of Thermoelectric Effect in Semiconductor Thin Films — •Sunao Shimizu[1], Kazumoto Miwa[2], Kazuyasu Tokiwa[3], and Shimpei Ono[1] — [1]Toyama Prefectural University, Toyama, Japan — [2]CRIEPI, Kanagawa, Japan — [3]Tokyo University of Science, Tokyo, Japan

Thermoelectric energy conversion has recently regained an increased interest as a promising technology for renewable energy systems. It is highly required to investigate diverse semiconductors for developing thermoelectric modules with higher energy conversion efficiency. In this presentation, we report the systematic characterization of thermoelectric properties in WO3. We fabricated WO3 thin films by RF sputtering and applied an ionic liquid gating technique to precisely control the carrier density. Due to the high gate capacitance at the electric double layer [1], which is formed at the interface of WO3 and the ionic liquid, high density charge carriers were accumulated on the semiconductor surface by just applying several volts of the gate voltage. The temperature dependence of the sheet resistance in WO3 initially showed insulating behavior and was modified to be metallic by the ionic liquid gating. We also discuss the systematic change of the thermoelectric effect, showing the optimization of the thermoelectric power factor with changing the carrier density [2].

[1] S. Bisri, S. Shimizu, M. Nakano, Y. Iwasa, Adv. Mater. 29, 1607054 (2017). [2] S. Shimizu et al., Sci. Rep. 12, 7292 (2022).

DS 15.6 Thu 11:45 A 060

Imaging the Ettingshausen effect and cryogenic thermoelectric cooling in a van der Waals semimetal — •Tobias Völkl[1], Amit Aharon-Steinberg[1], Tobias Holder[1,2], Edan Alpern[1], Nasrin Banu[1], Arnab Pariari[1], Yuri Myasoedov[1], Martin Huber[3], and Eli Zeldov[1] — [1]1Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 7610001, Israel — [2]School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel — [3]Departments of Physics and Electrical Engineering, University of Colorado Denver, Denver, Colorado

Attaining viable thermoelectric cooling at cryogenic temperatures is of major fundamental and technological interest for novel electron-

ics and quantum materials applications. Here we develop nanoscale cryogenic imaging of a magneto-thermoelectric effect and demonstrate absolute cooling and an ultrahigh Ettingshausen effect in exfoliated WTe_2 Weyl semimetal flakes at liquid He temperatures. Application of a current and perpendicular magnetic field gives rise to cooling via generation of electron-hole pairs on one side of the sample and heating by their recombination at the opposite side. In contrast to bulk materials, the cooling process is found to be nonmonotonic in magnetic field and in device size. The derived model of magneto-thermoelectricity in mesoscopic semimetal devices shows that the cooling efficiency and the induced temperature profiles are governed by the interplay between sample geometry, electron-hole recombination length, magnetic field, and flake and substrate heat conductivities.