I. Institute of Physics
Physics of New Materials
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**Topic for a Master Thesis**

# Investigating Metavalent Bonding in $(GeTe)_x(SnTe)_{1-x}$ Alloys for PCM Applications

Phase change materials (PCMs) are known for their stable amorphous and crystalline phases under ambient conditions, making them promising candidates for applications in neuromorphic computing and memory devices. This project focuses on exploring the pseudobinary alloy line $(GeTe)_x(SnTe)_{1-x}$, which exhibits unique metavalent bonding (MVB), a novel chemical bond type with distinct properties compared to traditional bonding mechanisms [1].

The primary goal is to deepen our understanding of metavalent bonding by investigating the $(GeTe)_x(SnTe)_{1-x}$ alloys. Specifically, we aim to explore the influence of SnTe content on the structural transition from rhombohedral (GeTe) to cubic (SnTe) phases. Additionally, we will investigate potential phase transitions upon cooling, providing valuable insights into metavalent bonding without altering stoichiometry.

The $(GeTe)_x(SnTe)_{1-x}$ samples will be fabricated using Molecular Beam Epitaxy (MBE), with a focus on optimizing the growth process for each targeted stoichiometry. In-situ techniques, including reflection high energy electron diffraction (RHEED), scanning electron microscopy (SEM), and x-ray diffraction (XRD), will be employed during the fabrication process. XRD, in particular, will be instrumental in analyzing sample structures, and its findings will be correlated with coherent phonon measurements.

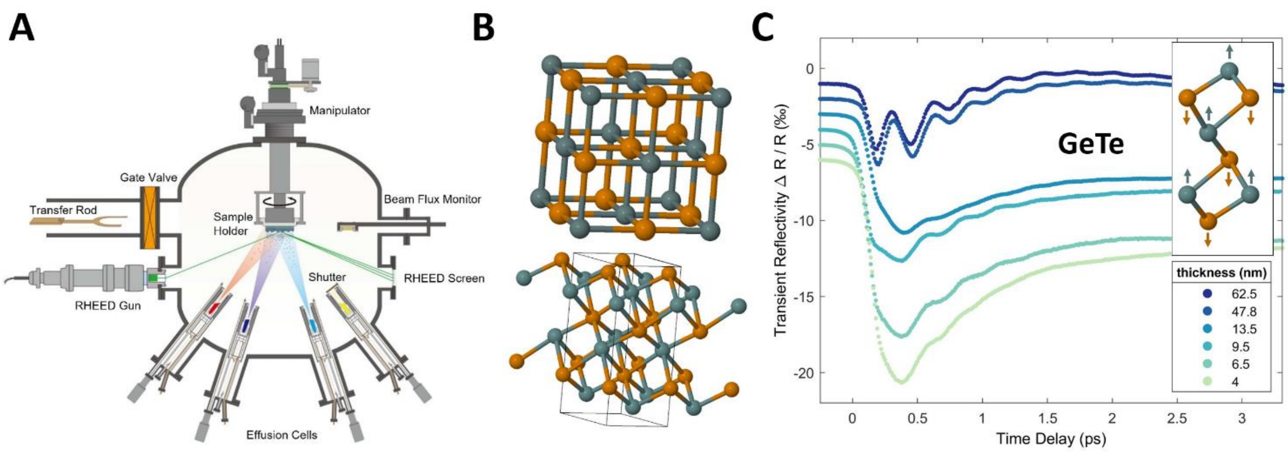


Figure **1**: (**A**) Schematic of a typical MBE system with all major components similar to the MBE chamber at the Nanocluster in the Forschungszentrum Jülich. Adapted from [2]. (**B**) Cubic structure of SnTe (top) and rhombohedral structure of GeTe (bottom) at room temperature. (**C**) Transient Reflectivity for GeTe on ultra-short timescales, revealing A1g phonon mode for different film thickness.

The experimental work will be carried out at the Forschungszentrum Juelich and the RWTH Aachen. Sample fabrication, including various analysis methods, will take place in Juelich, utilizing in-situ RHEED, SEM, and XRD. Coherent phonon investigations will be conducted in Aachen, employing a combination of optical femtosecond pump-probe spectroscopy and polarization resolved Raman measurements to gain a deeper understanding of the ultrafast lattice dynamics on different temperature scales.

This research not only contributes to the understanding of metavalent bonding in $(GeTe)_x(SnTe)_{1-x}$ alloys but also holds promise for the development of advanced PCM devices. The exploration of coherent phonons through sophisticated experimental techniques enhances the comprehensiveness of this investigation.

By combining materials science, MBE technology, and advanced characterization methods, this project aims to shed light on the unique properties of metavalent bonding and its potential applications in emerging technologies.

[1] M. Wuttig and B. Kooi. „Chalcogenides by Design: Functionality through Metavalent Bonding and Confinement. " Adv. Mater. (2020).

[2] M. Shimozawa et al. "From Kondo Lattices to Kondo Superlattices". Rep. Prog. Phys. (2016).

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