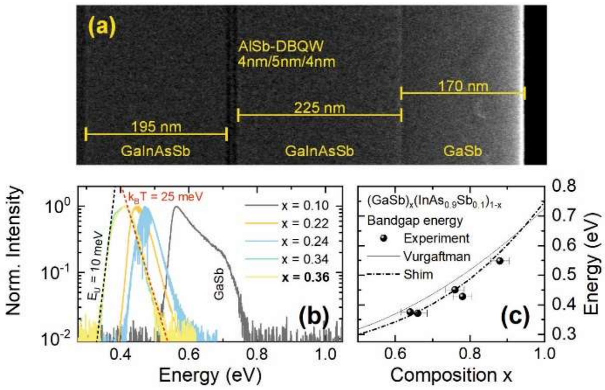
Mid-Infrared Photodetectors based on Resonant Tunneling Diodes

F. Hartmann,[1] A. Pfenning,[1] G. Knebl,[1] R. Weih,[1,2] A. Bader,[1] M. Meyer,[1] F. Rothmayr,[1,2] C. Kistner,[2] J. Koeth,[2] M. Kamp,[1] L. Worschech,[1] and S. Höfling[1]

[1]*Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Am Hubland, D-97074 Würzburg, Germany*

[2]*nanoplus Nanosystems and Technologies GmbH, D-97218 Gerbrunn, Germany*

From optical molecule and gas spectroscopy, optical coherence tomography (OCT) and light detection and ranging (LiDAR), to photonic quantum information technology, there has been an increasing demand for high-performance optoelectronic devices in the mid-infrared (MIR) spectral region above wavelengths of $\lambda \geq 2$ μm. Providing a huge variety of bandgap energies and band alignments, the so-called 6.1-Angstrom family (InAs, GaSb, AlSb, and compounds) is one of the material systems of choice for semiconductor devices covering the MIR. We discuss the status and future aspects of mid-infrared photodetectors based on resonant tunneling diodes (RTDs) and that RTDs composed of semiconductors from the 6.1-Angstrom family can cover the MIR spectral wavelength region. First, we highlight the photodetection principle of RTD photodetectors that is based on the modulation of a majority charge carrier resonant tunneling current via an electro-static interaction of photogenerated, accumulated minority charge carriers at the tunneling barrier structure. We present in detail the physical limitations[1] and peculiarities of RTD photodetectors based on semiconductors from the 6.1-Angstrom family. In particular, we will focus on RTD photodetectors composed of the quaternary alloy GaInAsSb[2,3]. $(GaSb)_x(InAs_{0.91}Sb_{0.09})_{1-x}$ can be grown lattice matched on GaSb (as seen in the cross-sectional scanning electron microscopy (SEM) image of a grown RTD in (a)) and dependent on the compositions x, the bandgap energy (see Photoluminescence emission spectra (b) and extracted band gap energies in (c)) can be tuned in a broad wavelength range.



RTD device layout and properties. (a) Cross-sectional scanning electron microscopy (SEM) image of the grown RTD. **(b)** Photoluminescence emission spectra for lattice-matched $(GaSb)_x(InAs_{0.91}Sb_{0.09})_{1-x}$ with different compositions x. **(c)** Bandgap energy vs. composition x.

[1] A. Pfenning et al., *"GaSb/AlAsSb resonant tunneling diodes with GaAsSb emitter prewells"*, Applied Physics Letters 111 (17), 171104

[2] E.D. Guarin Castro et al., *"Resonant tunneling of electrons in AlSb/GaInAsSb double barrier quantum wells"*, AIP Advances 10 (5), 055024

[3] F. Rothmayr et al., *„Resonant Tunneling Diodes: Mid-Infrared Sensing at Room Temperature "*, Nanomaterials (Basel) 12 (2022), DOI: 10.3390/nano12061024