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Increasing System Efficiency and Functionality of Microelectronics: Multipurpose Group IV alloys

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Microelectronics is a core of world technology, touching every aspect of modern life. After decades of downscaling being the technology driver, this has been replaced in recent years by energy efficiency and increased functionality. In particular, the integration with photonics by adding optical devices such as waveguides, modulators, detectors, and lasers, has been aimed for. Moreover, the explosion in data traffic calls for new computing paradigms and, combined with the demand to get access to data at almost any time and place, underlines the necessity for autonomous, grid-independent energy-efficient devices. Thermoelectric technology (TE) is one of the green technologies that have the potential to improve energy efficiency by improving system efficiency and recovering waste heat in multiple application fields, including data centres, mobile devices and various industrial production processes. Consequently, developing new high-performance thermoelectric materials is critical in expanding the range of large-scale thermoelectric applications.
In recent years, significant progress has been made in developing devices based on non-classical group IV alloys, particularly those containing Sn, such as GeSn. In contrast to the well-established Si and Ge-based materials, which have an indirect band gap, epitaxial GeSn layers exhibit a direct band alignment for Sn concentrations exceeding 8%. GeSn alloys with lower Sn concentration can be converted into a direct semiconductor by adding tensile strain. To this aim, it is paramount to correctly evaluate the effect of composition, strain, and the deposition process on the crystal quality of GeSn layers. For this purpose, Raman spectroscopy is an effective experimental technique to determine these properties, as it is a non-destructive, contactless, fast and spatially-resolved technique.
Moreover, GeSn alloys provide lower thermal conductivity than Ge or SiGe and better thermoelectric performance. We examined the thermal conductivity k of high-quality epitaxial GeSn layers with Sn content between 5% - 14% by Raman thermometry. In this method, the phonon energy is measured via Raman spectroscopy and is correlated to the heating induced by a laser beam. Subsequently, we determined the material's thermal conductivity by a semi-analytical model. The result is that k decreases from 56 W/m·K for pure Ge to 4 W/m·K for a Ge0.86Sn0.14 alloy. Measurements on SiGeSn show an even larger reduction down to 2 W/m·K.
Thus, GeSn is potentially suitable as the material basis for CMOS technology's monolithic integration of light emitters and thermoelectrics. These pave the way for thermoelectric devices fully compatible with CMOS technology toward a monolithic integration of electronics, photonics, and thermoelectric on the same chip.

Category

Solid State (Experiment)

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