GeSn binary alloys for Room Temperature CMOS compatible energy harvesting applications

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Thermoelectric materials for energy harvesting applications present a promising approach to reducing the overall energy consumption of modern technologies that require substantial processing power, such as machine learning. These technologies generate significant waste heat, which could be recovered to improve energy efficiency. While various materials have been proposed for this purpose, a CMOS-compatible option that operates efficiently at room temperature has yet to be identified.

Silicon (Si) and silicon-germanium (SiGe) alloys have long dominated the electronics industry; however, their high lattice thermal conductivity (κ_lat) limits their thermoelectric performance, despite their favorable Seebeck coefficient and electrical conductivity. Recently, theoretical predictions of κ_lat reduction in germanium-tin (GeSn) alloys have been experimentally confirmed, demonstrating a significant decrease to 4 W/mK with increasing Sn concentration—compared to 60 W/mK for pure Ge. These findings position GeSn as a promising candidate for CMOS-integrated thermoelectric applications. However, to fully assess its potential, experimental validation of the ZT figure of merit is required, necessitating the measurement of the Seebeck coefficient and electrical conductivity. Here, we present experimental results for the thermoelectric parameters, specifically the lattice thermal conductivity (κ_lat) and the Seebeck coefficient, in a series of epitaxial GeSn layers with varying Sn content. The samples were grown by chemical vapor deposition on 200 mm Si wafers using industrial epitaxy reactors. The layer thickness and Sn concentration were determined by fitting the Rutherford Backscattering Spectrometry (RBS) spectrum, while strain analysis and additional compositional confirmation were obtained via X-ray diffraction (XRD). The carrier concentration of the intrinsically p-doped layers was measured using electrochemical capacitance-voltage (ECV) profiling.

Preliminary data for the in-plane Seebeck coefficient were acquired through an electrical method at approximately 300 K for Sn concentrations ranging from pure Ge to 11%. The results indicate a high Seebeck coefficient with no clear trend as a function of Sn composition. However, further analysis is required to isolate the contributions of different layers involved in the experiment, which will also be discussed.
Additionally, preliminary measurements of electrical conductivity were performed using the circular Transfer Length Method (c-TLM). These findings represent an important step toward the experimental determination of the ZT figure of merit for GeSn binary alloys.