Heteroepitaxy of PbSe-SnSe semiconductors on GaAs for infrared optoelectronics

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The IV-VI semiconductor alloy of PbSe-SnSe has rich materials physics and several device applications[1]. This narrow band gap semiconductor system spans a 3D-bonded rocksalt structure on the PbSe-rich side and a closely related Van der Waals bonded 2D/layered-orthorhombic structure on the SnSe-side, and has long been studied for its rare electronic, photonic, and thermal properties. We present results from epitaxial integration of IV-VI semiconductor films with III-V templates using molecular beam epitaxy to understand how we may harness their properties for emerging applications infrared optoelectronics.

With attractively low temperatures for epitaxy below 300 °C, we describe the nucleation and growth of IV-VI materials on III-V substrates and the formation of extended crystal defects that arise due to integration[2]. We find bright band-edge photoluminescence in the mid-infrared (3–4 µm) from PbSe and PbSnSe epitaxial films on ~8% mismatched GaAs at room temperature, despite a threading dislocation density exceeding $10^9/cm^2$. We present measurements of carrier recombination in PbSe and show preliminary results from junction devices of mid-infrared light emitting diodes and photodetectors that highlight the promise of this materials platform.

The IV-VI on III-V template also enables us to probe deeper into the structural phase boundaries and miscibility gaps in PbSnSe, with an aim to harness the high contrast in optical properties across the transition between 3D/rocksalt to 2D/layered bonding. We show that MBE synthesis can stabilize the layered phase deep in the bulk miscibility gap. Close to a composition of $Pb_{0.5}Sn_{0.5}Se$, we find evidence for a displacive or martensitic transformation (without composition change) between the rocksalt and layered phases in our thin films. These results, in agreement with recent reports in high temperature quenched samples[3], point the way to phase change devices.

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