

Molecular Beam Epitaxy (MBE) Growth and Characterization of III-V Semiconductors

G. N. Gopakumar, M. R. McDonough, and S. Law.

Abstract: III-V semiconductors are a class of materials that have been used for decades in electronics, photonics, spintronics, and photovoltaics. Molecular Beam Epitaxy (MBE) is an ultrahigh vacuum technique used to synthesize these thin film materials with high purity and a low number of defects. Ongoing research topics include the synthesis of metamaterials for infrared (IR) sensing applications and the synthesis of novel topological materials. Thin film topological materials have unique optical and electronic properties, lending them to applications in long-wave infrared (LWIR) sensors, on-chip interconnects, and thermoelectrics. The primary materials of interest are the III-Bi materials, called the bismides, which include AlBi, GaBi, and InBi. These materials are all predicted to have topologically non-trivial band structures and have not been extensively studied experimentally. Here, we present our recent results on the synthesis and characterization of AlBi thin films. We are broadly interested in studying the synthesis-structure-property relationships in the bismides. Additionally, since the bismides are predicted to have the zinc blende crystal structure like other III-V semiconductors, we expect to be able to integrate these materials into electronic and optoelectronic devices.

We also present efforts in fabricating rolled-up semiconductor tubes by utilizing a strained bilayer that can be released from a substrate using lithography and wet etching techniques. Strain in the thin films can be tuned using alloying elements in III-V heterostructures such as $\text{Ga}_{1-x}\text{In}_x\text{Sb}$ and $\text{In}_{1-x}\text{Ga}_x\text{As}$. By combining this concept with hyperbolic metamaterials, we create rolled up metamaterials that can magnify subdiffractional information in the mid-IR. These materials have a negative real part of the permittivity tensor along at least one direction and a positive permittivity along at least one other direction, leading to an open isofrequency surface, in contrast to the closed isofrequency surface of normal materials. In a rolled-up hyperbolic material, the wavevector of the light decreases as it propagates radially, and the image is magnified, enabling super-resolution imaging.

