Non-Contact Free Carrier Density Measurements for Compound Semiconductors

Transport of free carriers is central to the operation of all optoelectronic devices, and reliable measurement of the carrier properties is critical. Hall or capacitance-voltage measurements are traditionally used to obtain this information, but require electrical contact. This precludes the use of these techniques in situ during growth or processing and, typically, even on actual device layers. Raman spectroscopy is an optical technique that can be used for transport property determination with electrical contact. In addition, it is non-destructive, spatially resolved, and can be applied to a specific buried layer, which is sometimes a problem for traditional electrical measurements. A number of issues are central to determining the accuracy and precision of this method, including the semiconductor investigated her. These include the measurement system parameters and the model used to fit the measured Raman spectra. NIST is systematically addressing these issues.

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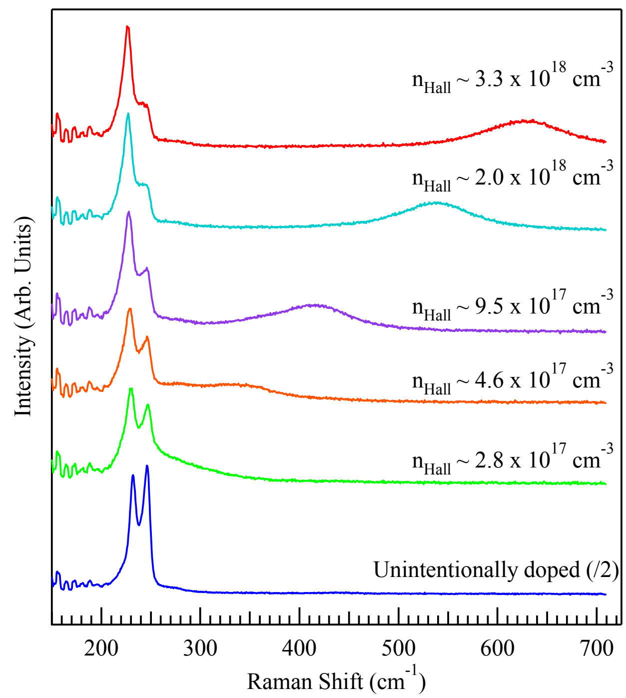
In order to develop non-contact measurement methods of electrical carrier, free carrier, and mobility in optoelectronic materials, NIST researchers are investigating a range of materials with properties suitable for use in optoelectronic devices operating at different regions of the electromagnetic spectrum. Our focus is on narrow band gap group III-antimonide materials and wide band gap group III-nitride materials. Spectroscopic systems were optimized for each set of materials after examining thin films of narrow band gap GaSb, GaAsSb, GaInSb, and GaInAsSb and wide band gap GaN and AlGaN, obtained from various collaborators. Modeling of the Raman spectra from the different materials requires several models that account for the differences in physical properties that make these materials suitable for different applications. Spectral models of various levels of sophistication have been developed and analyzed for n-type doped GaSb, p-type GaSb, n-type GaInAsSb, and n-type GaN. We are comparing the results of the various spectral models with electrical measurements to determine the suitability of the models.

The Raman spectra of n-type doped GaInAsSb epilayers show a strong dependence on carrier density. The carrier density determined from the Hall effect measurement is indicated. The spectra are offset on the vertical scale for clarity.



The results of the NIST work facilitate the utilization of Raman spectroscopy for spatially resolved, off-line characterization as well as process monitoring and control during film growth and subsequent patterning processes.