# INFRARED ABSORPTION STUDIES OF $GA_XIN_{1-X}AS$ BULK CRYSTALS

By

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An Abstract of a Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Electrical, Computer and Systems Engineering

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

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Rensselaer Polytechnic Institute
Troy, New York
September 2006
(For Graduation December 2006)

## Abstract

The III-V alloy semiconductor $Ga_xIn_{1-x}As$ covers the mid-IR wavelength range between 0.85 and 3.4 µm and is suitable for optoelectronic devices such as laser diodes, photodetectors and thermo-photovoltaic cells. However, only few compositions of the $Ga_xIn_{1-x}As$ system have been extensively researched, mostly in thin film form. For example, $Ga_{0.47}In_{0.53}As$ is being widely used for commercial laser diodes and photodiodes in fiber optics communication. Recently there has been considerable interest in the non-linear optical properties of $Ga_xIn_{1-x}As$, for which bulk wafers with thickness up to several millimeters (mm) and high optical transparency is necessary. The primary goal of this research was to understand the fundamental optical absorption mechanisms in $Ga_xIn_{1-x}As$ spanning a wide composition range between GaAs and InAs. Correlation between the band structural parameters of the alloy and the below bandgap absorption mechanisms has been established by theoretical analysis of our experimental electrical and optical measurement data.

Various dependencies of the electron and hole absorption mechanisms as a function of alloy composition have been studied for the first time in $Ga_xIn_{1-x}As$. These include, the free electron and free hole absorptions, electron transitions between different conduction band valleys and hole transitions between heavy hole, light hole and spin-orbit split bands. In case of undoped InAs and $Ga_xIn_{1-x}As$ compositions with $x < 0.2$, the free electron absorption is the dominant absorption mechanism. There is no significant change in the transmission properties caused due to the changes in the energy band structure for alloy compositions between $x = 0$ and $x = 0.2$. For alloy compositions $0.46 > x > 0.2$, the free carrier absorption by electrons and inter valence transitions by holes contribute equally. For alloy compositions $x > 0.46$, the contribution of various absorption mechanisms varies due to the changes in the band structural properties of the compound. The interaction between the various subbands in the conduction band changes significantly for this range of gallium (Ga) mole fraction in the alloy. Transitions of electrons between the conduction band minimas becomes appreciable. This results in a marked difference in the transmission properties of the alloys for the near band edge wavelength region ($\lambda < 5$ µm). Additionally the decreasing free electron concentration with increasing Ga mole fraction reduces the scattering by free electrons in the longer wavelength region ($\lambda > 10$ µm). Interestingly, the absorption mechanism for intrinsic (semi-insulating) GaAs was found to be completely due to inter-valence band absorption. A comparative study between different alloys having similar bandgaps (such as Ga-rich GaInSb versus In-rich GaInAs) has been carried out to study the effects of band structure parameters on the absorption profile of the material.