

X-RAY STUDIES OF Mn DOPED III-V MATERIALS

Abstract

by

Aaron M. Stuckey

Two x-ray techniques have been employed to study two classes of semiconductors. X-ray Absorption Fine-structure Spectroscopy (XAFS) was used to examine the Mn environment in the dilute magnetic semiconductors $\text{Ga}_{1-x}\text{Mn}_x\text{As}$ and $\text{Ga}_{1-x-y}\text{Mn}_x\text{Be}_y\text{As}$. X-ray reflectivity was used to characterize the structure of InMnAs heterostructures and InAlP oxide films.

XAFS measurements of the Mn local environment were performed in order to match structural parameters such as coordination numbers, bond lengths, and XAFS Debye-Waller factors to the ferromagnetic properties of the materials. The Mn local environment in $\text{Ga}_{1-x}\text{Mn}_x\text{As}$ materials with $x = 0.01, 0.03, 0.05,$ and 0.08 was found to be that of a Mn ion substituting for a Ga ion in the GaAs lattice (Mn_{Ga}). The Mn local environment of the $\text{Ga}_{1-x-y}\text{Mn}_x\text{Be}_y\text{As}$ materials was also measured for six samples with constant $x = 0.05$ and $y = 0.0, 0.01, 0.03, 0.05, 0.08$ and 0.11 . The Mn local environment depended upon the concentration of Be in the material. At $y = 0.0$ and $y = 0.01$ the Mn local environment was found to be that of the Mn_{Ga} site. The percentage of Mn in this local environment decreased as the Be concentration of the samples increased. Meanwhile, the percentage of Mn in an interstitial site and the percentage of Mn in a precipitate MnAs site both increased. No evidence of Mn-Mn or Mn-Be pairing was found in the $\text{Ga}_{1-x-y}\text{Mn}_x\text{Be}_y\text{As}$ materials.

The x-ray reflectivity measurements were used to characterize the structure of InMnAs and InAlP in order to improve understanding of the structural characteristics. This improvement can then be used to improve the growth parameters in order to create materials upon which device development may be undertaken. The InMnAs materials were found to have a structure closely matching the expectations from growth with the addition of a low density surface film. The InAlP oxide films were found to have an additional layer at the interface between the substrate and the oxide film which has higher electron density than the oxide film and large roughness. This layer could be a precipitate layer based upon the thickness of the layer and its roughness.