MAR05-2004-010137

Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Nanometer-Scale Structure and Properties of Dilute Semiconductor Alloys

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For many compound semiconductors, the addition of dilute concentrations of impurities leads to dramatic changes in the electronic, optical, and magnetic properties. For example, the introduction of a few percent nitrogen into GaAs leads to a band gap reduction of 100s of meV. Furthermore, the incorporation of a few percent manganese into GaAs enables a combination of semiconducting and ferromagnetic behavior. The resulting dilute semiconductor alloys are promising for several applications ranging from long-wavelength light-emitters and high efficiency solar cells to spin-electronics and spin-optoelectronics. In both cases, the nanometer-scale details of impurity incorporation are critical to understanding and controlling the observed properties. In this talk, I will discuss our recent investigations of the growth, nanometer-scale structure, and properties of dilute GaAsN and GaMnAs alloys, using nuclear reaction analysis and scanning tunneling microscopy, in conjunction with several other measurements. In GaAsN, we examine the role of surface reconstruction on the incorporation of nitrogen into substitutional vs. interstitial lattice sites, as well as the effect of nitrogen incorporation mechanisms on electronic and optical properties [1]. In the case of GaMnAs, we quantify clustering of Mn_{Ga} and As_{Ga} point defects, and its effect on electronic and magnetic properties [2]. [1] M. Reason, H. McKay, W. Ye, S. Hanson, V. Rotberg, and R.S. Goldman, "Mechanisms of Nitrogen Incorporation in GaAsN Alloys," *Appl. Phys. Lett.* **85**, 1692 (2004). [2] J.N. Gleason, M. Hjelmstad, V.D. Dasika, R.S. Goldman, S. Fathpour, S. Charkrabarti, and P.K. Bhattacharya, "Nanometer-scale Studies of Point Defect Distributions in GaMnAs Alloys," *Appl. Phys. Lett.,* in press (January 3, 2005).