Effects of Composition and Layer Thickness on the Magnetic and Structural Characteristics of GaMnN

G. T. Thaler, M. Overberg, R. Frazier, C. R. Abernathy, S. J. Pearton, F. Ren, Y. D. Park[1], R. Rairigh[2], J. Kelly[2], J. S. Lee[1], N. Theodoropoulou[2], A. F. Hebard[2]
Department of Materials Science & Engineering
University of Florida, Gainesville, FL USA
[1]School of Physics, Seoul National University, Seoul, Korea
[2]Department of Physics, University of Florida, Gainesville, FL USA

Research in the field of spintronics, particularly III-V semiconductors doped with magnetic impurities, has received an increasing amount of theoretical and experimental attention due to the potential for application of these materials in device structures.[(1-10)] A number of recent studies have reported the room temperature ferromagnetism in GaMnN, however, little is yet known about the role of impurity concentration on the electronic and magnetic behavior of this material. In this paper we will discuss the effect of Mn concentration on the lattice constant and bandgap of GaMnN, followed by preliminary results on the effects of co-doping GaMnN with Si and O.

Epitaxial growth was performed using Gas Source Molecular Beam Epitaxy. Films with magnetic transition temperatures above room temperature were produced for a variety of growth temperatures and Mn concentrations. It was found that the addition of 3% Mn increased the bandgap slightly, though further addition of Mn did not produce further significant change. The lattice constant initially decreased upon the addition of 3% Mn then increased as the Mn concentration was increased from ~ 3% to 5% to ~ 9%, as shown in Figure 1. These results suggest that the concentration of substitutional Mn saturates at ~3%. XRD and XTEM show that this Mn is not present in the form of a second phase, suggesting that the additional Mn may be incorporating interstitially. This is further supported by the magnetic characterization, which shows the moment measured by SQUID magnetometer to saturate at 3%. One method which has been proposed to improve the ferromagnetic ordering of Mn in GaMnN is co-doping of GaMnN with oxygen. We have preliminary evidence that the addition of oxygen does appear to be beneficial. In films grown at 925 °C with 4% Mn, the moment per manganese increases from 0.06 to 0.035 Bohr magnetons when ~ 8% oxygen is incorporated during growth, Figure 2. Finally, we have explored the effect of layer thickness by depositing GaMnN(10nm)/AlN(10nm) heterostructures. RHEED patterns taken during growth showed a streaky pattern indicative of smooth interfaces, a conclusion further supported by the XRD pattern, shown in Figure 3. Ferromagnetic ordering was observed in this structure suggesting that thin layers of the sort required for fabrication of a number of spin transport devices can retain their magnetic functionality. This work was supported by the Army Research office under: ARO-DAAD19-01-1-0701 and by NSF under: ECS-0224203.

1. H. Ohno, Science **281**, 951 (1998).
2. H. Munekata et. al., APL. **63**, 2929(1993).
3. G. Prinz, Science 282, 1660 (1998).
4. B. T. Jonker, et. al., P.R.B **62**, 8180 (2000).
5. T. Dietl et. al., Science 287, 1019 (2000).
6. W. Gebicki et. al., Appl. Phys. Lett. **76**, 3870 (2000).
7. M. Zajac et. al., Appl. Phys. Lett. **78**, 1276 (2001).
8. M. L. Reed et. al., Appl. Phys. Lett. **79**, 3473 (2001).
9. N. Theodoropoulou et. al., J. Nanosci. Nanotech., **1** 101(2001).
10. M. E. Overberg et. al., Appl. Phys. Lett. **79**, 1312 (2001), and **79**, 3128, (2001).

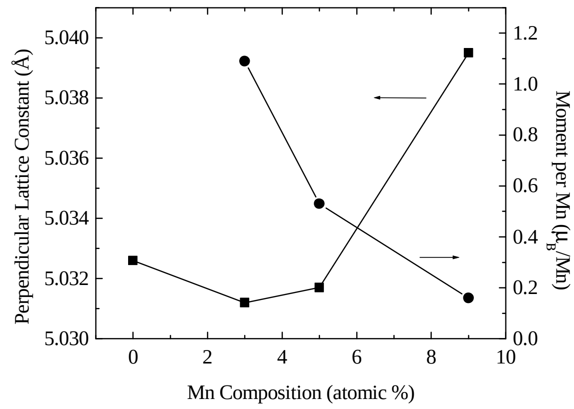

Figure 1. Variation of lattice constant and magnetic moment with Mn concentration in GaMnN grown using GSMBE.

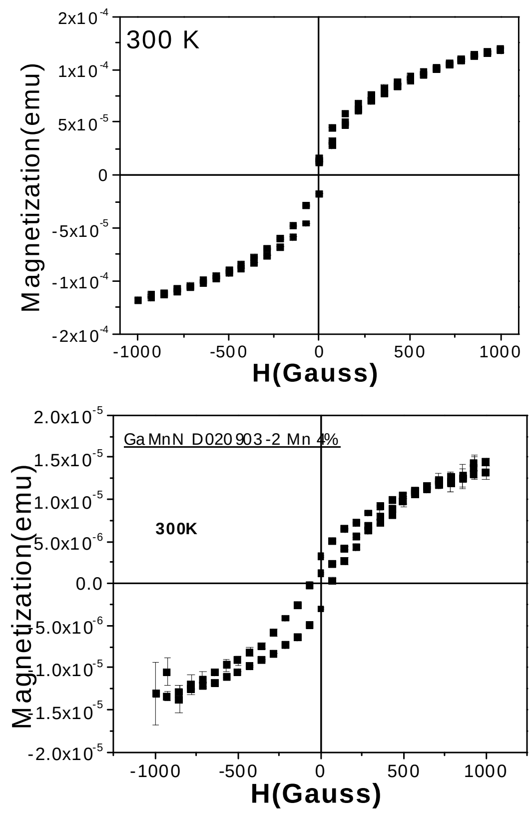

Figure 2. 300K M vs. H plots for GaMnN grown with (top) and without (bottom) 8% oxygen contamination. The Mn concentration was 4%.

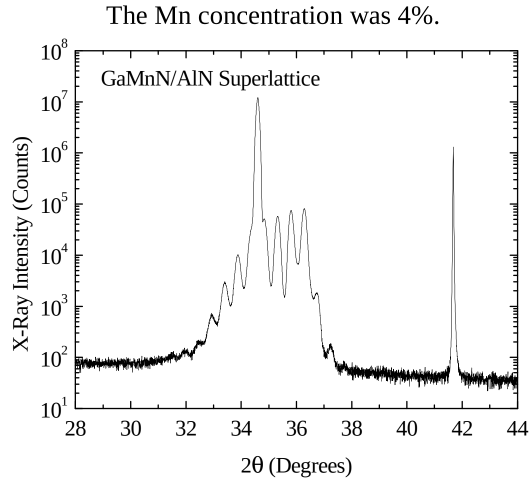

Figure 3. X-ray diffraction scan of 20 period GaMnN(10nm)/AlN(10nm) superlattice.