Growth and Characterization of GaMnN Dilute Magnetic Semiconductors

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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 optential for application of these materials in device structures.(1-4) Of particular interest for device applications are spintronic materials that have a ferromagnetic transition temperature (T_C) at or above room temperature, which have been predicted for magnetically doped wide bandgap materials such as GaMnN and SiMnC. (5) The promise of adding magnetic capability to the high power and optical functionality of GaN has produced a large activity in this area.(6-8) To date we have reported the first production of ferromagnetic GaMnN by ion implantation and molecular beam epitaxy, as well as ferromagnetic GaMnP by molecular beam epitaxy.(9-10) In this paper we report on recent work to achieve room temperature magnetism in GaMnN and explore the effect of growth conditions on the structural and magnetic propeties of the material.

Epitaxial growth of the ferromagnetic semiconductor GaMnN was been investigated by Gas Source Molecular Beam Epitaxy (GSMBE). The Mn incorporation was found to depend on growth temperature, with lower temperatures producing higher concentrations, as shown in Figure 1. The maximum concentration which could be obtained in single phase material was also found to be higher at lower growth temperatures. All films were n-type with resistivities ranging from 300 to 0.3 Ohm-cm, depending upon the growth conditions and Mn concentration. Films grown at 700°C showed hysteresis at 300 K, as shown in Figure 2, while temperature-dependent magnetization measurements indicate that the magnetism may persist to much higher temperatures (> 325 K). As was found for implanted GaMnN, a Mn concentratrion of ~3% appears to be the optimum concentration in terms of maximizing the moment per Mn atom. Samples of AlGaMnN with ~50% Al and AlMnN have also been prepared for the first time that show improved surface morphology and structural quality as compared to GaMnN, as shown in Figure 3. However, the material shows only paramagnetic behavior, presumably due to the absence of carriers in the highly resistive films. Growing the GaMnN on MOCVD grown GaN buffers was also found to improve the structural quality of the layers. In some cases the RHEED pattern was completely streaky as compared to the spotty pattern obtained when growing the layers on sapphire. Surface morphologies tended to improve with decreasing Mn concentration or increasing temperature.

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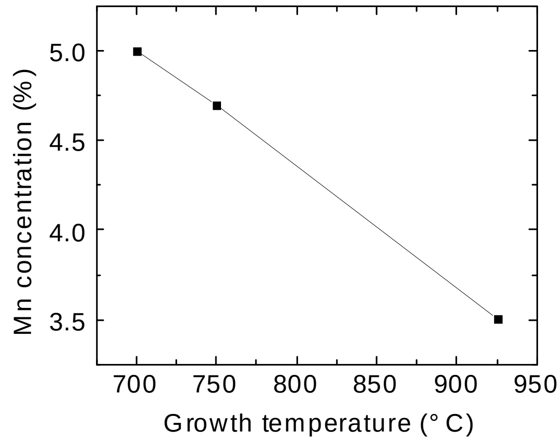

Figure 1. Variation of Mn concentration with substrate temperature for GaMnN grown using a Mn cell temperature of 620°C.

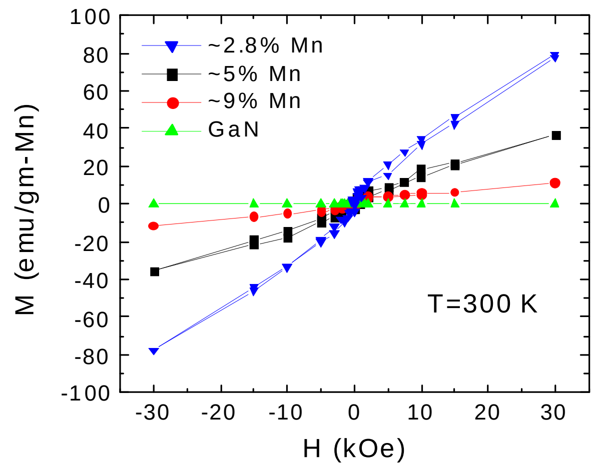

Figure 2. M vs. H behavior of GaMnN grown at 700°C using Mn cell temperatures of 615°, 620° and 625°C.

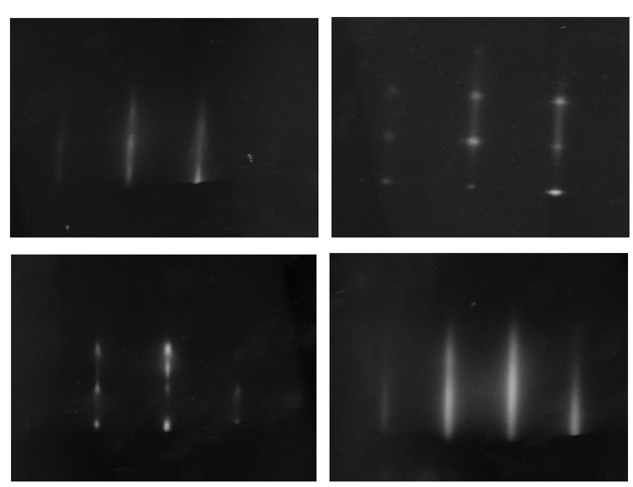

Figure 3. RHEED diffraction patterns taken from GaN (upper left), GaMnN (upper right and lower left) and AlGaMnN (lower right). All layers were grown on sapphire at 700°C except for the GaMnN depicted at lower left which was grown on an MOCVD buffer. The Mn cell temperature for all layers was 620°C.