AT13

Origin of Colossal Magnetic Moment of Gd in Very Weakly Gd Doped GaN

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Very weakly Gd doped GaN is found to exhibit an unprecedented magnetic behavior. The average value of the magnetic moment per Gd atom is found to be as high as 4000 μ_B as compared to its atomic moment of 8 μ_B. Moreover, the material system is found to exhibit ferromagnetism well above room temperature. These two findings indicate a long range spin-polarization of the GaN matrix by the Gd atoms [1]. Recently, molecular beam epitaxy grown GaN layers are implanted with 300 keV Gd^{3+} ions at room temperature by focused ion beam implantation (FIB) at doses 2.4 x 10^{11} and 1.0 x 10^{15} cm^{-2}, which corresponds to an average Gd concentration of 2.4 x 10^{16} and 1.0 x 10^{20} cm^{-3}, respectively. The magnetic moment per Gd atom in these samples is found to be even larger as compared to that is found in epitaxially grown layers for a given Gd concentration [2]. The effect of annealing on the magnetic and the structural properties of Gd implanted GaN samples is also investigated [3]. Implanted samples are rapid thermally annealed in flowing N_2 gas up to 900 °C for 30 sec. X-ray diffraction results indicate the presence of Ga- and N-interstitials in the implanted layers. Their densities are found to reduce upon annealing [Fig. 1(a)]. At the same time, magnetic measurements on these samples clearly show a reduction in the saturation magnetization as a result of the annealing [Fig. 1(b)]. These findings suggest that Gd might be inducing magnetic moment in Ga- and/or N-interstitials in giving rise to an effective colossal magnetic moment of Gd and the associated ferromagnetism observed in Gd:GaN. The combination of these findings offers few exciting oppertunities for application in spintronics, and optoelectronics.

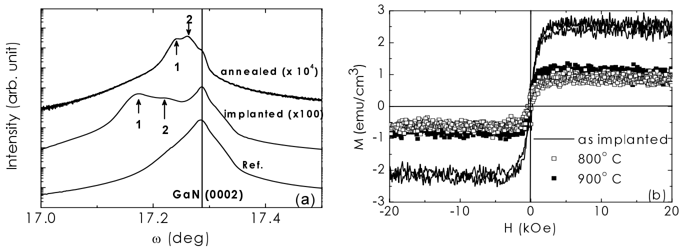

Fig. 1. (a) X-ray diffraction ω-2θ symmetric scans on the reference GaN sample and the implanted sample with Gd concentration of 1.0 x 10^{20} cm^{-3} before and after the annealing. Arrows showing the peaks related to the Ga (arrow 1) and N (arrow 2) interstitial dominated zones. (b) Magnetization loops obtained at 300 K for samples with Gd concentration of 2.4 x 10^{16} cm^{-3} before and after the annealing at different temperatures.

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AT14

The Configurations of Magnetic Domains during the Reversal Process in Ferromagnetic GaMnAs Film

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The magnetization reversal process of ferromagnetic GaMnAs film with dominant cubic anisotropy has been carefully investigated by planar Hall effect (PHE). Typical two-steps switching behavior between two values, in which only two different directional magnetizations are involved, was observed in the field scan data when the field direction is away from the magnetic easy axes. When the applied field direction (φ_H) lies near the one of easy axes of the film, however, the coexisting configuration of three different magnetizations, which leads to the decrease of planar Hall resistance (PHR) amplitude, is realized during reversal process. [1] Such configurations of magnetic domains have been simulated by using magnetic free energy and domain wall propagation theory. The sample parameters, such as pinning energy and magnetic anisotropy field, required for simulation have been obtained from field scan data and angular dependent PHE. Two different configurations were obtained in the regions of φ_H where the amplitude of PHR is reduced. In one configuration, two domain walls (DW), which separated the three different magnetic domains, proceed sequentially from one end to the other end along the sample. In the other configuration, the 2nd DW, which produced later, catches up with 1st DW so that the part of sample area completes its 180° magnetization reversal without experiencing 90° rotation. The simulation results provide detail understanding on the magnetization reversal process of GaMnAs film observed in the PHE measurement.

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