Probing Location of Rare-Earth Ions in Zinc Oxide Matrix by RBS Channeling for Spintronic Applications

P.P. Murmu[1], and J. Kennedy[1,2]
[1] *National Isotope Centre, GNS Science, PO Box 31312, Lower Hutt 5010, New Zealand*
[2] *The MacDiarmid Institute for Advanced Materials and Nanotechnology, New Zealand*

Zinc oxide (ZnO) is a promising dilute magnetic semiconductor (DMS) host material with the potential to show room temperature ferromagnetism (RTFM) under suitable doping conditions [1]. Transition-metal doped ZnO remains the most widely studied ZnO-based DMS, although conflicting magnetic order has been reported in similar systems. Rare-earth (RE) elements were shown to induce large magnetic moments in semiconductors such as GaN, and in principle can also be incorporated into ZnO to form DMS [2-5]. A systematic investigation is required for better insight into location and magnetic interactions in RE doped ZnO (ZnO:RE), as the observed magnetic coupling is often associated with the defects [4].

We report results obtained from 30-40 keV RE (Gd, Er and Tb) ions implanted into ZnO single crystals with fluences ranging from 6.6×10^{14} to 3.0×10^{16} cm^{-2} resulting in 0.7 to 12% RE atoms at an average depth of ~12 nm. Rutherford backscattering spectrometry in channeling condition (RBS/C) were carried out to study the location of RE in ZnO matrix using 2 MeV Helium beam obtained from 3 MV Van De Graff Accelerator. RBS/C revealed that for 9.0×10^{14} cm^{-2} ZnO:RE around 100% of the Gd/Er atoms occupied Zn substitutional lattice sites [2,5]. Annealing at 650 ˚C had profound effects on the Gd/Er atomic positions and only around 78 to 81% were found at substitutional sites and the rest driven out to random interstitials. Energy-filtered TEM revealed that interstitial RE atoms may form RE-rich nanocrystals. Temperature dependent resistivity results showed characteristics of degenerate semiconductors, with an anomalous feature at low temperatures [3]. ZnO:Gd samples exhibited negative magnetoresistance (MR) with lower MR values in annealed samples, suggesting reduced free scattering centres due to enhanced magnetic ordering. RTFM was observed in annealed ZnO:RE with a hint of mixed magnetic phases as seen in the M(T) data. Possible mechanisms for magnetic order, supported by structural, magnetotransport, and magnetization measurements, will be presented in the conference.

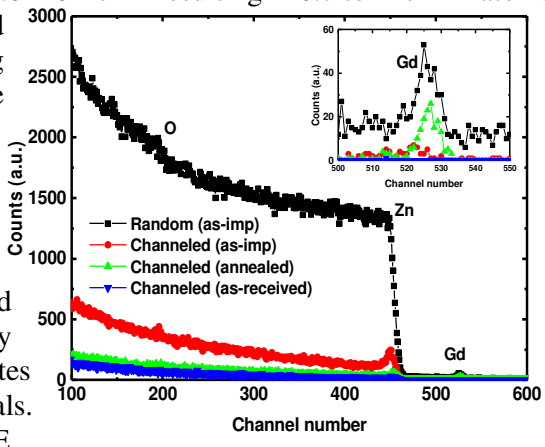

Fig. 1: Random and [0001]-aligned RBS spectra of 9.0×10^{14} Gd cm^{-2} implanted and annealed ZnO [2]. Inset: magnified Gd peaks.

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