Impact of Mg Doped Cladding Layers on Ferromagnetism of (Ga,Mn)N Thin Films

K. Gas [1,2], G. Kunert [3,4], S. Figge [4], S. Stefanowicz [2], T. Baraniecki [3], P. Dłużewski [2], B. Kurowska [2], R. Jakieła [2], G. Mazur [2], D. Hommel [3,1,4], and M. Sawicki [2]

[1] *Institute of Experimental Physics University of Wrocław, Wrocław, Poland*
[2] *Institute of Physics, Polish Academy of Sciences, Warsaw, Poland*
[3] *Wrocław Research Center EIT+ Sp. z o.o., Wrocław, Poland*
[4] *Institute of Solid State Physics, University of Bremen, Bremen, Germany*

Since GaN has reached the status of the second most important semiconducting material after Si the prospect of spintronics functionalization of GaN have gained in significance. However, the most obvious way of magnetic functionalization of GaN by alloying it with transition metals (mainly Mn) showed that due to a short range of superexchange Mn-Mn interaction the Curie temperature, T_C, does not exceed 13 K even for as high Mn content as 10%, despite exhibiting the highest saturation magnetization in the whole dilute ferromagnetic semiconductors family [1,2]. On the other hand, an extending of the effective range of the magnetic coupling in such a high Mn-content material should lead to a substantial increase of T_C. For example, a presence of mobile holes is expected to bring the T_C above the room temperature (RT) in this material system [3].

Here we show that a substantial, up to 50% increase of the magnitude of T_C in (Ga,Mn)N is possible when a thin (5 nm thick) layer gets sandwiched between Mg-doped GaN. To this end we investigate two sets of GaN:Mg/(Ga,Mn)N/GaN:Mg structures grown by molecular beam epitaxy (MBE) on GaN templated c-plane Al_2O_3. Targeting the same Mn content in the first set we vary the Mg content in the GaN:Mg cladding layers by changing the Mg flux from 0 to 2×10^{-8} Torr. In the second set we vary the Mn incorporation into (Ga,Mn)N film by changing the substrate temperature from 600 to 730^{o}C under a constant Mg flux of 1×10^{-8} Torr. Structural properties are examined by XRD, SIMS and HRTEM. Both Mn concentration and values of T_C are established from highly elaborated and dedicated SQUID magnetometry allowing to fully mitigate spurious magnetic artifacts originating from residual magnetism of MBE substrates and materials used for sample holder construction. Interestingly, whereas the highest Mg flux used to grow GaN:Mg layers practically prevented Mn incorporation into the middle layer, the structures grown with the mid-high Mg flux of 1×10^{-8} Torr show up to 50% higher T_C than equivalent plane thick (Ga,Mn)N films [4]. On the other hand, a very high RT resistivity of these layers preclude a simplistic explanation of hole mediated coupling and calls for more detailed studies of the Mn incorporation and final distribution in GaN during Mg-assisted MBE growth.

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This work has been supported by the National Science Centre (Poland) through grants FUGA (DEC-2014/12/S/ST3/00549) and OPUS (DEC-2013/09/B/ST3/04175), by the EU 7th Framework Programme "EAgLE" (REGPOT-CT-2013-316014) and by Wrocław Research Center EIT+ within the project "The Application of Nanotechnology in Advanced Materials" - NanoMat (P2IG.01.01.02-02-002/08) co-financed by the European Regional Development Fund (operational Programme Innovative Economy, 1.1.2).