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Evidence of p-type doping in Mn doped AlGa_N following ⁵⁷Mn/⁵⁷Fe implantation

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Currently, intensive research in group III nitrides is focussed on improving the performance of commercial devices. This includes their heterostructures and/or alloys with other group III elements. Amongst the latter are ternary semiconductors such as Al_xGa_{1-x}N, which are expected to give rise to unexpected photonic and magnetic functionalities when doped with magnetic ion species. This has prompted our study of the lattice sites, valence states and annealing behaviour of Fe ions in virgin and Mn (1 at.%) doped Al_xGa_{1-x}N using ⁵⁷Fe emission Mössbauer spectroscopy (eMS). Radioactive ⁵⁷Mn⁺ ($T_{1/2} = 1.5$ min.) ions were implanted with 50 keV energy at ISOLDE/CERN into Al_xGa_{1-x}N films grown by metalorganic vapour phase epitaxy (MOVPE) on sapphire substrates. eMS measurements were performed in the temperature range of 100 - 800 K. The room temperature spectra for Al_{0.2}Ga_{0.8}N acquired at emission angles (θ_E) of 60° and 0° show the presence of magnetically-split sextets in the “wings”, similar to features observed in GaN and AlN[1] and attributed to Fe³⁺ on Al/Ga sites showing slow paramagnetic relaxations[2]. The central part of the spectra is characterised by paramagnetic Fe²⁺ on Al/Ga sites associated with nitrogen vacancies. However, with Mn doping, the contribution of Fe³⁺ is considerably reduced or negligible. This is coupled with the corresponding emergence of a single line component with Mössbauer parameters typical of Fe⁴⁺ on Al/Ga sites, which are acceptors in AlGa_N, suggesting the possibility of *p*-type doping. Results will be discussed and compared with Si doping.

[1] H. Masenda, *et al.*, Journal of Magnetism and Magnetic Materials, **401** (2016) 1130.

[2] H. P. Gunnlaugsson, *et al.*, Applied Physics Letters, **97** (2010) 142501.

Authors: MASENDA, Hilary (University of Witwatersrand); GUNNLAUGSSON, Haraldur Pall (University of Iceland (IS)); TARAZAGA MARTÍN-LUENGO, Aitana (Johannes Kepler Universität); NAIDOO, Deena (University of the Witwatersrand); BHARUTH-RAM, Krish; JOHNSTON, Karl (CERN); MANTOVAN, Roberto; ADHIKARI, Rajdeep (Johannes Kepler Universität); BONANNI, Alberta (Johannes Kepler Universität); MOLHOLT, Torben Esmann (CERN); UNZUETA SOLOZABAL, Iraultza (Universidad del País Vasco / Euskal Herriko Unibertsitatea (ES)); KRASSTEV, Petko (Bulgarian Academy of Sciences (BG)); ADOONS, Vanthini Nelson (U); NCUBE, Mehluli (U); MOKHLES GERAMI, Adeleh (K.N Toosi University of Technology (IR)); OLAFSSON, Sveinn (University of Iceland (IS)); GISLASON, Hafliði (University of Iceland); MATVEYEV, Yuri (Moscow Institute of Physics and Technology); LANGOUCHE, Guido (Katholieke Universiteit Leuven)

Presenter: MASENDA, Hilary (University of Witwatersrand)

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