On the growth of Mn doped GaN: Molecular beam epitaxy under different conditions

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Manganese doped gallium nitride is a diluted magnetic semiconductor with promising applications in the field of semiconductor spintronics. Curie temperatures higher than room temperature are predicted for materials with Mn content of 5 %. This high amount of Mn is difficult to incorporate into GaN. The predicted solubility limit of 0.032 % for Mn in GaN can theoretically be increased for different surface conditions [1]. Especially nitrogen rich conditions were reported to have positive influence on Mn incorporation [2].

In this work different conditions for the growth of $Ga_xMn_{1-x}N$ by molecular beam epitaxy (MBE) are investigated. The goal is to create homogeneous ferromagnetic layers with Curie temperatures above room temperate. All samples were grown on GaN templates prepared by metal-organic vapor-phase epitaxy on sapphire substrates. An EPI930 MBE chamber equipped with a RF-plasma source was used to fabricate the samples. Low temperature and high temperature growth of GaMnN was investigated.

For the first set of samples a growth temperature of 550 °C was chosen. This comparably low temperature is reported to have positive influence on Mn incorporation due to large adhesion coefficients of Mn. III/V-ratio is close to the stoichiometric point on the metal rich side. Manganese contents of 1.75 to 4.6 %, as determined by SQUID measurements, were reached for GaMnN. These samples possess spontaneous magnetization below 6 K and they show quasi Brillouin-behaviour. Hysteresis can be detected at 2 K but coercivity is small (≈275 Oe) for 4.6 % of Mn. Small crystallites with diameters of about 100 nm form for these amounts of Mn.

The second set of samples was grown in c-orientation at temperatures of 760 °C. Slightly nitrogen rich growth conditions lead to rough surfaces for low fluxes of Mn. In contrast, for metal fluxes exceeding the stoichiometric point smooth layers are created. The high vapor pressure of Mn is benefical in this case. Excess Mn re-evaporates from the surface. The samples were investigated with high resolution x-ray diffraction. In 2Θ-Ω-scans template and GaMnN layer can be clearly identified. Omega-Scans of both show smaller FWHM for MBE grown GaMnN layers indicating lower defect density in these layers. GaN layers, having Mn concentrations of 4.1 % show a strong, above-Brillouin response, but no coecivity is present. Superparamagnetic states are assumed.

[1] Z. T. Chen, L. Wang, X. L. Yang, C. D. Wang and G. Y. Zhang; Mechanism of ultrahigh Mn concentration in epitaxially grown wurtzite $Ga_xMn_{1-x}N$, *Applied Physics Letters* **97**, 22, 2010

[2] M. Kocan, J. Malindretos, M. Roever, J. Zenneck, T. Niermann, D. Mai, M. Bertelli, M. Seibt and A. Rizzi; Mn incorporation in GaN thin layers grown by molecular-beam epitaxy *Semicond. Sci. Technol.*, **21**, 2006