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Magnetic Phase Diagram and Critical Exponents of
Magnetic Insulator (Ga,Mn)N

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The thesis is focused on investigation of (Ga,Mn)N, which is one of two compounds [together with (GaMn)As] which arguably demonstrate the highest potential for studying semiconductor spintronics-related phenomena. The importance of (Ga,Mn)N stems from a different origin of magnetism than in (Ga,Mn)As and dominating role of GaN in photonics and high power electronics, which allowed it to reach the status of the second most significant semiconductor materials after Si. Due to occupation of mid band gap position in GaN by Mn^{2+/3+} acceptor level (Ga,Mn)N has been classified as dilute magnetic insulator. Therefore magnetic properties especially critical behavior at temperature driven magnetic phase transition, and more generally magnetic phase diagram become a very important topic for scientific investigation.

The first aim of this thesis is to experimentally establish the magnetic phase diagram for insulating (Ga,Mn)N. The second goal is to describe the static critical behavior of the (Ga,Mn)N by critical exponents analysis.

The thesis consists of six chapters. The first chapter contains selected literature information about the investigated material and briefly describes the forms of magnetic interactions between magnetic moments. The second chapter introduces Landau phase transition and the concept of critical exponents. The third chapter is devoted to a detailed description of the experimental procedure used to perform measurements in commercial SQUID magnetometers and in a homemade SQUID-based magnetometry set-up installed in a ³He/⁴He dilution fridge. The results of structural characterization of the investigated samples, e.g. TEM measurements, are presented in the fourth chapter. The fifth chapter contains analysis of magnetic properties and is concluded with the magnetic phase diagram for (Ga,Mn)N. The six chapter is devoted to analysis of critical behavior of the (Ga,Mn)N and determination of critical exponents. The thesis ends by summary and appendix which contains the author's scientific achievements and list of publications.

The main result of the studies is the establishment of the magnetic phase diagram for Ga_{1-x}Mn_xN with 0.01 < x < 0.1. The observed there power law dependency, $T_C \sim x^{2.2}$, supports the view that ferromagnetic superexchange is the dominant coupling mechanism between Ga-substitutional Mn³⁺ ions in (Ga,Mn)N. Because of a short-range character of the coupling, measured and modeled values of T_C are rather low. Additionally it is shown that: (i) the critical behavior of this dilute magnetic insulator is similar to critical behavior observed for disordered ferromagnets, (ii) the susceptibility critical exponent γ exhibits a highly nonmonotonic behavior, and (iii) the ferromagnetic-paramagnetic phase transition is considerably smeared, which can be explained either by the Griffiths effects or by macroscopic inhomogeneities in the spin distribution. A developed in the thesis phenomenological model supports the latter possibility qualitatively. The obtained in this study values of critical exponents are close, but larger than the expected ones for XY or Heisenberg universality class.