IR-magnetotransmission investigations on p-type cubic GaN layers in magnetic fields up to 700T

I. Stolpe[1], N. Puhlmann[1], M. von Ortenberg[1], O.M. Tatsenko[2], V.D.Selemir[2], I.M.Markevtsev[2], V.V.Platonov[2], and D. Schikora[3]

[1] Institute of Physics, Chair for Magnetotransport in Solids, Humboldt-University at Berlin, Invalidenstrasse 110, D-10115 Berlin, Germany

[2] Russian Federal Nuclear Centre, All-Russia Research Institute of Experimental Physics (VNIIEF), Pr. Mira 37, Sarov, Nizhni Novgorod Region, 607190, Russia

[3] University / GH Paderborn, Warburgerstrasse 100, D-33095 Paderborn, Germany

Abstract:

We report on IR-magnetotransmission experiments on p-type epitaxial layers of cubic GaN in extremely high magnetic fields up to 700 T.

The epitaxial layers were grown in a RIBER-32 MBE system with rf-activated plasma source on (001)-GaAs substrates. To optimise the growths parameters the GaN surface reconstruction phase diagram was used [1]. The stoichiometric composition of the surface during the growth process was controlled by *in situ* RHEED. To ensure As-stabilised growth conditions a GaAs buffer layer was first grown under (2x4) reconstruction. The nucleation of the cubic GaN at 600°C was stopped after 10-20 mono-layers and the substrate temperature was raised to 680-740°C. The growth was continued at this higher temperature to establish near stoichiometric growth conditions and finally stopped at about 1µm layer thickness. The samples were additionally doped by magnesium to result definitely in p-type. The doping profile of the layers was determined by SIMS measurements. The carrier system was characterised by temperature dependent conductivity and Hall-effect measurements. For both, mobility and carrier concentration a strong temperature dependence was observed. Typical values are for the mobility in the order of 200 cm^2/Vs and for the hole concentration of 10^{17} cm^{-3} at room temperature.

To obtain detailed information on carriers with such low mobility using a magneto-resonance experiment, megaggauss spectroscopy has to be applied to enforce a reasonable line width of the resonance. Such successful experiments on p-type cubic GaN in magnetic fields up to 270 T using the semi-destructive single-turn coil technique were reported recently and compared with the theoretical expectation of the established quasi-cubic k*p-model for GaN [2]. Due to the sophisticated experimental technique even in the environment of an “electromagnetic pulse” changes in the relative transmission smaller 1% could unambiguously be detected, so that also very weak resonances could be identified. Both, experimental and theoretical results of [2] were a challenge to extend the investigation into the magnetic field range

well beyond the possibilities of the single-turn coil technique limited to about 300 T, since several additional resonance lines were expected in the high-field range.

Magnetic fields beyond 300 T ranging up to 700 T and more can only be realised using the explosive flux-compression. This method involves, however, several pronounced disadvantages. Not only that the experiment is completely destructive and needs quite a high financial investment, but also the field generation process is accompanied by an extremely strong transient electromagnetic noise. Due to the sophisticated shielding and data processing features developed in Berlin, however, these techniques could be successfully transferred to the open-air firing point of the flux compression experiment in Sarov, Russia. The magnetic field was produced by the magneto cumulative MC-1-generator using three cascades and driven by a total of 16 kg explosive (50% TNT and 50% Hexogen). The sample was similar to that used before [2]. In Faraday configuration the sample was exposed to CO_2-laser radiation having a fixed wavelength of 10.6 µm at a temperature of about 270 K. Since contrary to the single-turn coil technique in a flux-compression experiment only the up-sweep for the magnetic field is available for data detection, special care was taken of time synchronisation for the magnetic field pulse of only some µsec length. The recorded data are of extraordinary quality in comparison to those obtained for optical experiments in failing previous attempts. In the "low field" range up to 270 T the data reproduce exactly the measurements recorded in Berlin using the single-turn coil technique. For higher fields now not only the second resonance of the Berlin-experiment is completely resolved but also at even higher magnetic fields a third strong resonance, centred at around 425 T, is completely recorded. To the best of our knowledge no experimental resonance data in the IR using explosive flux compression have been reported so far. All of the observed three resonance lines are interpreted as inter-valence band transitions. It should be noted that the fundamental cyclotron resonance is expected at magnetic fields of about 1500 T, which is a challenge for the future, since magnetic fields up to 2800 T were already generated using flux-compression technique [3].

[1] D. Schikora, M. Hankeln, D.J. As, K. Lischka, T. Litz , A. Waag, T. Buhrow and F. Henneberger , Phys. Rev B **54**, R8381 (1996)

[2] N. Puhlmann, I. Stolpe, H.-U. Müller, O. Portugall, M. von Ortenberg, D. Schikora, D.J. As, B. Schöttker, R. Lischka, Proceedings of the "24th Intnl. Conf. Of Semiconductors", Jerusalem 1998, *ed.* D. Gershoni, World Scientific p. 243 (1999)

[3] B.A. Boyko, A.I. Bykov, M.I. Dolotenko, N.P. Kolokol'chikov, I.M. Markevtsev, O.M. Tatsenko, A.M. Shuvalov Proc. VIII-th Intern. Conf. on Megagauss Magnetic Field Generation and related topics", Tallahassee, October 18-23, (1998)