Free charge carrier properties in group-III nitride high electron mobility transistor structures determined by optical Hall effect

Philipp Kühne[1,2,3,*], Nerijus Armakavicius[1,2,3], Vallery Stanishev[1,2,3], Jr-Tai Chen[2,3], Olle Kordina[2,3], Mathias Schubert[1,3,4] and Vanya Darakchieva[1,2,3]

[1] *Terahertz Materials Analysis Center (THeMAC), Department of Physics, Chemistry and Biology (IFM), Linköping University, SE-58183 Linköping, Sweden*
[2] *Center for III-Nitride Technology, C3NiT-Janzén, Linköping University, SE-58183 Linköping, Sweden*
[3] *Semiconductor Materials Department of Physics, Chemistry and Biology (IFM), Linköping University, SE-58183 Linköping, Sweden*
[4] *Department of Electrical and Computer Engineering, University of Nebraska-Lincoln, Lincoln, Nebraska, 68588-0511, USA*

Corresponding author e-mail address: philipp.kuhne@liu.se

The optical Hall effect (OHE) is a physical phenomenon which manifests itself as optical birefringence caused by a static external magnetic field acting on free charge carriers. An excellent tool to quantify the OHE is generalized spectroscopic ellipsometry. Depending on the free charge carrier parameter i.e. carrier concentration, mobility and effective mass, the optimal spectral range to detect the OHE may lay between the mid-infrared to the terahertz (THz). For free charge carriers in 2-D materials or in 2-dimensional electron gases, the OHE is best studied at THz frequencies. Furthermore, for the effective masses in common semiconductors, such as silicon, germanium or group-III nitrides, the cyclotron frequency falls into the THz spectral range for magnetic fields of several tesla.

Here we employed the THz Frequency-Domain Ellipsometer of the Terahertz Materials Analysis Center at Linköping University [1] to determine temperature and magnetic field dependent free charge carrier properties in GaN based high electron mobility structures (HEMTs). The results reveal strong changes in the effective mass and mobility parameters that are assigned to the penetration of the electron wave function into the barrier [2,3]. We study the influence of the barrier material (AlGaN *vs.* AlInN) on the electron confinement and analyze the temperature-dependence of the carrier scattering, employing models that include the temperature dependence of the effective mass. In addition, in order to disentangle effects from the magnetic field and the temperature on the effective mass parameter the magnetic field dependence of the OHE is measured and analyzed.

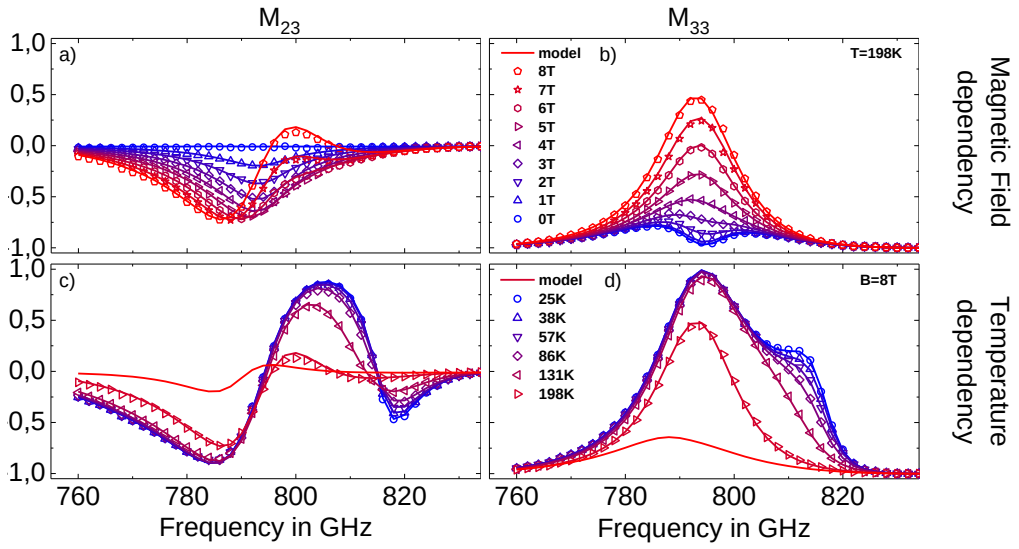

Figure 1: Experimental OHE data (symbols) and best model calculations (lines) from a GaN based HEMT structure. While panels a) and b) depict the magnetic field dependency, show panels c) and d) the temperature dependency of the OHE, each for a representative on-block-diagonal (panel a and c) and off-block-diagonal element (panel b and d) of the Mueller matrix. Best model parameter for the mobility range from 1350Vs/cm² to 30200Vs/cm and a strong temperature dependence of the effective mass is observed and used to analyze the temperature-dependence of the carrier scattering.

References

1. P. Kühne, *et al.*, IEEE Transactions on Terahertz Science and Technology **8**, 257 (2018)
2. N. Armakavicius, *et al.*, phys. stat. sol. C **13**, 369 (2016)
3. T. Hofmann, et al., Appl. Phys. Lett. 101, 192102 (2012)