ELECTRON EFFECTIVE MASS IN $In_{0.33}Ga_{0.67}N$ DETERMINED BY INFRARED OPTICAL HALL EFFECT

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Due to its band gap tunability and high electron saturation drift velocity, InGaN is very attractive for optoelectronic, high frequency and high power applications. Knowledge of free charge carrier effective mass parameter in InGaN is important for modelling the device performance and developing new designs. Typically, cyclotron resonance and Shubnikov-de Haas measurements are used to determine the effective mass. However, they require high carrier mobilities and thus low temperatures with high external magnetic fields. Due to difficulties in growth of high In content $In_xGa_{1-x}N$ ($x > 0.3$), material suffer from high concentration of defects and low mobility parameters. Thus, the reports of the effective mass parameter in $In_xGa_{1-x}N$ are scarce.

External magnetic fields alter the optical response of the free charge carriers in conductive materials that results in optical birefringence called optical Hall effect (OHE) [1]. Probing of the OHE by Mueller matrix ellipsometry at infrared and terahertz spectral ranges allows the determination of effective mass at room temperatures together with free carrier concentration and mobility parameters in bulk materials and thin layers.

Mid-infrared OHE measurements are used to determine the free charge carrier parameters of wurtzite structure *c*-plane oriented $In_{0.33}Ga_{0.67}N$ epitaxial layer [2]. Room temperature electron effective mass parameters of $m_{\perp}^{*} = (0.205 \pm 0.013)m_0$ and $m_{\parallel}^{*} = (0.204 \pm 0.016)m_0$ for polarization perpendicular and parallel to the *c*-axis, respectively, were determined. The free electron concentration was obtained as $(1.7 \pm 0.2) \times 10^{19}\ \mathrm{cm}^{-3}$. Within our uncertainty limits we detect no anisotropy for the electron effective mass and we estimate the upper limit of the possible effective mass anisotropy as 7%. We discuss the influence of band nonparabolicity on the electron effective mass parameter as a function of In content. The effective mass parameter is consistent with a linear interpolation scheme between the conduction band mass parameters in GaN and InN when the strong nonparabolicity in InN is included. The $In_{0.33}Ga_{0.67}N$ electron mobility parameters were found to be anisotropic supporting previous experimental findings for wurtzite structure GaN, InN, and AlGaN epitaxial layers with *c*-plane growth orientation. In addition, our data analysis reveals a surface charge depleted layer confirming previous findings showing that depletion of the electrons at the surface occurs in $In_xGa_{1-x}N$ with *x* below 0.4.

Keywords: effective mass; free charge carriers; optical Hall effect; III group nitrides; epitaxial graphene

References

[1] M. Schubert, P. Kühne, V. Darakchieva, T. Hofmann, J. Opt. Soc. Am. A 33, (2016), 1553-1568.
[2] N. Armakavicius, V. Stanishev, S. Knight, P. Kühne, M. Schubert, V. Darakchieva, (2017), arXiv:1712.01738 [cond-mat.mtrl-sci].