Appendix A: Calculation of band parameters

The valence band of wurtzite GaN is split into three, namely, heavy hole (hh) band, light hole (lh) band and crystal-field split-hole (ch) band.[28] The effective mass for the density of states $m_{\mathrm{Xh}}^{\mathrm{dos}}$ and the effective mass m_{Xh}^{*} in each band (Xh represents hh, lh or ch) is given by

$$m_{\mathrm{Xh}}^{\mathrm{dos}} = (m_{\mathrm{Xh}}^{\parallel} \times m_{\mathrm{Xh}}^{\perp} \times m_{\mathrm{Xh}}^{\perp})^{1/3} \ , \tag{A1}$$

$$\text{and } m_{\mathrm{Xh}}^{*} = 3\left(\frac{1}{m_{\mathrm{Xh}}^{\parallel}} + \frac{1}{m_{\mathrm{Xh}}^{\perp}} + \frac{1}{m_{\mathrm{Xh}}^{\perp}}\right)^{-1} \ , \tag{A2}$$

where $m_{\mathrm{Xh}}^{\parallel}$ and $m_{\mathrm{Xh}}^{\perp}$ represent the components of the hole effective mass in the k_z direction and in the $k_x k_y$ plane, respectively.

Therefore, the effective mass for the density of states in valence band, $m_{\mathrm{h}}^{\mathrm{dos}}$ considering the occupation probability of each band can be expressed by

$$m_{\mathrm{h}}^{\mathrm{dos}} = \left[(m_{\mathrm{hh}}^{\mathrm{dos}})^{3/2} + (m_{\mathrm{lh}}^{\mathrm{dos}})^{3/2} \times \exp\left(-\frac{\Delta_2}{kT}\right) + (m_{\mathrm{ch}}^{\mathrm{dos}})^{3/2} \times \exp\left(-\frac{\Delta_1}{kT}\right)\right]^{2/3} , \tag{A3}$$

where $\Delta_1 = \Delta_{\mathrm{cr}}$ is the crystal-field splitting and $\Delta_2 = 1/3\Delta_{\mathrm{so}}$ (Δ_{so} is spin-obit splitting).

The effective density of state of valence band N_{V} is expressed by

$$N_{\mathrm{V}} = 2(2\pi m_{\mathrm{h}}^{\mathrm{dos}} kT/h^2)^{3/2}. \tag{A4}$$

And, acceptor degeneracy factor g is obtained by summing over the degeneracy factors (each being 2) of individual bands weighted with the appropriate Boltzmann factors giving

$$g = 2 \times \left[1 + \exp\left(-\frac{\Delta_2}{kT}\right) + \exp\left(-\frac{\Delta_1}{kT}\right)\right]. \tag{A5}$$

The influence of three valence bands is again considered. The proportion of holes in each band is related to the effective density of state and the occupation probability. Therefore, m_{h}^{*} is expressed as

$$m_{\mathrm{h}}^{*} = \frac{m_{\mathrm{hh}}^{*} \times (m_{\mathrm{hh}}^{\mathrm{dos}})^{\frac{3}{2}} + m_{\mathrm{lh}}^{*} \times (m_{\mathrm{lh}}^{\mathrm{dos}})^{\frac{3}{2}} \times \exp\left(-\frac{\Delta_2}{kT}\right) + m_{\mathrm{ch}}^{*} \times (m_{\mathrm{ch}}^{\mathrm{dos}})^{\frac{3}{2}} \times \exp\left(-\frac{\Delta_1}{kT}\right)}{(m_{\mathrm{hh}}^{\mathrm{dos}})^{\frac{3}{2}} + (m_{\mathrm{lh}}^{\mathrm{dos}})^{\frac{3}{2}} \times \exp\left(-\frac{\Delta_2}{kT}\right) + (m_{\mathrm{ch}}^{\mathrm{dos}})^{\frac{3}{2}} \times \exp\left(-\frac{\Delta_1}{kT}\right)}. \tag{A6}$$

All the band parameters above are calculated based on 3D fit values reported by Yeo *et al.*[28] and listed in Table A-1.

Table A-1. Band parameters calculated based on 3D fit values in Ref. 28.

m_{hh}^{*} (m_0)	m_{lh}^{*} (m_0)	m_{ch}^{*} (m_0)	$\boldsymbol{m_{\mathrm{h}}^{*}}$ **(m_0)**	$m_{\mathrm{hh}}^{\mathrm{dos}}$ (m_0)	$m_{\mathrm{lh}}^{\mathrm{dos}}$ (m_0)	$m_{\mathrm{ch}}^{\mathrm{dos}}$ (m_0)	$\boldsymbol{m_{\mathrm{h}}^{\mathrm{dos}}}$ **(m_0)**	$\boldsymbol{N_{\mathrm{V}}}$ **(cm^{-3})**	$\boldsymbol{g}$
1.90	0.20	0.37	**1.65**	1.90	0.34	0.81	**2.13**	**7.78×10^{19}**	**4.62**