Probing the Internal Electric Field in GaN/AlGaN Nanowire Heterostructures

Jan Müßener,[1] Jörg Teubert,[1,*] Pascal Hille,[1] Markus Schäfer,[1] Jörg Schörmann,[1] Maria de la Mata,[2] Jordi Arbiol,[2,3] and Martin Eickhoff[1]

[1] *I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany*

[2] *Institut de Ciencia de Materials de Barcelona, ICMAB-CSIC, Campus de la UAB, 08193 Bellaterra, CAT, Spain*

[3] *Institucio Catalana de Recerca i Estudis Avançats (ICREA), 08010 Barcelona, CAT, Spain*

SUPPORTING INFORMATION

In addition to the sample with thick (16 nm) CBLs we performed bias dependent PL measurements on samples with thin (8 nm) and without CBLs. Figure S1a shows the dependence of the PL spectra on external bias for a NW with 8 nm CBLs. We observe a reversible quenching of the PL intensity over the entire spectral range with increasing external voltage $|U_{\mathrm{ext}}|$ which is accompanied by a broadening of individual spectral features. The quenching occurs in similar fashion for both voltage polarities, however, exhibits a certain asymmetry related to the asymmetric band profile as explained below. The quenching initiates at the break through voltage of the I-V-characteristics (cf. Figure 3) and is current induced. Samples without CBLs show an instant PL quenching already at low voltages ($|U_{\mathrm{ext}}| < 5\,\mathrm{V}$). The PL quenching is assigned to an electric self-heating of the NWHs [1] clearly confirmed by temperature dependent PL measurements (without applied voltage) as depicted in Figure S1b showing similar behavior of the PL spectra

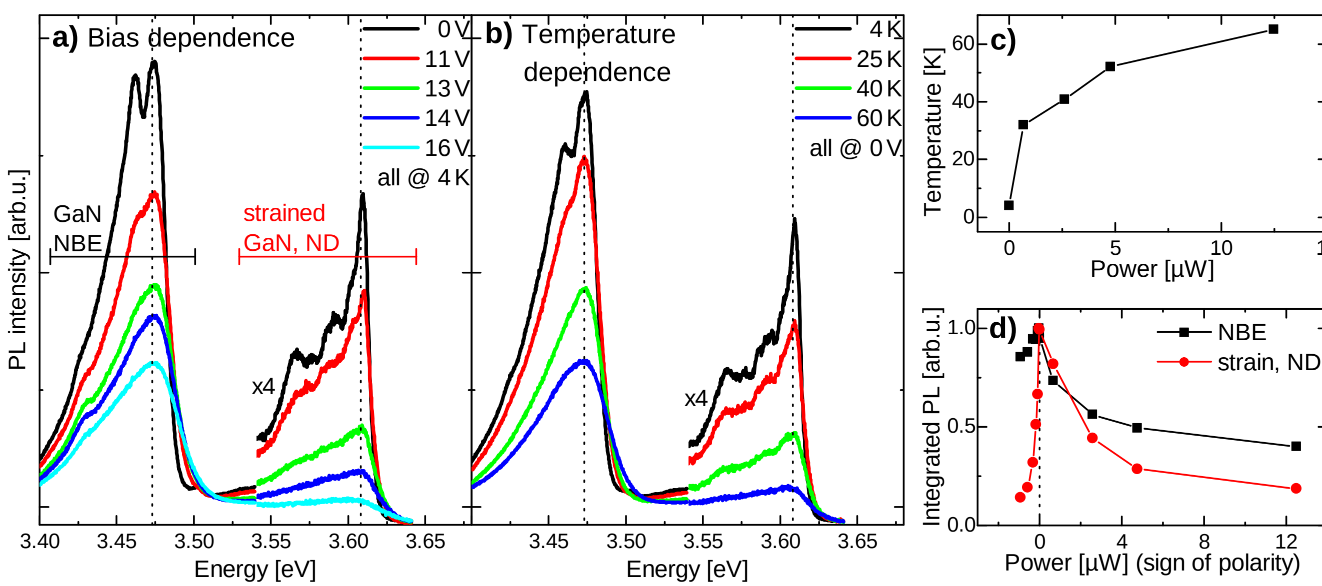

FIG. S1. PL emission of a single NWH with thin (8 nm) CBLs under the influence of an external bias (a) or temperature (b). (c) Correlation of (a) and (b) by their similar quenching behavior yields the NWH temperature as a function of the the electrical power dissipated in the NWH. (d) Integrated PL intensity of the GaN NBE emission (black squares) or strained GaN and ND emission (red dots) as a function of the dissipated electrical power (including the sign of external bias polarity).

* Joerg.Teubert@exp1.physik.uni-giessen.de

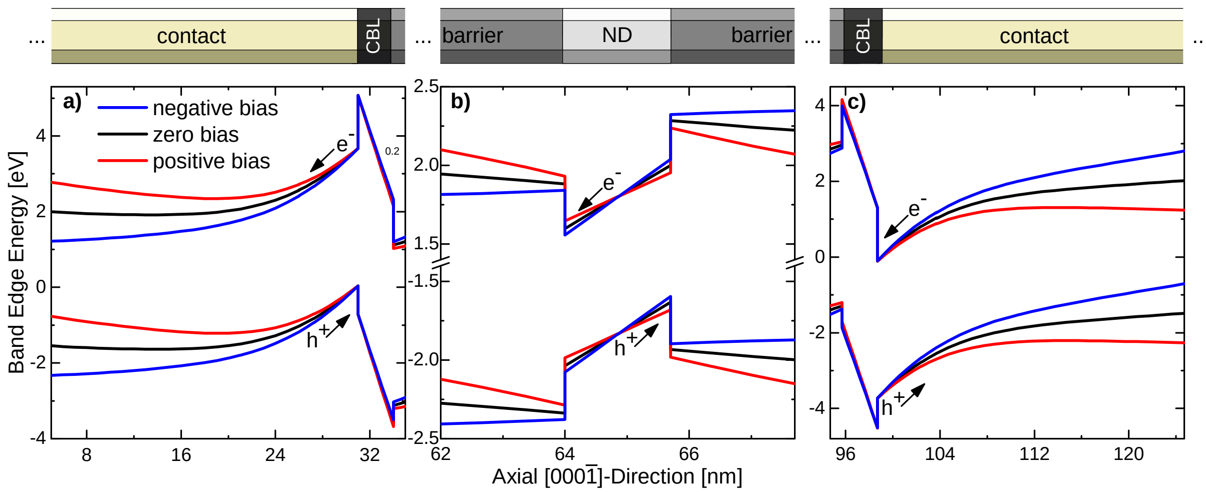

FIG. S2. Band profile of CB and VB along the NW centre axis at the lower (a) and upper (c) interface of GaN to AlN CBL and at the ND (b) simulated for zero bias (black) and schematically for positive (red) and negative (blue) external voltage.

with increasing temperature. The comparison of Figure S1a and b allows for a correlation of the NWH temperature and the dissipated electrical power (Figure S1c) indicating a temperature increase to 60 K for a dissipated power of 10 µW. These measurements emphasize the importance of heating effects in single NW electrical characterization.

While the quenching of the GaN NBE emission is almost symmetric with respect to the applied voltage polarity, the emission related to the strained GaN and ND shows an asymmetry, i.e. exhibits stronger PL quenching for negative polarity (Figure S1d). This can be explained by the asymmetry of the axial band profile arising from the internal polarization charges which also accounts for the effect of bias application on the intensity of the strained GaN emission for samples with 16 nm CBLs (cf. discussion of Figure 4d). Figure S2a and c schematically show the band profiles at the lower and upper interfaces between the CBLs and the strained GaN regions. Without external bias (black dataset) the GaN regions at the interfaces are characterized by significant axial electric fields leading to electron hole separation and an attractive potential for holes (electrons) is formed at the lower (upper) interface. For negative external voltage (blue line) the electrons (holes) are further separated from the lower (upper) interface resulting in increased carrier separation and PL quenching. On the contrary, the effect of carrier separation is reduced for positive external voltage (red line) due to band flattening. As these effects are restricted to the GaN/CBL interface regions, i.e. the region of strained GaN, the asymmetry with respect to bias polarity only shows in the corresponding emission band (3.5–3.65 eV) while the NBE shows symmetric PL quenching behavior.

[1] Prades, J. D.; Jimenez-Diaz, R.; Hernandez-Ramirez, F.; Barth, S.; Cirera, A.; Romano-Rodriguez, A.; Mathur, S.; Morante, J. R. *Appl. Phys. Lett.* **2008**, *93*, 123110.