Supporting Information for:
Near-Field Control and Imaging of Free Charge Carrier Variations in GaN Nanowires

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Gating Kinetics and Surface Traps

As noted in the manuscript, the spatial gating response is dependent on the tip scan direction and speed, primarily due to the long-term kinetics of surface traps. Shown in Fig. S1 are the $I_{\rm NW}$ of the trace and retrace of the image shown in Fig. 2(f) of the manuscript, with scan directions as indicated. A distinct asymmetry is seen for each scan direction, where the current decreases as the tip passes over the wire, and recovers only slowly once the tip has passed. It can also be seen that the trace (blue, acquired previous to the green line) has a higher average current, showing that the current does not recover entirely after each pass of the tip. As a consequence, all current measurements shown are averaged over the trace and retrace in order to cancel out the scan direction-dependent drift.

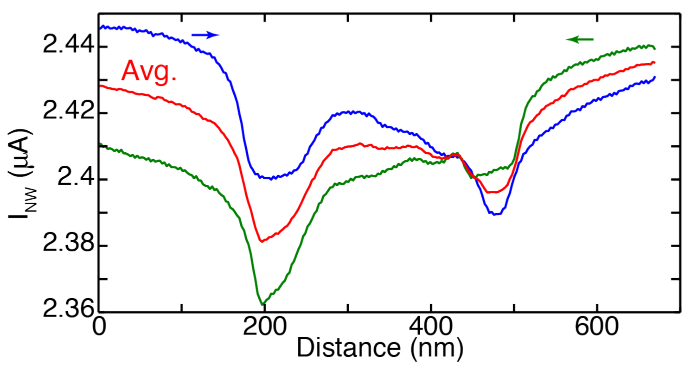

FIG. S1: Source-drain wire current as function of tip position with scan direction as indicated.

This long term-change in wire current is responsible for the observed current hysteresis. As expected, the degree of hysteresis and the current recovery between scan lines is dependent on scan speed, though it is important to note that the bias at which the wire current is completely suppressed appears to be largely independent of scan speed.

We further studied the influence of a sub-bandgap optical excitation on current variations and hysteresis. As illustrated in Fig. 1(d), an optical beam with $\lambda = 406$ nm is focused onto the tip-sample region with top illumination at an angle of incidence $\phi \sim 70°$ on the forward-pointing tip to prevent shadowing. These results are from a different wire, as the one described in the manuscript was damaged during measurements. We use a photon energy of 3.07 eV to excite deep traps and surface states, including those in the bandgap near the valence band maximum. Shown in Fig. S2 is the spatial dependence of wire current on tip position for increasing illumination intensities as indicated. Values of $V_{\rm t}$ used for all illumination intensities correspond to the onset of complete current suppression across most of the wire. With an increasing concentration of photogenerated free carriers, a larger $V_{\rm t}$ is required to entirely suppress the wire current. For higher illumination intensities the rapid depopulation and passivation of trap states also results in rapid current recovery as the tip moves away from the wire, while dark and lower illumination conditions see little or no recovery.

While the image shown is the average of the AFM trace and retrace, the individual scans together with the scan rate can be used to infer recovery time kinetics. We find that for the dark case the time for the current to begin recovery is greater than 2.1 s. For weak illumination at 10 mW/cm^2, the current begins to recover after 0.8 s, however it recovers only by ∼1% over 2 s. As the illumination intensity is increased, the recovery time decreases significantly. When the intensity is increased to 150 mW/cm^2, the wire recovers to 90 % of the non-gated current in 200 ms, and the recovery time further decreases to 100 ms for 500 mW/cm^2.

We also studied the influence of the global backgate, which is grounded throughout all measurements shown. In particular, we found that a positive (negative) $V_{\rm BG}$ increased (decreased) the overall wire current, increased (decreased)

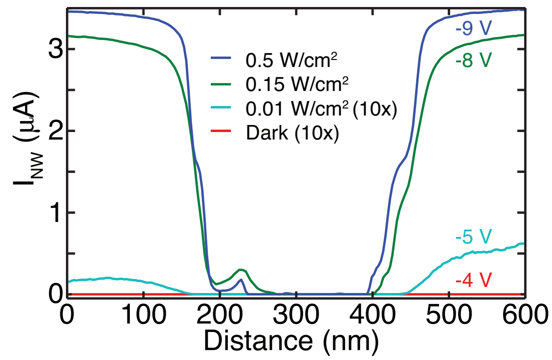

FIG. S2: I_{NW} with monochromatic illumination at $\lambda = 406$ nm with intensity and V_{t} as indicated

the V_{t} magnitude necessary to induce local depletion and prevent current flow, and decreased (increased) the amount of current hysteresis observed upon cycling the tip bias. Similarly, we found that a more positive V_{BG} increases current recovery rates while negative V_{BG} decreases the recovery rates (not shown). This behavior is as expected and no significant qualitative changes in wire behavior in response to the backgate bias was observed.

Current Fluctuations

Although long-term drift in I_{NW} is seen in response to negative tip bias as discussed above, the overall wire response is highly repeatable between lines and shows little or no variation along the wire length. In contrast, for positive values of V_{t} where current injection into the wire occurs, the spatial injection of current appears to vary stochastically as the tip passes over the side facets and vertices. Shown in Fig. S3 are the AFM topography (a), the corresponding S_{11} image, and the absolute current (c) for $V_{\mathrm{t}} = 0.4$ V. Deviation from ideal wire shape is due to AFM drift. Although the absolute wire current is higher than shown in Fig. 3 of the manuscript, V_{t} is set immediately above the threshold for current injection, resulting only in small current changes.

The line-to-line repeatability of current injection overall is low, though regions of increased probability appear to be reproducible. Overall, the origin of this effect is unclear, though local variations may originate in contamination of the tip or wire, possibly due to residual photoresist.

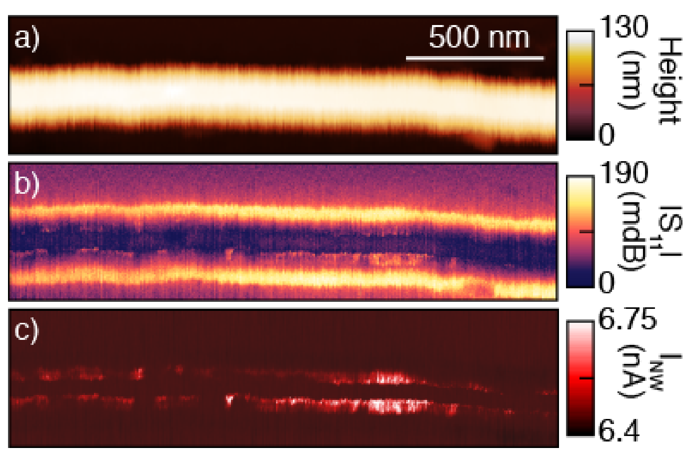

FIG. S3: AFM topography (a), S_{11} signal (b), and absolute current (c) for $V_{\mathrm{t}} = 0.4$ V.