Supporting Information for Engineering the Photoresponse of InAs Nanowires

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1. InAs nanowire transfer characteristics

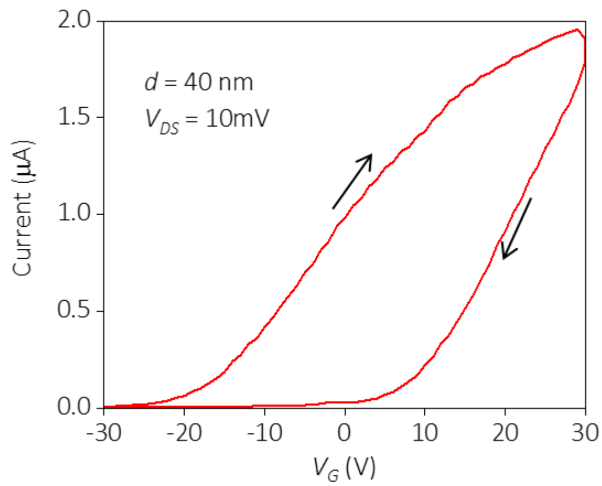

Figure S1 – *The transfer curve for the InAs nanowire device characterised in Figure 1b.*

2. Sweep delay dependence of output characteristics

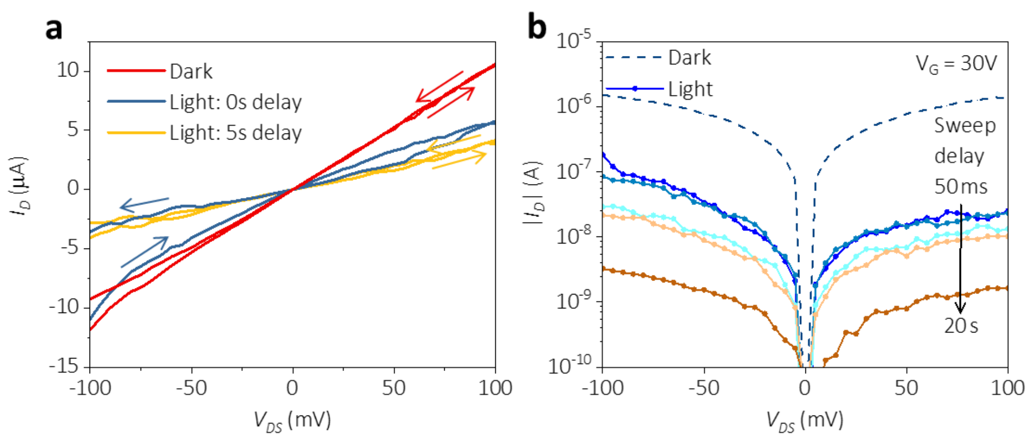

Figure S2 – *No additional time delay was set between sweeping V_G to the desired voltage and the start of the V_{DS} sweep shown in Figure 1d and e of the main text. As such, evidence of the NPC decay can be observed in the output characteristics under illumination. If an additional delay is included between setting V_G and sweeping V_{DS}, for a 40 nm diameter nanowire, the time dependent output characteristics follow a comparable behaviour to that shown in Figure 1b. a) Time delay (the time between setting the gate voltage and starting to sweep V_{DS}) dependent output characteristics for a 40nm diameter InAs nanowire devices showing up and down sweeps. b) $|I_D|$ as a function of V_{DS} at V_G = 30 V for a 40 nm diameter nanowire in dark and photoexcited conditions with a sweep delay set to 50 ms, 200 ms, 1 s, 2 s, and 20 s.*

3. Characterisation of nanowire diameter distribution

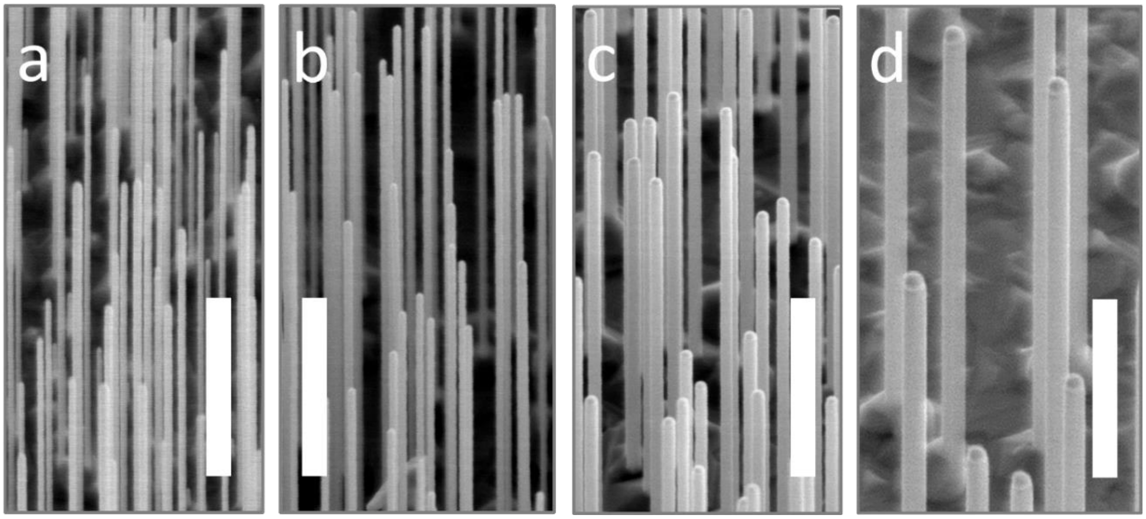

Figure S3 – *Scanning electron microscopy images of the as grown InAs nanowire for d = 30±5 nm (a), 40±5 nm (b), 65±5 nm (c), and 110±5 nm (d), where the error represents one standard deviation. All scale bars are 1 µm.*

4. Sweep rate dependent hysteresis for different diameter nanowires

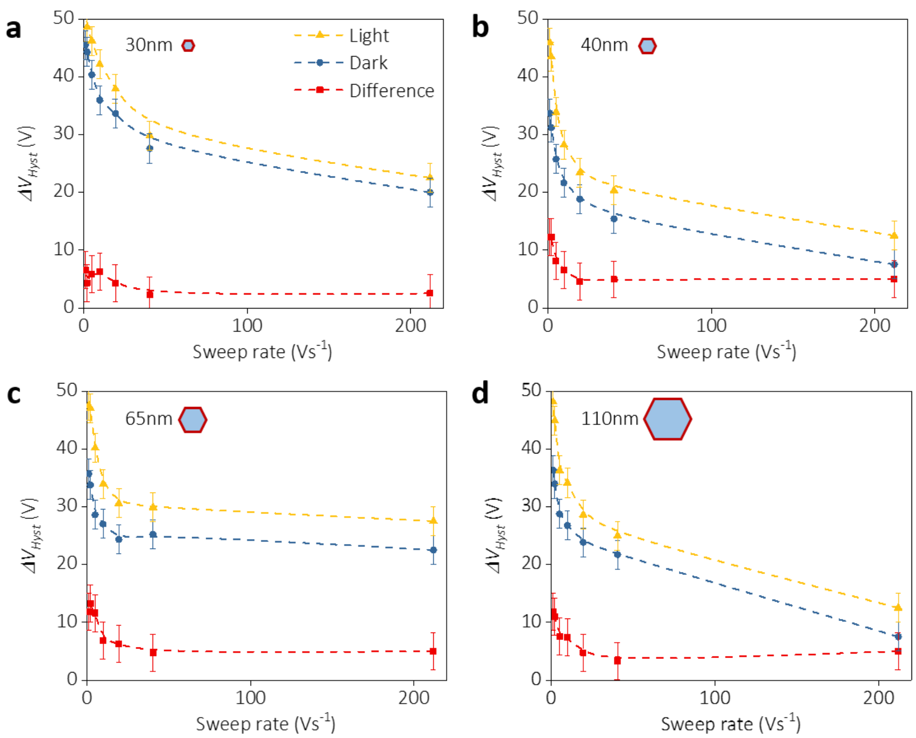

Figure S4 – *The sweep rate dependence of the gate hysteresis for a series of nanowire devices with diameter d=30 nm, 40 nm, 65 nm, and 110 nm (a-d respectively) where $V_G^{Max} = -V_G^{Min} = 40$ V. Dashed lines are guides to the eye.*

5. Characteristics of devices after $(NH_4)_2S$ etch

To confirm the influences of the native oxide on the (opto)electronic properties described in the main text, we characterised InAs nanowire devices after etching the native oxide from the channel. We removed the native oxide using the same treatment used at the contact regions prior to metallisation (2 % aqueous $(NH_4)_2S$ solution at 40 °C for 10 minutes). When the native oxide is no longer present along the channel there are no signatures of NPC under photoexcitation observed within our measurement sensitivity (Figure S5a). Hot carrier trapping, indicated by an increase in gate hysteresis under photoexcitation, is also no longer present (Figure S5b,c). This confirms that the native oxide is responsible for hot carrier trapping and the resulting NPC. However, we observed that the process of etching significantly degrades the electronic properties of the nanowire. Specifically, at slow sweep rates (dV_G/dt < 10 Vs^{-1}), the on-state current and peak field effect mobility were significantly reduced after etching, indicating the presence of etching induced defects. The effects of defects can be seen firstly in the transient response of the nanowire (Figure S5a), where the substantial initial drop in current in the dark is due to charge trapping[1]. Secondly, the magnitude of hysteresis, in particular at low sweep rates, is much larger than non-etched nanowire devices described in the main text and above (Figure S4). This degradation of nanowire performance can be circumvented by using the ALD passivation technique described in the main text where hot carrier trapping and NPC is reduced without damaging the nanowire.

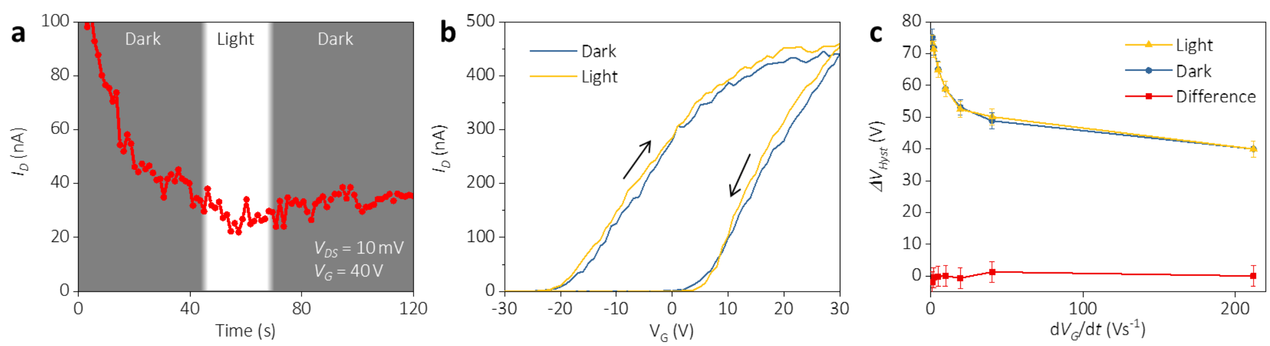

Figure S5 – *a) Transient photoresponse during photoexcitation (white) in a 40 nm diameter InAs nanowire device after the native oxide was removed from the channel. b) Transfer characteristics under dark and illuminated conditions at a constant sweep rate of 40 Vs^{-1}. Arrows represent the gate voltage sweep direction. c) Sweep rate dependence of hysteresis under dark and illuminated conditions for a 40 nm diameter InAs nanowire after etching the native oxide ($V_G^{Max} = -V_G^{Min}$ = 40 V). No difference in hysteresis under photoexcitation is observed, within errors.*

6. Atmospheric effects on hysteresis

We performed a series of measurements of gate hysteresis at room temperature under ambient atmosphere, N_2, and under vacuum (10^{-4} mbar), shown in Figure S6. Under ambient atmosphere at low sweep rates (dV_G/dt < 1 Vs^{-1}) adsorbates on the nanowire surface, such as H_2O, give rise to an increased density of slow charging traps compared to those measured under N_2 and vacuum. The device characteristics measured under N_2 and vacuum are very similar to each other, as observed in previous reports[2,3], The majority of hysteresis (>70%), due to charge traps in the gate dielectric, is not removed by removing the atmospheric adsorbates. Thus, the reduction in hysteresis observed following ALD is not simply due to a removal of atmospheric effects.

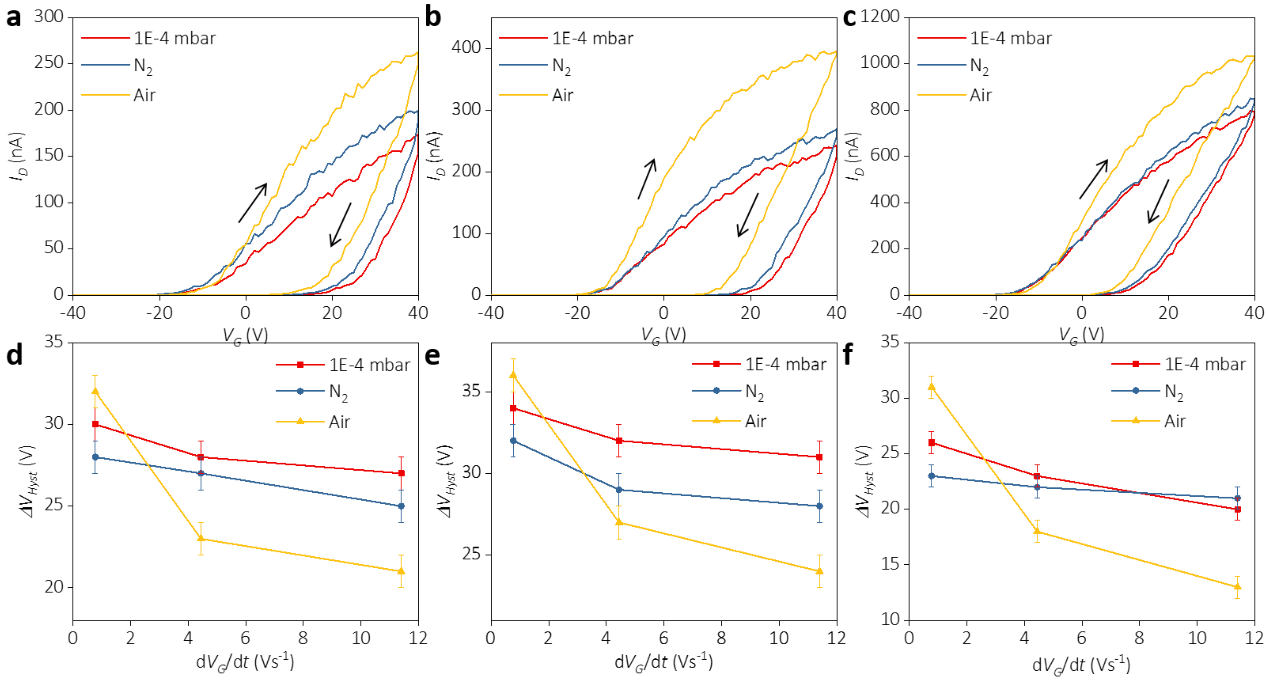

Figure S6 – *a-c) Transfer curves for three individual InAs nanowires with d=40 nm, under ambient atmosphere, N_2 and 10^{-4} mbar vacuum, at a fixed sweep rate dV_G/dt = 4.4 Vs^{-1}. d-f) Gate hysteresis as a function of sweep rate for the same devices shown in a-c respectively.*

7. Transient positive photoconductivity after ALD

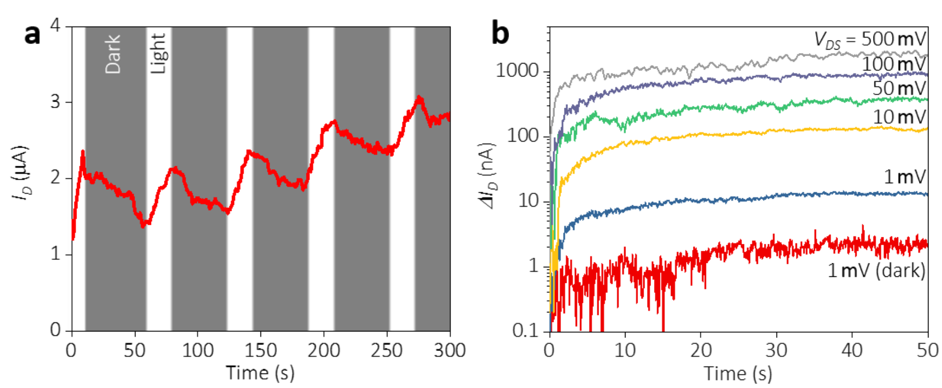

Figure S7 – *a) Positive photoconductivity for a 40 nm diameter nanowire after ALD passivation during repeated cycles of photoexcitation at V_{DS}=500 mV and V_G=-20 V. b) Transient photoresponse $\Delta I_D (t) = I_D^{light} (t) - I_D^{dark} (t=0)$, as a function of V_{DS} under constant photoexcitation starting at t=0 s.*

8. Transmission electron microscopy

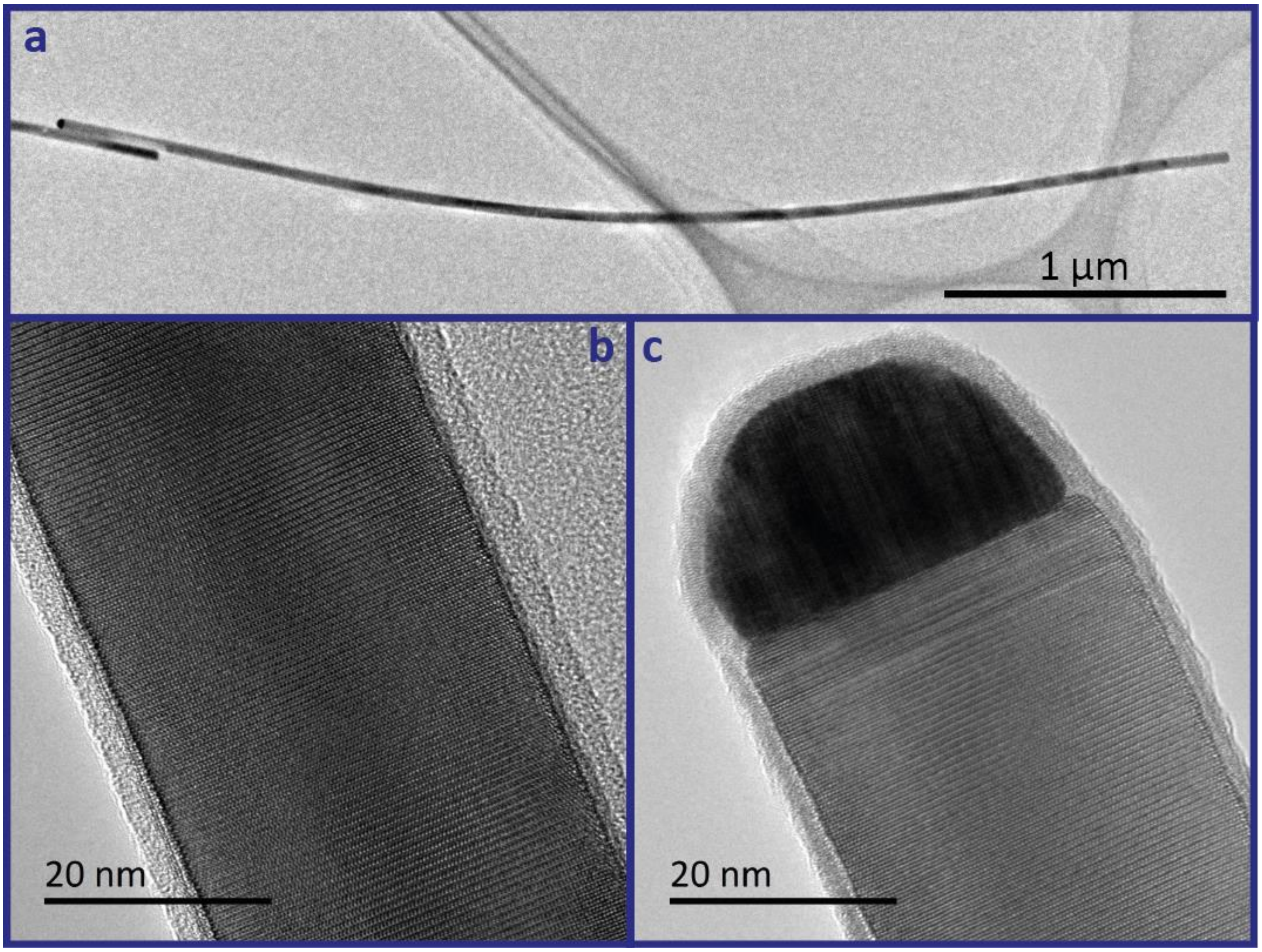

Figure S8 – *Transmission electron microscopy (TEM) results for wurtzite InAs nanowires: a) TEM micrograph of a typical nanowire, b) HRTEM image showing the wurtzite crystal structure of another typical nanowire with surface oxide clearly visible, and c) HRTEM image of the tip of the same nanowire as in b with the Au nanoparticle.*

References

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(3) Ullah, A. R.; Joyce, H. J.; Tan, H. H.; Jagadish, C.; Micolich, A. P. The Influence of Atmosphere on the Performance of Pure-Phase WZ and ZB InAs Nanowire Transistors. *Nanotechnology* **2017**, *28* (45), 454001.