Supplementary information for:

Kinked p-n Junction Nanowire Probes for High Spatial Resolution Sensing and Intracellular Recording

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This file includes:

Device sensitivity model

Supplementary Figures S1– S3

Semi-quantitative model for device sensitivity

We first use n-type depletion region as an example of calculating resistance change of p-n junction under gating potential. We have: $\sigma_n = nq\mu$, $n = N_C e^{-(E_C - E_F)/kT}$, where σ is the electrical conductivity, n is the carrier concentration of electrons, q is the charge of an electron, μ is the mobility of electrons, N_c is the density of states at the conduction band edge. Assuming that carrier concentration distribution within the depletion region along the nanowire is linear ($n = n_i + lk_D$), it follows that:

$$\Delta\sigma_n = \Delta nq\mu = nq\mu(\Delta Vq/kT) = \Delta Vq\sigma_n/kT$$

$$\Delta\rho_n = -\Delta\sigma_n/\sigma_n^2$$

$$\Delta\rho_n = -\Delta V/(n\mu kT) = -\Delta V/[(n_i + lk_D)\mu kT]$$

$$\Delta R_n = \int_0^{l_D} \frac{\Delta\rho_n}{\pi r^2} dl = \int_0^{l_D} -\frac{\Delta V}{\pi r^2 \mu kT[(n_i + lk_D)]} dl = -\frac{\Delta V}{\pi r^2 \mu kTk_D} Ln(\frac{N_D}{n_i})$$

, where ρ and R are the resistivity and resistance, respectively.

Using the same method, we can have resistance change of the p-type depletion region as:

$$\Delta R_p = \int_{-l_A}^{0} \frac{\Delta\rho_p}{\pi r^2} dl = \int_{-l_A}^{0} \frac{\Delta V}{\pi r^2 \mu kT[(n_i - lk_A)]} dl = \frac{\Delta V}{\pi r^2 \mu kTk_A} Ln(\frac{N_A}{n_i})$$

So the total resistance change can be expressed as:

$$\Delta R = \Delta R_n + \Delta R_p = \frac{\Delta V}{\pi r^2 \mu kT}[\frac{1}{k_A} Ln(\frac{N_A}{n_i}) - \frac{1}{k_D} Ln(\frac{N_D}{n_i})]$$

, thus

$$\Delta R = \frac{\Delta V}{\pi r^2 \mu kT}[\frac{l_A}{N_A} Ln(\frac{N_A}{n_i}) - \frac{l_D}{N_D} Ln(\frac{N_D}{n_i})]$$

Because: $l_D N_D = l_A N_A$, $l_D k_D \cong N_D$, $l_A k_A \cong N_A$

We have: $\frac{k_D}{k_A} = (\frac{N_D}{N_A})^2$, and $\Delta R \cong A\Delta V[\frac{1}{N_A^2} Ln(N_A) - \frac{1}{N_D^2} Ln(N_D)]$

When $N_D > N_A$ and $\Delta V > 0$, $\Delta R > 0$, the device behaves as a p-type FET

When $N_D < N_A$ and $\Delta V > 0$, $\Delta R < 0$, the device behaves as an n-type FET

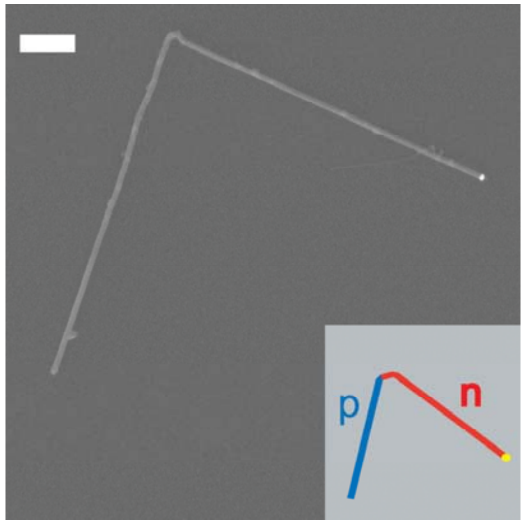

Figure S1. Representative SEM image of a kinked p-n SiNW with a 60° overall geometry (yield <10%). Scale bar, 1 μm. Inset: Schematic of the structure of kinked p-n nanowires with 60° tip angles. The blue and red lines designate the p-doped and n-doped arms, respectively. The 60° angle is the result of introducing two 120° kinks in a *cis* arrangement in the nanowire as described previously (see ref. 2, main text). Further studies to optimize the growth conditions will be needed to increase the yield of the 60° kinked nanowires.

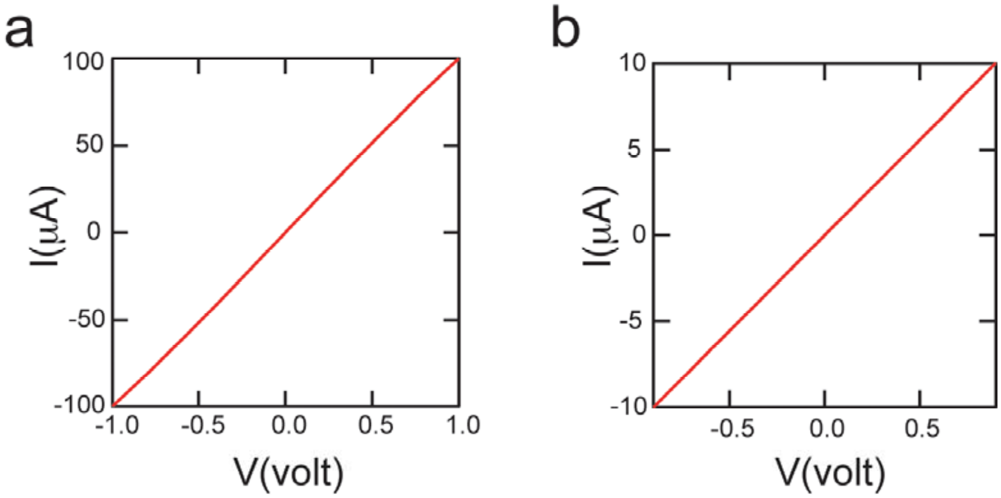

Figure S2. Arm conductance of kinked p-n nanowires. a, *I*-*V* data recorded from the n-type arm of a representative kinked p-n nanowire device. The spacing between electrodes was 1.5 μm. No barrier was present at metal contact. Dopant concentration of n-type arm was estimated to be 9×10^{19} cm^{-3}**.** **b**, *I*-*V* data recorded from the p-type arm of the same device. The spacing between electrodes was 1.5 μm. No barrier was present at metal contact. Dopant concentration of p-type arm was estimated to be 9×10^{18} cm^{-3}.

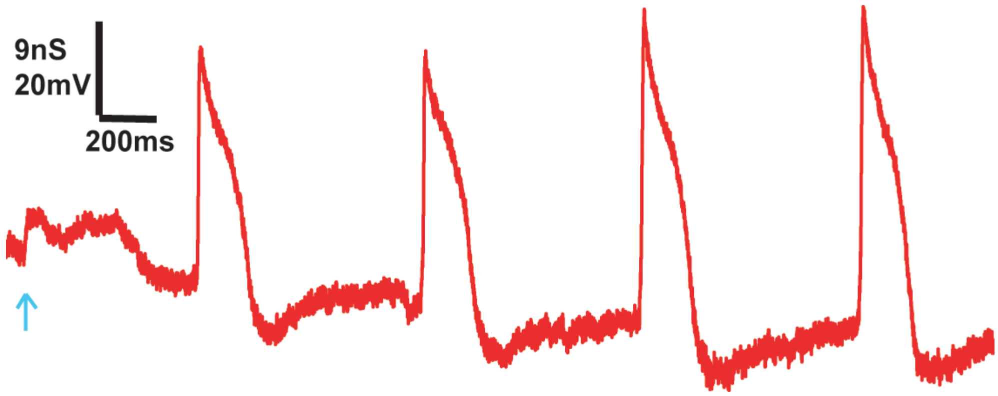

Figure S3. Transition from extracelluar to intracellular recording. The blue arrow marks the initial transition to intracellular signals. The calculated base line shift is ~20 mV.