Supplementary Information for

**Ultrafast, superhigh sensitivity visible-blind UV detector and optical logic gates based on nonpolar a-axial GaN nanowire**

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Figures S1-S3

Supplementary Discussion: the transport characterization of MSM GaN NW PD.
Figure S1

Figure S1. (a) EDS data of a single GaN NW grown on patterned Si; (b) the electron diffraction data with the electron beam perpendicular to the axis of a typical GaN NW.
Figure S2

Figure S2a. typical linear scale I-V characteristics of the fabricated GaN NW PD both in the dark (black curve) and upon 325 nm UV light illumination with power density of 1 mW/cm$^2$ (red curve).

Figure S2b. light density dependent photocurrent curve at a voltage of 1 V
Figure S2c and d. the light density dependent spectra responsivity ($R_\lambda$) at a voltage of 1V (c). the light density dependent external quantum efficiency (EQE) at a voltage of 1 V (d).
Figure S2e. Time dependent photocurrent response of the GaN PD device in the light density of 50, 300 and 1100 $\mu$w/cm$^{2}$ when the UV light turned on and off with a period of $\sim$10 s (at a bias of 1 V).

Figure S3. Schematic diagram of polar (c-axis) and non-polar (m and a axis) crystal orientation in wurtzite structure GaN.
Supplementary Discussion:

Figure S4. The energy-band diagram for the Schottky barrier that is formed at the metal-GaN interface.

The back-to-back MSM GaN NW PD can be regarded as a nanowire connected with a forward-biased SB diode and a reverse-biased SB diode in series. **Fig. 3d** in the main text shows the energy-band diagram for the GaN NW PD device. The reverse biased SB height ($\Phi_R$) is much higher than that of forward biased ($\Phi_F$). The reverse biased Schottky contact area is the bottleneck for the current transport in the device. **Fig.S3** shows the energy-band diagram for the Schottky barrier that is formed at the metal-GaN interface. The original SB height $\Phi_{SB}$ is determined by the work-function difference between the metal and GaN, and the interface states. As for the forward-biased SB diode, the current passing through this barrier can be described by the thermionic-emission (TE) theory. The total current density is given by: $^{1, 2}$
\[ J_n = \left[ A'T^2 \exp\left( -\frac{q\phi_{SB}}{kT} \right) \right] \left[ \exp\left( \frac{qV}{kT} \right) - 1 \right] \]

\[ = J_{TE} \exp\left( \frac{qV}{kT} \right) - 1 \]

Therefore,

\[ I_{TE} = S A'T^2 \exp\left( -\frac{q\phi_{SB}}{kT} \right) \] (2)

and

\[ A' = \frac{4\pi q m^* k^2}{\hbar^3} \] (3)

in which \( S \) is the area of the Schottky contact, \( A' \) is the effective Richardson constant, \( T \) is the temperature, \( q \) is the unit electronic charge, \( k \) is the Boltzmann constant, and \( V \) is the applied voltage. And for the reverse-biased SB diode, the current can be described by the thermionic-emission-diffusion theory (for \( V \sim 3kT/q \sim 77 \) mV) as:\(^1,^2\)

\[ I_{TED} = S A''T^2 \exp\left( -\frac{q\phi_{SB}}{kT} \right) \exp\left( \frac{1}{4} q^2 N_D (V + V_{bi} - kT/q)^2 \right) \frac{\varepsilon_s^3}{kT} \] (4)

and

\[ V_{bi} = \Phi_{SB} - (E_c - E_F) \] (5)

in which \( A'' \) is the effective Richardson constant, \( N_D \) is the donor impurity density, \( V_{bi} \) is the built-in potential, and \( \varepsilon_s \) is the permittivity of GaN. The depletion layer formed at the SB area has a width of:
\[ W_D = \frac{2\varepsilon_S}{qN_D} \left( V_{bi} - V - \frac{kT}{q} \right) \] (6)

Considering Equation 2, 4, and 6 we can conclude that the current passing through the Schottky contact is very sensitive to the Schottky barrier height and barrier width, especially under reverse-bias conditions. Therefore, the photocurrent transport characteristics of the M-S-M structure-based PD devices are mainly dictated by the reverse biased Schottky diode.

Reference