

Rapid Detection of SARS-CoV-2 Antigens using High-Purity Semiconducting Single-Walled Carbon Nanotube-based Field-Effect Transistors

Wenting Shao,[†] Michael R. Shurin,[‡] Sarah E. Wheeler,[‡] Xiaoyun He,[†] Alexander Star^{†, §}*

[†] Department of Chemistry, University of Pittsburgh, Pittsburgh, Pennsylvania 15260, United States

[‡] Department of Pathology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania 15260,
United States

[§] Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pennsylvania 15261, United States

*Corresponding author. Email: astar@pitt.edu

Table of contents

Figure S1. UV-vis-NIR adsorption spectrum of sc-SWCNT.....	S-3
Figure S2. Functionalization of enhanced green fluorescent protein (EGFP) antibody on a SWCNT FET device.....	S-4
Figure S3. XPS spectra of sc-SWCNT FET devices.....	S-5
Figure S4. Comparison of source-drain current and gate leakage current.....	S-6
Figure S5. FET characteristic curves and calibration curve of S antigen detection using S antibody functionalized FET devices	S-7
Figure S6. FET characteristic curves and calibration curve of S antigen detection using N antibody functionalized FET devices	S-8
Table S1. Number of devices (n) tested for each clinical sample.....	S-9

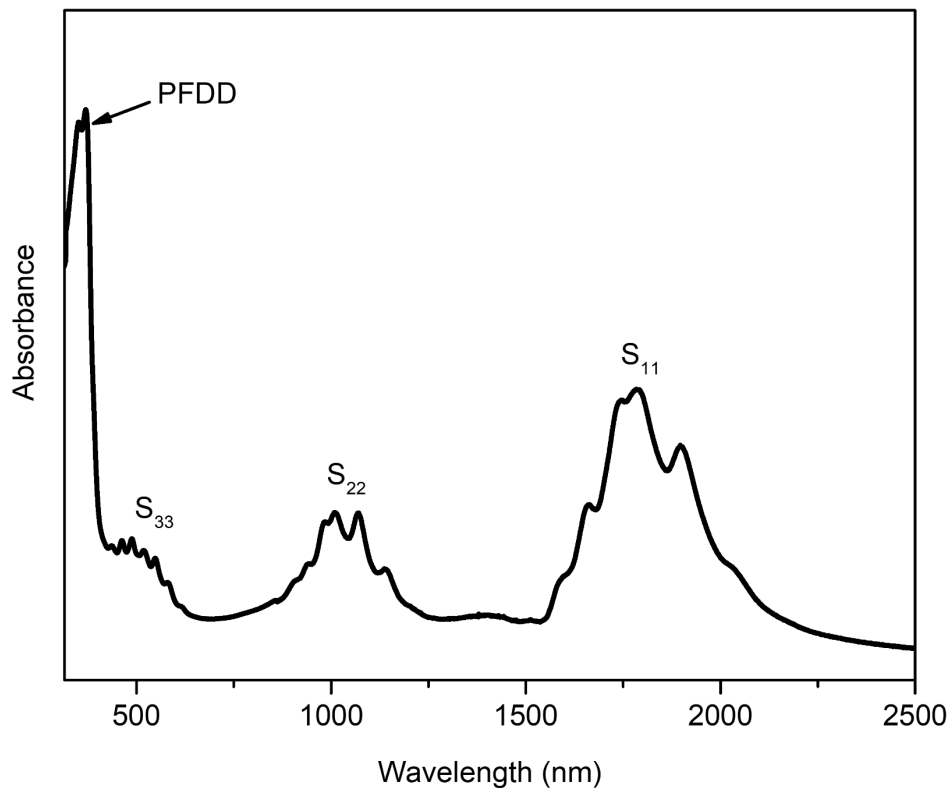


Figure S1. UV-vis-NIR spectrum of sc-SWCNT. The S₁₁, S₂₂ and S₃₃ peaks are characteristic of the semiconducting SWCNTs. The absence of M₁₁ peak further confirms the high-purity semiconducting content of sc-SWCNT samples. The sharp peak at 392 nm can be attributed to polyfluorene-dodecyl (PFDD) polymer coating on sc-SWCNT due to the commercial sorting process.

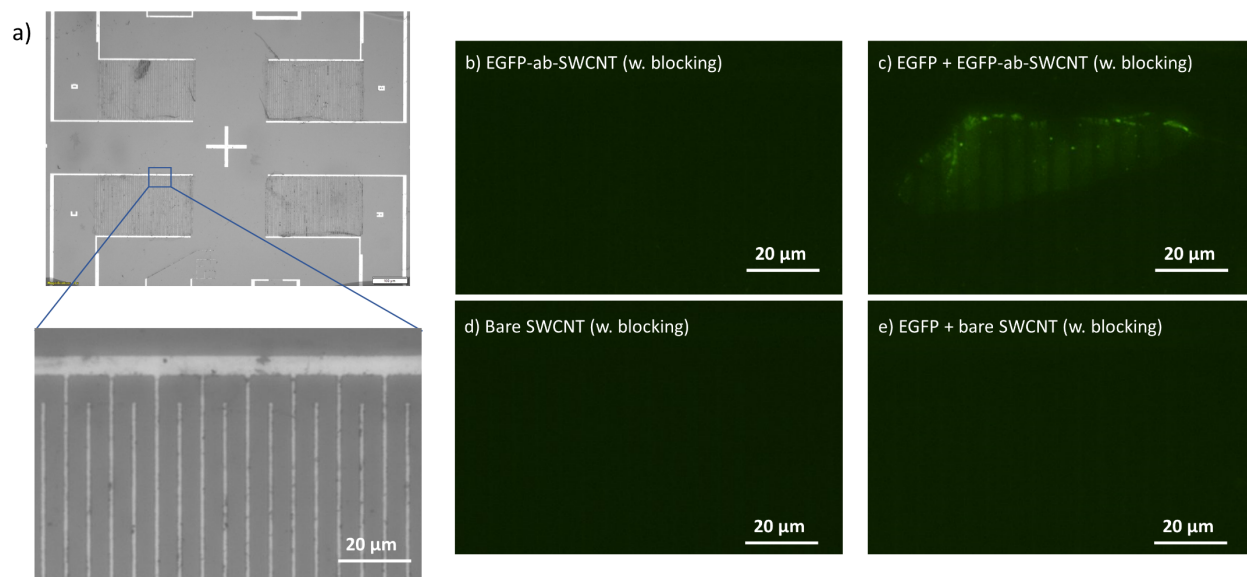


Figure S2. Functionalization of enhanced green fluorescent protein (EGFP) antibody on a SWCNT FET device. a) Top: Microscopic image of the 4-device FET biosensing chip. (Scale bar: 200 μm) Bottom: Zoomed in image shows the area where fluorescence images were taken. b-c) Fluorescence images of EGFP antibody functionalized SWCNT FET device b) before and c) after EGFP binding. d-e) Fluorescence images of a blocked bare SWCNT FET device d) before and e) after EGFP binding. Green fluorescence was observable when EGFP was added to EGFP antibody functionalized device but not on bare SWCNTs without EGFP antibody, indicating the successful functionalization of EGFP antibody on the SWCNT surface.

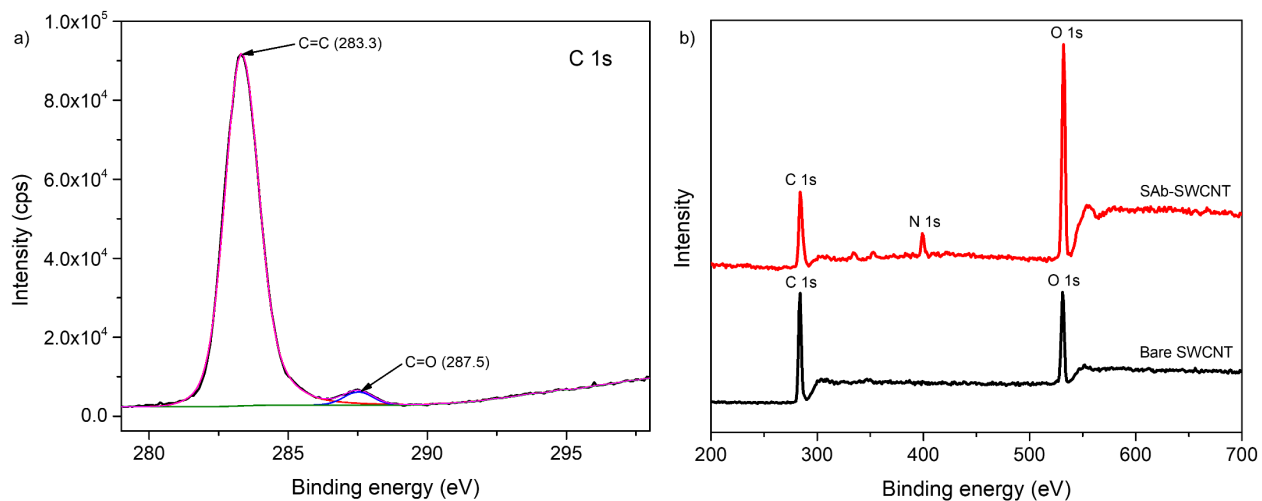


Figure S3. XPS spectra of sc-SWCNT FET devices. a) High resolution C 1s XPS spectrum of sc-SWCNT. The deconvoluted C 1s spectrum indicated the presence of C=C (283.3 eV) and C=O (287.5 eV), thus confirming the presence of COOH functional groups on sc-SWCNT. b) XPS survey of sc-SWCNT device before and after SAb functionalization. N 1s peak appeared after SAb functionalization, and the atomic percent of N increased from 0% to 5%, suggesting the successful immobilization of SAb on SWCNTs.

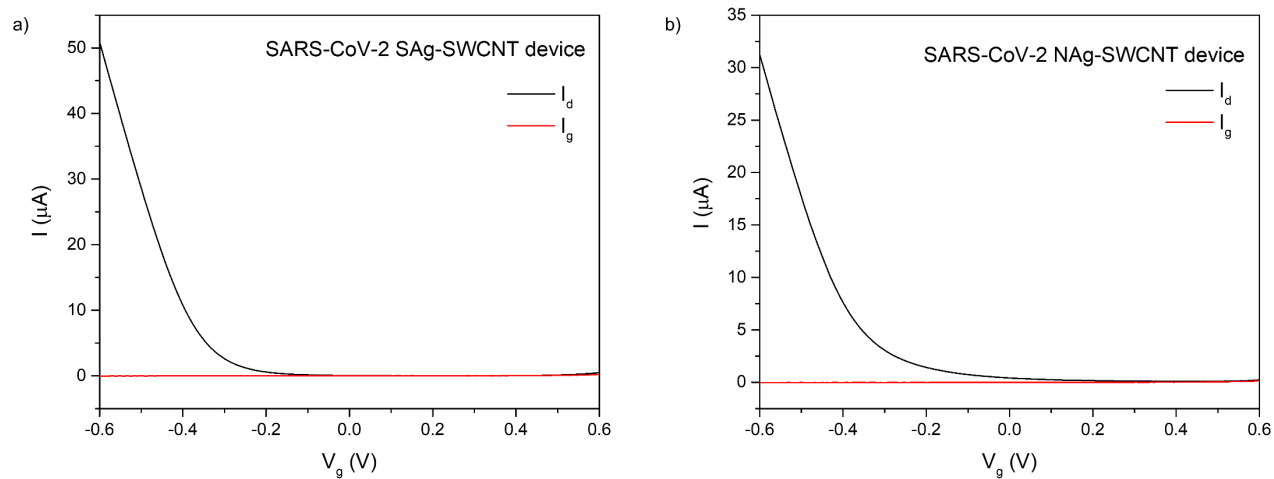


Figure S4. Comparison of source-drain current (I_d) and gate leakage current (I_g) of a) SAb-SWCNT FET device and b) NAb-SWCNT FET device. The effect of leakage current is negligible as I_g is insignificant compared to I_d .

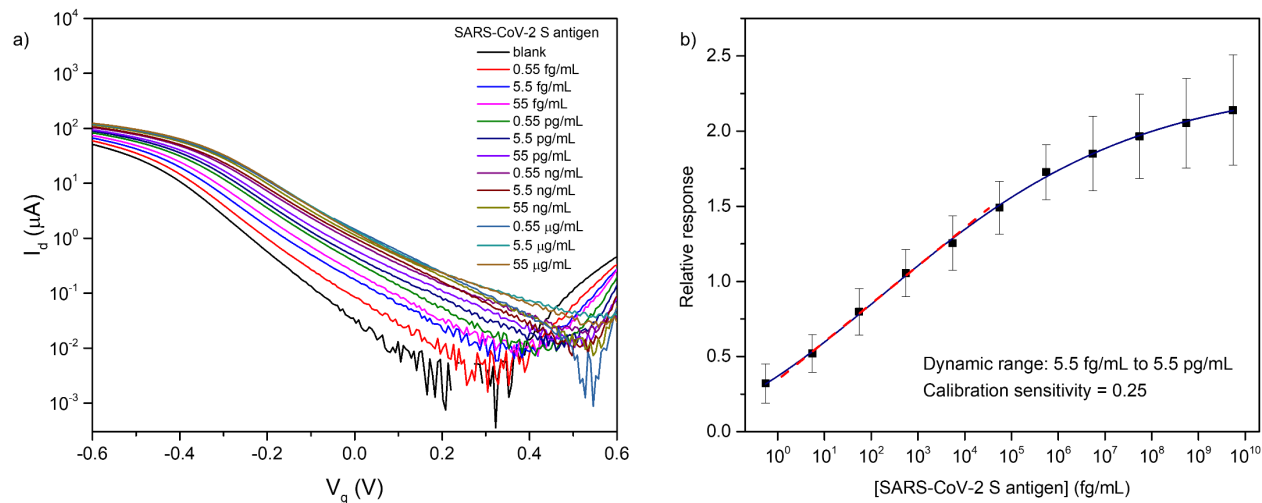


Figure S5. FET characteristic curves and calibration curve of S antigen detection using S antibody functionalized FET devices. a) I_d - V_g curves of the SAb-SWCNT FET device showed shift of the threshold voltage towards the more positive region with increasing concentration of SAg. b) The calibration curve was fit using a five-parameter logistic model. The dynamic range was indicated by the dashed red line. The calibration sensitivity, defined as the slope of the linear region of the calibration curve, was determined to be 0.25.

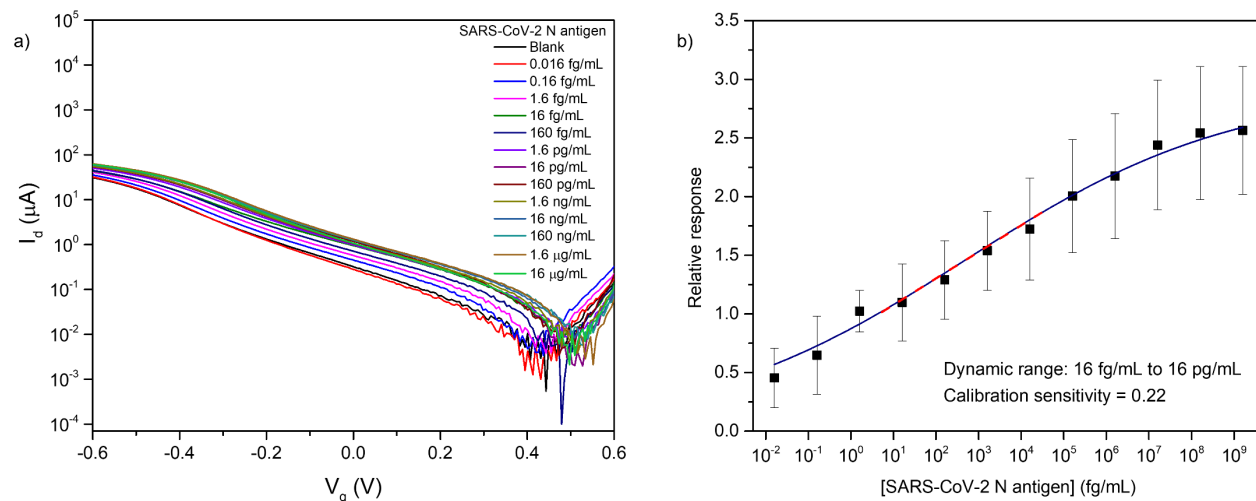


Figure S6. FET characteristic curves and calibration curve of N antigen detection using N antibody functionalized FET devices. a) I_d - V_g curves of the NAb-SWCNT FET device showed shift of the threshold voltage towards the more positive region with increasing concentration of NAg. b) The calibration curve was fit using a five-parameter logistic model. The dynamic range was indicated by the dashed red line. The calibration sensitivity, defined as the slope of the linear region of the calibration curve, was determined to be 0.22.

Table S1. Number of devices (n) tested for each clinical sample.

Sample	S antibody functionalized FET device	N antibody functionalized FET device
Positive 1	n = 4	n = 3
Positive 2	n = 3	n = 3
Positive 3	n = 4	n = 3
Positive 4	n = 3	n = 4
Positive 5	n = 4	n = 3
Positive 6	n = 3	n = 2
Positive 8	n = 2	n = 3
Positive 9	n = 1	n = 4
Positive 10	n = 4	n = 4
Positive 12	n = 4	n = 3
Positive 13	n = 3	n = 3
Positive 14	n = 4	n = 4
Positive 15	n = 2	n = 2
Positive 16	n = 1	n = 3
Positive 17	n = 3	n = 3
Positive 18	n = 2	n = 3
Positive 19	n = 4	n = 3
Positive 20	n = 3	n = 3
Positive 21	n = 3	n = 2
Positive 22	n = 2	n = 4
Positive 23	n = 3	n = 2
Positive 24	n = 3	n = 3
Positive 25	n = 3	n = 2
Positive 26	n = 1	n = 3
Positive 27	n = 4	n = 4
Positive 28	n = 4	n = 3
Positive 29	n = 3	n = 4
Positive 30	n = 2	n = 3
Negative 1	n = 2	n = 4
Negative 2	n = 3	n = 4
Negative 3	n = 3	n = 2
Negative 4	n = 3	n = 3
Negative 5	n = 3	n = 1
Negative 6	n = 3	n = 2
Negative 7	n = 2	n = 2
Negative 8	n = 3	n = 2
Negative 9	n = 3	n = 2
Negative 10	n = 4	n = 3