

Electronic Supplementary Information for

**Polymer-Coated Graphene Films as Anti-Reflective Transparent
Electrodes for Schottky Junction Solar Cells**

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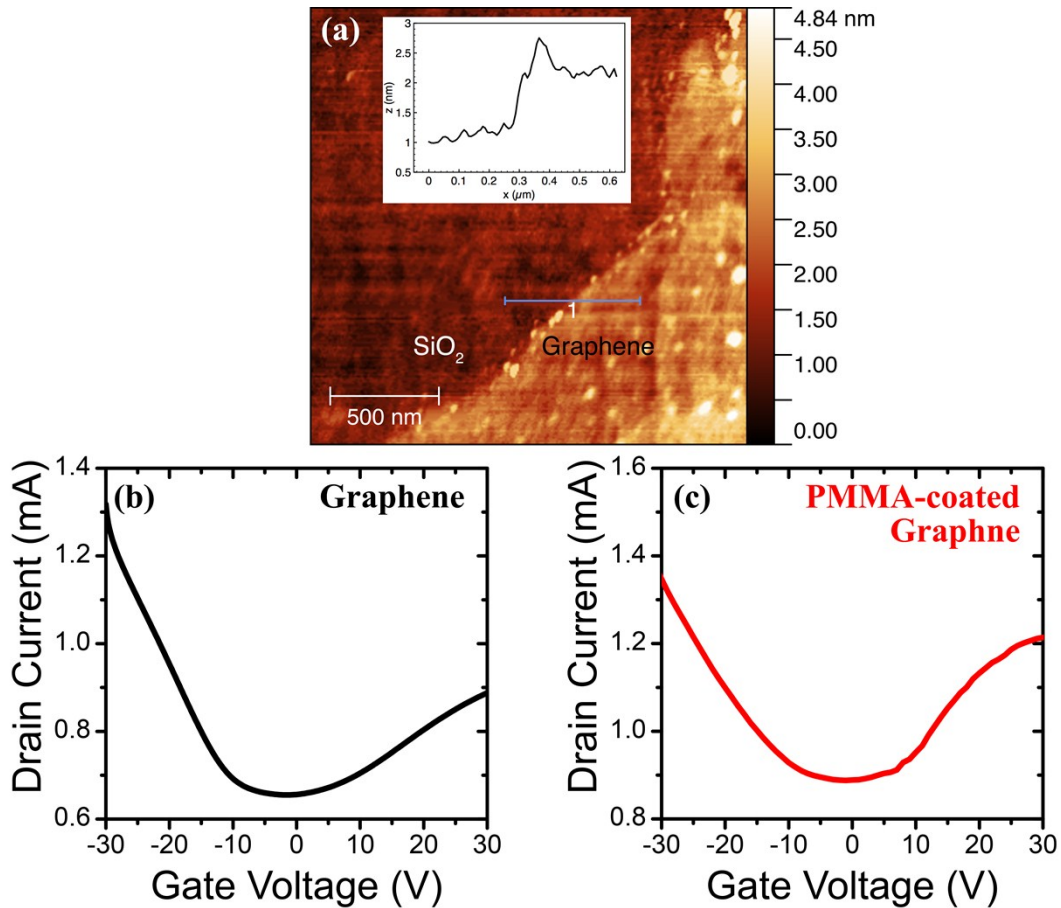


Fig. S1. (a) Atomic force microscope image of as-synthesized graphene sample on SiO₂/Si wafer. Inset is the height profile along the blue line. The bright dots (higher particles) might be PMMA residue induced during transfer. The thickness of the graphene is ~ 1 nm. Characteristics of $I_{\text{ds}}-V_{\text{g}}$ of the field effect transistors (FET) fabricated with (b) bare graphene film and (c) PMMA-coated graphene. The drain-to-source voltage V_{ds} was set at 2.0 V. The graphene sample was the same as those used in the fabrication of G/Si solar cells. Graphene sample with PMMA coating was first transferred on to Si wafer with 300 nm SiO₂. After removing PMMA with acetone, the source and drain electrodes were formed by using conductive silver paste. Gate electrode was formed by applying eutectic Ga-In alloy onto the back side of the wafer.

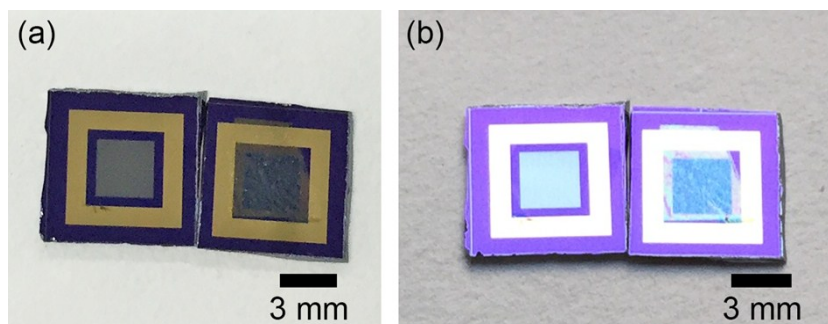


Fig. S2. Digital photo of PMMA-removed (left) and PMMA-coated (right) G/Si solar cells under the illumination of (a) fluorescent lamp and (b) sunlight.

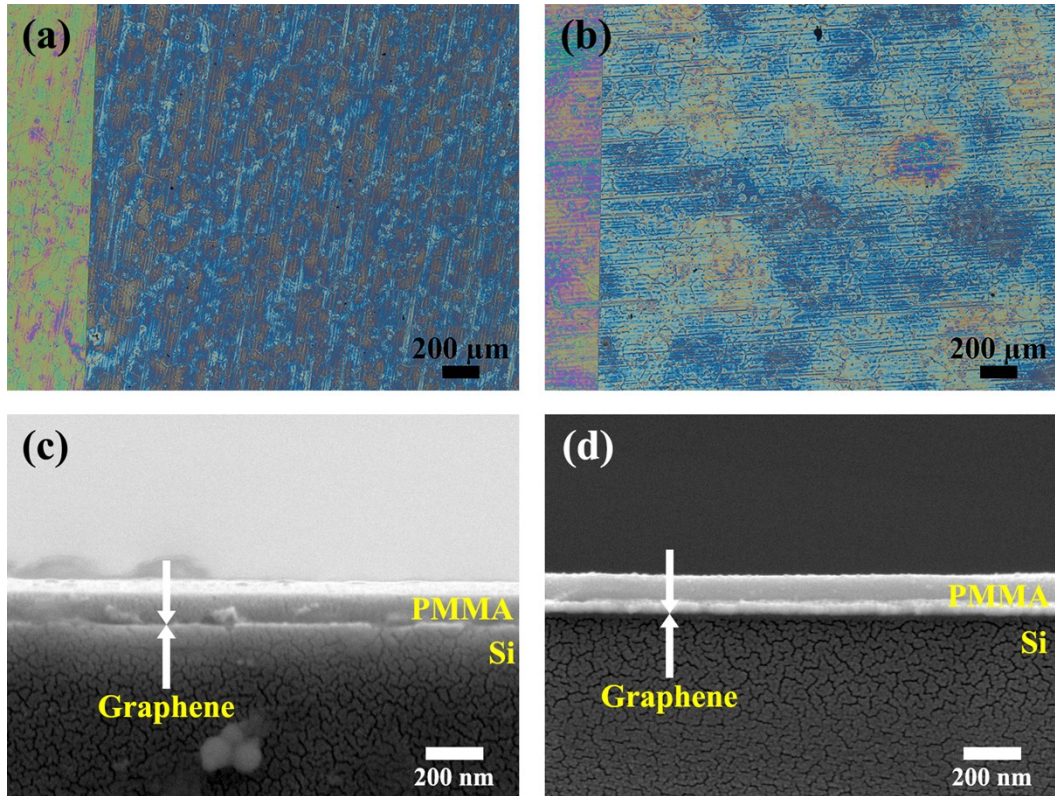


Fig. S3. Optical microscope images of G/Si solar cells with PMMA coated at (a) 3000 rpm and (b) 1000 rpm. Cross-section SEM images of G/Si solar cells with PMMA coated at (c) 3000 rpm and (d) 1000 rpm. The solution used was 4 wt% PMMA ($M_w \approx 50,000 \text{ mol g}^{-1}$) in ethyl lactate. By using the cross-section SEM images, thicknesses the PMMA layer coated at 3000 and 1000 rpm are measured as 94 and 133 nm, respectively.

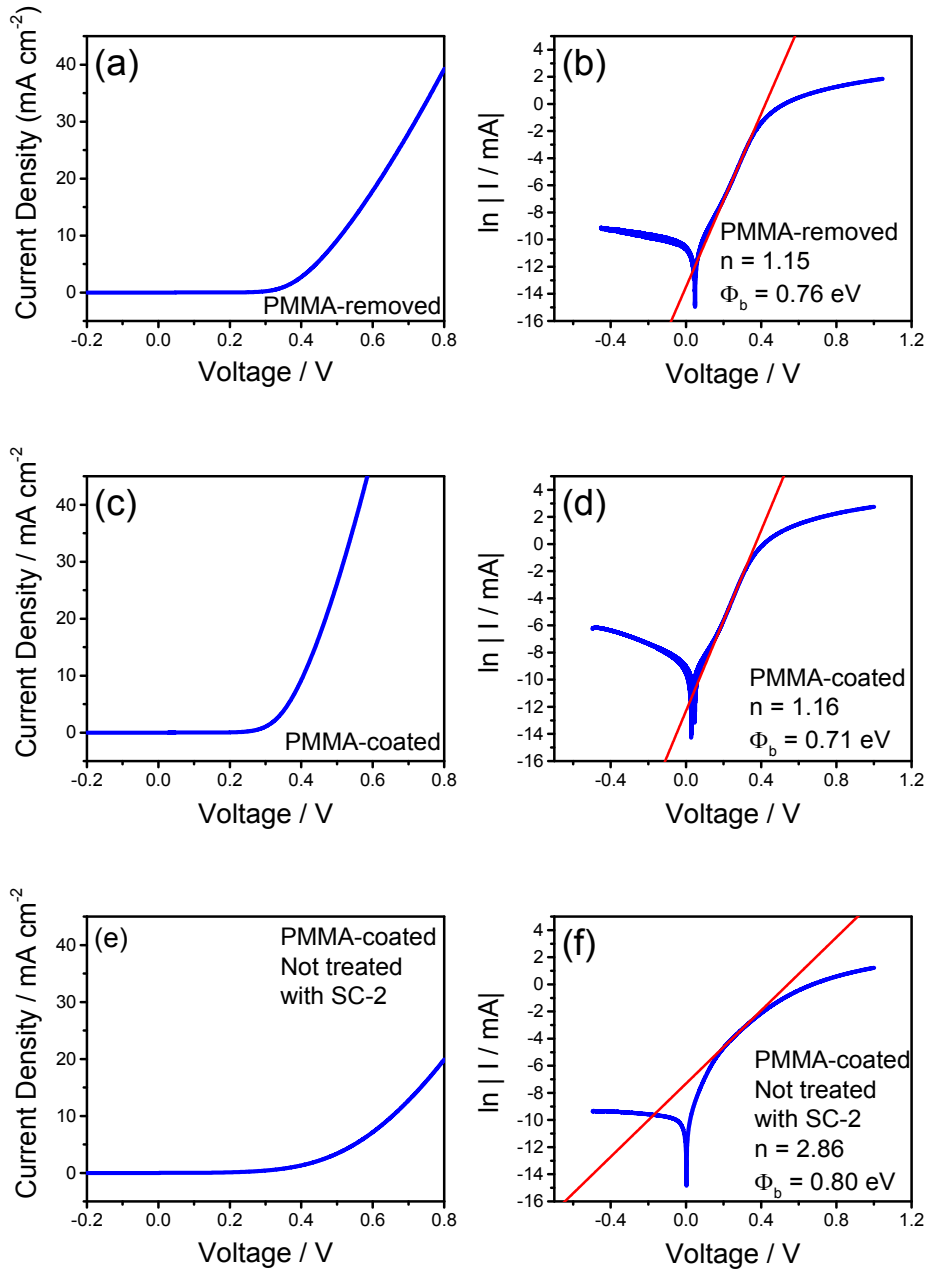


Fig. S4. (a) Dark J - V curve of PMMA-removed G/Si solar cells and (b) corresponding logarithm plot. (c) Dark J - V curve of PMMA-coated (2000 rpm) G/Si solar cells and (b) corresponding logarithm plot. (e) Dark J - V curve of PMMA-coated G/Si solar cells (without SC-2 treatment on graphene sample) and (f) corresponding logarithm plot. To determine the ideality factor from the logarithm plots, linear fittings are applied in the voltage range of 0.2-0.3 V.

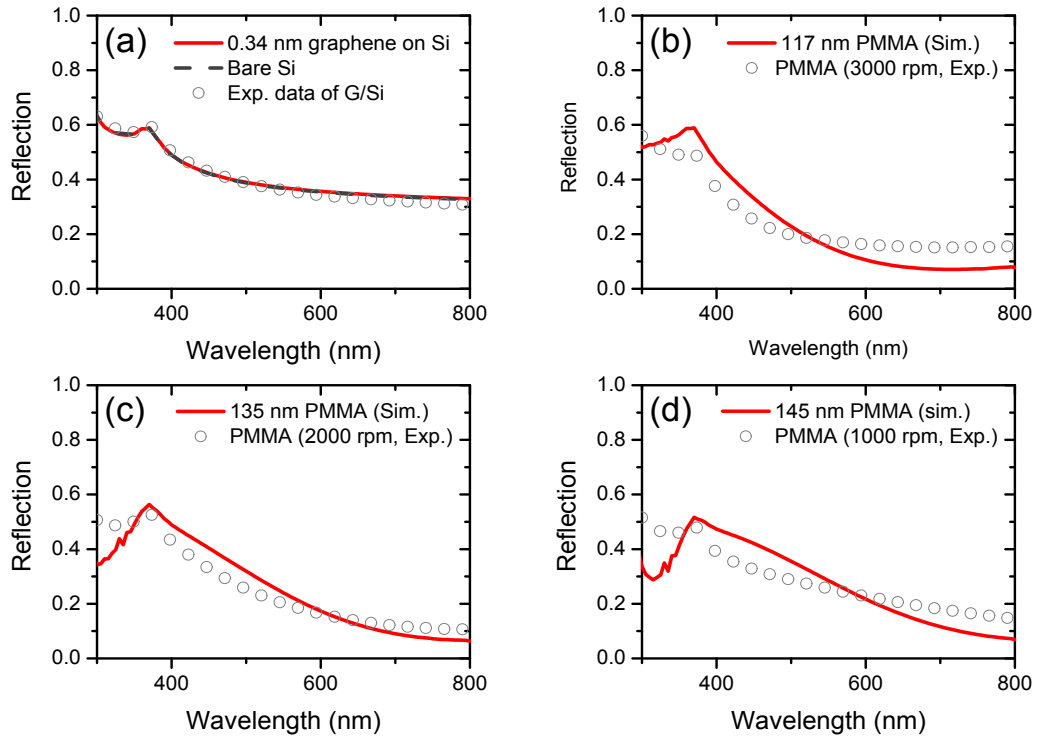


Fig. S5. Simulated reflectance spectra of (a) bare Si and graphene-coated Si. Simulated reflectance spectra of planar G/Si solar cells coated with PMMA layers with thicknesses of (b) 117 nm, (c) 135 nm and (d) 145 nm. The experimental data of (a) graphene on Si and (b–d) PMMA-coated G/Si are also plotted as circles.

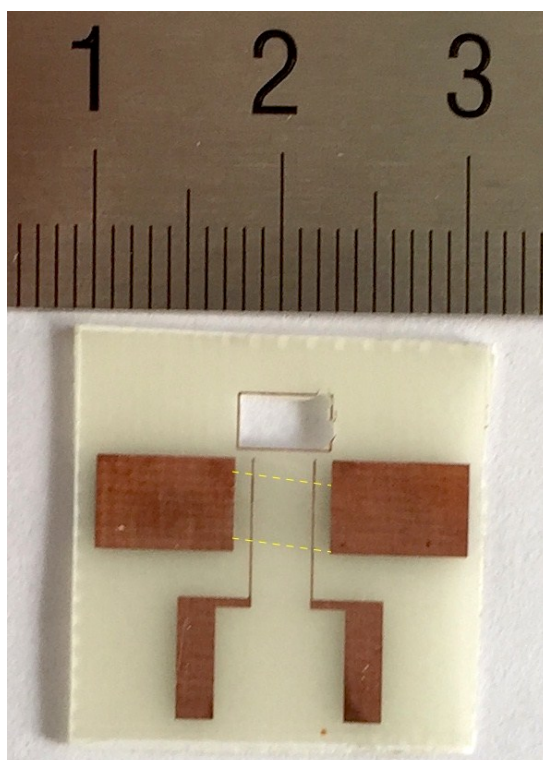


Fig. S6. Digital photo of the patterned print circuit board (PCB) used for resistance measurements of polymer-coated graphene. Graphene sample was transferred between two yellow dash lines.

Table S1. Morphology parameters of various polymer-coated graphene samples on Si wafer.

Sample	Average thickness [nm]	Rooted mean squared roughness [nm]	Minimum thickness [nm]	Maximum thickness [nm]
PMMA coated at 1000 rpm [a]	134.2	19.7	86.4	177.0
PMMA coated at 1000 rpm, HNO ₃ doped [a]	133.5	21.8	75.9	183.4
PMMA coated at 2000 rpm [a]	108.4	19.5	55.8	143.1
PMMA coated at 2000 rpm, HNO ₃ doped [a]	109.4	18.1	58.5	156.8
PMMA coated at 3000 rpm [a]	89.0	13.2	57.6	118.2
PMMA coated at 3000 rpm, HNO ₃ doped [a]	90.1	8.9	58.5	119.5
PMMA coated at 1000 rpm [b]	257.1	65.2	49.5	384.1
PMMA coated at 3000 rpm [b]	138.7	24.1	65.1	195.3
PMMA coated at 5000 rpm [b]	71.5	8.4	53.1	91.2
CYTOP coated at 5000 rpm	96.0	74.3	83.3	115.4

[a] 4 wt% PMMA ($M_w \approx 50000 \text{ g mol}^{-1}$) in ethyl lactate. [b] 3 wt% PMMA ($M_w \approx 550000 \text{ g mol}^{-1}$) in anisole.

Table S2. Photovoltaic properties of various G/Si solar cell samples.

Sample	V_{oc} [V]	J_{sc} [mA cm^{-2}]	FF [%]	PCE [%]
PMMA removed #1 [a]	0.428	22.61	32.22	3.12
PMMA removed #1 [b]	0.559	25.16	66.84	9.40
PMMA removed #1 after 66 days [b]	0.444	19.39	28.81	2.48
PMMA removed #2 [a]	0.489	23.39	36.90	4.22
PMMA removed #2 [b]	0.538	25.21	61.56	8.35
PMMA removed #2 after 66 days [b]	0.438	21.08	27.52	2.49
PMMA coated at 2000 rpm #1 [a, c]	0.427	33.64	45.56	6.55
PMMA coated at 2000 rpm #1 [b, c]	0.556	34.00	70.63	13.34
PMMA coated at 2000 rpm #1 after 72 days [b, c]	0.418	30.03	27.74	3.74
PMMA coated at 2000 rpm #2 [a, c]	0.386	32.70	35.00	4.42
PMMA coated at 2000 rpm #3 [a, c]	0.414	34.58	35.29	5.05
PMMA coated at 1000 rpm [a, c]	0.406	29.40	39.95	4.76
PMMA coated at 1000 rpm [b, c]	0.548	29.41	69.03	11.12
PMMA coated at 3000 rpm [a, c]	0.372	27.79	33.77	3.49
PMMA coated at 3000 rpm [b, c]	0.524	32.10	67.07	11.29
PMMA coated at 1000 rpm [a, d]	0.392	26.20	37.80	3.88
PMMA coated at 1000 rpm [b, d]	0.548	28.38	72.72	11.31
PMMA coated at 3000 rpm [a, d]	0.408	27.81	31.74	3.60
PMMA coated at 3000 rpm [b, d]	0.557	29.98	68.86	11.50
PMMA coated at 5000 rpm [a, d]	0.390	29.98	40.26	4.71
PMMA coated at 5000 rpm [b, d]	0.543	30.73	70.00	11.67
CYTOP coated #1 [a]	0.393	27.61	32.65	3.54
CYTOP coated #1 [b]	0.523	32.52	66.97	11.39
CYTOP coated #1 after 72 days [b]	0.448	29.44	48.00	6.33
CYTOP coated #2 [b]	0.391	27.17	33.98	3.61
CYTOP coated #3 [b]	0.380	27.13	33.58	3.46

[a] Pristine device. [b] HNO_3 doped device. [c] Coated by PMMA with $M_w \approx 50000 \text{ g mol}^{-1}$.

[d] Coated by PMMA with $M_w \approx 550000 \text{ g mol}^{-1}$.

Table S3. Performances of G/Si solar cells with TiO₂ coatings.

Sample	V_{oc} [V]	J_{sc} [mA cm ⁻²]	J_{sat} [mA cm ⁻²]	FF [%]	PCE [%]
TiO ₂ coated #1 [a]	0.387	5.58	33.56	15.80	0.34
TiO ₂ coated #1 [b]	0.499	9.78	33.27	15.29	0.75
TiO ₂ coated #2 [a]	0.433	21.72	33.48	20.65	1.94
TiO ₂ coated #2 [b]	0.484	10.51	32.58	14.14	0.72
TiO ₂ coated #3 [a]	0.137	10.09	32.23	25.19	0.35
TiO ₂ coated #3 [b]	0.479	6.11	33.31	13.34	0.39

[a] Pristine device. [b] HNO₃ doped device

Table S4. Performances of G/Si solar cell fabricated with PMMA-coated ($M_w \approx 50000$ g mol⁻¹, 2000 rpm) graphene samples without SC-2 treatment.

Sample	V_{oc} [V]	J_{sc} [mA cm ⁻²]	FF [%]	PCE [%]	Series Resistance [Ω]
Without SC-2 #1	0.346	8.31	20.4	0.59	127
Without SC-2 #2	0.341	9.42	19.9	0.64	83