Electronic Supporting Information

Planar integration of flexible micro-supercapacitors with ultrafast charge and discharge based on interdigital nanoporous gold electrodes on a chip

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Electrochemical characterization and analysis

The mass of MnO_2 in the electrodes was calculated using the following equation (1):

$$m = \frac{Q}{nF} \times M \quad (1)$$

Where m is the mass of MnO_2; Q is total electric quantity for the electrochemical plating by potentiostatic deposition with three electrodes; n is the charge transfer number; F is the faradic constant; and M is the relative molecular mass.

The deposited PPy mass can be evaluated based on the following equation (2):

$$m = \frac{Q}{(2+\mathrm{y})F} \times M \quad (2)$$

Where m, Q, y, F are the mass of the deposited PPy, polymerizing charge, a stoichiometric factor evaluating the PPy insertion degree, and the faradic constant, respectively. M is the molecular weight of the polymer monomer unit ($M = M_{Py} - 2$), and M_{Py} is pyrrole molecular weight. A degree of insertion (0.2) was applied.

The areal/volumetric capacitance of the MSC was calculated from galvanostatic charge/discharge curves according to the following equation:

$$C_S = \frac{I \times \Delta t}{S \times \Delta V} \quad (3)$$

$$C_V = \frac{I \times \Delta t}{V \times \Delta V} \quad (4)$$

Where I is the constant discharge current; Δt is the time for a full discharge; S (V) is the planar area of active materials in the two working electrodes; and ΔV is the voltage drop on discharge.

The volumetric energy density (E) and power densities (P) against two electrodes in the device were calculated using the following formulas:

$$E_V = \frac{C_V \times \Delta V^2}{2 \times 3600} \quad (5)$$

$$P_V = \frac{E}{\Delta t} \times 3600 \quad (6)$$

Where ΔV is the operating voltage; C_V is the total capacitance of the device; and Δt is the time for a full discharge.

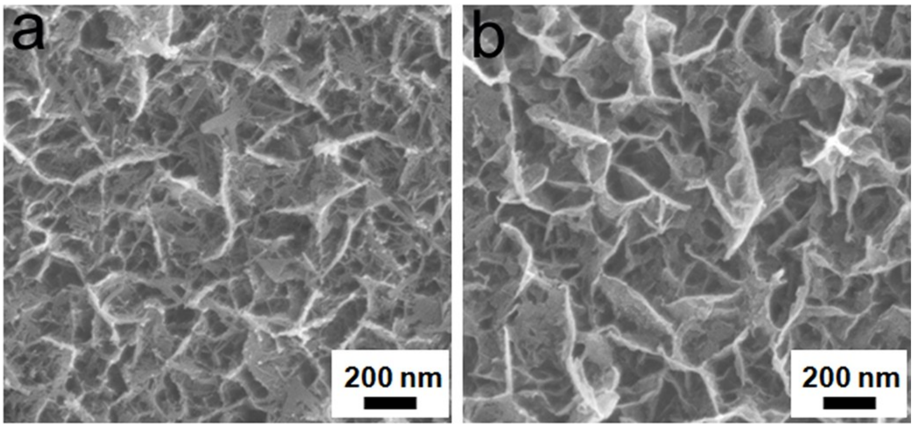

Figure S1. SEM images of NPG/MnO_2 composites with the MnO_2 plating time of (a) 20 min, (b) 30 min.

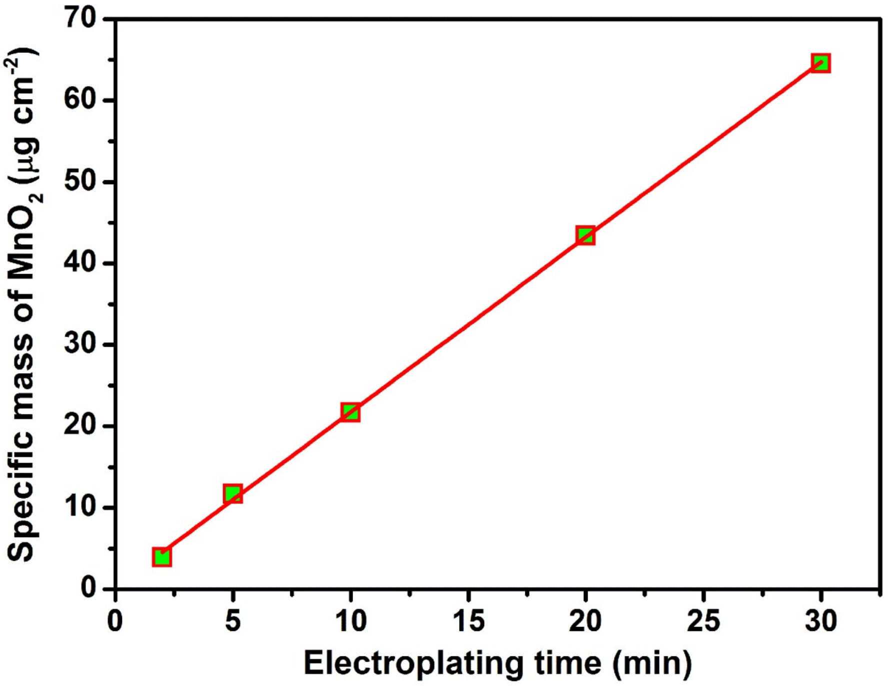

Figure S2. The plated mass of MnO_2 films versus the electroplating time.

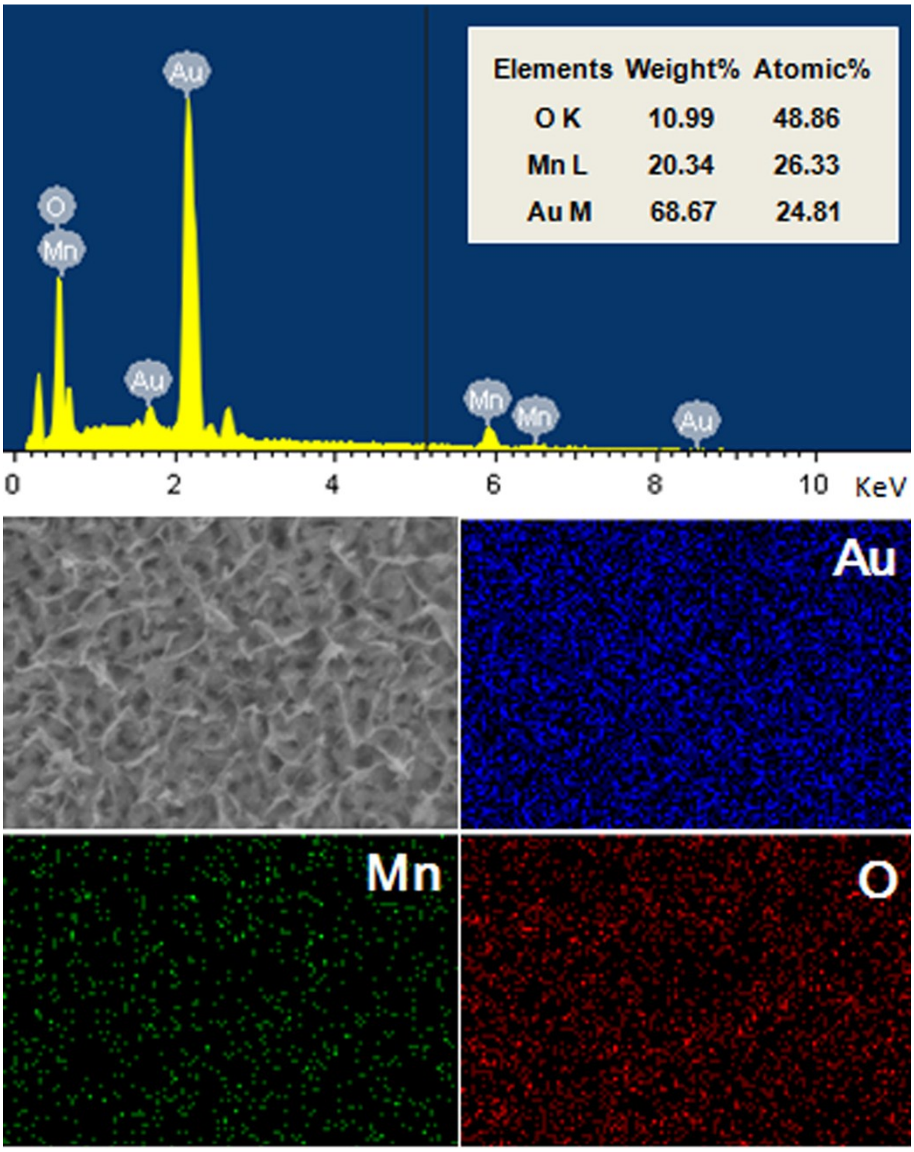

Figure S3. EDX spectrum and elemental mapping images of the NPG/MnO_2 composite.

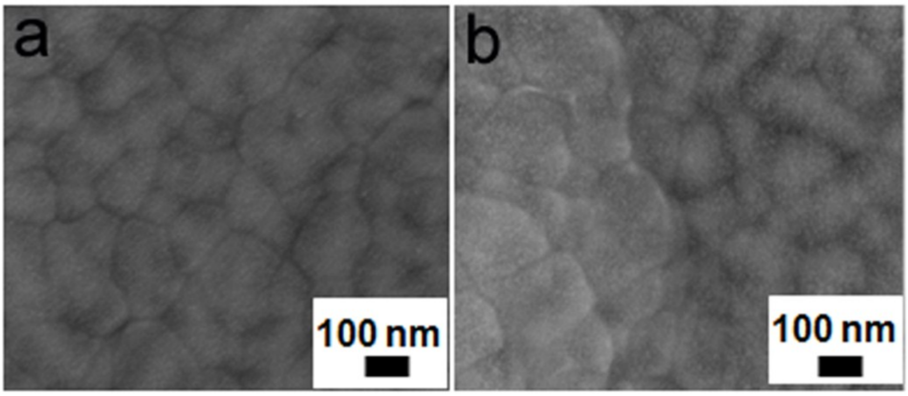

Figure S4. SEM images of NPG/PPy composites with the PPy plating time of (a) 20 s, (b) 30 s.

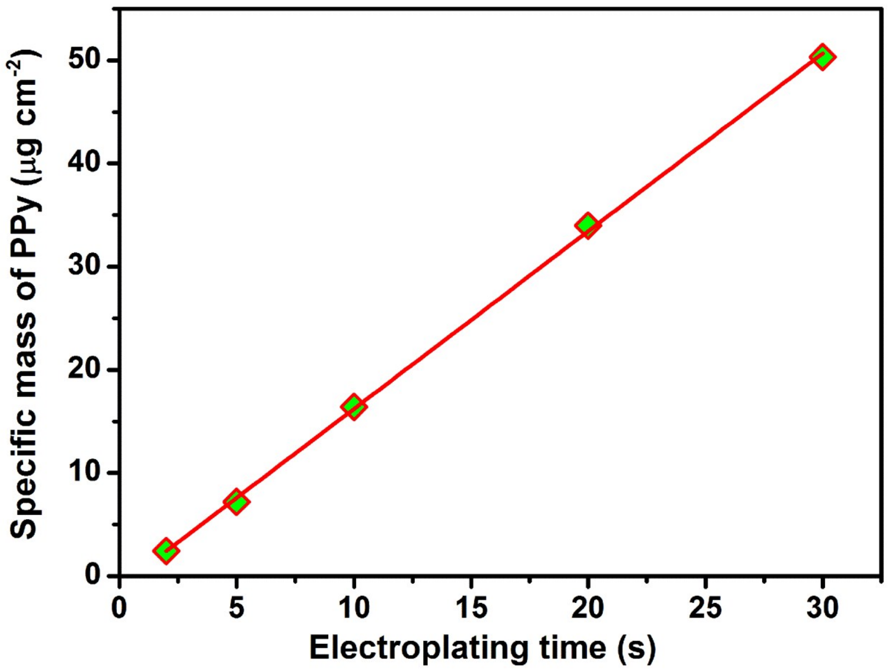

Figure S5. The plated mass of PPy films versus the electroplating time.

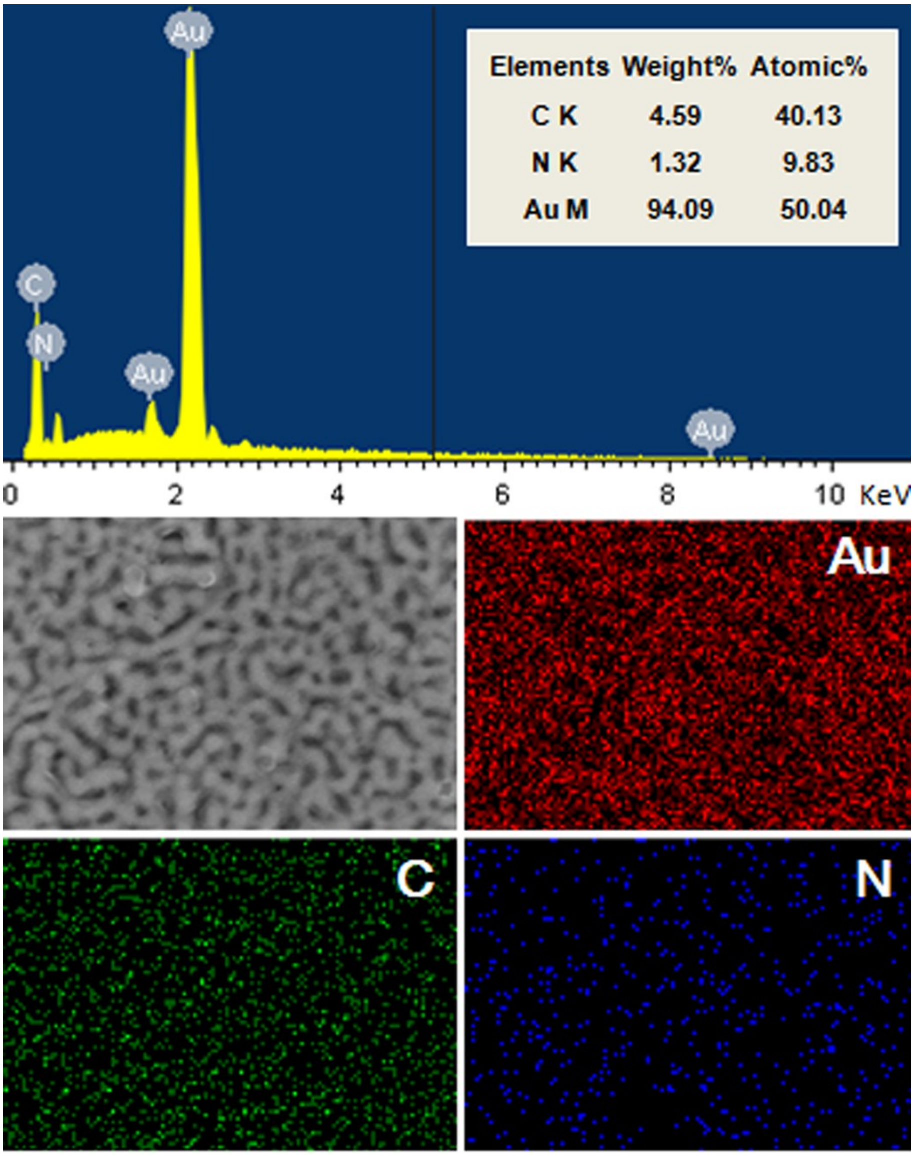

Figure S6. EDX spectrum and elemental mapping images of the NPG/PPy composite.

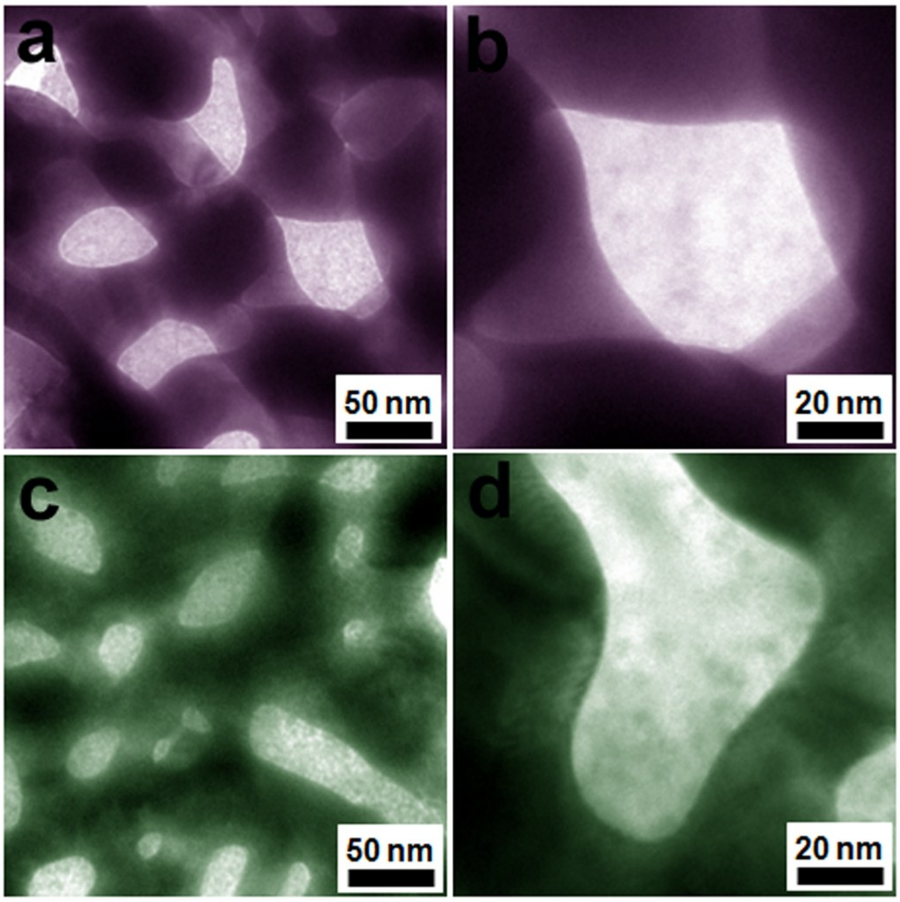

Figure S7. TEM images of NPG/MnO_2 (a) and NPG/PPy (c); High magnified TEM images of NPG/MnO_2 (b) and NPG/PPy (d).

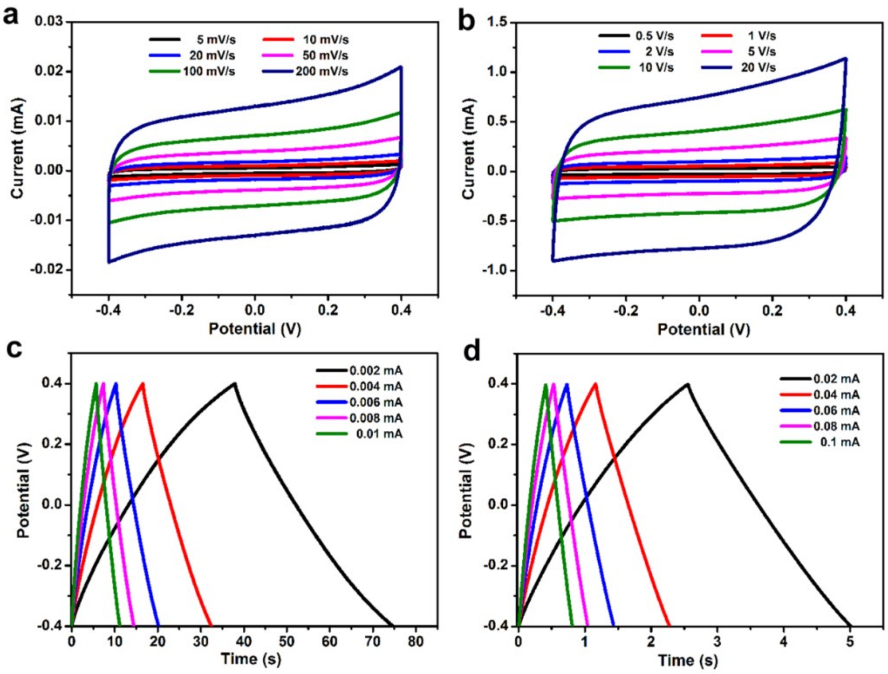

Figure S8. CV curves of NPG/MnO_2 MSC with the MnO_2 plating time of 2 min at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/MnO_2 MSC with the MnO_2 plating time of 2 min at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

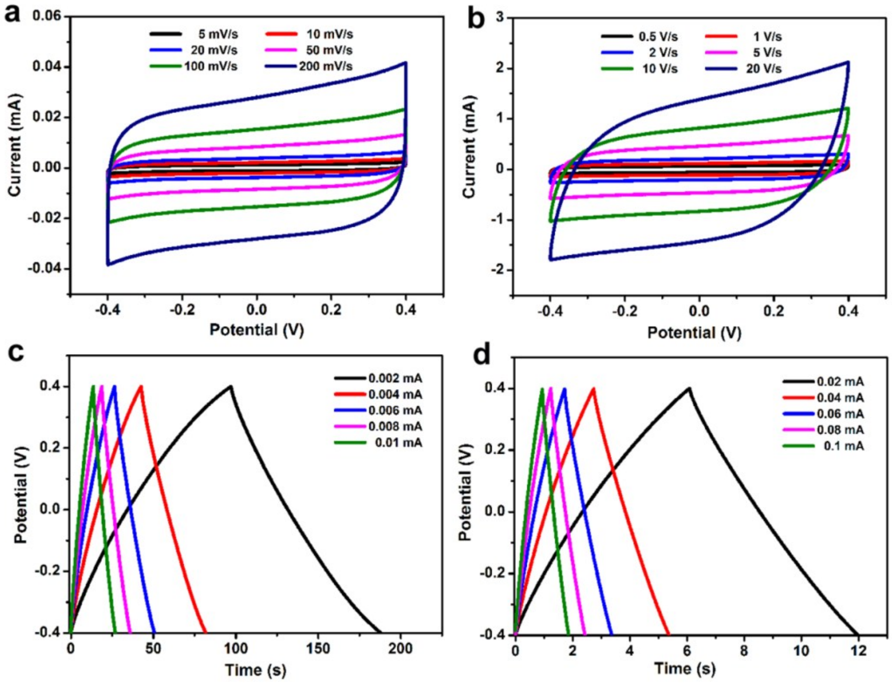

Figure S9. CV curves of NPG/MnO_2 MSC with the MnO_2 plating time of 5 min at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/MnO_2 MSC with the MnO_2 plating time of 5 min at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

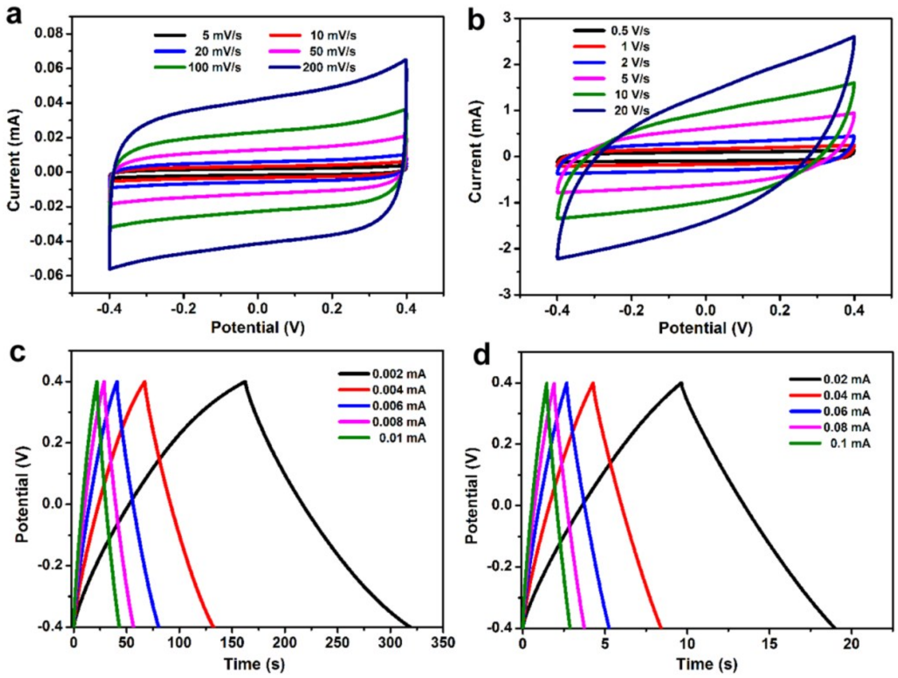

Figure S10. CV curves of NPG/MnO_2 MSC with the MnO_2 plating time of 10 min at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/MnO_2 MSC with the MnO_2 plating time of 10 min at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

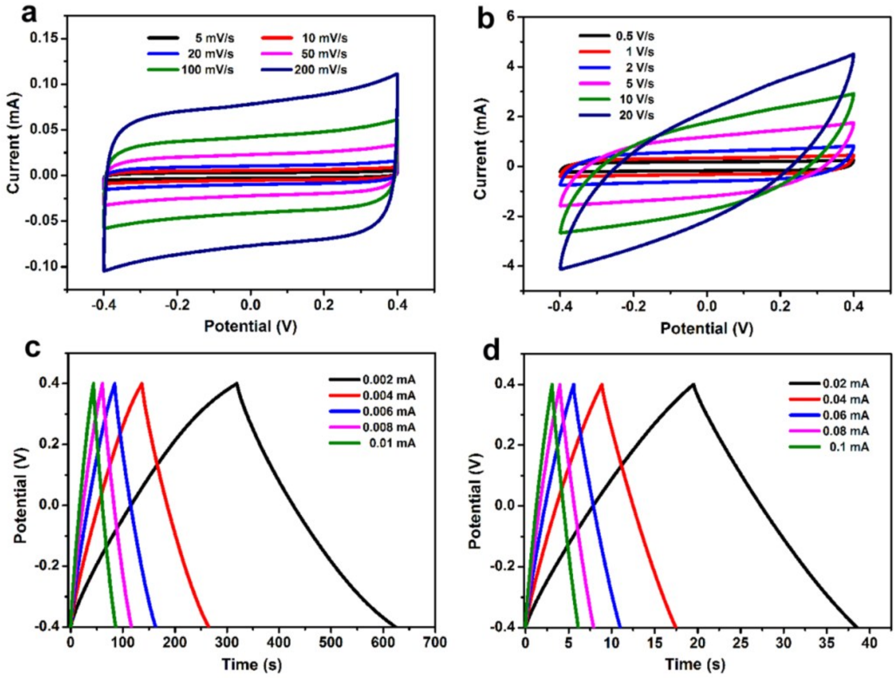

Figure S11. CV curves of NPG/MnO_2 MSC with the MnO_2 plating time of 20 min at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/MnO_2 MSC with the MnO_2 plating time of 20 min at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

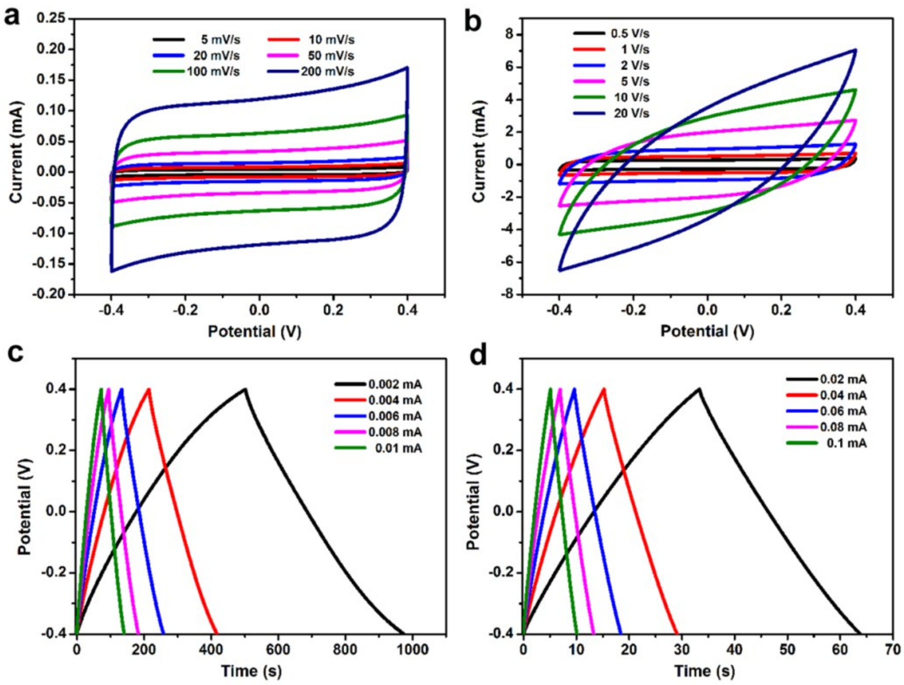

Figure S12. CV curves of NPG/MnO_2 MSC with the MnO_2 plating time of 30 min at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/MnO_2 MSC with the MnO_2 plating time of 30 min at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

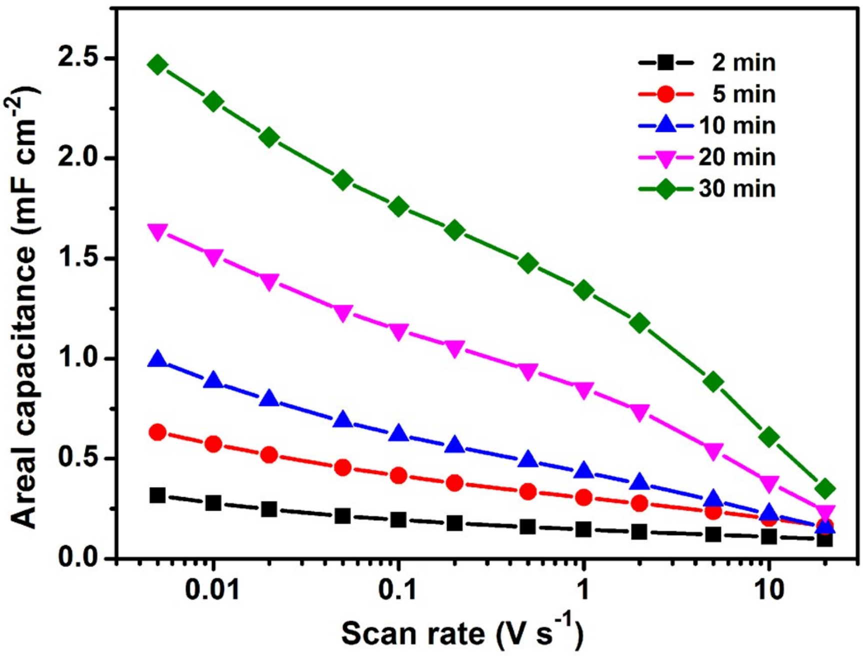

Figure S13. Evolution of the areal capacitance of MSC with various mass loadings of MnO_2 as a function of scan rate.

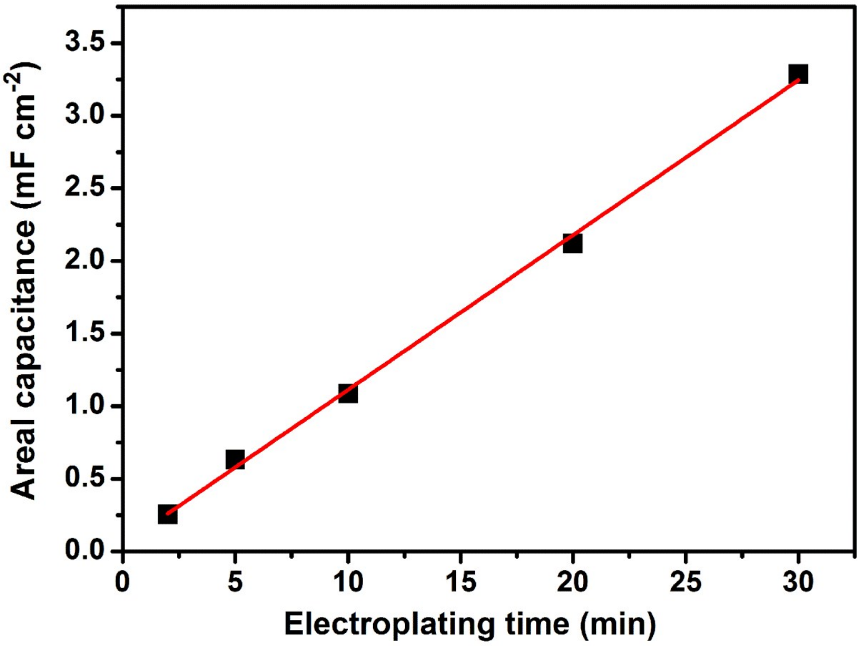

Figure S14. Areal capacitance of NPG/MnO_2 MSCs versus the MnO_2 plating time.

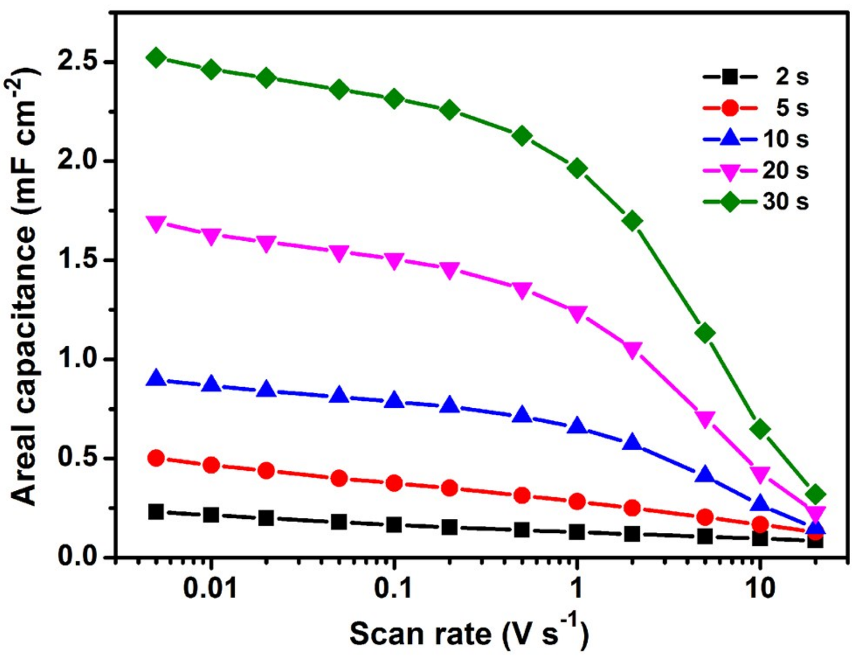

Figure S15. Evolution of the areal capacitance of MSC with various mass loadings of PPy as a function of scan rate.

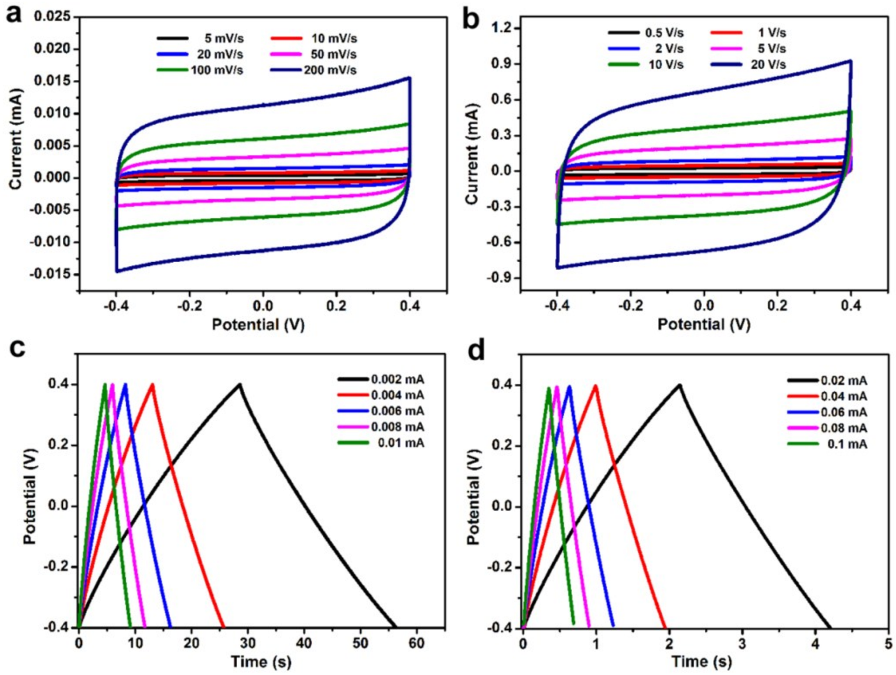

Figure S16. CV curves of NPG/PPy MSC with the PPy plating time of 2 s at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/PPy MSC with the PPy plating time of 2 s at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

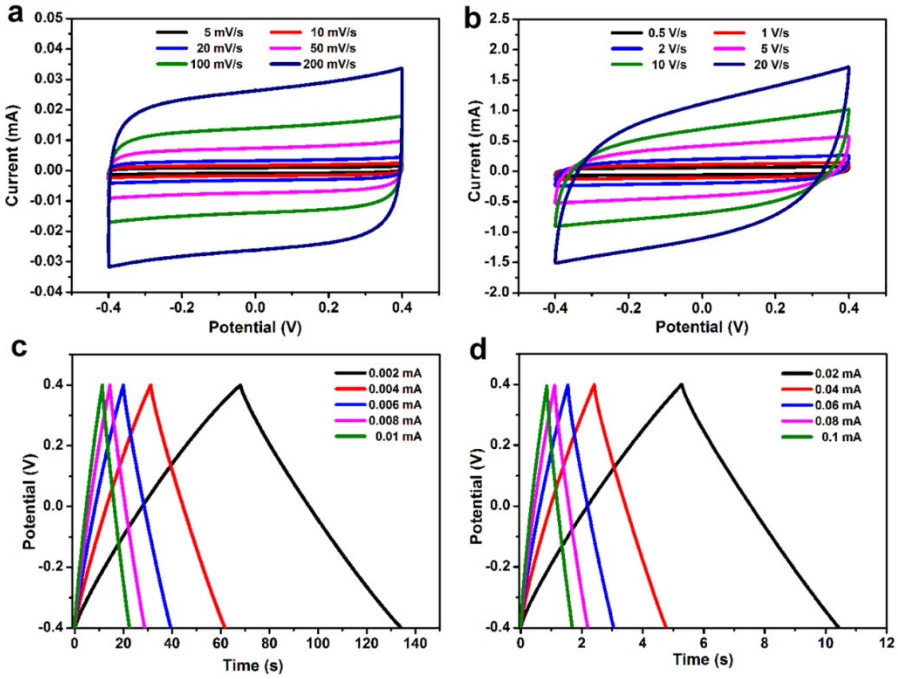

Figure S17. CV curves of NPG/PPy MSC with the PPy plating time of 5 s at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/PPy MSC with the PPy plating time of 5 s at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

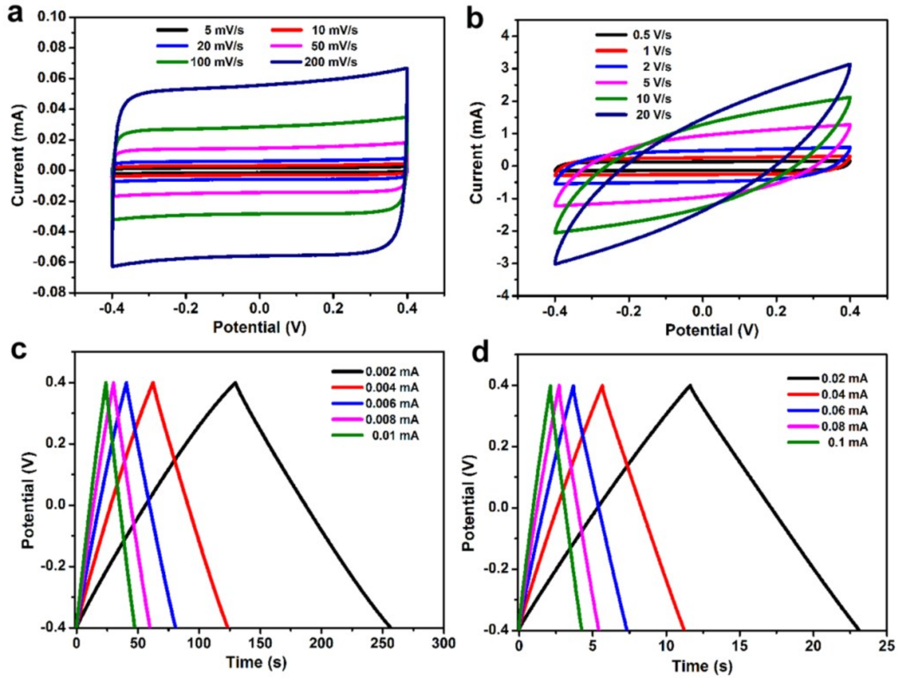

Figure S18. CV curves of NPG/PPy MSC with the PPy plating time of 10 s at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/PPy MSC with the PPy plating time of 10 s at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

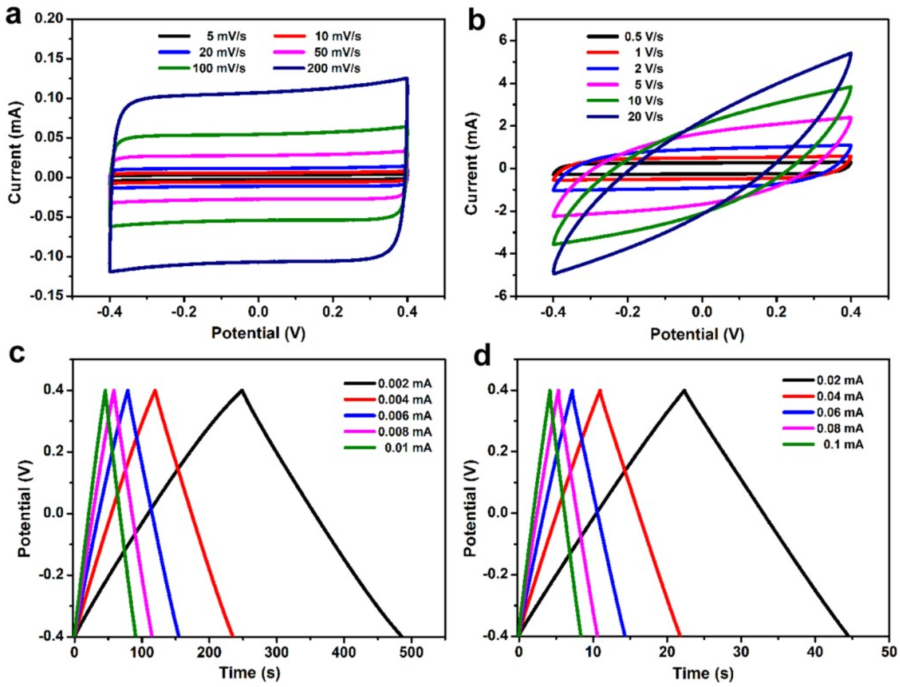

Figure S19. CV curves of NPG/PPy MSC with the PPy plating time of 20 s at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/PPy MSC with the PPy plating time of 20 s at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

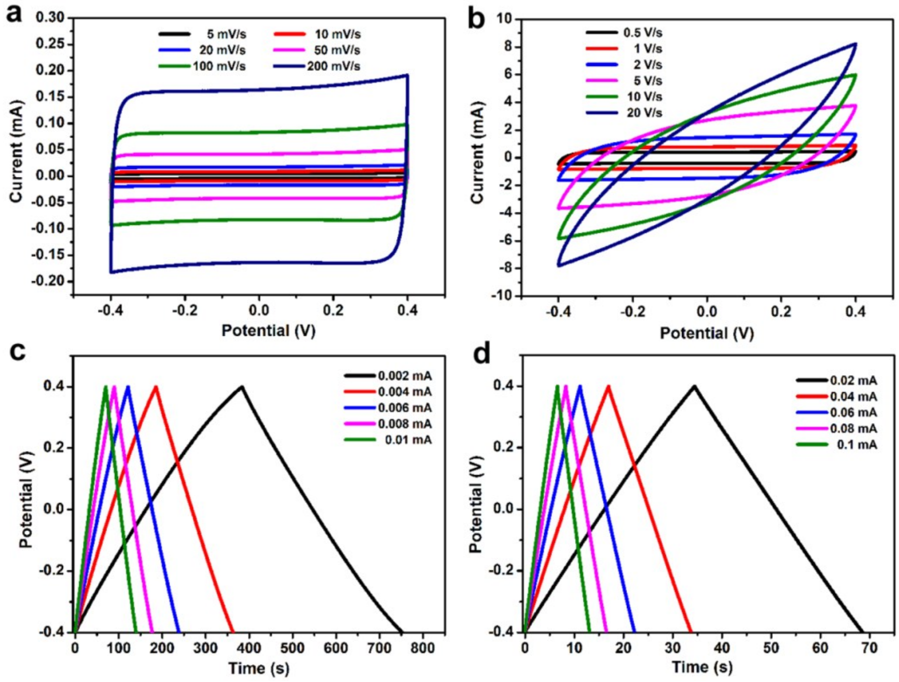

Figure S20. CV curves of NPG/PPy MSC with the PPy plating time of 30 s at scan rates ranging from (a) 5 to 200 mV s^{-1}; (b) 0.5 to 20 V s^{-1}. Galvanostatic charge/discharge curves of NPG/PPy MSC with the PPy plating time of 30 s at different current from (c) 0.002 to 0.01 mA; (d) 0.02 to 0.1 mA.

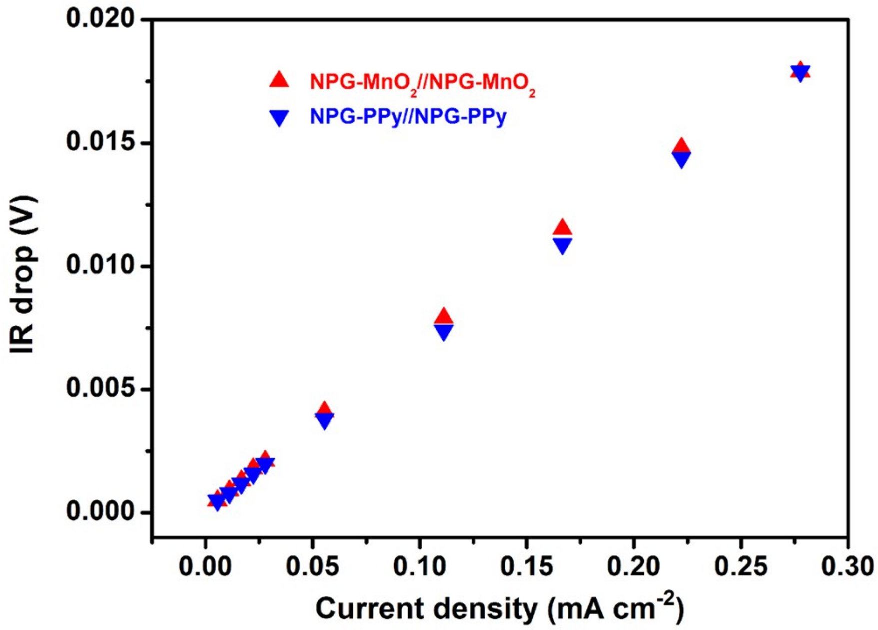

Figure S21. IR drop of NPG based MSC with the MnO_2 plating time of 10 min or the PPy plating time of 10 s at various current densities.

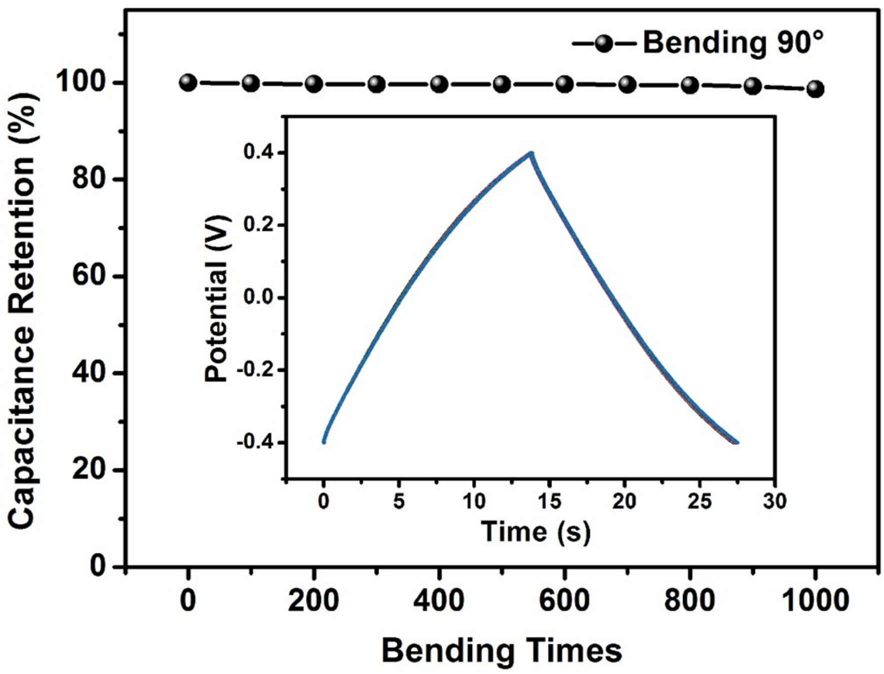

Figure S22. Capacitance retention of the flexible device after 1000 bending cycles with a bending angle of 90º. The inset is the galvanostatic charge/discharge curves of NPG/MnO_2 MSC after bending.

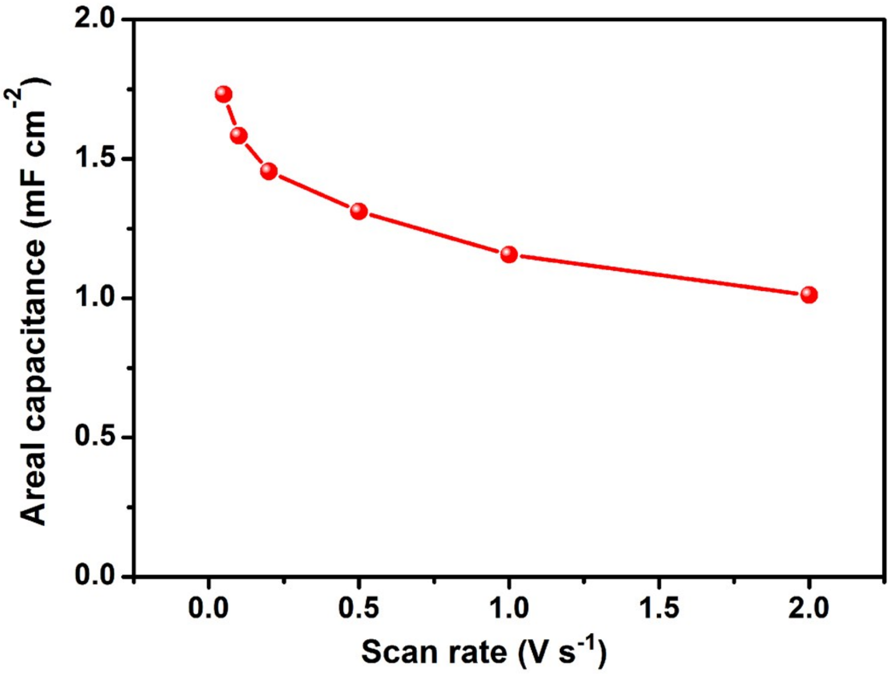

Figure S23. Areal capacitance of AMSC based 10 min MnO_2 plating and 10 s PPy plating as a function of scan rate.