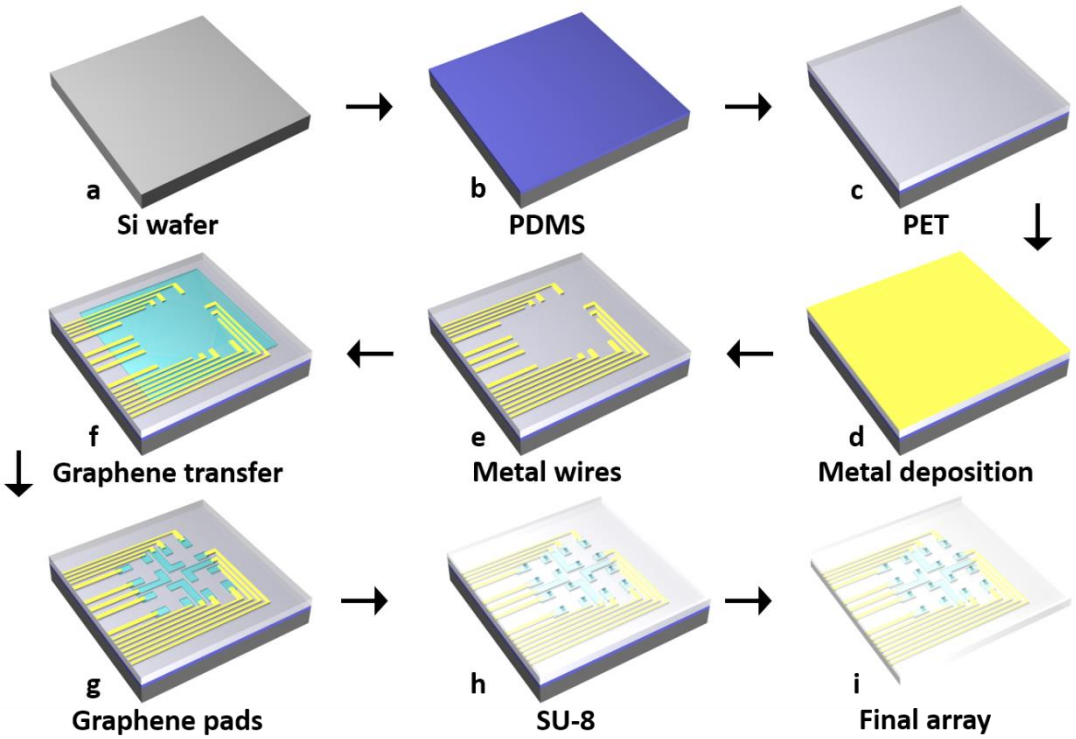
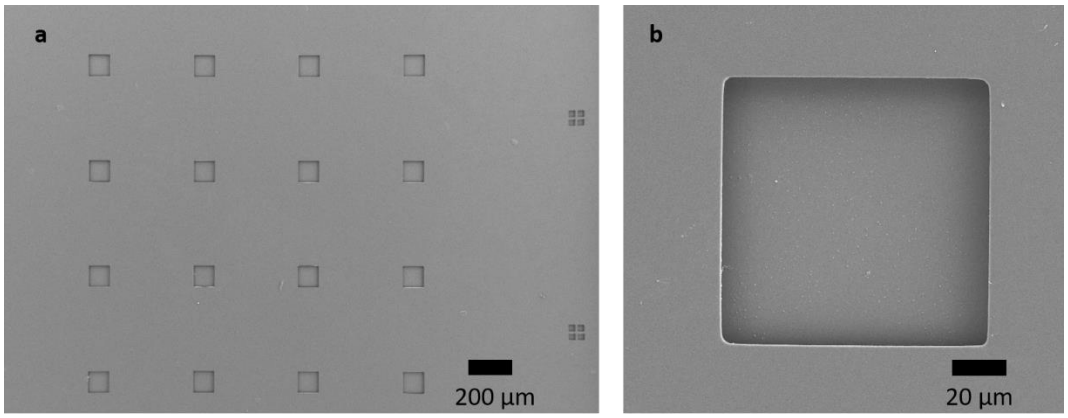
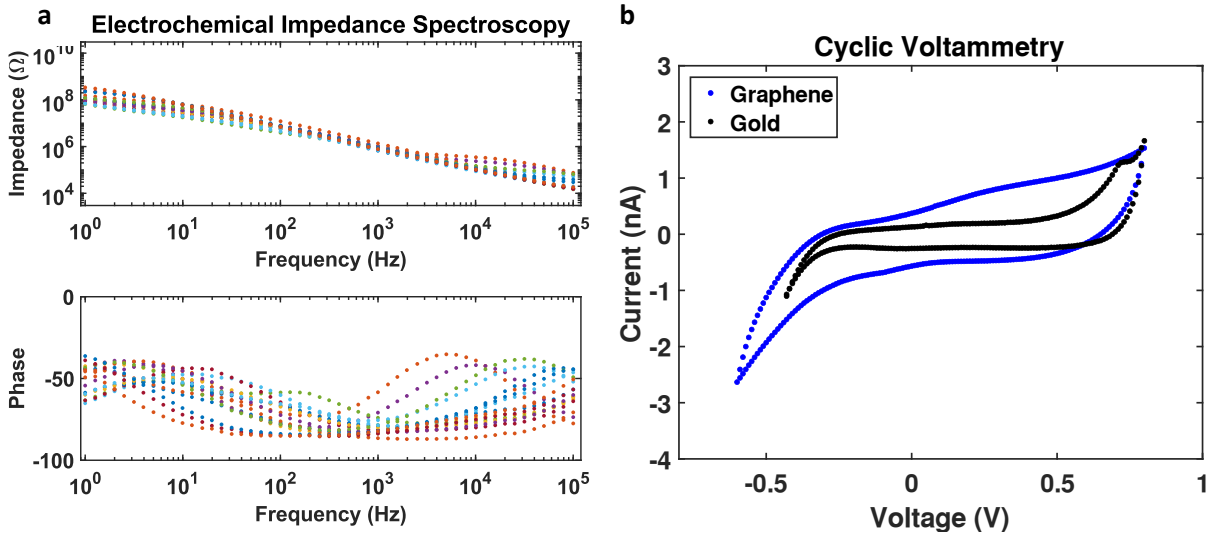
Supplementary Information



Supplementary Figure S1. Fabrication flow. (a) Fabrication starts with a 4-inch silicon wafer, fully cleansed and dehydrated. (b) Polydimethylsiloxane (PDMS) is spin-coated at 3000 rpm as the adhesive layer. (c) 50 µm thick polyethylene terephthalate (PET) substrate is placed on top to PDMS layer. (d) 10 nm chromium and 100 nm gold are sputtered on to PET substrate. (e) Metal wires are patterned with photolithography and wet-etching. (f) "Bubbling" method is adopted for graphene transfer. (g) Graphene pads are patterned with AZ1512/PMGI SF3 bilayer photolithography and oxygen plasma etching. (h) 8 µm thick SU-8 2005 encapsulated the array with square openings of 100 µm side length. (i) Peeled the off from the PDMS/Si wafer, the array is ready for electrochemical characterization.

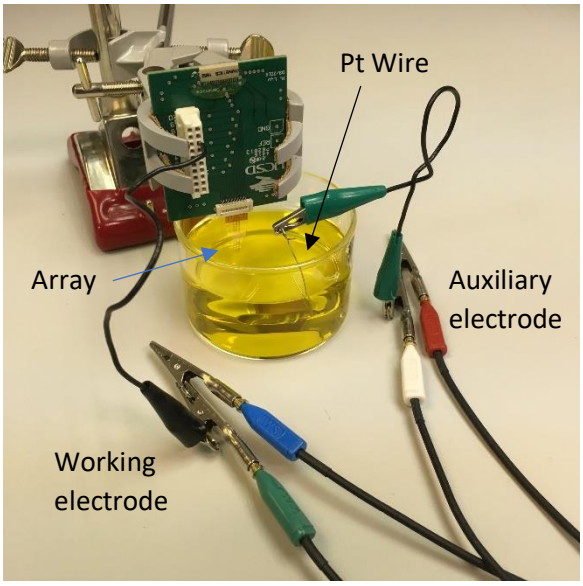


Supplementary Figure S2. Scanning Electron Microscopy Images. (a) The center-to-center spacing between two adjacent openings is 400 µm and the side length of the opening is 100 µm. (b) SU-8 encapsulation is well-defined by the photolithography process, there is no cracks in the SU-8 layer and no obvious polymer residual on the graphene surface.

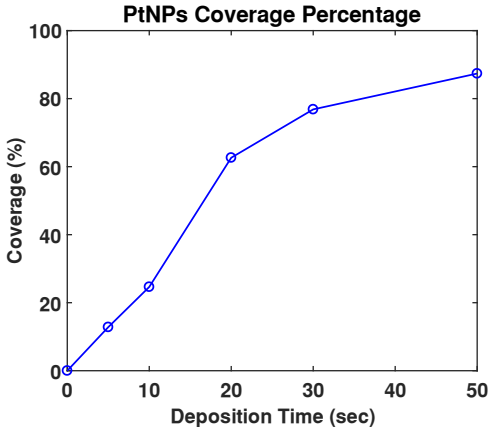


Supplementary Figure S3. Electrochemical Characterizations of Original Graphene Electrodes. (a) Electrochemical impedance shows all 16 channels are working, with an average impedance of 872.9 KΩ at 1 KHz. The moduli and phases are shown in the top and bottom panel respectively. (b) Cyclic voltammetry of a representative channel shows no redox peaks, which is typical for

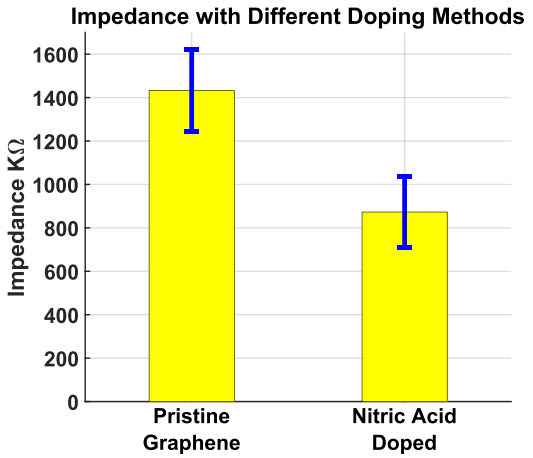
graphene/solution interface. In comparison, CV of a gold channel has one peak at 0.7 V indicating redox reaction.



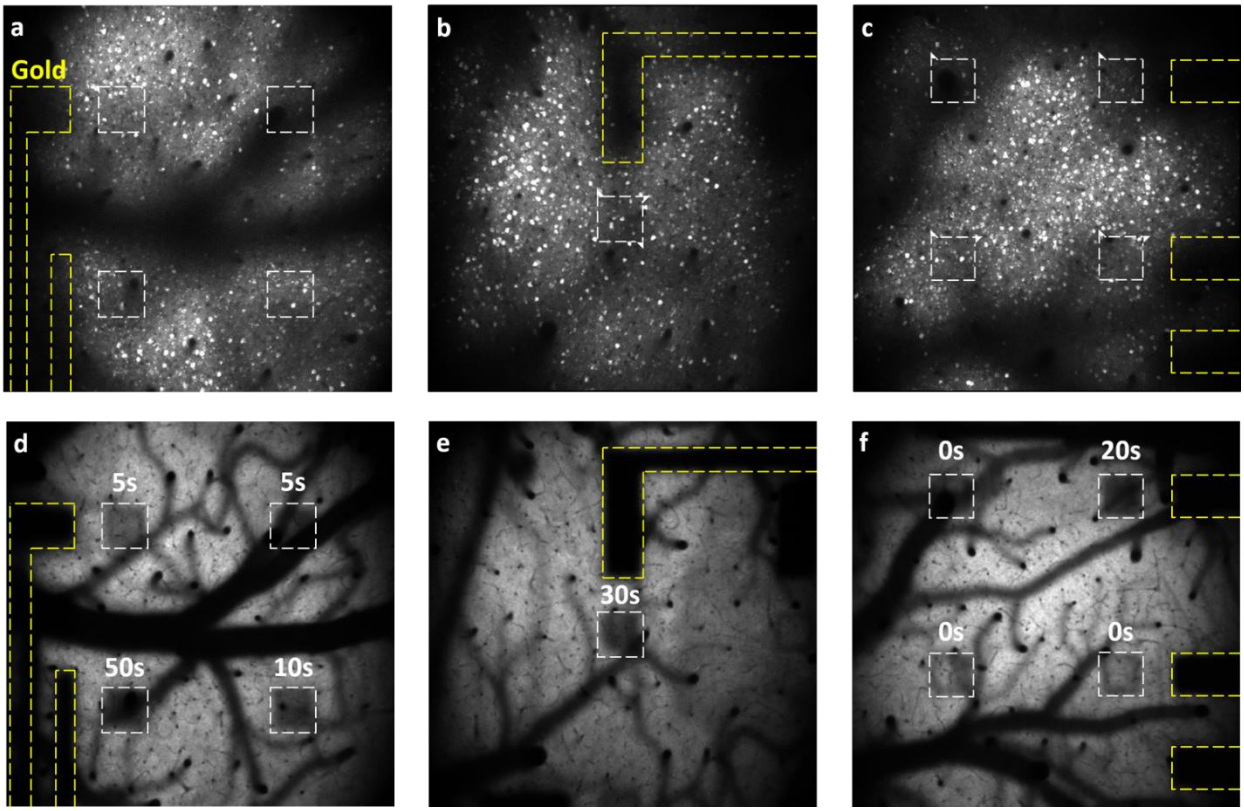
Supplementary Figure S4. Set up for PtNPs Electrodeposition. The solution concentration is 1 mM H_2PtCl_6 and 10 mM K_2HPO_4, deionized water (R~18MΩ) is used as solvent so that no additional electrolyte is included. A two electrodes cell is constructed with Gamry 600 plus, where the graphene electrode is connected to the working/working sense and a platinum wire (0.5 mm diameter) to the counter/reference.



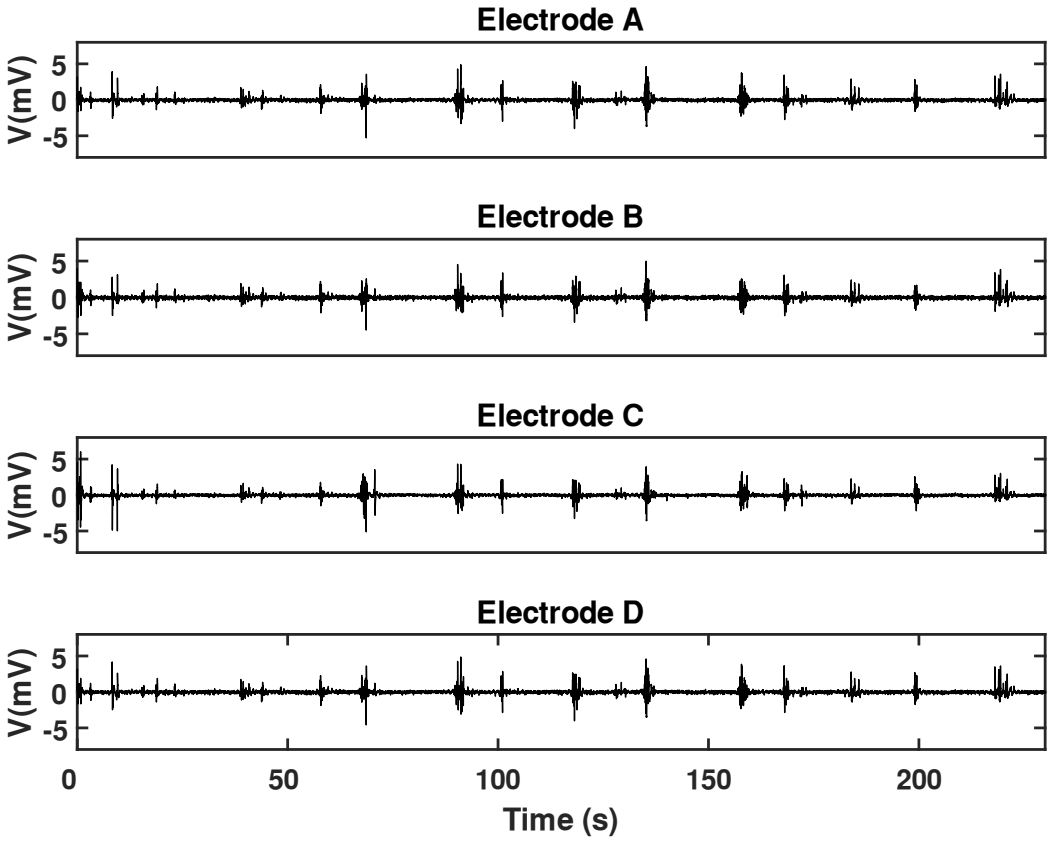
Supplementary Figure S5. PtNPs Coverage. To estimate the PtNPs coverage, SEM images were loaded into MATLAB and converted to gray scale. A threshold mask was applied to all the pixel points so that most of the background graphene pixels were labeled correctly. Later, the morphological closing was performed to correctly label the "shadow" pixels on large PtNPs. The coverage is obtained by calculating the ratio of the PtNP pixel number and the total pixel number.



Supplementary Figure S6. Nitric Acid Doping Effect. 16 pristine graphene channels have an average impedance of 1.43 MΩ. 16 channels doped with 35% nitric acid have average impedances of 872.9 KΩ. 70% nitric acid may decrease the impedance further, however, high concentrated nitric acid attacks polymers including PET and PMMA and hence makes transfer extremely difficult.



Supplementary Figure S7. Two-photon *In Vivo* Calcium Imaging. The top row is images focused at 250 μm deep, the bottom row at 50 μm. Two images in the same column have the exactly same position, where SU-8 opening and gold wires are marked with white and golden dash lines respectively. The number under each electrode channel indicates the deposition time of PtNPs. At 250 μm, neuron activities can be clearly seen (light dots) unless blocked by blood vessels or gold wires.



Supplementary Figure S8. Electrical recordings from Electrode A, B, C, and D, with deposition time of 10, 50, 5, and 5 seconds respectively. The noise level for these four electrode channels are similar to each other.

Supplementary Note 1. Equations for equivalent circuit models

Constant phase element:

$$Z_{CPE} = \frac{1}{(j\omega)^{A} C_{dl}}$$

Bounded Warburg element:

$$Z_{W_B} = \frac{W_B}{\sqrt{j\omega}} \tanh\left(\frac{\sqrt{j\omega}}{B}\right)$$

Infinite Warburg element:

$$Z_{W_I} = \frac{W_I(1-j)}{\sqrt{\omega}}$$