Supplementary Material (ESI) for Analyst

Supporting Information

Probing chemical induced cellular stress by non-Faradaic electrochemical impedance spectroscopy using *Escherichia coli* capacitive biochip

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EXPERIMENTAL METHODS

Immobilization of CNTs on GID electrode capacitor arrays. The bare GID electrode capacitor array chip was immersed into a solution of 1 mM 95% cysteamine (Sigma-Aldrich) in ethanol for 24 h. The chip was removed and washed with ethanol and dried under a stream of N_2 gas. The self-assembled monolayer (SAM) of cysteamine formed on gold surface through –SH groups contained free -NH_2 groups that were utilized to covalently attach carboxylated multiwalled carbon nanotubes (carboxy-CNTs). For this, 100 µL of 1 mg/mL carboxy-CNTs (Arry®, Germany) in 99.9% dimethyl sulfoxide (Sigma-Aldrich) was mixed with equal volume of a mixture of 200 mM of 1-Ethyl-3-[3-dimethylaminopropyl] carbodiimide hydrochloride (EDC) and 100 mM *N*-hydroxysuccinimide (NHS) and ultrasonicated with alternative cycles of 10 s pulse after every 10 s interval for 5 min using ultrasonicator probe (Vibra cell 75043). The carboxy-CNTs suspension was incubated for 4 h at room temperature. About 5 µL of this suspension was dropped on each GID electrode covering an area of 3 mm^2 of a each capacitor in an array capacitors on SiO_2 wafer that were previously activated with cysteamine self-assembeled monolayer. The capacitor chips were then incubated in airtight moist chamber for 24 h for covalent attachment of carboxy-CNTs. The capacitor arrays were then washed first with 50% DMSO in water followed by washing with acetone to remove traces of unbound carboxy-CNTs and dried over N_2 gas. A capacitor array without carboxy-CNT immobilization was used as a control for the comparison. A schematic diagram is shown in Supporting Information (SI) Figure S-1.

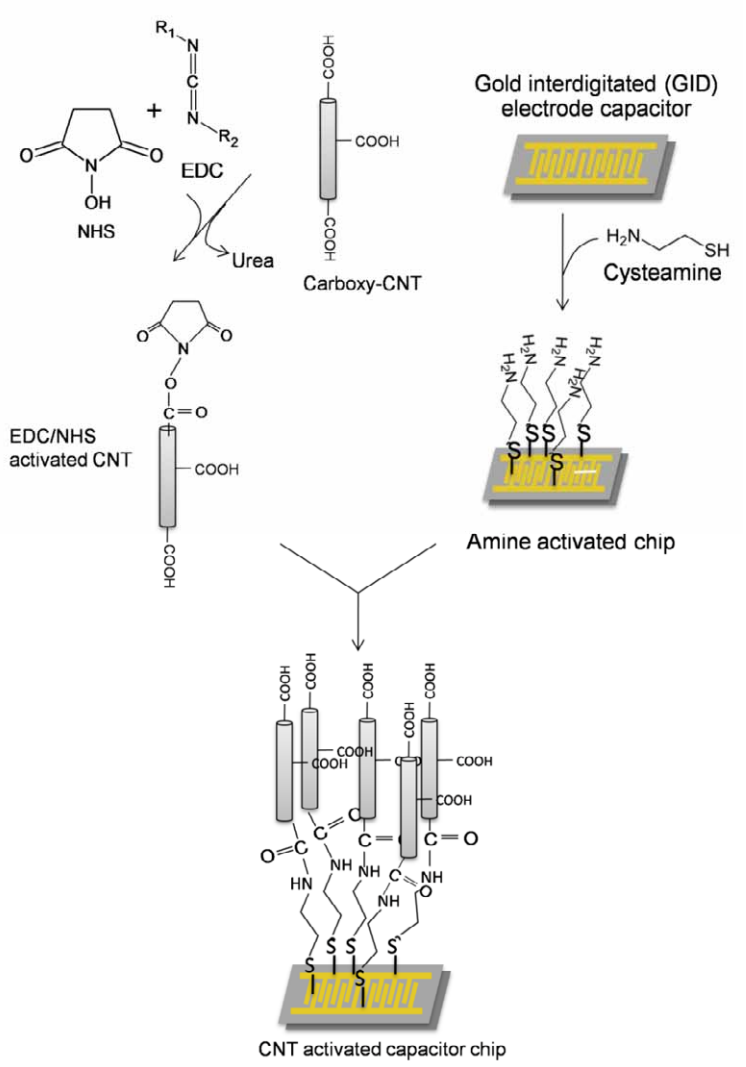

Fig. S-1. Schematic diagram of activation of gold interdigitated electrode capacitor chip with carboxy-CNT fictionalization.

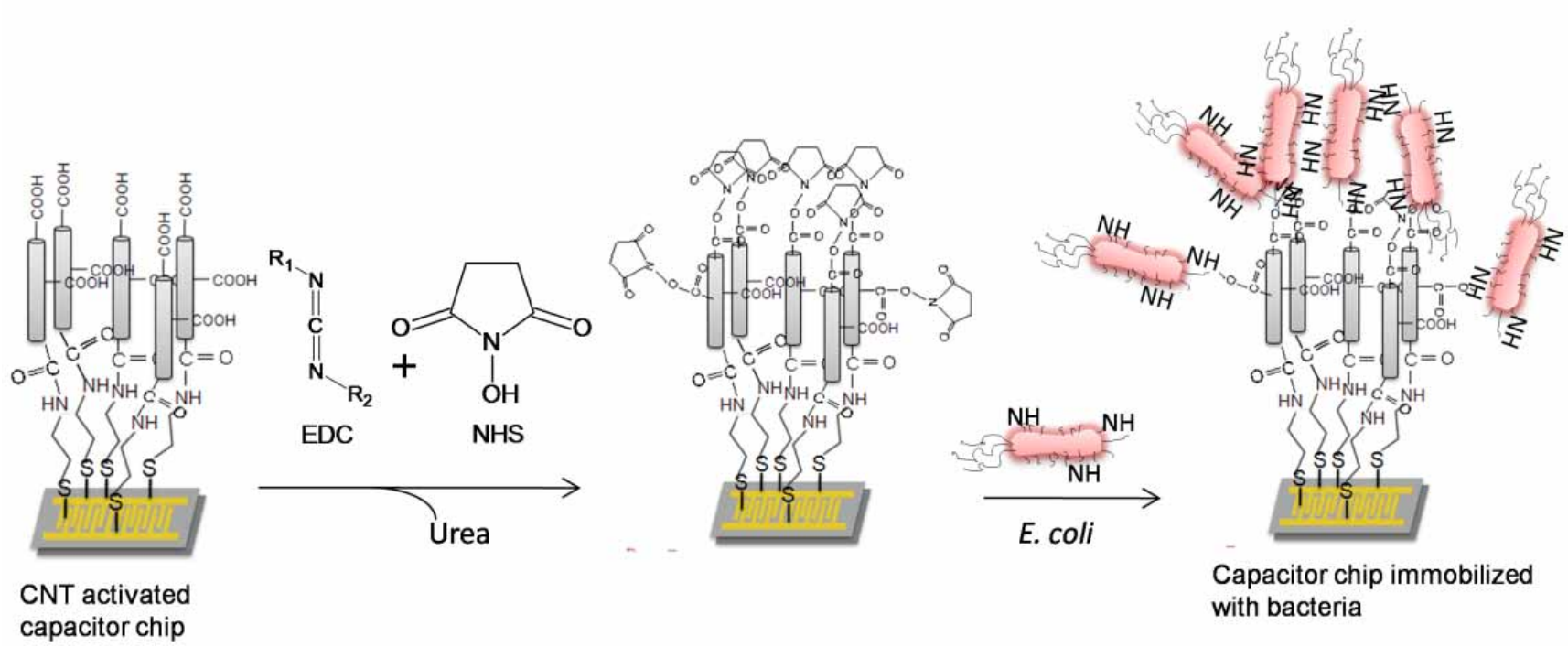

Fig. S-2. Schematic diagram of biofunctionalization of carboxy-CNT activated GID capacitor chip and immobilization of *E. coli* cells to develop biochip.

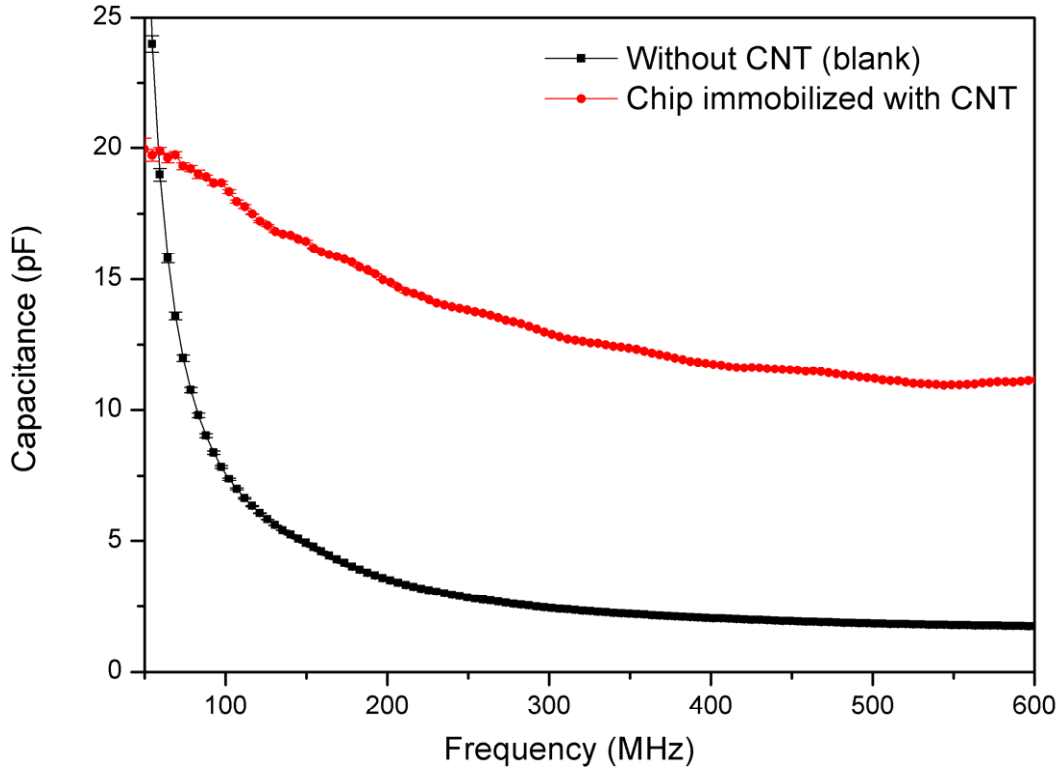

Fig. S-3. Capacitive response of gold interdigitated capacitor chip before and after carboxy-CNT immobilization.

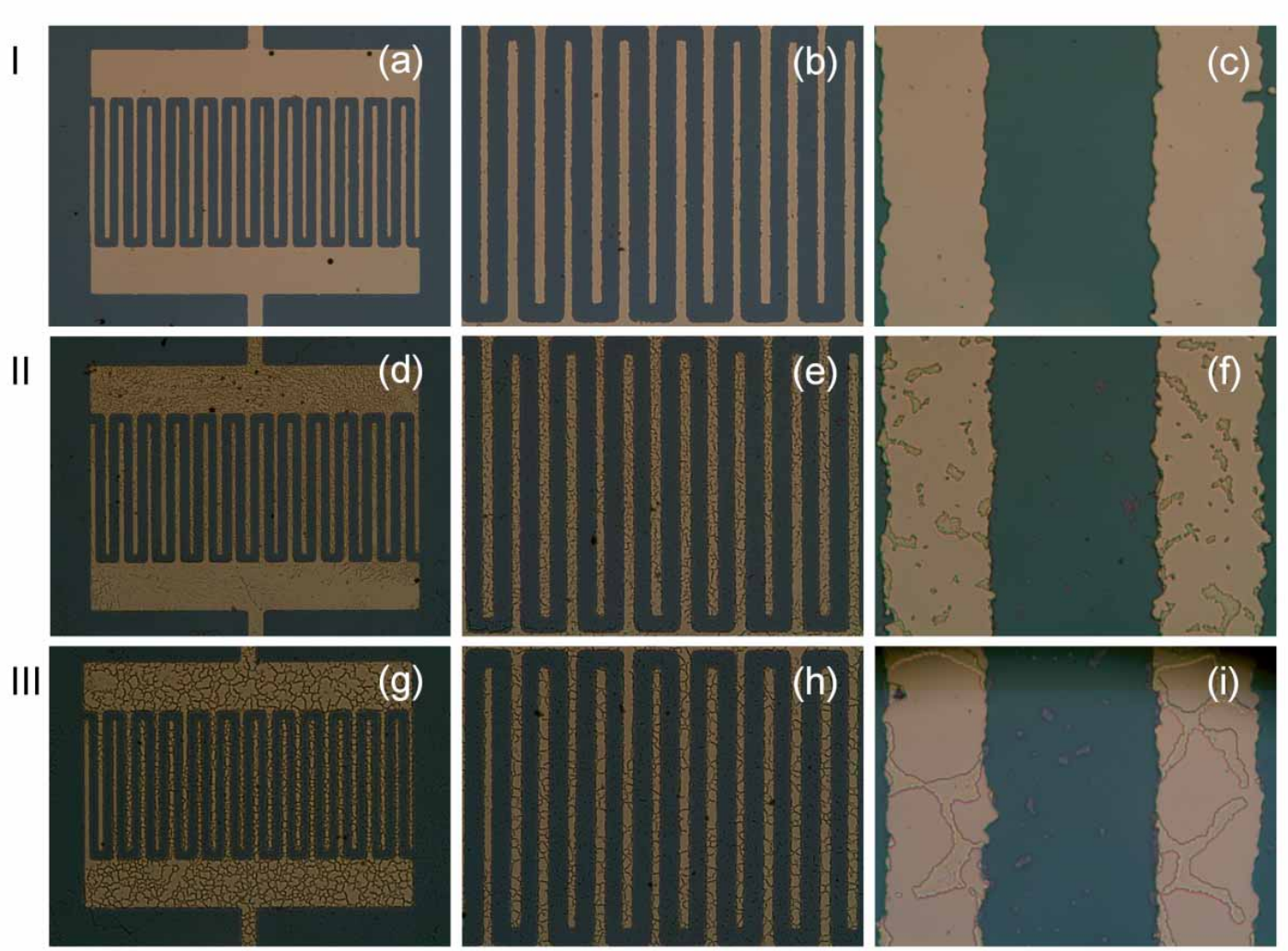

Fig. S-4. Optical micrographs of gold interdigitated capacitor surface: (I) activated with carboxy-CNTs (control), and carboxy-CNT activated chips immobilized with *E. coli* with concentrations of (II) 8.7×10^6 cells and (III) 1.7×10^7 cells. The rows (a-c, d-f and g-i) indicate optical resolutions of 5X, 10X and 100X, respectively.

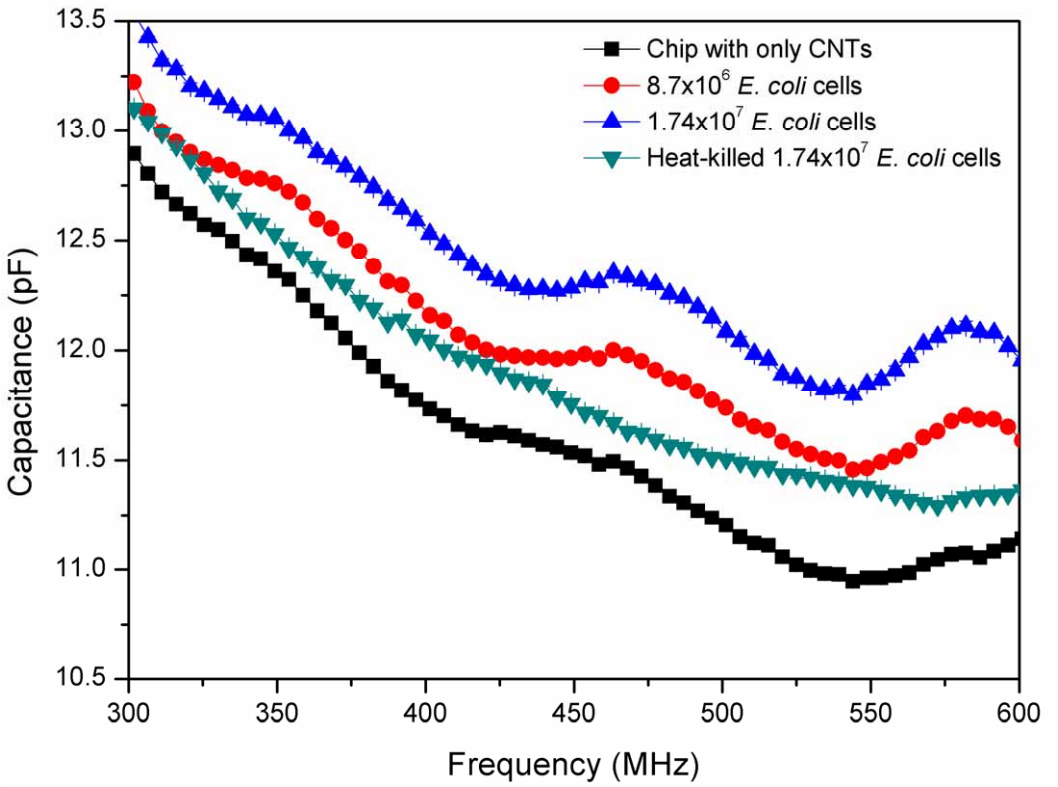

Fig. S-5. Capacitive response of bare GID surface covalently linked with only carboxy-CNTs (shown in black); biochip immobilized with viable 8.7 × 10^6 cells (red) and 1.74 × 10^7 cells (blue); and heat-killed 1.74 × 10^7 cells (green) on GID surface that was previously activated with carboxy-CNTs. The capacitive responses were observed at a frequency range of 300-600 MHz.

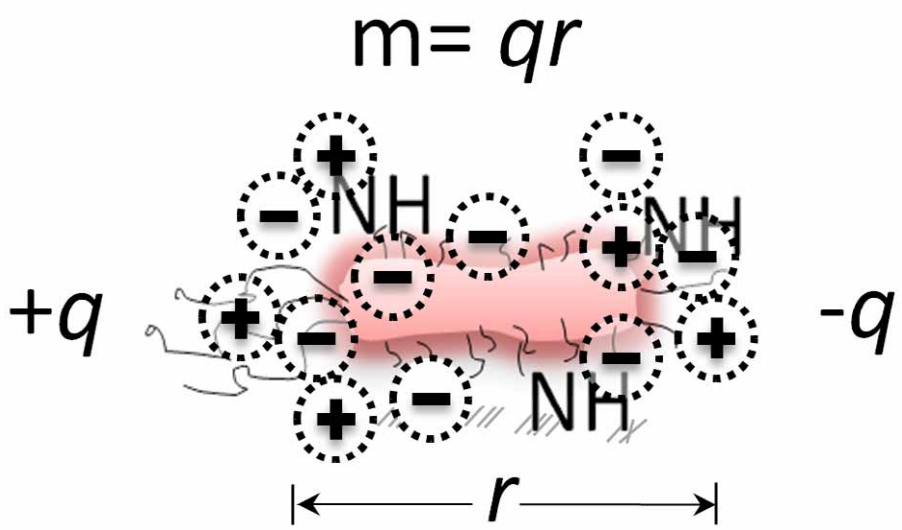

Fig. S-6. Schematic diagram of a typical cell surrounded by a cloud of charges that constitutes a molecular dipole *m* by two equal and opposite unit charges, separated by a distance *r* on an outer cell surface.