Supplemental material to:

How to embed three-dimensional flexible electrodes in microfluidic devices for cell culture applications

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Frequency analysis of the flexible electrodes

Prototype devices were designed and fabricated in order to characterize the electrode impedances in terms of their frequency response. The devices, consisting of five independent and parallel straight channels (20mm long, 100µm wide and 50µm high), were molded out of PDMS. Input and output ports were punched to each channel end, right before plasma bonding on a glass substrate (Fig. S1a). Steel couplers were connected to the device ports and used to inject the electrodes; following a further curing step in oven (3 hours at 80°C), they served to perform electrical measurements across the channels. A digital signal generator and an oscilloscope (TDS3012C, Tektronix Inc) were used to measure the electrical behavior of the CNT mixture within the channels. Sinusoidal voltage signals in a range of frequencies between 1Hz and 10MHz were applied to the circuit, and current amplitudes and phase shifts were recorded. A frequency analysis was carried out and the corresponding average Bode diagrams were calculated (Fig. S1b). A gradual phase shift, trending toward -π/2 at high frequencies, suggested a capacitance effect in parallel with the resistance of the electrodes. Fig. S1c shows the identified RC electrical model, whose R and C values were calculated yielding to 55.5±8.03kΩ and 1.13±0.07pF with an average cutoff frequency of 2.54MHz.

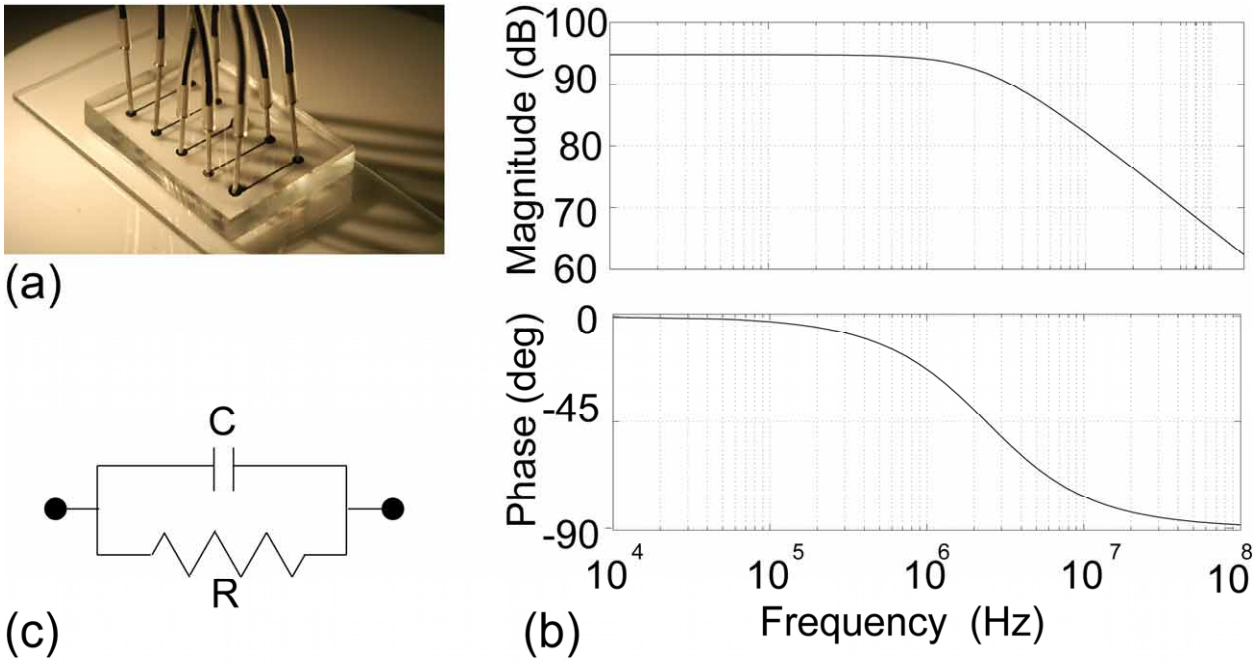

Fig. S1 (a) Picture of a PDMS device consisting on 5 parallel channels (20mm long, 100µm wide and 50µm high) filled with the nanocomposite material. (b) Bode diagrams from the frequency response in terms of electrical impedance of the electrodes. The gradual phase shift trending toward -π/2 at high frequencies, suggests a capacitance effect in parallel with the resistance of the electrodes. (c) An RC model was used to solve for resistance and capacitance, yielding to 55.5±8.03kΩ and 1.13±0.07pF, respectively. Fifteen channels were tested and used to compute the frequency response. No significant variations after reuse were noticed.