352f Bacteria Capture, Concentration and Detection Based on Ac Dielectrophoresis, Electro-Osmotic Transport and Self-Assembly of Single-Wall Carbon Nanotubes

Ronghui Zhou, Ping Wang, and Hsueh-Chia Chang

Because they possess a range of extraordinary physical properties suitable for biosensor applications (such as extremely small size and high aspect ratio, easy conjugation with antibodies/functional groups and a rich spectrum of electrical properties), carbon nanotubes have spurred several sensitivity breakthroughs in biosensor design. The latest carbon nanotube biosensors exploit the sensitive conductance change (or field-gating effects) with respect to molecular, viral or organism docking and employ pretemplated nano-wires between two micro-electrodes or on electrode surfaces. Such sensitive nanowire sensors can register individual docking events. In fact, nanotube biosensors have such a fast and sensitive response after docking that the rate-limiting step for any detection task now lies in the transport of the detection target to the nanowire sensors. In this report, we exploit the high electrokinetic mobility and large polarizability of single-wall carbon nanotubes (SWNT) (endowed by their high surface charge, relative length and huge aspect ratio) to significantly reduce the above transport time. The strategy can rapidly (<10 minutes) capture and detect low numbers of bacteria (<10000 cells/ml) and sub-micron particles in ml-sized samples. Concentrated SWNT solutions are mixed with the sample and a high-frequency AC field, with frequency higher than the inverse RC time of a typical SWNT bundle, is applied by a micro-electrode array to enhance bulk docking between SWNT and the particles (bacteria or nanoparticle substitutes) by dipole-dipole interaction and by dielectrophoresis (DEP). The conducting SWNT produces a high-field region around each suspended nanotube that can attract nearby bacteria that suffer positive DEP. The concentrated SWNT represents a much smaller diffusion length (by a factor of 1000) than the sample dimension. Moreover, DEP motion due to field concentration by SWNT increases the bacteria mobility by a factor of 10. As a result, the docking time is reduced by four orders of magnitude. The SWNT bundles also form linear aggregates due to the induced AC dipoles, thus significantly increasing their size, dipole moment and DEP mobility. The frequency of the AC field is then changed to a lower value, corresponding to the inverse RC time of the micro-electrode array, to produce a fast (>100 microns/s) converging stagnation AC electro-osmotic (ACEO) flow. This rapid directed flow convects the SWNT bundles and aggregated (some with docked bacteria) to a specific region of the micro-electrode array with a high field where the SWNT bundles are trapped and self-assembled into linear wires between two arrays of point electrodes. The assembled nanowires are held together by vdw forces even after the electric field is turned off. The nanowires significantly increase the conductance and the existence of single docked bacteria can be detected by comparing the signals of the entire array of point electrodes. Trapping of bacteria and particles is recorded in real time with fluorescence imaging to analyze the effect of docked bacteria on the nano-wire self-assembly process. The above electrokinetic strategy that exploits the high AC polarizability of nanotubes, leading to fast DEP capture and self-assembly, and the fast ACEO flow of micro-electrodes hence promises to reduce the detection time by several orders of magnitude. Work is underway to conjugate the nanotubes with antibodies to offer specificity.