Integration of Vertically-Aligned Carbon Nanofiber Arrays with Live Cells for Interrogation and Modulation of Cellular Processes

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Vertically-aligned arrays of carbon nanofibers provide a powerful nanoscale interface that might be used for cellular, subcellular, and even molecular scale probing and actuation (1). Their size scale (nanometer tip radii and micron lengths), their robust conical geometry (2), and the ability to deterministically synthesize them as vertically aligned arrays (3,4) provides structures appropriate for insertion into cellular matrices and even directly into live cells. In this work, we will overview our most recent research results implementing carbon nanofiber-based devices for biochemical and electrochemical modulation and interrogation of live cell matrices. We will discuss application of arrays of vertically-aligned carbon nanofibers for massively parallel microinjection of cells with macromolecules, including fluorescent dyes and plasmid DNA, and the ability to genetically transform cells using fiber-delivered plasmid as well as plasmid covalently bound to a penetrant nanofiber scaffold (figure 1). We will also highlight efforts employing carbon nanofibers as electrochemical interfaces to both mammalian cellular matrices, as well as bacterial biofilms – ubiquitous, self-packaged communities of whole cells that have attracted much attention due to their resilence and their impact (both detrimental and benign) in industrial, environmental, and medical processes (figure 2).

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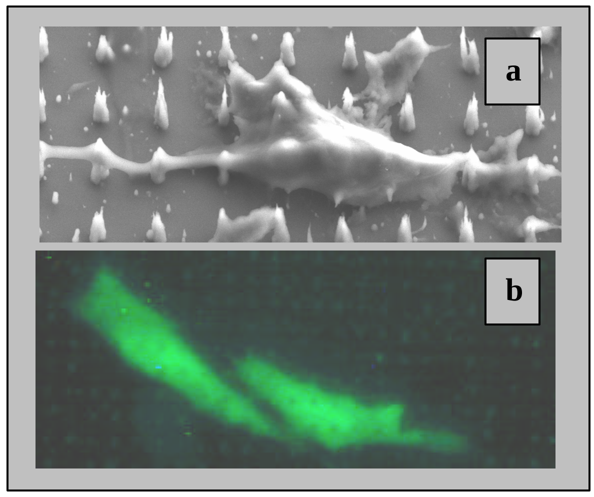

Figure 1. Carbon nanofibers provide an interface that may be integrated with cellular matrices to provide both electrochemical and biochemical modulation of cellular processes. Here, Chinese hampster ovary cells are integrated with arrays of vertically-aligned nanofibers that were coated with plasmid DNA (a). The nanofiber array serves as a massively parallel microinjection platform, resulting in gene delivery and expression within large numbers of cells on the substrate (b).

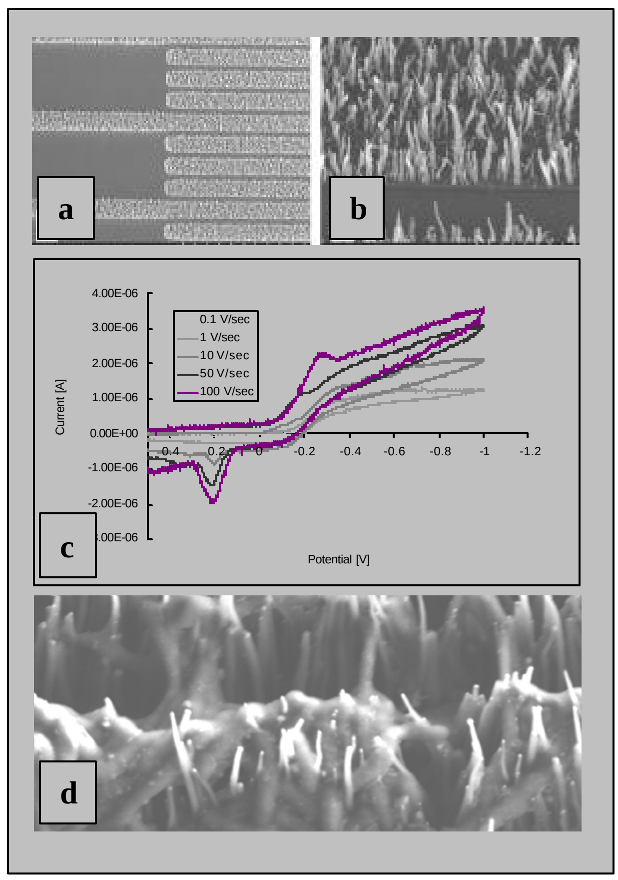

Figure 2. Nanofiber electrodes may be deterministically synthesized on patterned metallic interconnects, providing vertical dimensionality to traditionally planar electrode devices. Here nanofibers are grown on interspersed electrodes of 2 micron width (a,b). Fast scan cyclic voltammogram of an individual nanofiber electrode vs Ag/AgCl using 1 mM solution of $Ru(NH_3)_6Cl_3$ in 100 mM KCl (c). A bacterial biofilm of lux+ *e. coli* grown upon the nanofiber electrode interface (d).