

TOWARD A BIOMOLECULAR-HYBRID ELECTRONIC DEVICE

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The growing interest in electronic devices that are on the nanoscale has driven the microelectronics industry toward investigating novel methods of integrating solid state devices with molecules that display interesting electronic behavior, such as carbon nanotubes. Biology present a range of molecules with unique electronic functions: examples include proteins that function as electron pumps, and as catalysis for redox chemistry; and short segments of DNA that may support direct electron transfer (i.e., act as molecular wires). In addition, the natural biological functions of many proteins are to act as simple computational elements (e.g., amplifiers and integrators) in the control of cell function. Success in fabricating molecular-hybrid devices would provide a pathway toward devices that operate at extremely high speeds (Thz or beyond), have very high power efficiency, and can be densely-packed on a single microchip. Unfortunately, interfacing molecules with metallic electrodes has proved difficult.

In this talk, we present our efforts toward fabricating a first-generation biomolecular-hybrid electronic device. Currently, we are investigating new strategies that allow us to interface biological molecules directly with electrodes. Our initial approach is focused on coupling redox-active enzymes -- proteins that catalyze the oxidation or reduction of substrate molecules via an active redox center -- to nanoelectrodes. It has already been shown that such enzymes can transfer electrons efficiently to micron-sized electrodes through control of the interfacial chemistry between the enzyme and the electrode. Our aims are (i) to reduce the length scale of these electrodes to nanometer size, (ii) to produce electrodes which have either a single or few enzyme molecules on their surface, (iii) to use non-covalent assembly and electrophoretic deposition to address individual electrodes in an array with different enzymes. We are also examining a variety of interfacial chemistries, from the immobilization of enzymes in multilayer films, to the wiring of enzymes using redox-active polymers, to optimize the efficiency of electron transfer. Crucial to our strategy is the fabrication of extremely small electrodes using electron-beam lithography. As we will show, we are able to use this approach to produce 100 Angstrom-sized metallic electrodes on silicon substrates. By immobilizing enzymes in thin multilayer films of polymers or of bilayers of amphiphilic molecules, we are able to interface these electrodes with the redox active sites of various enzymes.