Interfacing Micro-/Nano-Scale Biological and Abiological Materials for Bio/Abio Hybrid Systems

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The emergence of a micro- and nano-scale bio/abio hybrid technology that makes use of the advantages of both micro-/nano-scale biological and abiological materials is evident, owing to the unique properties of biological micro-/nano-materials, such as DNA, proteins and cells, as well as those of abiological materials, such as carbon nanotubes (CNTs) and nanoparticles. However, the major challenges for making this merger feasible are integration and interfacing of the bio- and abio-materials. To this end, we are investigating the realization of the bio/abio hybrid systems to address this issue through developing (1) a cellular motor based self-powered micro-actuator (CMMA), and (2) a DNA-based CNT wire (DNA/NTW) nanosensor.

The CMMA is realized through the tethering of *Escherichia coli* cells to a MEMS-based micro fluidic channel and applies nano-sized flagellar motors along with the micro-sized cells to actuate the fluid flow in the microchannel. In a free moving state, an *E. coli* cell 'swims' by rotating its flagella, driven at the base by a rotary motor. When a cell is attached to a surface by a single shortened flagellar filament (~ 500 nm long), the motor turns the entire cell body at a high rotational speed. The CMMA utilizes this mechanism to transport liquid in a micro fluidic channel through viscous pumping. The DNA/NTW sensor is developed through controlled DNA-nanotube interfacing and DNA-directed assembly by taking advantage of the unique properties of carbon nanotubes (CNTs) and DNA. NTW network platform is accomplished through an assembly of CNTs directed by DNA. Sensing is achieved electrically through NTW when DNA to DNA hybridization occurs on the surface of NTW. DNA for self-assembly is carefully designed to minimize undesirable cross-hybridization. DNAs are attached to CNTs (for assembly) and NTW (for detection) through chemical functionalization of DNA and CNTs and their controlled interfaces. This paper discusses our efforts to understand and develop the nanoscale interfaces of bio- and abio-components, *i.e.* flagellum-substrate and DNA-CNT, to achieve the next generation bio/abio hybrid engineered systems.