Directed Biomolecular Assembly of Functional Nanostructures

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A significant percentage of what are called "nanostructures" and "nanomaterials" are created by solution or vapor phase synthesis, and they are generally processed and treated in an ensemble fashion. This places severe constrains on the spheres of application in which the remarkable properties of these materials can be exploited. For example, active plasmonic nanomaterials such as gold and silver nanoparticles can be synthesized in kilogram quantities, but creating engineered plasmonic nanosystems with these nanoparticles has proven challenging. Similarly, most applications of quantum dot nanoparticles demonstrated to date are restricted to solutions or random dispersions. And carbon nanotubes, whose outstanding electronic properties make them a prime candidate for future nanoelectronics, have yet to be integrated into anything resembling a complex circuit.

We have been exploring new strategies toward the creation of engineered nanosystems based on functional nanostructures by integrating them with selected biomolecules and controlling their interactions on patterned surfaces. Biomolecular interactions achieve a high degree of specificity by balancing chemical affinities and shape complementarity in a polyvalent fashion. We seek to leverage these interactions by (a) modifying given nanostructures so that they are functionalized with a biomolecule of choice in a specific configuration; and (b) using lithographic patterning to control where the biomolecular binding takes place. Thus, we are able to take advantage of both the spatial precision of nanolithography and the chemical specificity of biomolecular recognition, to create custom-designed assemblies of functional nanostructures with a high degree of selectivity.

In this talk, we will present strategies for directing the assembly of metallic nanoparticles, quantum dots and carbon nanotubes using biomolecules such as selected proteins and DNA. DNA is a particularly interesting tool for nanoassembly, and we have been exploring its use as a linker, surfactant, scaffold and molecular wire for potential applications in nanoelectronics, as well as in biology and medicine. We will provide examples of directed assembly of zero-dimensional and end-functionalized, one-dimensional nanostructures on molecular-scale anchors facilitated by monovalent and bivalent interactions, and we will show how the assembly can be tuned by controlling the strength of these interactions. We will also show how lithographic patterning can be used to locally modulate surface energy, facilitating the precise placement of DNA scaffolds and DNA-surfacted nanostructures to form functional electronic devices. Finally, we will discuss the formation of complexes consisting of single-wall carbon nanotubes and various molecular moieties having different structure and function, an important step toward the creation of hybrid systems with functionalities that transcend those of the individual constituents.