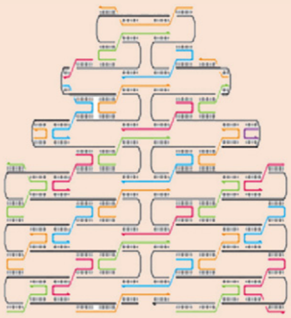
Molecular architecture using DNA

BIOMATERIALS

The assembly of nanostructures according to one's wishes is one great goal of today's materials science. Probably the most promising approach for molecular construction deals with the utilization of DNA-strands that can be combined with atom point precision. Faisal Aldaye and coworkers from the Department of Chemistry, McGill University, Montreal, and the Canadian Institute of Advanced Research, Toronto, have reviewed the various ways in which DNA has been used for nanoscale assembly so far (Science, 321, 1795-1799, 2008). The idea is to create DNA-strands that connect to each other specifically, forming building blocks for macromolecular structures. Most importantly, these DNA parts assemble themselves when brought in proximity with each other – as do many biological structures, such as biomembranes.

In order to manufacture rigid molecular entities, scientists do not combine single DNA-strands but more robust, interconnected double helices, thus producing three basic building blocks: planar tiles formed from various parallel helices, branched junctions, constructed with several DNA arms radiating from a point, and curved helix bundles made from non-coplanar DNA helices. Using these basic units, scientists were able to assemble an impressive variety of DNA constructs. This ranges from simple square grid arrays, actual chains of mechanically interlocked DNA rings, up to three-dimensional DNA cages in the shapes of tetrahedra, cubes, octahedra or even buckyballs. Another intriguing way of shaping DNA are so-called DNA origamis, where computationally designed single strands are continuously folded into desired shape (one example is representing a smiley image). Besides the astonishing fact of being able to shape molecules more or less arbitrarily, these accomplishments promise much more important applications in biotechnology and nanotechnology: DNA can be combined with other organic or inorganic components, as used in supramolecular chemistry, e.g. photoactive, redox active or magnetic molecules. Consequently, researchers picture the organization quite complex structures, such as artificial photosystems. "The question is, can DNA be used as a positioning molecule to create such arrays that can convert solar to electrical energy?" asks Hanadi Sleiman, the corresponding author. Other possible applications are protein "enzyme factories", DNA arrays as templates, models for single electron transport etc. "One can imagine the use of DNA capsules as vehicles for the delivery of drugs on demand," explains Sleiman, "and similarly, if we learn to increase complexity in the DNA-patterns, then we might, one day, assemble a functioning nano-, rather than microelectronic circuit." At any rate, Watson and Crick would never have guessed that our genetic material would be used as building blocks for molecular machinery!

Michel Fleck



In DNA origami, a long DNA strand is folded into the desired structure and is held into shape using many stapling strands (left). This approach is used to access a number of 2D architectures, including a 'smiley face' (right)

More from less with SWNT

NANOTECHNOLOGY

Single Wall carbon NanoTubes (SWNTs) offer excellent electronic and mechanical properties making them suitable for a vast range of potential applications. Researchers at Florida International University, in a project funded by the the Air Force Office of Scientific Research at the U.S. Department of Defense, have shown that controlling the length of SWNTs can improve their photoelectrochemical activity, opening opportunities in the fabrication of efficient optoelectronic devices, nanotube optical detectors or emitters. (Chen-Zhong Li *et al*, doi:10.1016/j.electacta.2008.06.059)

The lab team implemented a fundamental study of the electron transfer phenomenon of bio and nano materials, such as DNA, carbon nanotubes, graphene, and their nano-bio complexes, including the study of the finite size effect on photo-induced electron transfer in carbon nanotubes. Although some previous studies have suggested that carbon nanotubes are photoelectrochemically active and generate photocurrent upon visible excitation, the team's results demonstrated that a more efficient conversion of photo-to-electric energy could be achieved by manipulating the nanostructure of the material.

Both cathodic and anodic photocurrents were observed on shortened SWNT formed thin films. The incident photon conversion efficiency was measured at eight-fold higher compared to the longer SWNTs, suggesting their electronic structure and photoelectrochemical properties were dramatically altered.

Team leader Chen-Zhong Li comments, "Although previous theoretical and experimental studies have predicted that carbon nanotubes have a tremendous potential application for photoelectronic application, the low photo-to-electricity conversion efficiency has limited the development for real applications."

The higher efficiency seen in the conversion of photo-energy to electric energy will broaden the practical application of carbon nanotubes in solar energy and optoelectronic sensing devices. "This is a remarkable discovery, and the novel photo electrochemical activities of finite size carbon nanotube will allow us to improve the overall photo-to-electricity efficiency of solar energy conservation, the relative enhanced current induced by light irradiation will allow us to engineer highly sensitive optical sensors," continues Dr Chen-Zhong Li.

The Florida team is now looking at the potential applications offered by the discovery. It is envisaged that the photo-to-electricity conversion efficiency can be further improved by using the assembly of finite-sized SWNTs with other semiconducting materials or photo sensitive polymers, the combined features of the complex materials making them ideal building blocks for future, new generation solar cell and photoelectronic devices.

Jon Hobden