DNA tiles set pattern for assembly

BIONANOTECHNOLOGY

Researchers at Duke University and the Korea Research Institute of Standards and Science have assembled DNA tiles into arrays, where each tile has a programmed position and can be addressed individually [Park et al., Angew. Chem. Int. Ed 2006, 45, 10 1002/anie.200503797]. The control and patterning achieved by this assembly strategy could see the DNA arrays used as templates for organizing elements into nanoscale optical or electronic circuits.

"The process we’ve described creates lattices with specified pattern at least tenfold smaller than the best lithography being used right now," says Thomas H. LaBean of Duke. "Our method’s programmability and flexibility should enable it to be used with DNA that is preorganized into a single-stranded ‘sticky’ end. By carefully designing these sticky ends to be complementary only to the neighboring tile, the position of the tiles in the array is guaranteed."

Modifying some of the tiles to include biotin allows the protein streptavidin to bind. The researchers designed 4 x 4 arrays of tiles that were programmed to bind streptavidin at specific locations to give a desired pattern. Atomic force microscope images in buffer solution revealed the letters D, N, and A, demonstrating that individual points within the DNA array could be addressed.

In future studies, the team plans to generate larger grids and attach molecules to form simple circuits or bind biological structures that could act as nanoscale sensors.

Jonathan Wood

Mixing nanoparticles for a variety of structures

BIONANOTECHNOLOGY

NANOPARTICLES

Nanoparticles of two different compositions can self-assemble to form binary superlattices. It simply requires a substrate to be placed inside a vial with a solution of the two particles and the solvent allowed to evaporate under reduced pressure. The maximization of packing density was thought to be the driving force for formation of binary nanoparticle superlattices (BNSLs), but this would produce only a few stable structures. Now, researchers from IBM Research Division, Columbia University, and the University of Michigan have observed an amazing variety of BNSL structures using semiconducting, metallic, and magnetic nanocrystals [Shevchenko et al., Nature (2006) 443, 39]. "We were able to produce a large family of novel materials by varying combinations of the building blocks and packing them into different structures," says Dmitri V. Talapin, IBM. The method could be a simple way to fabricate materials with desired properties and controlled placement of the components. "BNSLs of magnetic and semiconducting nanoparticles are promising for magneto-optic data storage and spintronic devices, while superlattices built of two different semiconductors can be employed for a new generation of solar cells and thermoelectric devices," explains Talapin. "Finally, BNSLs could be a tool for designing efficient catalysts with precise arrangement of the catalytic centers." By characterizing the electrical charges present on the nanoparticles in solution, the researchers showed that the Coulomb energy between the BNSLs and other properties of the BNSLs are tunable.

Dmitri V. Talapin and colleagues at the University of Oxford, UK and Vrije Universiteit in The Netherlands have synthesized DNA tetrahedra that are structurally robust and could prove to be useful building blocks in the manufacture of complex nanostructures [Goodman et al., Science (2005) 310, 1661]. Crucially, the tetrahedra self-assemble from four synthetic oligonucleotides in a single-step hybridization reaction that takes only seconds and gives a yield of 95%. "Previous attempts at DNA nanotechnology in the shape of a cube or octahedron were very laborious and gave limited quantities," comments Turberfield. The DNA tetrahedra could also be joined together to form larger structures by using linker oligonucleotides to bind to single-stranded gaps in the sides of the tetrahedra. Vrije Universiteit researchers used an atomic force microscope tip to compress the DNA tetrahedra. The response is linear and reversible up to ~100 pN, allowing the axial compressibility of DNA tetrahedra to be measured, after which the tetrahedra buckle suddenly and deform irreversibly.

Jonathan Wood
RESEARCH NEWS

Memories determine cell motility

Researchers at the University of California at Berkeley and San Francisco and the Stanford University School of Medicine have adapted an atomic force microscope (AFM) to probe cell motility [Parekh et al., Nat. Cell Biol. (2005) 7, 1119]. Cell motility is a basic and necessary function of many cells including immune cells. It is driven by the growth of densely cross-linked actin networks, which form membrane protrusions in the cell to initiate cell motion. This type of energy conversion, from chemical to mechanical, which is commonly seen in molecular motors or filament polymerization, is characterized by force-velocity or Fv relationships. These describe the velocity in a biochemical system as a function of the applied force. “We used AFM to exert forces on a growing actin network and measure the growth-velocity under load,” explains Sapun H. Parekh.

The researchers created a differential AFM to increase the stability of long-time-scale force measurements. Two Si$_3$N$_4$ cantilevers, one of which is functionalized with a promotion factor that initiates the formation of an actin network between the cantilever and a nearby surface, are monitored separately and simultaneously to measure Fv values of the growing actin network. The instrument can be operated in two modes either allowing the actin network to deflect one of the cantilevers freely or to exert a constant force on the actin. An optical lever design is sensitive to nanoscale displacements of the actin-associated cantilever. The results reveal a complex picture, with no single Fv relationship representing the complete behavior of the system. “We’ve found that the growth of actin is dependent on its loading history,” says Daniel A. Fletcher. The researchers believe that this ‘memory’ of previous physical interactions may be a result of the remodeling of the actin filament network under different loads. “These findings could be of interest… because this is a growing polymer whose mechanical properties depend on the history of its physical interactions,” says Parekh. Further down the line, a better understanding of cell motility could lead to treatments that stop tumor cells moving to other parts of the body.

Cordelia Sealy

Biomimetic route to nanotube functionalization

BIONANOTECHNOLOGY

Inspired by marine diatoms, researchers from the Air Force Research Laboratory [AFRL] and Rice University have reported a simple method to disperse single-wall carbon nanotubes (SWNTs) and coat them with inorganics [Pender et al., Nano Lett. (2006) 6, 46]. A phage peptide display library was used to identify peptides with a strong affinity for HiPco (high-pressure carbon monoxide) produced SWNTs. The researchers found that the P1 dodecapeptide is able to disperse SWNTs in an aqueous solution. Such suspensions are stable up to 50°C and over a pH range of 4-10. Using the P1 peptide as a starting point, the researchers also designed a bifunctional peptide (P1R5) that contains a peptide domain capable of precipitating inorganics from precursor solutions onto the SWNT surfaces. The researchers used this technique to grow silica or titania around the nanotubes. “The main advantage is that this process exploits the mild synthesis conditions used by diatoms to synthesize inorganic structures,” says Rajesh Nall of AFRL. “This opens up the possibility of integrating our method with surfaces that cannot withstand high temperature treatments (e.g. polymers).” This use of peptides such as P1R5 represents a new, biomimetic route to the selective functionalization of SWNT surfaces, say the researchers.

Cordelia Sealy

Nanoparticles turn up the heat on amyloids

BIONANOTECHNOLOGY

Misfolded proteins can self-assemble into insoluble fibrous deposits that cause amyloidosis diseases such as Alzheimer’s, Parkinson’s, Huntington’s, and type II diabetes. Successful treatments for these diseases are still lacking. Now researchers from Spain and Chile are exploring an approach that has been proposed for cancer treatment, whereby biological tissue is remotely heated by irradiation mediated by inorganic nanoparticles. [Ojeda et al., Nano Lett. (2006) 6, 110].

The researchers linked Au nanoparticles (AuNPs) to the peptide H-Cys-Leu-Pro-Pro-Phenyl-Lys-His (Cys-PEP). This contains a sequence that selectively attaches to the amyloid beta protein (Aβ) involved in Alzheimer’s. When the AuNP-Cys-PEP conjugates are irradiated (with a 12 GHz signal), the amyloid deposits and aggregates dissolve. The signal itself is not harmful; the signal power is six times smaller than that currently produced by cell phones. AuNPs are well suited to this task because their size, 10 nm, allows them to penetrate cell membranes, survive endosomal/lysosomal processes, and carry target peptides. The AuNPs are pivotal to the breakup of the amyloid aggregates because, in their absence, macroscopic heating and microwave irradiation have the opposite effect on Aβ fibrils (i.e. aggregation rates increased). After seven days, the researchers observed a significant change in the treated samples, indicating a decrease in the potential to form amyloid fibrils. The results suggest that attaching AuNPs to a target and applying a microwave field can manipulate molecular aggregation in a novel way.

Cordelia Sealy
Assembling nanowires is a HOT topic

NANOWIRES

Semiconductor nanowires can be independently moved and assembled into complex structures using holographic optical traps (HOTs). [Agarwal et al., Opt. Lett. (2005) 30, 1790]. The new method developed by the groups of Charles M. Lieber and David G. Grier at Harvard and New York Universities, respectively, offers a way to control the orientation and assembly of nanosized structures rationally in three dimensions. The team’s holographic approach creates the large number of optical traps necessary to capture and manipulate multiple nanowires, in computer-generated holograms is imprinted into laser light using a spatial light modulator, and the light is then focused to form the desired array of optical traps. Each of the traps can be moved independently in three dimensions by projecting a sequence of holograms. CdS nanowires 50-150 nm in diameter and 5-100 µm in length were suspended in fluid between a glass microscope slide and coverslip. The team demonstrated the translation and rotation of individual nanowires using HOTs before cutting, organizing, and fusing several wires into complex structures. Cutting or fusing nanowires together was achieved by applying focused laser light in a well-focused trap. Lieber and Grier believe that further advances in holographic trapping technology will improve the approach, making it faster and more parallel. The HOT technique could also be used with other functional building blocks, such as nanotubes or nanoparticles, to form larger, hierarchical systems in conjunction with chemically directed self-assembly steps.

Sizing nanoparticles in microfluidic channels

CHARACTERIZATION

Daniel T. Chiu and colleagues at the University of Washington have developed a technique to determine the size of nanoparticles that can be used in microfluidic systems [Huyger et al., J. Am. Chem. Soc. doi: 10.1021/ja0569252]. Confocal correlation spectroscopy (CCS) is used for on-chip sizing of fluorescent and nonfluorescent nanoparticles that are 3.5-100 nm in size. Synthesis of nanoparticles in microreactors or microfluidic systems allows the size to be controlled precisely and enables a range of reaction conditions to be sampled simultaneously. Generally, the nanoparticles can only be characterized afterwards using conventional light-scattering or electron microscopy equipment. The ability to determine size in the microfluidic channels of the chip would offer real-time readout and the ability to optimize reactions. However, of the available methods, light scattering would require concentrated samples and scanning probe techniques would not work for nanoparticles in solution. “We developed this technique in part, because there is no generalized method currently available for sizing dilute concentrations of nanoparticles confined to small volumes, such as those found in microfluidic systems,” explains Chiu. He believes CCS will have particular advantages in characterizing colloids, polymer beads, and biological particles such as viruses, vesicles, and DNA.

The setup introduces an L-shaped dead end into a microchannel that catches some of the particles flowing past. In this dead volume, the nanoparticles move solely by Brownian motion. A laser in confocal geometry is focused on the dead volume, and backscattered photon bursts are recorded as nanoparticles pass through the laser probe volume. Autocorrelation curves for the photon bursts are used to determine the size of the particles. “Currently, we are testing this method to measure even smaller particles, as well as applying this method to biological studies,” says Chiu.

Jonathan Wood
RESEARCH NEWS

Nanoparticles provide multicolor barcodes

BI NANOT ECHNOLOGY

NP samples dipped with different dye combinations under the same ultraviolet illumination. (© 2005 American Chemical Society.)

Bioanalysis and molecular imaging are driving demand for fluorescent nanoparticles to use as tags. Quantum dots are attracting particular interest as they have broad excitation spectra and tunable emission wavelengths. They do, however, have some disadvantages. The preparation of quantum dots is still not satisfactorily reproducible, a full understanding of surface modification chemistry is lacking, and their ‘blinking’ emission limits usage in confocal microscopy and flow cytometry.

Now researchers from the University of Florida have taken a new strategy to generate multicolor nanoparticle tags [Wang and Tan, Nano Lett. (2006) 6, 64]. Three organic dyes were incorporated into silica nanoparticles using a modified Stöber synthesis method and, by varying their doping ratios, the researchers were able to tune the fluorescence resonance energy transfer (FRET)-mediated emission signatures. This produces NPs that exhibit different colors when excited by a single wavelength. “Compared with other barcoding NPs, these NPs exhibit advantages such as easy preparation, intensely fluorescent, less toxic, non ‘blinking’, more hydrophilic and biocompatible, and providing versatile colors,” says Weihong Tan. In addition, the large Stokes shift generated by the acceptor emission of the FRET NPs implies broad applications in labeling and imaging. It is also relatively easy to coat the silica NPs, so that additional functionality can be introduced.

These highly fluorescent, photo stable NPs allow the simultaneous and sensitive detection of multiple targets. “By using these NPs, one can envision a dynamic, multicolor, colocalization methodology to follow proteins, nucleic acids, molecular machines, and assemblies within living systems,” says Tan. Cordelia Sealy.

Hollow victory for ZnS nanostructures

FABRICATION

Hollow nanostructures have many potential applications from photonic crystals to delivery systems to fillers and catalysts. Semiconducting nanocrystals, in particular ZnS, are of considerable interest because of their superior luminescence characteristics. However, the synthesis of hollow ZnS nanostructures has lagged behind other material systems and requires the use of silica and polystyrene spheres as sacrificial templates. Researchers from Shandong University and East China University of Science and Technology have now reported a simple, one-step chemical route to synthesise hollow and solid ZnS nanoparticles [Gu et al., Langmuir (2005) DOI: 10.1021/la052539m].

The process consists of a simple refluxing of an aqueous solution of the reactants using thioacetamide as the 5th source at a temperature of 100°C. Primary ZnS nanocrystals are produced, which form spheres by oriented aggregation. The morphology and size of the nanospheres can be tuned by adjusting the experimental parameters. “Well-defined hollow and solid ZnS nanospheres have been synthesized without using templates or laborious days,” says Yong Gu of East China University of Science and Technology. The process can be easily scaled-up to produce gram quantities of the nanospheres. “This strategy may provide a new outlook in the exploration of modern chemical synthesis of well-defined nanostructures,” adds Gu.

The researchers are now optimising the experimental conditions for more precise control of the morphology and size of the nanostructures, and applying it to other materials such as chalcogenide semiconductors.

Cordelia Sealy.