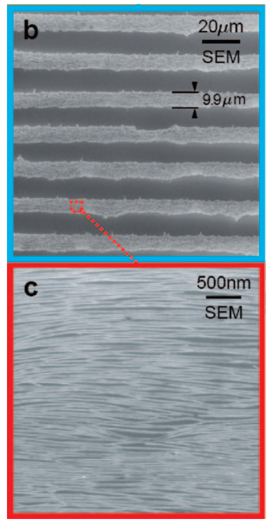
Carbon Nanotube Transistors, Inspired by Coffee Rings

Thin film transistors have the possibility to transform the market for displays, sensors, and flexible electronics. However, finding channel materials with optimal qualities for performance while remaining compatible with low-temperature processing has been a challenge. To date, most research in this area has focused on organics and amorphous silicon. Single-walled carbon nanotubes (CNTs) are a natural direction for exploration with their high mobilities and capacity to be solution-processed; however, CNTs present several key challenges: they are difficult to place and align over large areas, and they have low on/off current ratios due to a significant percentage of metallic nanotubes mixed with semiconducting ones.

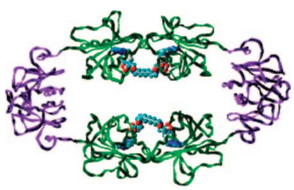
Seeking to overcome these difficulties, Engel *et al.* (p 2445) developed a new strategy for creating thin film transitors from CNTs. The researchers used an evaporation method that placed concentric rings of nanotube residues on silicon chip substrates, similar to the phenomenon in which droplets of coffee leave ring-shaped residues when they evaporate on surfaces. The CNTs self-aligned into strips several micrometers wide, forming regular arrays of dense, highly aligned films that covered the entire surface of the



chips. To address the problem of low on/off current ratios, the team used a purified solution of 99% semiconducting nanotubes, relying on density gradient ultracentrifugation to achieve this enrichment. The resulting devices showed low resistance and high on/off current ratios, as well as strong photocurrents and electro- and photoluminescence. The authors suggest that these qualities could make their CNT thin film transistors contenders for a variety of optoelectronic applications.

With This Nanoring

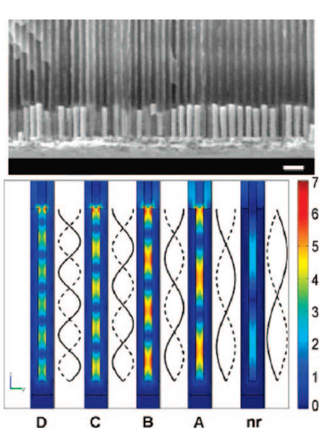
Interest continues to grow in designing and producing biological-based assemblies that can be used for the fabrication of advanced nanomaterials, with applications in areas such as microelectronics, tissue engineering, and drug delivery. Substantial advances have been made in developing nanostructures based on DNA since the rules of nucleic acid assembly are well-understood. However, progress toward protein-based nanostructures has been slower, largely due to the highly idiosyncratic nature of protein surfaces, creating a challenge for the *de novo* design of protein–protein interfaces.



Recently, Chou *et al.* discovered a method to create protein nanorings by fusing molecules of the enzyme dihydrofolate reductase (DHFR) with peptide chains of variable length, using a dimeric enzyme inhibitor to dimerize DHFR. The sizes of these nanorings, varying between 8 and 30 nm diameter, depended on the length of the linker peptide between the two DHFRs. In a new study (p 2519), the researchers sought to increase the size of their nanorings by replacing a portion of the amino acid linker by a rigid protein, human Hint1. The new technique generated larger protein macrocyles, ranging in size from 38 to 70 nm as confirmed with atomic force microscopy. The researchers confirmed that ring size was dependent on the length and composition of the peptide linking the fusion proteins. Testing the catalytic activity of their engineered nanorings, Chou *et al.* found that efficiency varied with ring size, with a reduction in size corresponding to a reduction in efficiency. The authors suggest that the findings represent a significant step in engineering new protein nanostructures.

Gold Plasmonic Cavity Resonators in Harmony

The collective excitation of free electrons at metal–dielectric interfaces, known as surface plasmons, can generate interesting optical responses that researchers have sought to exploit for a variety of applications, including biosensors. Metal nanoparticles and nanostructured films have their own unique interaction with light, resulting in localized surface plasmon resonances (LSPRs) with wavelength-selective extinction sensitive to both surface dielectric and particle size and shape. These effects become even more pronounced in nanoparticle arrays, which produce LSPRs that are often tightly localized between particles and can be modulated by changes in the ratio of diameter to spacing and other structural factors.



Lyvers *et al.* (p 2569) sought to explore these effects in 2D hexagonal arrays of Au nanorods. The researchers generated the nanorods in aluminum oxide templates, then tested their plasmonic response to light using both experimental and computational methods. The arrays displayed discrete plasmon resonance modes at visible and near-infrared wavelengths. Arrays mounted on a thin Au baseplate showed reflectance spectra with multiple resonant attenuations that varied with nanorod height and the dielectric medium. Computer simulations suggested that the arrays were capable of generating harmonic sets of longitudinal standing waves in cavities between nanorods, patterns similar to the acoustic waves generated by musical instruments. These harmonics could be adjusted with nanorod height, diameter-spacing ratio, and the refractive index of the host medium. The authors note that the discovery of standing-wave modes in 2D nanorod arrays could eventually extend into a variety of interesting opportunities for nanophotonics.

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