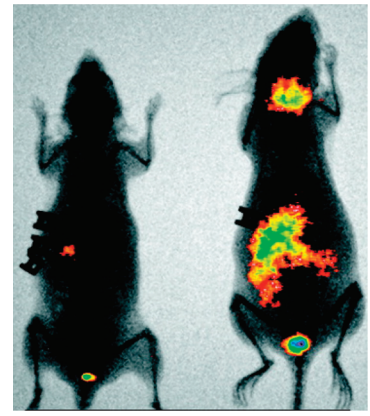
"Theranostic" Nanoparticles for Cancer Diagnosis, Treatment

Despite many advances in cancer diagnosis and therapy, drug-resistant and highly metastatic cancers continue to cause high mortality. Since long-term favorable prognoses often depend on early diagnosis and quick treatment, there is considerable need for new modalities that have the capabilities to improve both diagnoses and treatments of cancers.

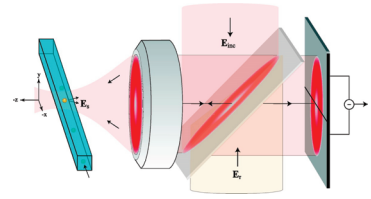
In a new study, Barth *et al.* (p 1279) tested calcium phosphosilicate nanoparticles (CPNPs) to fill this role. While previous studies have shown that these nanoparticles function as nontoxic vehicles for delivering a diverse range of therapeutic and imaging agents in biological systems, the researchers looked further by modifying CPNPs to target breast and pancreatic cancer cells actively. CPNPs were synthesized and embedded with indocyanine green, a near-infrared imaging agent. Since transferrin receptors are present in high numbers on breast cancer cells and gastrin receptors are predominantly present on pancreatic cells, the team then functionalized the surfaces of these nanoparticles by bioconjugating human holotransferrin, an antitransferrin antibody, or short gastrin peptides *via* an avidin−biotin or PEG−maleimide coupling strategy. The researchers showed that the functionalized CPNPs effectively targeted their selected tissues *in vivo* in a mouse model. Additionally, the team found that the gastrin-targeted nanoparticles cross the blood−brain barrier and accumulate in brain cells, which also express gastrin receptors. The findings suggest that similarly functionalized nanoparticles might have the potential to help image and treat several cancers with poor prognoses, including those in the breast, pancreas, and brain.



Hunting Viruses with Heterodyne Detection

Despite the need for rapid and sensitive identification and quantification of viruses, time-consuming methods such as the plaque titer method remain the standard. Further, most viral load tests use PCR and currently lack sufficient sensitivity. Several recent studies have focused on developing new and improved optical techniques for particle detection, including viruses, with interferometric detection providing single nanoparticle sensitivity and the potential for real-time detection. However, the phase sensitivity of standard interferometric measurements makes it difficult to characterize target particles accurately.

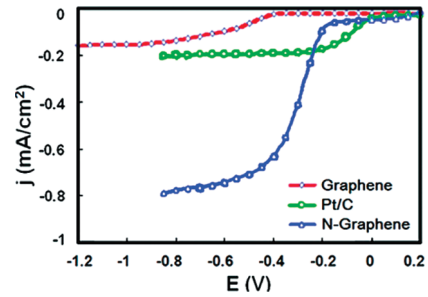
Seeking a new particle detection scheme, Mitra *et al.* (p 1305) relied on a variant of optical heterodyne detection. This scheme collects two independent measurements of a particle's scattered field, thereby making it possible to separate amplitude and phase. Using nanofluidic channels in combination with optical interometry, the researchers collected heterodyne signals for both stationary and moving polystyrene or gold nanoparticles of various sizes. Their dual measurements removed phase variations due to different particle trajectories, leading to better detection and size accuracy compared to homodyne detection using only one scattered field. Further experiments showed that this method could characterize nanoparticles in mixtures of different particle sizes. Lastly, the researchers show that heterodyne signals effectively detected and classified an assortment of viruses, including HIV, influenza, and Sindbis, both on the single-virus level and in mixtures of different virus types. The researchers suggest that this method may eventually find applications in biodetection, contamination, and quality control.



Graphene Trumps Platinum as Fuel Cell Electrocatalyst

Platinum nanoparticles have long been considered the most effective catalyst for the oxygen reduction reaction (ORR) in fuel cells. However, Pt is plagued with several problems, including susceptibility to time-dependent drift, CO deactivation, high cost, and limited natural reserves. These limitations have largely prevented fuel cells based on Pt nanoparticle catalysts from being mass-marketed. Consequently, several research teams are pursuing innovative materials to reduce or to replace Pt-based electrodes in fuel cells.

Building on previous work suggesting that vertically aligned nitrogen-containing carbon nanotubes can be effective metal-free ORR electrocatalysts, Qu *et al.* (p 1321) evaluated nitrogen-doped graphene (N-graphene) in the same role. The researchers synthesized this material through chemical vapor deposition of methane in the presence of ammonia. Characterization of the resulting films through various methods, including atomic force microscopy, Raman analysis, and X-ray photoelectron spectroscopy showed high-quality graphene with incorporated N atoms. The researchers tested this material's electrocatalytic properties for ORR, finding that an N-graphene electrode in alkaline conditions had a steady-state catalytic current density about 3× higher than that of a Pt/C electrode over a large potential range. Compared to a Pt/C electrode, which showed a 40% decrease in current upon the addition of 2% methanol, the N-graphene electrode showed only a 2% decrease. Similarly, while the Pt/C electrode was rapidly poisoned when 10% CO in air was introduced into the electrolyte, no obvious decrease in current occurred in the N-graphene electrode. The findings suggest that the N-graphene electrode, similar to its carbon nanotube counterpart, could be a promising metal-free catalyst for the ORR in fuel cell applications.



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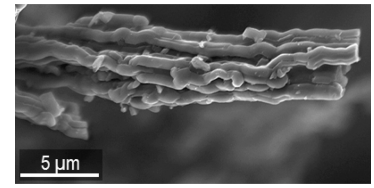
A Template for Success in Electrical Double-Layer Capacitors

Researchers are increasingly interested in developing advanced electrical double-layer capacitors (EDLCs) and improving the current understanding of the transport and adsorption phenomena of electrolyte ions within nanoporous carbon media. Activated carbons typically employed for commercial EDLCs commonly exhibit a wide distribution of irregularly curved pores, which may dramatically slow down ion transport and thus limit the power characteristics of the EDLC. Using inorganic precursors, such as carbides, and selective etching of non-carbon species leads to small, straight, uniformly sized pores. However, these small pores show relatively slow ion transport and thus a moderate rate of charge and discharge. Alternatively, carbon nanotube (CNT) arrays have demonstrated ultrafast transport of ions, but CNT electrodes offer only a moderate specific capacitance.

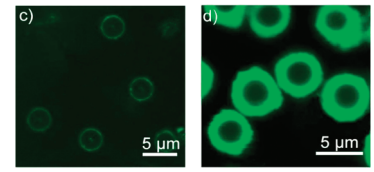
Seeking another option that combines the advantages of these various materials, Korenblit *et al.* (p 1337) developed a novel carbide-derived carbon (CDC) material having a combination of straight mesopore channels for fast ion transport and subnanometer pores in the volume between the larger channels for high specific capacitance. Synthesis of this material involved a silicon carbide (SiC) precursor and a mesoporous SiO_2 template. Tests showed that the resulting ordered mesoporous channels in the CDC material served as "ion highways", enabling fast ionic transport into the bulk of the CDC particles. This enhanced transport led to 85% capacity retention at current densities up to about 20 A/g. The novel CDC material showed a high specific surface area and a specific capacitance up to 170 F/g when tested in the most common electrolyte solution used in electrochemical capacitors in the U.S. The authors suggest that this approach could overcome previous limitations of carbon electrodes.



Bigger and Better Artificial Cells

The development of artificial cells is a growing focus of research due to their potential therapeutic and biological research applications. An important feature of these cellular mimics is the ability to maintain a compartmentalized assembly for the purpose of performing specific, spatially separated cellular functions. Several groups have reported success in creating artificial cells through various approaches, including vesosomes (liposomes inside a liposome), polymersomes within a polymersome, and capsosomes (liposomes incorporated into a polymer carrier capsule).

Capsosomes are formed by sequentially layering liposomes and polymers onto a sacrificial colloidal template, sealed with a polymer membrane. They are particularly promising as artificial cells because they maintain compartmentalization, retaining their cargo within the subcompartment. Further, they perform a triggered enzymatic reaction upon lysis of the liposome subcompartment. Seeking to refine the design further, the same team of Chandrawati *et al.* (p 1351) synthesized new capsosomes with several more liposome layers and the ability to initiate an enzymatic reaction repeatedly without decomposition of the liposomal components. Using various polymer separation layers and liposomes, the researchers succeeded in creating capsosomes with a maximum of 160 000 liposome subcompartments, assembled in seven deposition steps. An enzymatic reaction in capsosomes assembled with β-lactamase-loaded liposomes confirmed the assembly of multiple layers of intact liposomes within a capsosome. Experiments showed that the loaded enzymes could be utilized repeatedly in several subsequent conversions using temperature as a trigger for the enzymatic reaction. The authors suggest that similar capsosomes could be a promising platform toward creating artificial cells.



Creating Captivating DNA Cages

The unique self-assembly properties of DNA make this material ideal for creating predesigned nanostructures using a bottom-up approach. So far, researchers have built an array of increasingly complex, three-dimensional nanostructures, including truncated octahedrons, tetrahedrons, dodecahedrons, and a DNA buckyball.

Recently, researchers demonstrated the assembly of a covalently closed truncated octahedral cage composed of double-stranded B-DNA (the most common natural conformation of DNA) interrupted by single-stranded linkers of seven thymidines using a one-step assembly procedure. The assembly yield of ~30% was surprisingly high for such a complex structure. To investigate the determinants of assembly yields within the basic framework of this structure, the same research team of Oliveira *et al.* (p 1367) tested the effect of successively decreasing the single-stranded linker length from 7 to 2 thymidines on the yield and structural properties of the assembled cages. Gel electrophoresis analysis suggested that the yields of cages from 7 to 3 thymidines were all ~30%, though cages with 2 thymidines did not form. Small-angle X-ray scattering showed that, with increasing linker length, there is a systematic increase of cage size and decrease of the twist angle of the double helices. Hydrogen bond deformation energy calculations showed that the high local distortion experienced by the double-stranded arms is the main reason the cages do not assemble with 2 thymidine linkers, indicating that the length of the single-stranded thymidine linker appears to be the critical parameter for efficient assembly of these truncated octahedral cages. The findings may serve as useful guidelines for future design and efficient assembly of three-dimensional DNA nanostructures.