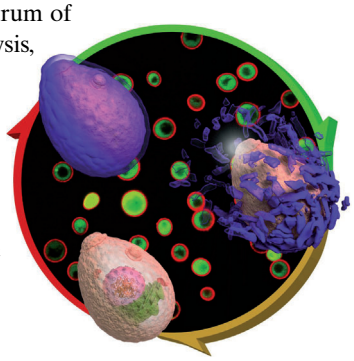
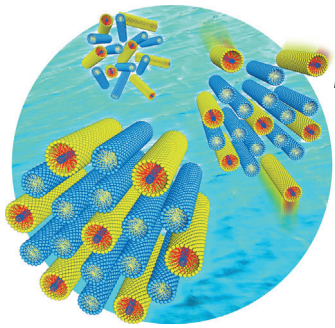
... in our everyday lives, from medicine and information storage to sunscreens and cosmetics. With so many applications, its risks also need to be considered. This issue, which starts with an Editorial by Y. Xia on page 12268, gives an overview of the most recent developments and challenges of nanotechnology. It contains five Reviews on current topics including nanosafety research, nanoparticles in the environment, inorganic nanoparticles, soot nanoparticles, and nanoparticles for drug delivery, as well as Communications that cover the whole spectrum of nanotechnology, from fundamental studies to catalysis, energy, and materials research.



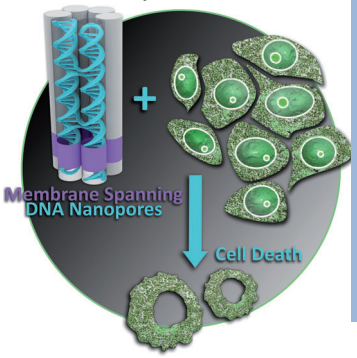
Nanoshells

F. Caruso, Y. Lee, I. S. Choi, and co-workers show in their Communication on page 12420 that a cytoprotective nanoshell can be formed on individual yeast cells from a coordination complex of tannic acid and Fe^{III} ions.



Binary Superlattices

In their Communication on page 12548 ff., S.-M. Choi et al. report highly ordered binary superlattices of 1D nano-objects obtained from single-walled carbon nanotubes and cylindrical surfactant micelles.



DNA Nanotechnology

S. Howorka et al. report in their Communication on page 12466 ff. how nanopores composed of folded DNA featuring a hydrophobic belt of ethyl phosphorothioate groups insert into bilayer membranes and kill cancer cells.

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Editorial

"... As our synthetic capabilities for nanomaterials continue to evolve, we should not forget to channel those new creations into commercial applications ... Only when this relatively new and still seemingly bizarre realm of nano is able to make a positive and long-lasting impact on every aspect of our society, can we finally declare the arrival of the nano era ..."
Read more in the Editorial by Younan Xia.

Front Cover

Service

Author Profile

"My favorite painter is Johannes Vermeer, who drew the Art of Painting.
If I had one year of paid leave I would go to France and visit many small and beautiful villages ..."
This and more about Masatake Haruta can be found on page 12294.

News

E. Betzig

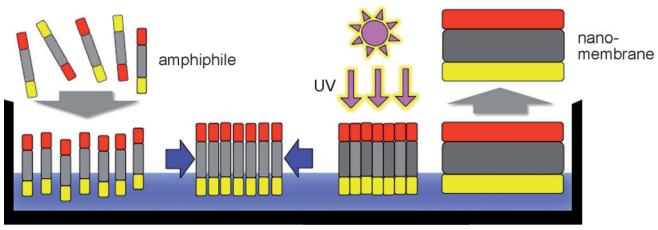
S. W. Hell

W. E. Moerner

Books

Highlights

Nanomembranes



Carbon nanomembranes are constructed from monolayers of molecular amphiphiles assembled on a water surface. The floating molecular film is cross-linked to form a mechanically stable nanomembrane. By varying the type of molecules, the surface area, and the exposure condition, the membrane's stiffness, thickness, and permeability can be tailored.

Reviews

Nanotoxicology

A question of safety: This Review discusses how far the human toxicological evaluation of synthetic nanomaterials has come, for which over 10000 publications have appeared since 2000. Four core themes have been analyzed: the uptake of nanomaterials by the three main pathways of the lungs, gastrointestinal tract, and skin as well as the assessment of the methods for lung exposure studies.

For the USA and Canada:
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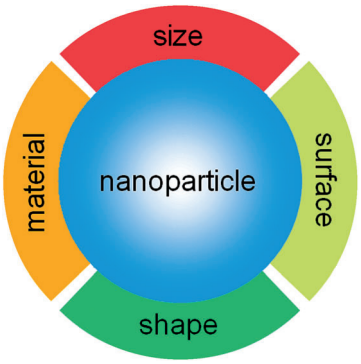
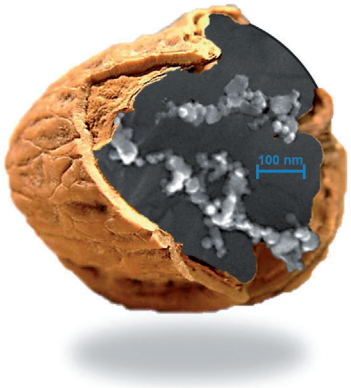


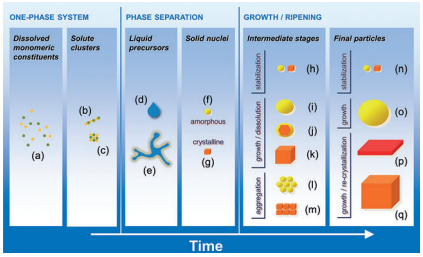
On the way to nanomedicine: Considerable advances in the development of nanoparticles for cancer therapy have been made in recent years. Nanoparticle-based drug-delivery systems offer advantages with regard to multidrug resistance, systemic delivery, and clearance, and enable for example specific tumor targeting and controlled release of therapeutic agents.

Nanomedicine



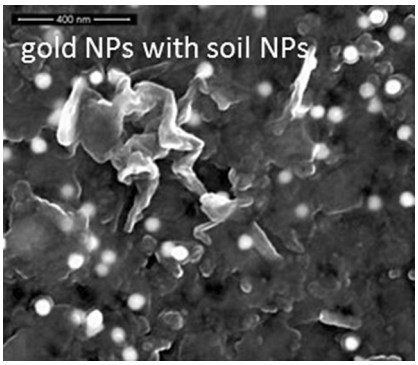
What is soot? Soot nanoparticles produced by engines are a threat to human health. The comprehensive characterization of soot will be essential to meet future low-emission standards. This Review describes the many properties of soot nanoparticles and the possibilities to characterize them, from analysis of its morphology and biological reactivity, to its simple combustion, photoacoustic spectroscopy, and Raman scattering.

Soot Nanoparticles



Intermediate nanostructures occurring during crystallization reactions play an important role in understanding and controlling the formation of particles and hybrid materials. The use of polymers allows the range of achievable properties to be broadened through their specific effects at the nanoscale—as is exemplified in this Review with calcium carbonate, zinc oxide, and cementitious systems.

Nanostructures



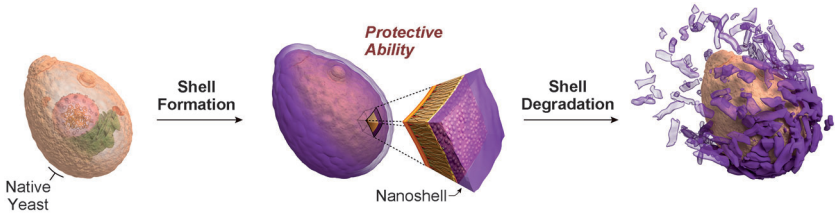
Does nano = risk? This Review critically compares the existing knowledge about naturally observed nanoparticles and the processes they undergo in natural aquatic systems with those found for engineered or manufactured nanoparticles to identify the new "nanospecific" properties of manufactured particles and describe critical knowledge gaps relevant for the risk assessment of manufactured nanomaterials in the environment.

Environmental Chemistry

Communications

Artificial Spores

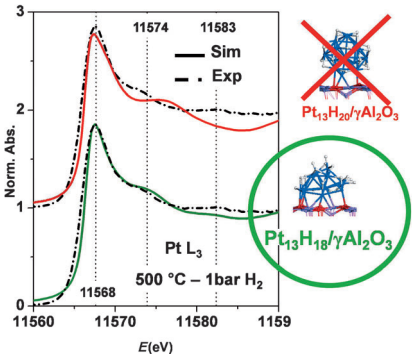
Frontispiece



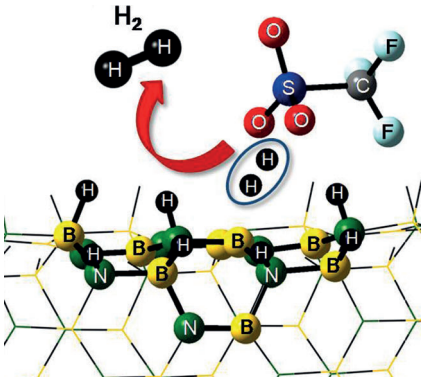
Cell shells: A cytoprotective tannic acid/Fe^{III} nanoshell was formed on individual yeast cells. Cell division was halted by formation and restarted by degradation of the nanoshell. The shell protected the cell from lytic enzymes, silver nanoparticles, and UV-C (λ: 100 to 280 nm) irradiation.

Supported Nanoparticles

Identifying the morphology of platinum nanoclusters supported on γ-alumina and the hydrogen coverage at a given temperature and hydrogen pressure is possible. The use of state-of-the-art methodologies combining high-resolution X-ray absorption near edge structure (XANES) in situ experiments, quantum molecular dynamics calculations, and XANES simulations gives unrivalled insights into catalyst characterization.

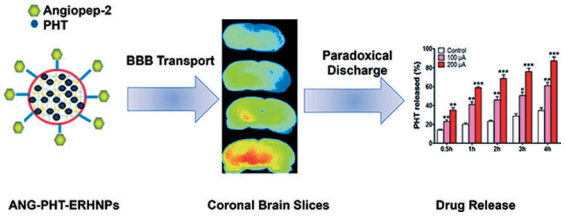


Hydrogen Storage



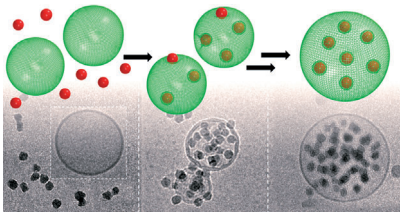
Metal-Free H_2 release: Theoretical investigations unveil a first example of a metal-free catalytic strategy to release H_2 molecules (chemisorbed hydrogens) from hydrogenated boron nitride nanotubes under mild conditions using a Brønsted acid catalyst.

Smart Therapeutic Nanoparticles

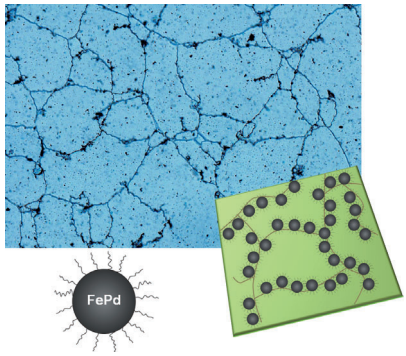


Smart vesicles: Electro-responsive hydrogel nanoparticles (ERHNPs) modified with angiopep-2 (ANG) were loaded with the antiepileptic drug phenytoin sodium (PHT). The complex ANG-PHT-ERHNPs can easily transport the drug into the brain and a fast release could be achieved by the application of an electric field, leading to a reduction of the severity of the seizure onset.

Hybrid colloids: The internalization of silica nanoparticles (SiNPs) into fluid liposomes was followed under conditions under which the process proceeds slowly allowing for the observation of the different steps of the mechanism (see picture). The finally formed well-defined SiNP-filled vesicles are long-time stable hybrid colloids, controlled by the initial mixing ratio of nanoparticles and liposomes.

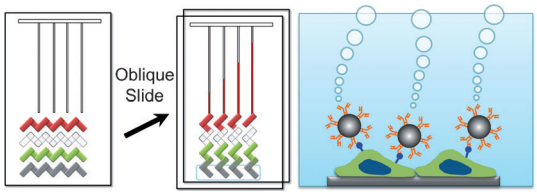


Phospholipid Membranes



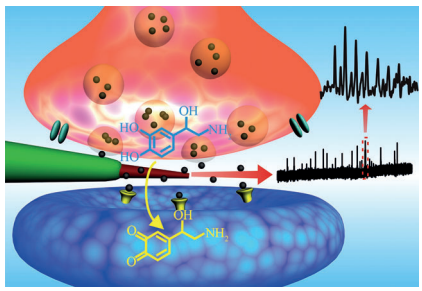
Hybrid soft magnet: Liquid crystals were used as molecular templates to organize superparamagnetic FePd nanoparticles into two-dimensional arrays. The anisotropy of the liquid crystal can be transferred to the network of nanoparticles, enabling the formation of a hybrid soft magnet.

Liquid Crystals



No more (or less) than meets the eye: Platinum nanoparticles (PtNPs) efficiently catalyze the reaction of H_2O_2 to form oxygen gas, the generation of which can be measured by microfluidics technology. Thus, when integrated with ELISA, a volumetric bar-chart chip (see picture) enabled the quantitative visual detection of cancer biomarkers in serum and on the cell surface on the basis of the catalase-like activity of PtNPs.

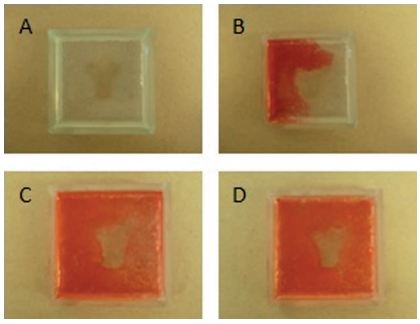
Microfluidic Chips



Chemical neurotransmission occurs at chemical synapse, but up to now there was no means for direct monitoring of neurotransmitter exocytosis and its precise kinetics from inside individual infinitesimal synapse. A novel finite conical nanoelectrode is fabricated and used in a newly developed amperometric method (see picture) for probing inside what appears to be single synapses.

Nanobioanalysis

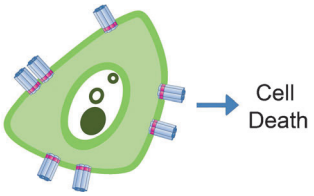
Multidomain Gels



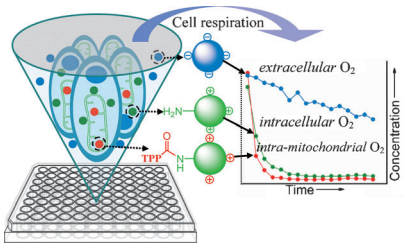
The best of both worlds: Forming polymer gel networks embedded within a low-molecular-weight gel matrix using photoirradiation allows the generation of multicomponent nanoscale soft materials. The different gel domains have different properties, for example, with regard to the diffusion of small molecules, such as dyes, depending on which nanoscale networks they contain (see picture).

DNA Nanotechnology

DNA-based cytotoxic agents: Nanopores composed of folded DNA featuring a hydrophobic belt of ethyl phosphorothioate groups insert into bilayer membranes and kill cancer cells (see picture). The mode by which the pores achieve cell killing is elucidated with confocal microscopy.

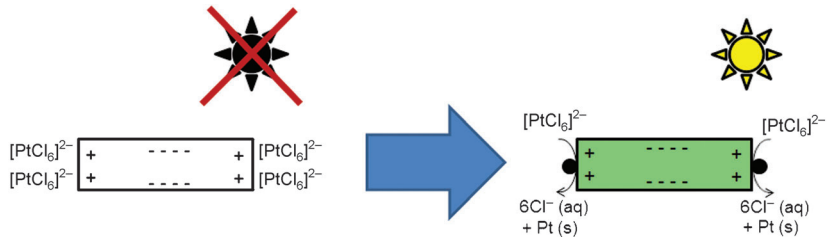


Oxygen Sensing

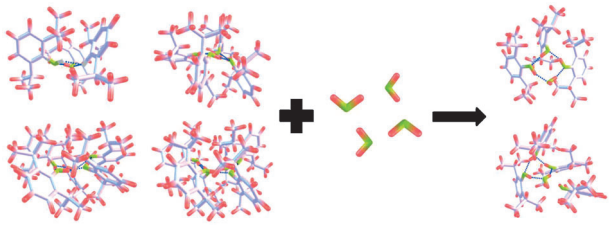


Three phosphorescent oxygen nanosensors with specifically modified surface are targetable for extracellular, intracellular, and intramitochondrial O_2. The cell respiration is studied with a time-resolved fluorescence microplate reader and expressed in terms of the O_2 consumption rates and (intra)cellular O_2 gradients. Thereby, the status of the mitochondrial function can be accurately assessed.

Metal Deposition

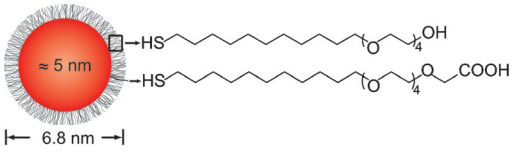


Positioned for action: Understanding of the mechanism behind the structure-directed photodeposition of metals is highly relevant for the optimization of photocatalysts. The preferential deposition of Pt on WO_3 was found to be the result of intrinsic surface-charge differences of specific facets, rather than of the illumination-induced preferred spatial separation of electrons and holes (see picture).



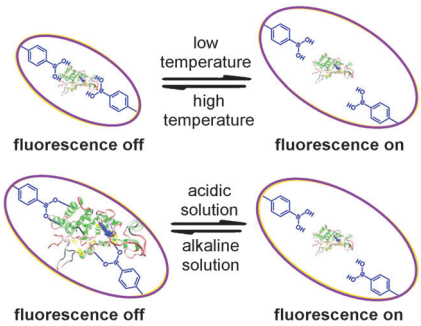
Caught! The hydration of nanomicelles in the gas phase is observed by spectroscopic methods and quantum chemical calculations. The trimer of propofol with a water molecule forms cyclic hydrogen-bond networks but, the tetramer encapsulates the water molecule within the hydrophilic core.

Supramolecular Chemistry



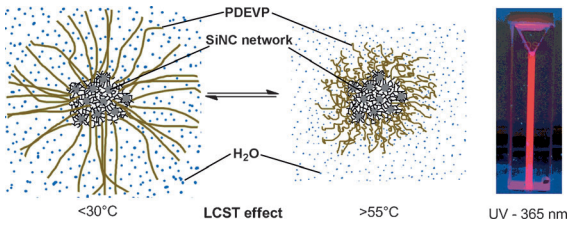
Small quantum dots (sQDs; see picture) as fluorescent probes enable AMPA receptors better access to neuronal synaptic region than commercially available quantum dots. Combined with three-dimensional super-resolution imaging of the postsynaptic density, AMPA receptors labeled with sQDs can be investigated by single-particle tracking for their diffusion patterns at the synaptic cleft.

Fluorescence Spectroscopy



An excellent fit: A fluorescence nanosensor based on the boronate affinity of the target was developed for the quantitative detection of glycoproteins. The recognition performance of the nanosensor, which was successfully used for the detection of horseradish peroxidase in biological fluids, was regulated by controlling the pH value and the temperature (see scheme).

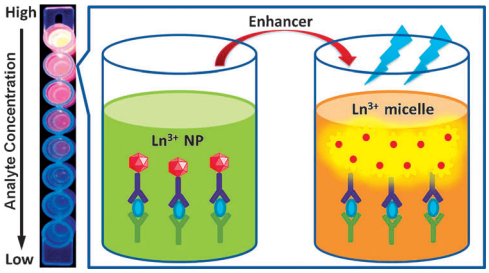
Molecular Recognition



Polymer–nanoparticle hybrids are synthesized using a rare earth metal catalyst. Applying surface-initiated group transfer polymerization, poly(diethyl vinylphosphonate) (PDEVP) is grafted from the silicon nanoparticle surface. The obtained products exhibit the coexistence of the bright photoluminescence of the silicon nanocrystals under UV irradiation and the thermoresponsive behavior of the PDEVP in water.

Functional Nanoparticles

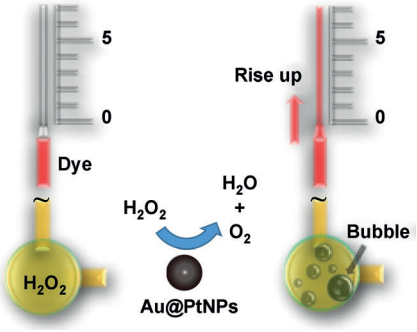
Lanthanide Nano-Bioprobes



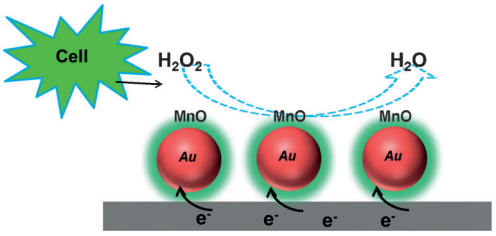
An ultrasensitive bioassay, based on the dissolution-enhanced luminescence of inorganic lanthanide (Ln^{3+}) nanoparticles (NPs), was developed for the detection of carcinoembryonic antigen in human serum samples. As a result of the high Ln^{3+} labeling ratio, the detection limit is improved with a record-low value of 0.1 pg mL^{-1} (0.5 fM) compared to a commercial dissociation-enhanced Ln^{3+} fluoroimmunoassay.

Point-of-Care Testing

Seeing is believing: A simple and general quantitative method has been developed by integration of target-responsive hydrogels, Au core/Pt shell nanoparticles to catalyze the decomposition of H_2O_2 to O_2, and a volumetric bar-chart chip for a visual quantitative readout. A wide range of targets can be detected without any external electronic devices, as demonstrated for cocaine, with a detection limit of 0.33 μM in urine.

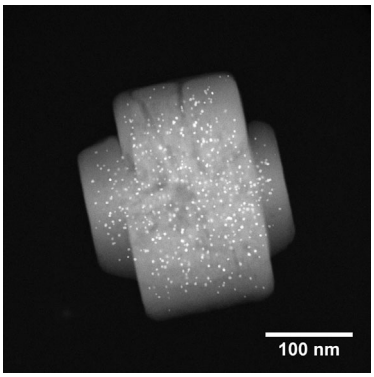


Electrocatalysis

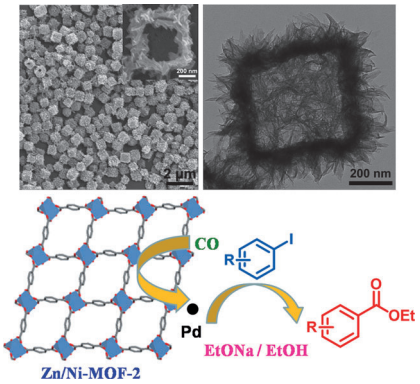


Cell sensing: AuMn alloy nanoparticles were synthesized through hydride reduction of manganese acetylacetonate in the presence of Au nanoparticles and were subsequently converted into Au/MnO nanoparticles through air annealing. The Au/MnO nanoparticles are active catalysts for the electrochemical reduction of H_2O_2 and can be used to measure the H_2O_2 levels from different types of cells for cancer detection.

Catalytic Oxidation



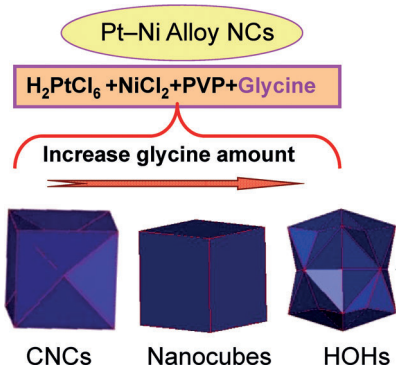
Gold nanoparticles were encapsulated inside recrystallized silicalite-1 crystals using a simple and cost-effective method that results in a narrow size distribution of the nanoparticles, which remain readily accessible through the inherent microporous structure. The encapsulated nanoparticles were demonstrated to be stable, highly active, and selective for the gas-phase oxidation of bioethanol to acetaldehyde.



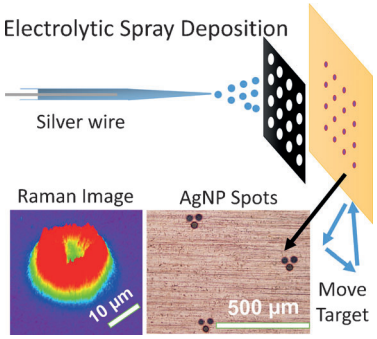
Cubed route: A facile surfactant-free solvothermal approach gives nanostructures that undergo a crystal-structure transformation from Zn/Ni-MOF-5 nanocubes to Zn/Ni-MOF-2 nanosheets. The nanosheets retain the cubic shape suggesting that the in situ synthesized nanocubes may act as a template. Immobilization of palladium in the nanosheet structure gives a catalyst for the alkoxycarbonylation of aryl iodides.

Hollow Nanostructures

In good shape: By varying the amount of glycine present, the shape of Pt–Ni alloy nanocrystals could be tuned from concave nanocubes (CNCs) to nanocubes and hexoctahedra (HOHs; see picture). Glycine was used to manipulate the nucleation and growth rates of the Pt–Ni alloy NCs for the formation of CNCs by self-assembly and HOHs by control of crystal growth. Pt–Ni CNCs and HOHs showed excellent electrocatalytic properties. PVP = polyvinylpyrrolidone.



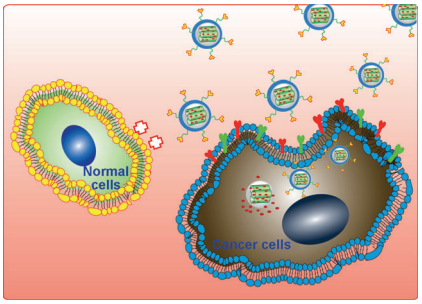
Nanocrystal Catalysts



Electrolytic spray deposition was employed for the formation of nanoparticle spots on various substrates in air. These materials are rugged, versatile substrates for surface-enhanced Raman spectroscopy, in which they lead to good enhancements. Lithographic applications of this method of ion deposition were also investigated.

Nanoparticle Spots

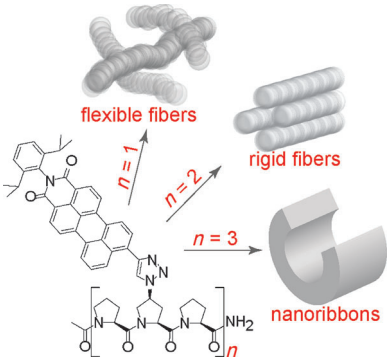
Au gets carried away: Cancer-targeted mesoporous silica nanoparticles for delivery of cytotoxic gold(III) porphyrin complexes are prepared. Encapsulation of the metal complex minimizes its toxic side effects on normal human cells and enhances its anticancer efficacy through inhibition of thioredoxin reductase activity and activation of signaling pathways mediated by reactive oxygen species.



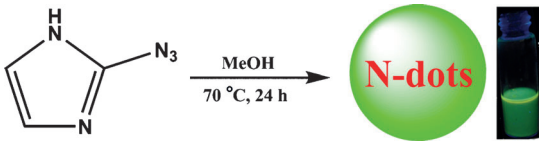
Drug Delivery

Supramolecular Structures

A perfect marriage: Sterically demanding chromophores conjugated with oligoprolines of increasing length and rigidity form supramolecular structures with increasing order, whereas the individual building blocks do not self-assemble. Subtle structural modifications tune the supramolecular morphologies.

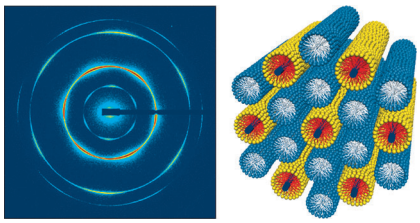


Quantum Dots



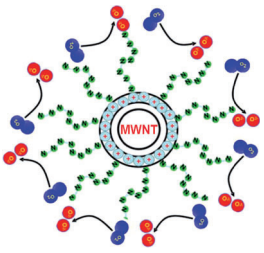
A new member of the family: Nitrogen-rich quantum dots were serendipitously synthesized at low temperature. These N-dots contain a high percentage of the element nitrogen and have unique photoluminescence properties. The photoluminescence behavior of N-dot solutions can be adjusted from blue to green simply by variation of reaction temperature. These N-dots show promising applications as fluorescent ink and biocompatible staining.

Binary Superlattices

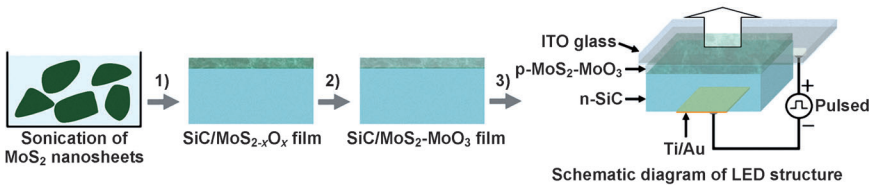


Binary superlattice of 1D nanoobjects: A highly ordered intercalated hexagonal binary superlattice was formed when hydrophilically functionalized SWNTs were added to a hexagonally packed $C_{12}E_5$ cylindrical-micellar system. In this binary superlattice, a hexagonal array of SWNTs is embedded in a honeycomb lattice of $C_{12}E_5$ cylinders (see picture), thus maximizing the free-volume entropies for both types of cylinders.

Electrocatalysts

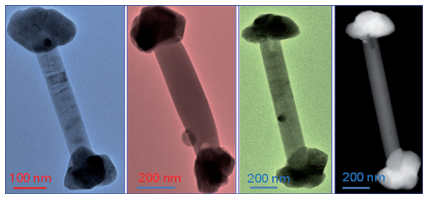


Putting the N into energy: A N_8^- polynitrogen stabilized on the positively charged sidewalls of multi-walled carbon nanotubes (MWNTs) is synthesized by cyclic voltammetry under ambient conditions. ORR experiments using MWNT$^+N_8^-$ as the cathodic catalyst (see picture; N green, O_2 blue, O^{2-} red) show that it is very active, giving an even higher current density than that of a commercial Pt/carbon.



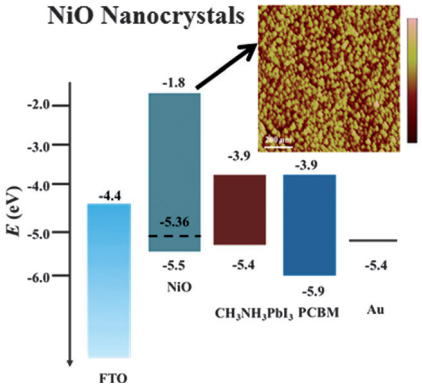
Hybrid Nanomaterials

LED's glow: MoS_2–MoO_3 hybrid nanomaterials are prepared by the heat-assisted partial oxidation of MoS_2 nanosheets in air (1) followed by a thermal-annealing-driven crystallization (2). The obtained hybrid nanomaterial exhibits p-type conductivity and is employed in a heterojunction of n-type SiC/p-type MoS_2–MoO_3 for light-emitting diodes (3), from which multi-wavelength electroluminescent emission is detected.



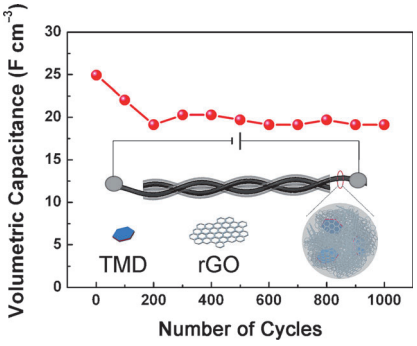
Nanocapsules

Access denied! Binary Sb_2S_3 nanotubes were sealed with ternary $AgSbS_2$ semiconductors by simply annealing the nanotubes in the presence of Ag^0 particles (see structures). In this way, unique dumbbell-shaped hollow nanocapsules were formed.



Perovskite Solar Cells

The advantages are crystal clear: A transparent layer of NiO nanocrystals fabricated by a simple sol–gel processing method acted as an efficient hole-transport layer in an inverted perovskite solar cell. With the NiO film (see picture), a cell efficiency of 9.11% was observed: by far the highest for a planar perovskite solar cell based on an inorganic hole-extraction layer.

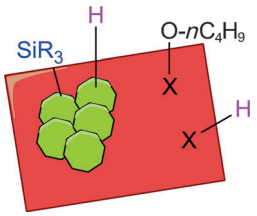


Supercapacitors

Two kinds of 2D materials, namely reduced graphene oxide (rGO) and transition-metal dichalcogenide (TMD) nanosheets, were used to prepare ultralong hybrid microfibers. As proof-of-concept application, supercapacitors were fabricated with these rGO–TMD hybrid fibers and showed greatly improved performance compared to those based on bare rGO fibers.

Graphene in Catalysis

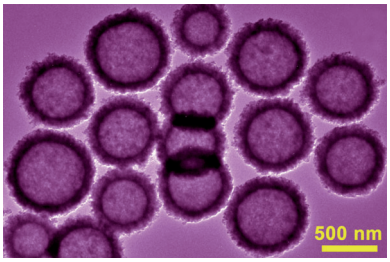
Dehydrogenative coupling: Graphene and doped graphene materials have been obtained by pyrolysis of biomass wastes and have been used as support of copper nanoparticles (see picture). The system exhibits superior catalytic activity for the formation of siloxanes.



Polymeric Nanoparticles

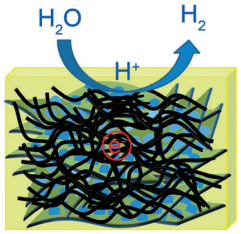
Making an impact: The oxidative doping and quantitative analysis of doping yield of single polymeric nanoparticles are demonstrated. This provides a simple and unique strategy to synthesize and characterize doped polymeric nanoparticles at the single-nanoparticle level.

Lithium Storage



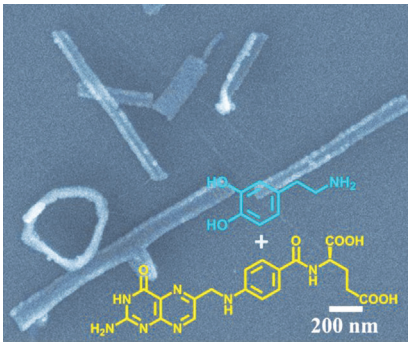
Empty vessels: Anatase TiO_2 hollow spheres composed of highly crystalline nanocrystals are prepared by a simple two-step template strategy. They exhibit superior lithium storage properties in terms of long-term cycling stability and an excellent rate capability which benefits from many structural features, including a hollow interior, small size, high crystallinity of primary nanocrystals, and shell robustness.

Electrocatalysis

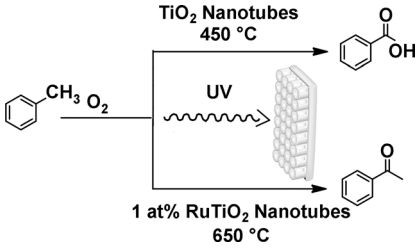


Hybrid composites: The fabrication of a flexible electrode based on cobalt sulfide/reduced graphene/carbon nanotube nanocomposite is reported. The CoS_2 nanosheets were self-assembled on a reduced graphene oxide matrix and then embedded in a porous network of carbon nanotubes. This conductive film showed a superior electrocatalytic activity for the hydrogen evolution reaction (see picture).

The magic of folic acid: When the oxidative self-polymerization of dopamine (turquoise) was conducted in the presence of folic acid (yellow), novel aggregated nanostructures of polydopamine (PDA) were generated: nanobelts and nanofibers (see SEM image). Supramolecular interactions between folic acid and protomolecules of PDA, such as π–π interactions and hydrogen bonding, appear to contribute to the formation of the nanobelts and nanofibers.

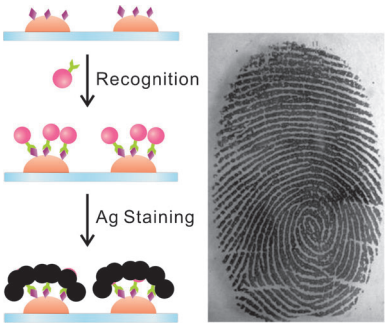


Nanostructures



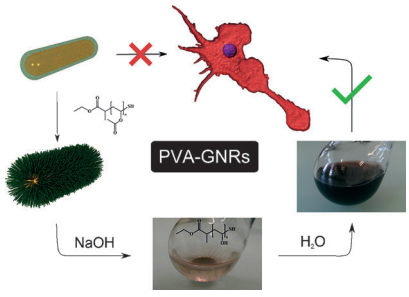
Game changers: Differently modified TiO_2 nanotubes were used to achieve a drastic change in the selectivity of a photocatalytic reaction. For the photocatalytic oxidation of toluene, depending on the electronic properties of TiO_2 (anatase, rutile, Ru-doped), a strong change in the main reaction product (namely benzoic acid versus benzaldehyde) can be achieved, and certain undesired reaction pathways can be completely shut down.

Photocatalysis



With bare eyes: The detection of latent fingerprints and biomolecules that are secreted by human eccrine sweat glands is possible by immunological multimetal deposition (iMMD). In this approach, gold nanoparticles serve as the nucleation sites for autometallographic deposition of silver particles from the silver staining solution and as the carriers of recognition molecules.

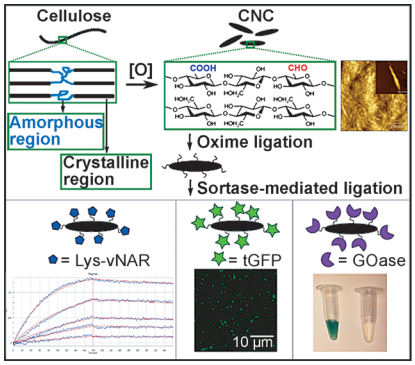
Fingerprints



Polymer grafting: Gold nanorods can be functionalized with polyvinyl acetate, which hydrolyzes to polyvinyl alcohol. An aqueous dispersion of the resulting colloidally stable and nontoxic nanorods was tested by exposure to primary human blood monocyte derived macrophages.

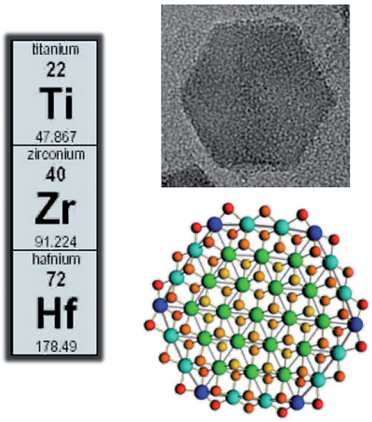
Bio-Nanomaterials

Bioconjugation



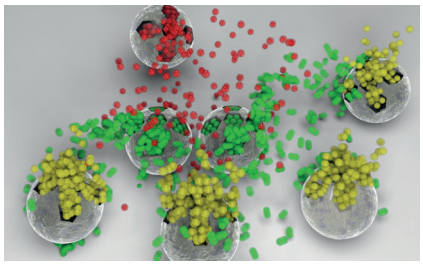
A modular approach was used for site-directed, bioorthogonal protein immobilization. The combination of enzyme-mediated ligation with highly efficient oxime ligation makes it possible to decorate sustainable nanocellulose platforms with fully functional proteins from different families.

Nanoflakes



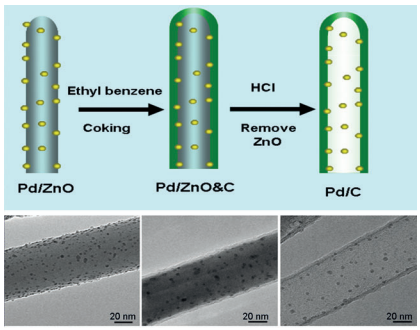
Six-sided flakes: Transition-metal dichalcogenide nanoflakes of composition MX_2 (where M = Ti, Zr and Hf; X = S and Se) grow preferentially in equilateral hexagons and exhibit a pronounced lateral quantum confinement. The hexagonal shape arises from the charge location at the edges and vertices and the resulting Coulombic repulsion.

Chemical Communication

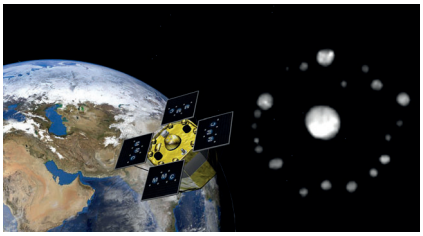


Talk to me! A hierarchically organized community of three different gated nanoparticles communicates with each other through the interchange of chemical messengers (see schematic representation).

Nanoparticle Catalysts



Inside out: A facile and versatile synthesis using a template-based procedure gives Pd nanoparticles uniformly embedded in the inner surfaces of carbon nanotubes (see picture). The nanocomposite is catalytically more active and sinter-resistant, than traditional carbon-nanotube-supported Pd catalysts.



Small world: Gold nanoparticles decorated with RAFT star polymers of different molecular weights can be used as scaffolds for the attachment of functional units at defined distances from the central core. This approach can result in planet–satellite nanostructures.

Nanoparticle Architectures

Supporting information is available on www.angewandte.org (see article for access details).

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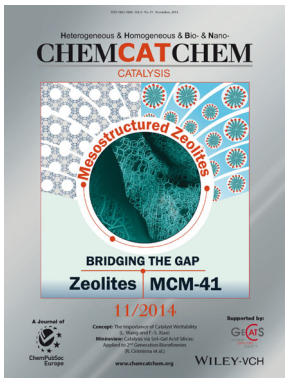

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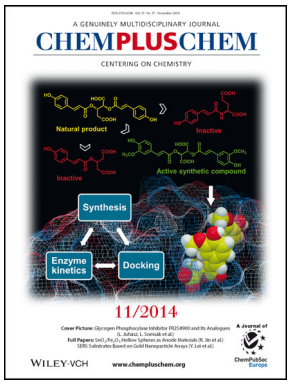

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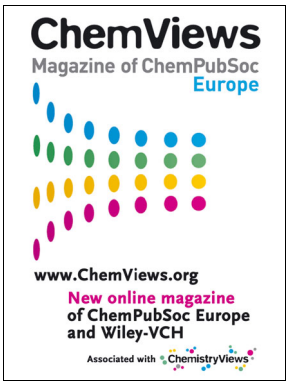

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