**Advanced Materials**

**Yolk–Shell Nanostructures: Design, Synthesis, and Biomedical Applications**

Yolk–shell nanostructures (YSNs) composed of a core within a hollow cavity surrounded by a porous outer shell have received tremendous research interest owing to their unique structural features, fascinating physicochemical properties, and widespread potential applications. Here, a comprehensive overview of the design, synthesis, and biomedical applications of YSNs is presented. The synthetic strategies toward YSNs are divided into four categories, including hard-templating, soft-templating, self-templating, and multimethod combination synthesis. For the hard- or soft-templating strategies, different types of rigid or vesicle templates are used for making YSNs. For the self-templating strategy, a number of unconventional synthetic methods without additional templates are introduced. For the multimethod combination strategy, various methods are applied together to produce YSNs that cannot be obtained directly by only a single method. The biomedical applications of YSNs including biosensing, bioimaging, drug/gene delivery, and cancer therapy are discussed in detail. Moreover, the potential superiority of YSNs for these applications is also highlighted. Finally, some perspectives on the future research and development of YSNs are provided. Yolk–shell nanostructures (YSNs) attract increasing attention because of their unique structural features, fascinating physicochemical properties, and widespread potential applications. Various strategies for the fabrication of yolk–shell nanostructures, such as hard-, soft-, and self-templating and multimethod combination synthesis, are discussed in detail. The biomedical applications of YSNs including biosensing, bioimaging, drug/gene delivery, and cancer therapy are also presented.

**Combined Effect of the Microstructure and Underlying Surface Curvature on the Performance of Biomimetic Adhesives**

The importance of the geometry of the micro-/nanosized attachment elements for adhesive characteristics of gecko-inspired microstructured surfaces has been comprehensively discussed in recent years. Due to the complex hierarchical structure of these systems, they possess a broad range of adhesion control capabilities by either passive or active adaptability of their underlying structures to the specific substrate and/or behavioral situation. Here, the influence of macroscopic geometry of backing layers hosting biomimetic microstructured surfaces is examined. The flat, convex, and concave macroscopic configurations of the bioinspired microstructured adhesive surfaces are examined on their adhesive performance under varying degrees of curvature and preloads. Microstructured surfaces demonstrated an adhesion range differing by up to a factor of 2 alone through varying backing layer configuration. The results can aid in understanding the influence of curvature geometry on hierarchically structured adhesive systems and the implementation of biomimetic structured surfaces in applications such as robots and grippers optimized for different sized objects. Bioinspired microstructured adhesives are able to provide dry glue-free stickiness. By modifying their backing layer geometries, it is possible to obtain superior attachment abilities and control over the adhesion forces.

**Utilization of Peroxide Reduction Reaction at Air–Liquid–Solid Joint Interfaces for Reliable Sensing System Construction**

The utilization of hydrogen peroxide (H2O2) cathodic reaction is an ideal approach to develop reliable biosensors that are immune to interferences arising from oxidizable endogenous/exogenous species in biological solutions. However, practical application of such a detection scheme is limited due to the significantly fluctuating oxygen levels in solutions, as oxygen can be reduced at similar potentials. Herein, this limitation is addressed by developing a novel electrode system with superhydrophobicity-mediated air–liquid–solid joint interfaces, which allows the rapid and continuous transport of oxygen from the air phase to the electrode surface and provides a fixed interfacial oxygen concentration. Using cathodic measurement of the enzymatic product H2O2, the sensing platform is applied to detect glucose,
a model analyte, achieving a remarkably high selectivity ($\approx 2\%$ signal modulation due to common biologic interferents), sensitivity (18.56 $\mu$A cm$^{-2}$ mm$^{-1}$), and a dynamic linear range up to $80 \times 10^{-3}$m. The utility of H$_2$O$_2$ reduction reaction at triphase interface to achieve reliable sensing platforms is general, and hence has broad potential in the fields of medical research, clinical diagnosis, and environmental analysis. A biosensor platform utilizing the electroreduction reaction of hydrogen peroxide (H$_2$O$_2$) at superhydrophobicity-mediated air–liquid–solid joint interfaces is described. The fixed oxygen concentration at the triphase interface enables the application of H$_2$O$_2$ reduction reaction to develop reliable sensor platforms that are essentially immune to interferences arising from oxidizable species in biological solutions. This strategy has broad potential in many fields.

3D-Printed Biomimetic Super-Hydrophobic Structure for Microdroplet Manipulation and Oil/Water Separation

Biomimetic functional surfaces are attracting increasing attention for various technological applications, especially the superhydrophobic surfaces inspired by plant leaves. However, the replication of the complex hierarchical microstructures is limited by the traditional fabrication techniques. In this paper, superhydrophobic micro-scale artificial hairs with eggbeater heads inspired by Salvinia molesta leaf was fabricated by the Immersed surface accumulation three dimensional (3D) printing process. Multi-walled carbon nanotubes were added to the photocurable resins to enhance the surface roughness and mechanical strength of the microstructures. The 3D printed eggbeater surface reveals interesting properties in terms of superhydrophobicity and petal effect. The results show that a hydrophilic material can macroscopically behave as hydrophobic if a surface has proper microstructured features. The controllable adhesive force (from 23 ?N to 55 ?N) can be easily tuned with different number of eggbeater arms for potential applications such as micro hand for droplet manipulation. Furthermore, a new energy-efficient oil/water separation solution based on our biomimetic structures was demonstrated. The results show that the 3D-printed eggbeater structure could have numerous applications, including water droplet manipulation, 3D cell culture, micro reactor, oil spill clean-up, and oil/water separation. A super-hydrophobic microsized eggbeater structure inspired by Salvinia molesta leaves is fabricated by an immersed surface accumulation 3D printing process. The 3D printed eggbeater structure shows potential applications such as nonloss microdroplet manipulation and as 3D cell culture platform in biomedical engineering. Furthermore, it demonstrates a new energy-efficient solution for oil absorption and oil/water separation.

Genetically Engineered Liposome-like Nanovesicles as Active Targeted Transport Platform

Ligand-targeted delivery of drug molecules to various types of tumor cells remains a major challenge in precision medicine. Inspired by the secretion process and natural cargo delivery functions of natural exosomes, biomimetic synthetic strategies are exploited to prepare biofunctionalized liposome-like nanovesicles (BLNs) that can artificially display a wide variety of targeting protein/peptide ligands and directly encapsulate medical agents for enhanced drug delivery. Here, as a proof of concept, genetically engineered BLNs, which display human epidermal growth factor (hEGF) or anti-HER2 Affibody as targeting moieties, are developed to, respectively, target two types of tumor cells. Notably, in comparison to synthetic liposomes covalently coupled with hEGF, it is demonstrated in this work that biosynthetically displayed hEGF ligands on BLNs possess higher biological activities and targeting capabilities. Additionally, treatments with doxorubicin-loaded BLNs displaying Affibody ligands exhibit much better antitumor therapeutic outcomes than clinically approved liposomal doxorubicin (Doxil) in HER2-overexpressing BT474 tumor xenograft models. These data suggest that BLN is suitable as a potent surrogate for conventional proteoliposomes or immunoliposomes as a result of excellent targeting capacities and facile production of BLNs. Genetically engineered biofunctionalized liposome-like nanovesicles (BLNs) serve as active targeted transport platform with higher efficacy and improved
safety profiles. The designed BLNs have great potential for precision nanomedicine by engineering a wide range of functional protein moieties and encapsulating drugs in a versatile manner.

**Interstitial P-Doped CdS with Long-Lived Photogenerated Electrons for Photocatalytic Water Splitting without Sacrificial Agents**

Photocatalytic hydrogen evolution from pure water is successfully realized by using interstitial P-doped CdS with rich S vacancies (CdS-P) as the photocatalyst in the absence of any electron sacrificial agents. Through interstitial P doping, the impurity level of S vacancies is located near the Fermi level and becomes an effective electron trap level in CdS-P, which can change dynamic properties of photogenerated electrons and thus prolong their lifetimes. The long-lived photogenerated electrons are able to reach the surface active sites to initiate an efficient photocatalytic redox reaction. Moreover, the photocatalytic activity of CdS-P can be further improved through the loading of CoP as a cocatalyst. Photocatalytic hydrogen evolution from pure water is realized by CdS-P. Through interstitial P doping, the impurity level of S vacancies is located near the Fermi level and becomes an effective electron trap level, which can change the dynamics of photogenerated electrons. The long-lived photogenerated electrons can reach the surface active sites for initiating the photocatalytic reaction.

**Blocking Energy-Loss Pathways for Ideal Fluorescent Organic Light-Emitting Diodes with Thermally Activated Delayed Fluorescent Sensitizers**

Organic light-emitting diodes (OLEDs) based on thermally activated delayed fluorescence-sensitized fluorescence (TSF) offer the possibility of attaining an ultimate high efficiency with low roll-off utilizing noble-metal free, easy-to-synthesize, pure organic fluorescent emitters. However, the performances of TSF-OLEDs are still unsatisfactory. Here, TSF-OLEDs with breakthrough efficiencies even at high brightnesses by suppressing the competitive deactivation processes, including direct charge recombination on conventional fluorescent dopants (CFDs) and Dexter energy transfer from the host to the CFDs, are demonstrated. On the one hand, electronically inert terminal-substituents are introduced to protect the electronically active core of the CFDs; on the other hand, delicate device structures are designed to provide multiple energy-funneling paths. As a result, unprecedentedly high maximum external quantum efficiency/power efficiency of 24%/71.4 lm W−1 in a green TSF-OLED are demonstrated, which remain at 22.6%/52.3 lm W−1 even at a high luminance of 5000 cd m−2. The work unlocks the potential of TSF-OLEDs, paving the way toward practical applications. By blocking energy-loss pathways for fluorescent organic light-emitting diodes with thermally activated delayed fluorescent sensitizers, high maximum external quantum efficiency/power efficiency of 24%/71.4 lm W−1 are demonstrated, which remain at 22.6%/52.3 lm W−1 even at a high luminance of 5000 cd m−2.

**Light-Responsive Biodegradable Nanorattles for Cancer Theranostics**

Cancer nanotheranotics, integrating both diagnostic and therapeutic functions into nanoscale agents, are advanced solutions for cancer management. Herein, a light-responsive biodegradable nanorattle-based perfluoropentane-(PFP)-filled mesoporous-silica-film-coated gold nanorod (GNR@SiO2-PFP) is strategically designed and prepared for enhanced ultrasound (US)/photoacoustic (PA) dual-modality imaging guided photothermal therapy of melanoma. The as-prepared nanorattles are composed of a thin mesoporous silica film as the shell, which endows the nanoplatform with flexible morphology and excellent biodegradability, as well as large cavity for PFP filling. Upon 808 nm laser irradiation, the loaded PFP will undergo a liquid–gas phase transition due to the heat generation from GNRs, thus generating nanobubbles followed by the coalescence into microbubbles. The conversion of nanobubbles to microbubbles can improve the intratumoral permeation and retention in nonmicrovascular tissue, as well as enhance the tumor-targeted US imaging signals. This nanotheranostic platform exhibits excellent biocompatibility and biodegradability, distinct gas bubbling phenomenon, good US/PA
imaging contrast, and remarkable photothermal efficiency. The results demonstrate that the GNR@SiO2-PFP nanorattles hold great potential for cancer nanotheranostics. A cancer-theranostic nanorattle with excellent uniformity, biocompatibility, and biodegradability is prepared. Light-responsive nanobubble generation allows for ultrasound/photoacoustic dual-modality imaging-guided photothermal therapy of melanoma.

**Photoactuated Pens for Molecular Printing**

The photoactuation of pen arrays made of polydimethylsiloxane carbon nanotube composites is explored, and the first demonstration of photoactuated pens for molecular printing is reported. Photoactuation of these composites is characterized using atomic force microscopy and found to produce microscale motion in response to modest illumination, with an actuation efficiency as high as 200 nm mW⁻¹ on the sub-1 s time scale. Arrays of composite pens are synthesized and it is found that local illumination is capable of moving selected pens by more than 3 µm out of the plane, bringing them into contact to perform controllable and high quality printing while completely shutting off the nonilluminated counterparts. In light of the scalability limitations of nanolithography, this work presents an important step and paves the way for arbitrary control of individual pens in massive arrays. As an example of a scalable soft actuator, this approach can also aid progress in other fields such as soft robotics and microfluidics. Photoactuated pens are demonstrated from polydimethylsiloxane–carbon nanotube composites and used to perform molecular printing. Upon modest light irradiation, the pens can expand out of plane by more than three micrometers. The photoactuation is rapid, energy efficient, and highly reversible.

**An Unfused-Core-Based Nonfullerene Acceptor Enables High-Efficiency Organic Solar Cells with Excellent Morphological Stability at High Temperatures**

Most nonfullerene acceptors developed so far for high-performance organic solar cells (OSCs) are designed in planar molecular geometry containing a fused-ring core. In this work, a new nonfullerene acceptor of DF-PCIC is synthesized with an unfused-ring core containing two cyclopentadithiophene (CPDT) moieties and one 2,5-difluorobenzene (DFB) group. A nearly planar geometry is realized through the F–H noncovalent interaction between CPDT and DFB for DF-PCIC. After proper optimizations, the OSCs with DF-PCIC as the acceptor and the polymer PBDB-T as the donor yield the best power conversion efficiency (PCE) of 10.14% with a high fill factor of 0.72. To the best of our knowledge, this efficiency is among the highest values for the OSCs with nonfullerene acceptors owning unfused-ring cores. Furthermore, no obvious morphological changes are observed for the thermally treated PBDB-T:DF-PCIC blended films, and the relevant devices can keep ≈70% of the original PCEs upon thermal treatment at 180 °C for 12 h. This tolerance of such a high temperature for so long time is rarely reported for fullerene-free OSCs, which might be due to the unique unfused-ring core of DF-PCIC. Therefore, the work provides new idea for the design of new nonfullerene acceptors applicable in commercial OSCs in the future. A new nonfullerene acceptor (DF-PCIC) is designed and synthesized by utilizing noncovalent interaction. Organic solar cells (OSCs) with DF-PCIC as the acceptor exhibit the best efficiency of 10.14% with a high fill factor of 0.72. More importantly, excellent morphological stability is achieved for DF-PCIC-based devices, which is meaningful for the future practical applications of OSCs.

**High Edge Selectivity of In Situ Electrochemical Pt Deposition on Edge-Rich Layered WS2 Nanosheets**

Recent studies show that the Pt electrode can be slowly dissolved into the acidic media and regenerate on the working electrode along with the long-time hydrogen evolution reaction (HER) test. However, to date, the relationship between the Pt deposition and the intrinsic properties of the working electrode...
remains elusive. Herein, for the first time, the edge selectivity of in situ electrochemical Pt deposition on layered 2H-WS2 nanosheets, whose edge surface with rich dangling bonds is chemically active to regulate their properties, especially the interfacial reaction occurring between the electrode surface and the adjacent thin layer of the solution, is theoretically elucidated and experimentally verified by controlling the cathode polarization test using Pt wire as the counter electrode in H2SO4 solution. It is revealed that the layered WS2 nanosheets with rich exposed edges show much stronger interaction with Pt atoms because the terminated S22− or S2− ligands on the edge exhibit much lower binding energy for Pt atoms compared with the apical S2− ligands on the terrace surface. The in situ electrochemical Pt-deposited WS2 nanosheets with rich exposed edges can act as a highly active hybrid electrocatalyst to accelerate HER kinetics and exhibit commercial Pt-like HER performance, especially in the alkaline media. Layered WS2 nanosheets with rich exposed edges show much stronger interaction with Pt atom because the terminated S22− or S2− ligands on the edge exhibit much lower adsorption energy for Pt atoms compared with the apical S2− ligands on the terrace surface.

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**Imperceptible Epidermal–Iontronic Interface for Wearable Sensing**

Recent development of epidermal electronics provides an enabling means to continuous monitoring of physiological signals and close tracking of physical activities without affecting quality of life. Such devices require high sensitivity for low-magnitude signal detection, noise reduction for motion artifacts, imperceptible wearability with long-term comfortableness, and low-cost production for scalable manufacturing. However, the existing epidermal pressure sensing devices, usually involving complex multilayer structures, have not fully addressed the aforementioned challenges. Here, the first epidermal–iontronic interface (EII) is successfully introduced incorporating both single-sided iontronic devices and the skin itself as the pressure sensing architectures, allowing an ultrathin, flexible, and imperceptible packaging with conformal epidermal contact. Notably, utilizing skin as part of the EII sensor, high pressure sensitivity and high signal-to-noise ratios are achieved, along with ultralow motion artifacts for both internal (body) and external (environmental) mechanical stimuli. Monitoring of various vital signals, such as blood pressure waveforms, respiration waveforms, muscle activities and artificial tactile sensation, is successfully demonstrated, implicating a broad applicability of the EII devices for emerging wearable applications. Epidermal-interfaced pressure sensing devices are reported using skin as part of sensor, with a single-sided configuration. This novel architecture enables an imperceptible and conformal epidermal/device contact. Both internal (body) and external (environmental) mechanical stimuli have been demonstrated to be detected, e.g., blood pressure pulsations, respiration rates, muscle activities, and hand tactile pressure distribution.

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**Synthesis of In-Plane Artificial Lattices of Monolayer Multijunctions**

Recently, monolayers of van der Waals materials, including transition metal dichalcogenides (TMDs), are considered ideal building blocks for constructing 2D artificial lattices and heterostructures. Heterostructures with multijunctions of more than two monolayer TMDs are intriguing for exploring new physics and materials properties. Obtaining in-plane heterojunctions of monolayer TMDs with atomically sharp interfaces is very significant for fundamental research and applications. Currently, multistep synthesis for more than two monolayer TMDs remains a challenge because decomposition or compositional alloying is thermodynamically favored at the high growth temperature. Here, a multistep chemical vapor deposition (CVD) synthesis of the in-plane multijunctions of monolayer TMDs is presented. A low growth temperature synthesis is developed to avoid compositional fluctuations of as-grown TMDs, defects formations, and interfacial alloying for high heterointerface quality and thermal stability of monolayer TMDs. With optimized parameters, atomically sharp interfaces are successfully achieved in the synthesis of in-plane artificial lattices of the WS2/WSe2/MoS2 at reduced growth temperatures. Growth behaviors as well as the heterointerface quality are carefully studied in varying
growth parameters. Highly oriented strain patterns are found in the second harmonic generation imaging of the TMD multijunctions, suggesting that the in-plane heteroepitaxial growth may induce distortion for unique material symmetry. In-plane multijunctions of the WS2/WSe2/MoS2 artificial 2D lattices with atomically sharp heterointerfaces are realized by multistep chemical vapor deposition (CVD) synthesis. Heterointerface quality and thermal stability of each constituted transition metal dichalcogenides are studied with controlled experiments. Unique symmetry induced by in-plane heteroepitaxial growth is identified with second harmonic generation, which opens a new route toward novel physical properties of optical nonlinearity.

**Perovskite Quantum Dots with Near Unity Solution and Neat-Film Photoluminescent Quantum Yield by Novel Spray Synthesis**

In this study, a novel perovskite quantum dot (QD) spray-synthesis method is developed by combining traditional perovskite QD synthesis with the technique of spray pyrolysis. By utilizing this new technique, the synthesis of cubic-shaped perovskite QDs with a homogeneous size of 14 nm is demonstrated, which shows an unprecedented stable absolute photoluminescence quantum yield ≈100% in the solution and even in the solid-state neat film. The highly emissive thin films are integrated with light emission devices (LEDs) and organic light emission displays (OLEDs). The color conversion type QD-LED (ccQD-LED) hybrid devices exhibit an extremely saturated green emission, excellent external quantum efficiency of 28.1%, power efficiency of 121 lm W−1, and extraordinary forward-direction luminescence of 8 500 000 cd m−2. The conceptual ccQD-OLED hybrid display also successfully demonstrates high-definition still images and moving pictures with a 119% National Television System Committee 1931 color gamut and 123% Digital Cinema Initiatives-P3 color gamut. These very-stable, ultra-bright perovskite QDs have the properties necessary for a variety of useful applications in optoelectronics. Spray-synthesized perovskite quantum dots (QDs) show an unprecedented cubic shape, and a stable photoluminescence quantum yield of ≈100% in both the solution and the solid-state neat film. The QD-LED (light emission device) and QD-OLED (organic light emission display) hybrid devices exhibit an excellent external quantum efficiency of 28.1%, a power efficiency of 121 lm W−1, and successfully demonstrate high-definition motion pictures.

**Foldable Electrode Architectures Based on Silver-Nanowire-Wound or Carbon-Nanotube-Webbed Micrometer-Scale Fibers of Polyethylene Terephthalate Mats for Flexible Lithium-Ion Batteries**

A crumply and highly flexible lithium-ion battery is realized by using microfiber mat electrodes in which the microfibers are wound or webbed with conductive nanowires. This electrode architecture guarantees extraordinary mechanical durability without any increase in resistance after folding 1000 times. Its areal energy density is easily controllable by the number of folded stacks of a piece of the electrode mat. Deformable lithium-ion batteries of lithium iron phosphate as cathode and lithium titanium oxide as anode at high areal capacity (3.2 mAh cm−2) are successfully operated without structural failure and performance loss, even after repeated crumpling and folding during charging and discharging. Crumply superflexible lithium-ion batteries based on current-collector-free and binder-free nanowire-around-microfiber electrode architectures are presented. The battery cells of high loading density at 3.2 mAh cm−2 are successfully operated under folding, crumpling, and even hammering.

**Polymer Encapsulants Incorporating Light-Guiding Architectures to Increase Optical Energy Conversion in Solar Cells**

The fabrication of a new type of solar cell encapsulation architecture comprising a periodic array of step-index waveguides is reported. The materials are fabricated through patterning with light in a photoreactive binary blend of crosslinking acrylate and urethane, wherein phase separation induces the
spontaneous, directed formation of broadband, cylindrical waveguides. This microstructured material efficiently collects and transmits optical energy over a wide range of entry angles. Silicon solar cells comprising this encapsulation architecture show greater total external quantum efficiencies and enhanced wide-angle light capture and conversion. This is a rapid, straightforward, and scalable approach to process light-collecting structures, whereby significant increases in cell performance may be achieved. Broadband waveguide array architectures are inscribed into polymer films as a new encapsulant material for solar cells. The architectures are grown in a binary-component, photocurable resin through light-induced self-writing, which elicits spontaneous formation of the core–cladding waveguide profile. Their light-collecting and light-guiding functions are inherited by the film, thereby enabling large-scale enhanced and wide-angle optical energy collection and conversion.

**Fabrication of Au25(SG)18–ZIF-8 Nanocomposites: A Facile Strategy to Position Au25(SG)18 Nanoclusters Inside and Outside ZIF-8**

Multifunctional composite materials are currently highly desired for sustainable energy applications. A general strategy to integrate atomically precise Au25(SG)18 with ZIF-8 (Zn(MeIm)2, MeIm = 2-methylimidazole), is developed via the typical Zn-carboxylate type of linkage. Au25(SG)18 are uniformly encapsulated into a ZIF-8 framework (Au25(SG)18@ZIF-8) by coordination-assisted self-assembly. In contrast, Au25(SG)18 integrated by simple impregnation is oriented along the outer surface of ZIF-8 (Au25(SG)18/ZIF-8). The porous structure and thermal stability of these nanocomposites are characterized by N2 adsorption–desorption isothermal analysis and thermal gravimetric analysis. The distribution of Au25(SG)18 in the two nanocomposites is confirmed by electron microscopy, and the accessibility of Au25(SG)18 is evaluated by the 4-nitrophenol reduction reaction. The as-prepared nanocomposites retain the high porosity and thermal stability of the ZIF-8 matrix, while also exhibiting the desired catalytic and optical properties derived from the integrated Au25(SG)18 nanoclusters (NCs). Au25(SG)18@ZIF-8 with isolated Au25 sites is a promising heterogenous catalyst with size selectivity imparted by the ZIF-8 matrix. The structural distinction between Au25(SG)18@ZIF-8 and Au25(SG)18/ZIF-8 determines their different emission features, and provides a new strategy to adjust the optical behavior of Au25(SG)18 for applications in bioimaging and biotherapy. The controlled embedding of nanoclusters into metal–organic frameworks is one of the major obstacles for the application of nanoclusters in catalysis. A general strategy to position Au25(SG)18 inside and outside ZIF-8 (Zn(MeIm)2, MeIm = 2-methylimidazole) is developed via the typical Zn-carboxylate type of linkage. The catalytic and optical properties of such nanocomposites are further investigated.

**Single-Carbon-Nanotube Manipulations and Devices Based on Macroscale Anthracene flakes**

Because of the outstanding mechanical and electrical properties of carbon nanotubes (CNTs), a CNT-based torsion pendulum is demonstrated to show great potential in nano-electromechanical systems. It is also expected to achieve various manipulations for further characterization and increase device sensitivity using ultralong CNTs and macroscale moving parts. However, the reported top-down method limits the CNT performance and device size by introducing inevitable contamination and destruction, which greatly hinders the development of single-molecule devices. Here, a bottom-up method is introduced to fabricate heterostructures of anthracene flakes (AFs) and suspended CNTs, providing a nondamaging CNT mechanical measurement before further applications, especially for the twisting behavior, and providing a controllable and clean transfer method to fabricate CNT-based electrical devices under ambient conditions. Based on the unique geometry of CNT/AF heterostructures, various complex manipulations of single-CNT devices are conducted to investigate CNT mechanical properties and prompt novel applications of similar structures in nanotechnology. The AF-decorated CNTs show high Young's modulus (=1 TPa) and tensile strength (=100 GPa), and can be considered as the finest and strongest torsional springs. CNT-based torsion balance enables to measure fN-level forces and the
torsional spring constant is two orders of magnitude lower than previously reported values. Schematics of growth-removal cycle of carbon nanotube/anthracene flake (CNT/AF) heterostructures are presented herein. A growth-removal cycle of AFs is formed from structure fabrication to in situ manipulation (measurements) and back to clean CNT samples after removal. These heterostructures provide ideal tools for nondamaging manipulations and further characterization of single ultralong CNT.

Rational Design of Statically and Dynamically Stable Lithium–Sulfur Batteries with High Sulfur Loading and Low Electrolyte/Sulfur Ratio

The primary challenge with lithium–sulfur battery research is the design of sulfur cathodes that exhibit high electrochemical efficiency and stability while keeping the sulfur content and loading high and the electrolyte/sulfur ratio low. With a systematic investigation, a novel graphene/cotton-carbon cathode is presented here that enables sulfur loading and content as high as 46 mg cm\(^{-2}\) and 70 wt% with an electrolyte/sulfur ratio of as low as only 5. The graphene/cotton-carbon cathodes deliver peak capacities of 926 and 765 mA h g\(^{-1}\), respectively, at C/10 and C/5 rates, which translate into high areal, gravimetric, and volumetric capacities of, respectively, 43 and 35 mA h cm\(^{-2}\), 648 and 536 mA h g\(^{-1}\), and 1067 and 881 mA h cm\(^{-3}\) with a stable cyclability. They also exhibit superior cell-storage capability with 95% capacity-retention, a low self-discharge constant of just 0.0012 per day, and stable poststorage cyclability after storing over a long period of six months. This work demonstrates a viable approach to develop lithium–sulfur batteries with practical energy densities exceeding that of lithium-ion batteries.

Scalable Green Synthesis and Full-Scale Test of the Metal–Organic Framework CAU-10-H for Use in Adsorption-Driven Chillers

The demand for cooling devices has increased during the last years and this trend will continue. Adsorption-driven chillers (ADCs) using water as the working fluid and low temperature waste energy for regeneration are an environmentally friendly alternative to currently employed cooling devices and can concurrently help to dramatically decrease energy consumption. Due to the ideal water sorption behavior and proven lifetime stability of [Al(OH)(m-BDC)] \(\cdot x \text{H}_2\text{O}\) (m-BDC\(^{2-}\) = 1,3-benzenedicarboxylate), also denoted CAU-10-H, a green very robust synthesis process under reflux, with high yields up to 95% is developed and scaled up to 12 kg-scale. Shaping of the adsorbent is demonstrated, which is important for an application. Thus monoliths and coatings of CAU-10-H are produced using a water-based binder. The composites are thoroughly characterized toward their mechanical stability and water sorption behavior. Finally a full-scale heat exchanger is coated and tested under ADC working conditions. Fast adsorption dynamic leads to a high power output and a good power density. A low regeneration temperature of only 70 °C is demonstrated, allowing the use of low temperature sources like waste heat and solar thermal collectors. Metal–organic frameworks (MOFs) can be implemented as active materials in adsorption-driven chillers. Therefore a green robust synthesis for the Al-MOF CAU-10-H, scalable to 12 kg-scale, is developed. Monoliths and coatings are produced using a water based binder and are investigated as composite material. Finally a full scale heat exchanger is coated and measured under adsorption-driven chiller working conditions.