Clean Graphene Surfaces

A new approach to clean the surface of graphene is reported by Hailin Peng, Zhongfan Liu, and co-workers in article number 1902978, who use a force-engineered “lint roller” to selectively removing the graphene’s intrinsic surface contaminants. The as-obtained super-clean graphene can be transferred to dielectric substrates with significantly reduced polymer residues, and it exhibits superior electronic and optical properties such as ultrahigh carrier mobility and low contact resistance.

Metal Fluoride–Lithium Batteries

Metal fluoride–lithium batteries are promising for the fabrication of lighter, thinner, and cheaper next-generation rechargeable batteries. In article number 1905146, Feixiang Wu, Yan Yu, and co-workers develop a 3D honeycomb architecture to synchronously achieve fast electron and Li$^+$ transport in an FeF$_3$@C cathode. The produced FeF$_3$@C composite cathodes offer unprecedented rate capability up to 100C and remarkable cycle stability within 1000 cycles.

Organic Electronics

In article number 1904201, Hirohiko Fukagawa and co-workers report a novel strategy for efficient electron injection into organic semiconductors, which is realized by forming hydrogen bonds between host semiconductors and bases. Both the operational stability and moisture resistance of devices fabricated employing this technique are higher than those of devices fabricated employing the conventional electron-injection technique using typical n-dopants.

Heterostructure Arrays

In article number 1904194, Seoung-Ki Lee, Jong-Hyun Ahn, and co-workers demonstrate a heterostructure array based on transition-metal dichalcogenides, via a solution-based self-assembly method. The heterostructure is composed of p-WSe$_2$ wires and n-MoS$_2$ wires in parallel- or cross-aligned structure. This WSe$_2$/MoS$_2$ p–n junction array exhibits outstanding electrical and optoelectrical properties, including high rectifying behavior and photoresponsivity with fast response time.
Big Data Studying biological processes with genomics, transcriptomics, and proteomics has become commonplace. Omics-based approaches can help study the vast nanomaterial chemical space as well as biological factors that affect the safety, toxicity, and efficacy of nanotechnologies. The generation and analysis of large datasets and their application to answer fundamental questions in nanotechnology-based drug delivery are reviewed.

K. Paunovska, D. Loughrey, C. D. Sago, R. Langer, J. E. Dahlman*........1902798

Using Large Datasets to Understand Nanotechnology

Hybrid halide perovskites and ferroelectric perovskites are two different classes of materials with analogies in their structure. Such analogies and state-of-the-art technologies based on these materials are reviewed so that future multisource energy conversion devices (which are capable of utilizing piezoelectric, pyroelectric, photovoltaic, and thermoelectric effects simultaneously) and storage devices can be created in a holistic manner.


Using Large Datasets to Understand Nanotechnology

Toughening mechanisms of light weight, strong, and tough biological materials constructed from the atomic- to macroscale are reviewed. The multiscale toughening mechanisms are validated via computational modeling, and subsequently translated to engineering materials through bioinspired processing such as freeze casting and additive manufacturing.


Multiscale Toughening Mechanisms in Biological Materials and Bioinspired Designs

A new approach to clean the surface of graphene is reported by using a force-engineered “lint roller”, which is enabled by selectively removing intrinsic surface contaminants on graphene. The as-obtained superclean graphene can be transferred to dielectric substrates with significantly reduced polymer residues and exhibits superior electronic and optical properties such as ultrahigh carrier mobility and low contact resistance.


A Force-Engineered Lint Roller for Superclean Graphene

FeF₃ nanoparticles (10–50 nm) are uniformly embedded in a 3D honeycomb architecture where the honeycomb walls and hexagonal-like channels provide sufficient pathways for fast electron and Li-ion diffusion, respectively. As a result, the as-produced 3D honeycomb FeF₃@C composite cathodes offer unprecedented rate capability up to 100C and remarkable cycle stability within 1000 cycles.

Efficient electron injection into organic semiconductors is achieved by hydrogen bond formation between the host materials and bases that are commonly used in organic synthesis as catalysts. The electron-injection efficiency in inverted organic light-emitting diodes, the electron-injection layer of which consists of the host and bases, is found to be almost proportional to the basicity of the bases.

A WSe₂/MoS₂-based p-n heterostructure array is realized by a solution-based direct growth method. WSe₂ wires are selectively stacked over the MoS₂ wires at the desired angle to form parallel- or cross-aligned heterostructures over a large area. The p-n heterojunction array has a clean interface, resulting in outstanding rectification. Additionally, a prototype photosensing device with good photoresponsivity and response time is demonstrated.
Fluid-like graphene shows macroscopic lubricity reaching a coefficient of friction of 0.01. The rigid 3D molecular interlocking groups (molecular bearing: triaminotriptycene, additive) create nanostructures by bonding (stabilizer: Meisenheimer complexation) to the 3,5-dinitrophenyl-functionalized graphene. Mechanical shearing converts these graphene composites into highly stable surface-bound tribolayers with a coefficient of friction (COF) of ≈0.01.

Artificial natural killer (NK) cells are constructed with minor limitations of the immunosuppressive tumor microenvironment for specific tumor killing and renegade macrophage re-education. The artificial NK cells exhibit efficient tumor inhibition and immune activation as a new sight to overcome tumors by simulating the functions of immune cells.

Ti$_3$C$_2$-based MXene contacts—spin-coated from an aqueous colloidal suspension onto a GaAs substrate—are compared with vacuum-deposited titanium/gold electrodes for the photodetection of light. Such an MXene-based device has better detectivity, quantum efficiency, and a higher dynamic range as compared to the conventional Au-based metal–semiconductor–metal devices.

Inspired by the natural physiological process of spores, a probiotic spore-based oral autonomous nanoparticles generator is developed for cancer therapy. This smart generator can not only germinate and colonize in the intestine but also form nanoparticles in the intestinal environment, enhancing the stability of drugs in the gastrointestinal tract, and overcome the multibiological barriers of the intestinal epithelium.
V₂VI₃ compounds including Bi₂Te₃, Bi₂Se₃, Sb₂Te₃ and β-As₂Te₃ exhibit a remarkable property portfolio. These properties can be related to a special bonding mechanism termed metavalent bonding, where σ-bonds between adjacent atoms are formed by half-filled p-bands. Metavalent bonding is characterized by modest levels of charge transfer and sharing of about one electron between adjacent atoms.

**Metavalent Bonding**


**Understanding the Structure and Properties of Sesqui-Chalcogenides (i.e., V₂VI₃ or Pn₂Ch₃ (Pn = Pnictogen, Ch = Chalcogen) Compounds) from a Bonding Perspective**

A solid-state lithium-ion battery, in which all components (current collector, anode and cathode, electrolyte, and packaging) are stretchable, is designed and fabricated. The thin-film full cell can be stretched up to 50% of its original length during the charge and discharge process.

**Stretchable Batteries**

X. Chen, H. Huang, L. Pan, T. Liu, M. Niederberger* .......................1904648

**Fully Integrated Design of a Stretchable Solid-State Lithium-Ion Full Battery**

Two ions with very different M—O bond energy are selected to construct a highly ordered Ni₆-ring superstructure within transition metal layers in a model compound (NaNi₁₂Sb₁₁O₂). The formed Ni₆-rings with super-exchange interaction by Ni/Sb ordering can greatly enhance the air stability and thermal stability of layered cathodes, increase the redox potential, and simplify the phase-transition process during battery cycling.

**Sodium-Ion Batteries**


**An Ordered Ni₆-Ring Superstructure Enables a Highly Stable Sodium Oxide Cathode**

Interfacial charge transfer is a crucial process in photovoltaic conversion. Plasmon-induced hot-electron transfer is demonstrated as a sufficiently fast charge-transfer process to realize high-speed photovoltaic conversion. A near-infrared photodetector with fast detection speed and extended spectral response to the communication band (1550 nm) is achieved built on a tungsten suboxide nanocystal arrays–graphene heterostructure.

**NIR Detectors**


**Fast Photoelectric Conversion in the Near-Infrared Enabled by Plasmon-Induced Hot-Electron Transfer**
**COMMUNICATIONS**

**Photodetectors**

Y.-L. Wu, K. Fukuda,*, T. Yokota, T. Someya*............................... 1903687

* A Highly Responsive Organic Image Sensor Based on a Two-Terminal Organic Photodetector with Photomultiplication

A highly responsive organic image sensor based on vertically stacked two-terminal pixels is achieved with pixels of a diode-type organic photodetector through photomultiplication. With an optimized injection electrode and additionally stacked rectifying layers, the organic image sensor with an extremely simple architecture exhibits a high pixel photoresponse and demonstrates a weak-light imaging capability at 1 μW cm$^{-2}$.

**Lithium–Sulfur Batteries**


* Implanting Atomic Cobalt within Mesoporous Carbon toward Highly Stable Lithium–Sulfur Batteries

Atomic cobalt implantation to mesoporous carbon enhances the sulfur kinetics in Li–S batteries. Atomic cobalt dopants with high polarity endow the mesoporous carbon (represented by the apes) with high affinity with polysulfides (represented by the bananas). Therefore, the shuttle effect is eliminated and the sulfur kinetics is improved, facilitating highly stable Li–S batteries.

**Organic Photovoltaics**

R. Wang, J. Yuan, R. Wang, C. Han, T. Huang, W. Huang, J. Xue, H.-C. Wang, C. Zhang, C. Zhu, P. Cheng, D. Meng, Y. Yi,*, K.-H. Wei, Y. Zou,*, Y. Yang* ...................... 1904215

* Rational Tuning of Molecular Interaction and Energy Level Alignment Enables High-Performance Organic Photovoltaics

By rationally tuning the molecular interaction and energy level alignments of the donors and acceptors, when both donor and acceptor are fluorinated or both are not fluorinated, high-performance organic photovoltaics can be realized. With the enlarged absorption, ideal morphology, and efficient charge transfer, devices based on the PBDB-T-F/Y1-4F blend and PBDB-T-F/Y6 exhibit power conversion efficiencies as high as 14.8% and 15.9%, respectively.

**Band Hybridization**

P. C. Rogge, P. Shafer, G. Fabbris, W. Hu, E. Arenholz, E. Karapetrova, M. P. M. Dean, R. J. Green, S. J. May*.......................... 1902364

* Depth-Resolved Modulation of Metal–Oxygen Hybridization and Orbital Polarization across Correlated Oxide Interfaces

Resonant X-ray reflectivity is used to quantitatively measure changes in band hybridization across transition metal oxide interfaces. Spatially determining the degree of metal versus oxygen character in a superlattice of SrFeO$_3$/CaFeO$_3$ reveals how interfaces can alter the orbital character of valence electrons and further reveal a new class of oxide interfacial reconstructions, that of metal–oxygen hybridization.
Molecular vibrations strongly impact the charge transport properties of weakly van der Waals bonded organic semiconductors. Quantum mechanical simulations, combined with low-frequency vibrational spectroscopy, enable resolution of vibrational modes and ensuing electron–phonon coupling constants. The long-axis sliding motion of molecular subunits is identified as a “killer” phonon mode, which in some materials contributes more than 80% to the total thermal disorder.

Fast gelation of Ti$_3$C$_2$T$_x$ MXenes is initiated by divalent metal ions in aqueous solution. Typically, Fe$^{2+}$ ions eliminate the electrostatic repulsion, networking MXene nanosheets into a 3D structured hydrogel. The wet hydrogel avoids nanosheet restacking and is ideal for applications highlighting the surface utilization, especially as freestanding electrodes for high-rate supercapacitors.

Boron dopants and nitrogen defects are simultaneously introduced into g-C$_3$N$_4$ through a simple NaBH$_4$ thermal treatment approach. With exceptionally modulated band structures for effective optical absorption and increased water-oxidation driving force, as well as engineered electronic structure for efficient electron excitation and facilitated charge transport, the resultant boron-doped and nitrogen-deficient g-C$_3$N$_4$ exhibits excellent activity for photocatalytic oxygen evolution.

An anomalous dependence of thermal conductivity on point defects is observed in epitaxial WO$_3$ thin films. In particular, an increase of the lattice thermal conductivity found in WO$_3$/YAO is accompanied by a lattice contraction upon the introduction of point defects, suggesting that the lattice volume rather than defect concentration plays the dominant role in determining the thermal conductivity.
**Communications**

**Zinc-Ion Batteries**

Q. Yang, G. Liang, Y. Guo, Z. Liu, B. Yan, D. Wang, Z. Huang, X. Li, J. Fan, C. Zhi

Do Zinc Dendrites Exist in Neutral Zinc Batteries: A Developed Electrohealing Strategy to In Situ Rescue In-Service Batteries

A first-in-class electrohealing methodology is developed to tackle Zn dendrites and prolong the lifespan of zinc-ion batteries (ZBs) by 410%, benefitting from the passivation of the initially sharp dendrite tips. This electrohealing strategy may promote research on metal dendrites in various batteries, evolving from passive prevention to active elimination, rescuing in-service batteries in situ to achieve elongated lifetime.

**Microfluidics**

H. Dai, C. Gao, J. Sun, C. Li, N. Li, L. Wu, Z. Dong, L. Jiang

Controllable High-Speed Electrostatic Manipulation of Water Droplets on a Superhydrophobic Surface

A revolution to the microfluidic device commonly used in biological processes and technological applications is demonstrated. The new approach, which moves drops at a high speed with low adhesion or retention by electrostatic attraction or repulsion on a superhydrophobic surface, can enable microfluidic experiments to be conducted more efficiently, cost-effectively, and at larger scales.

**Water Generation**


An Interfacial Solar-Driven Atmospheric Water Generator Based on a Liquid Sorbent with Simultaneous Adsorption–Desorption

A novel interfacial solar-driven atmospheric water generator can simultaneously adsorb and desorb water based on a liquid sorbent, 1-ethyl-3-methyl-imidazolium acetate. With enhanced desorption capability and continuous water supplement in the sorbent, this atmospheric water generator can achieve a high rate of water production ($\approx 0.5$ L m$^{-2}$ h$^{-1}$) and 2.8 L m$^{-2}$ d$^{-1}$ for the outdoor environment.

**Cancer Immunotherapy**


Development of an In Situ Cancer Vaccine via Combinational Radiation and Bacterial-Membrane-Coated Nanoparticles

Tumor-directed radiation therapy can result in immunogenic cell death and neoantigen release, yet on its own, it rarely induces a long-term antitumor immune response. Therefore, a bacterial membrane nanoparticle is designed to bridge innate and adaptive immune activation after radiation therapy and results in improved tumor responses in immunologically “cold” tumors.