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Review of MXenes as new nanomaterials for energy storage/delivery and selected environmental applications

Nanomaterial-based optical indicators: Promise, opportunities, and challenges in the development of colorimetric systems for intelligent packaging

Motif-mediated $\text{Au}_{25}(\text{SPh})_5(\text{PPh}_3)_{10}\text{X}_2$ nanorods with conjugated electron delocalization



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Contents

Review Articles

Review of MXenes as new nanomaterials for energy storage/delivery and selected environmental applications

Byung-Moon Jun¹, Sewoon Kim¹, Jiyong Heo², Chang Min Park³, Namguk Her², Min Jang⁴, Yi Huang⁵, Jonghun Han^{2,*}, and Yeomin Yoon^{1,*}

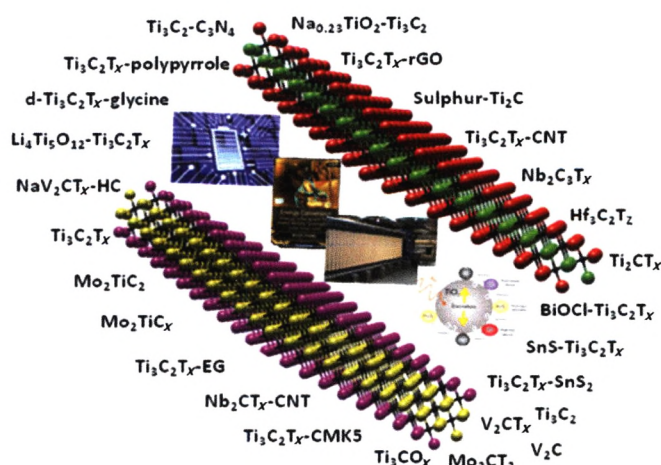
¹ University of South Carolina, USA

² Korea Army Academy at Young-Cheon, Republic of Korea

³ Kyungpook National University, Republic of Korea

⁴ Kwangwoon University, Republic of Korea

⁵ The University of Edinburgh, UK



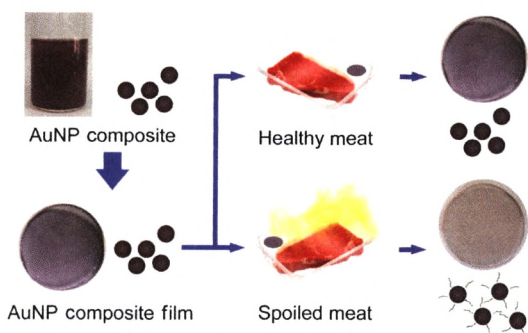
Recently, two-dimensional MXenes and MXene-based nanomaterials have attracted increasing interest because of their unique properties (e.g., remarkable safety, a very large interlayer spacing, environmental flexibility, a large surface area, and thermal conductivity). We present a comprehensive review of recent studies on energy and environmental applications of MXene and MXene-based nanomaterials, including energy conversion and storage, adsorption, membrane, photocatalysis, and antimicrobial.

471–487

Nanomaterial-based optical indicators: Promise, opportunities, and challenges in the development of colorimetric systems for intelligent packaging

Nattinee Bumbudsanpharoke and Seonghyuk Ko*

Yonsei University, Republic of Korea



The utilization of nanomaterial such as metal nanoparticles or photonic nanocrystals shows superior performance in novel communicative functions than the traditional colorimetric indicator because of their unique optical properties and high surface reactivity.

489–500

Research Articles

Motif-mediated $\text{Au}_{25}(\text{SPh})_5(\text{PPh}_3)_{10}\text{X}_2$ nanorods with conjugated electron delocalization

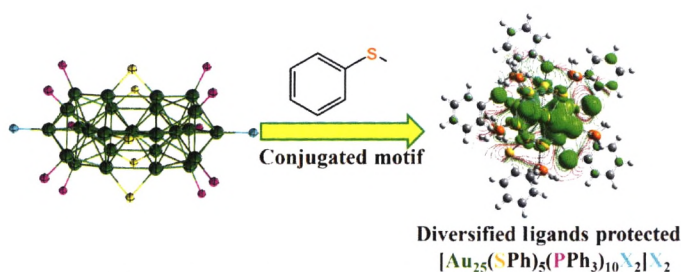
Kai Zheng^{1,2}, Jiangwei Zhang¹, Dan Zhao³, Yong Yang⁴, Zhimin Li^{1,2}, and Gao Li^{1,*}

¹ Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China

² University of Chinese Academy of Sciences, China

³ Shenyang Normal University, China

⁴ Peking University, China



A general and effective synthetic strategy is developed to afford aromatic thiolate-ligated Au_{25} nanorods. The conjugated delocalized π electrons can effectively tune the electronic properties of the Au_{25} kernel and its catalytic activity in the glucose oxidation.

501–507

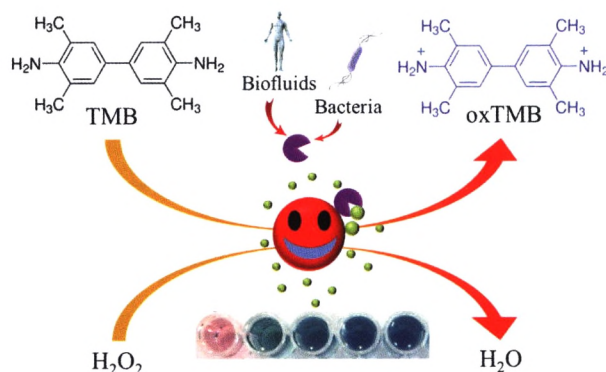
Unusual switchable peroxidase-mimicking nanozyme for the determination of proteolytic biomarker

Claire McVey¹, Natasha Logan¹, Nguyen T. K. Thanh^{1,2}, Christopher Elliott¹, and Cuong Cao^{1,*}

¹ Queen's University Belfast, UK

² University College London, UK

³ UCL Healthcare Biomagnetic and Nanomaterials Laboratories, UK



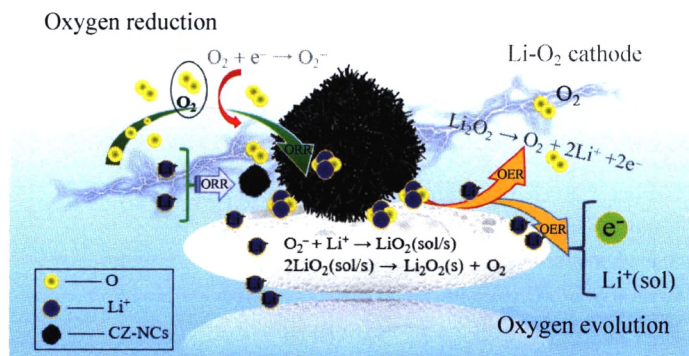
A simple, low cost, and easy to use nanosensor, based on the switchable peroxidase-mimicking activity of plasmonic gold nanoparticles (AuNPs) was developed for the detection of protease, an enzyme biomarker indicative of bacterial contamination or clinical infection. AuNPs were modified with casein which had dual function in the suppression of peroxidase-mimicking activity and also as recognition sites for protease, resulting in the degradation of casein and subsequent recovery of peroxidase-mimicking activity.

509–516

Well-defined carbon nanoframes containing bimetal-N-C active sites as efficient bi-functional electrocatalysts for Li-O₂ batteries

Tie Liu, Leidanyang Wang, Tao Huang, and Aishui Yu*

Fudan University, China



Pyridinic-N-dominated carbon frameworks with bimetallic (Co, Zn) nanoparticles as a promising bi-functional catalyst have been successfully prepared and applied into Li-O₂ batteries.

517–523

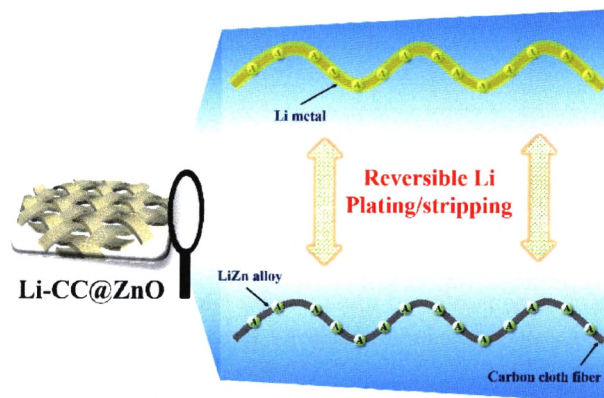
Infiltrating lithium into carbon cloth decorated with zinc oxide arrays for dendrite-free lithium metal anode

Xianshu Wang^{1,2}, Zhenghui Pan², Yang Wu³, Xiaoyu Ding², Xujia Hong¹, Guoguang Xu², Meinan Liu², Yuegang Zhang^{1,2,3,*}, and Weishan Li^{1,*}

¹ South China Normal University, China

² Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences, China

³ Tsinghua University, China



Li-CC@ZnO anode based on a carbon cloth decorated with vertical ZnO nano-wires arrays has been fabricated by thermal molten Li infiltration. This anode enables dendrite-free reversible Li plating/stripping at a high rate, and no electrode pulverization during cycling.

525–529

Black phosphorus inverter devices enabled by *in-situ* aluminum surface modification

Yue Zheng^{1,2}, Zehua Hu², Cheng Han³, Rui Guo⁴, Du Xiang², Bo Lei², Yanan Wang², Jun He⁴, Min Lai¹, and Wei Chen^{2,5,*}

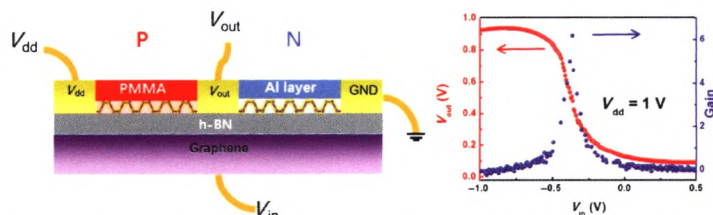
¹ Nanjing University of Information Science & Technology, China

² National University of Singapore, Singapore

³ Shenzhen University, China

⁴ Central South University, China

⁵ National University of Singapore (Suzhou) Research Institute, China



High gain inverter based on few-layer black phosphorus is obtained by aluminum surface modification.

531–536

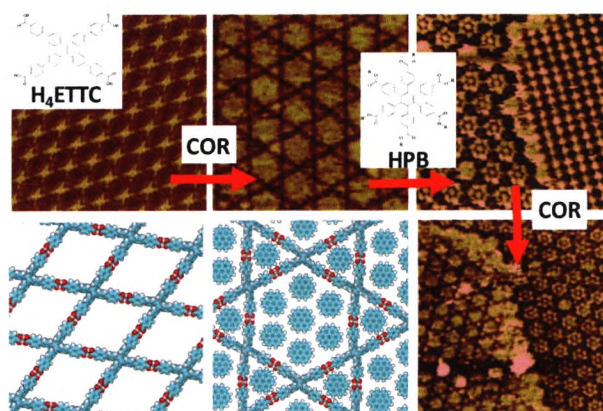
Guest selectivity in the supramolecular host networks fabricated by van der Waals force and hydrogen bond

Xuan Peng^{1,3}, Yanfang Geng^{1,3}, Min Zhang², Faliang Cheng^{2,*}, Linxiu Cheng^{1,3}, Ke Deng^{1,3,*}, and Qingdao Zeng^{1,2,3,*}

¹ National Center for Nanoscience and Technology (NCNST), China

² Dongguan University of Technology, China

³ University of Chinese Academy of Sciences, China



Coronene (COR) heptamers were formed in the supramolecular architectures of 4',4'',4'''-(ethene-1,1,2,2-tetra-yl)tetrakis-([1,1-biphenyl]-3-carboxylic acid) (H4ETTC) and hexaphenylbenzene (HPB), and showed preferential adsorption to HPB host network.

537–542

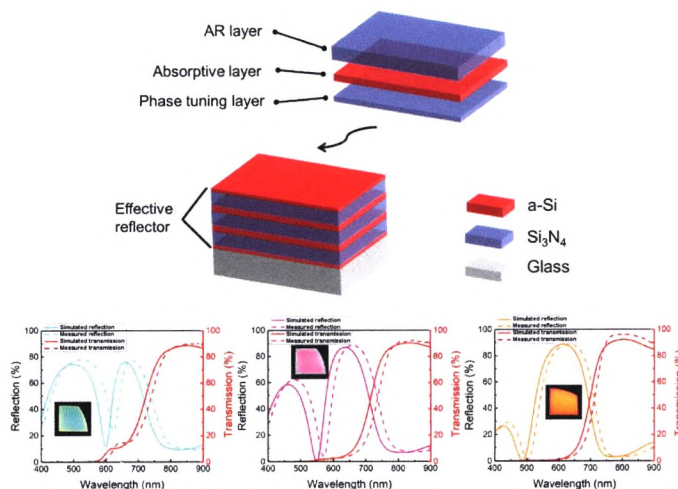
Decorative near-infrared transmission filters featuring high-efficiency and angular-insensitivity employing 1D photonic crystals

Chengang Ji¹, Chenying Yang^{1,2}, Weidong Shen^{2,*}, Kyu-Tae Lee³, Yueguang Zhang², Xu Liu², and L. Jay Guo^{1,*}

¹ The University of Michigan, USA

² Zhejiang University, China

³ Inha University, Republic of Korea



Decorative visibly-opaque but near-infrared (NIR)-transmitting filters that possess high-efficiency and angular-insensitivity are demonstrated employing one-dimensional ternary photonic crystals. Different reflective colors can be generated without affecting the NIR transmission performance, thus opening up new possibilities for a wide variety of applications such as image sensors, optical detections, and NIR decorations.

543–548

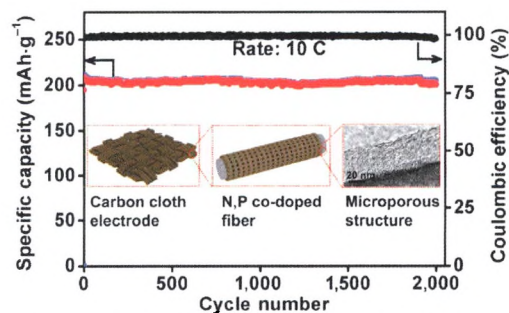
Nitrogen, phosphorus co-doped carbon cloth as self-standing electrode for lithium-iodine batteries

Kang Li¹, Song Chen¹, Si Chen¹, Xien Liu², Wei Pan³, and Jintao Zhang^{1,*}

¹ Shandong University, China

² Qingdao University of Science & Technology, China

³ Shandong Normal University, China



N, P co-doped carbon cloth electrode which possesses abundant micropores exhibits superior cycling stability at a high current density.

549–555

Panorama of boron nitride nanostructures via lamp ablation

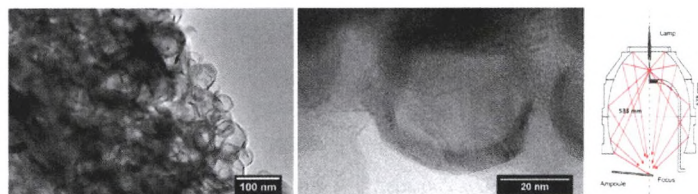
Sehrina Eshon¹, Weike Zhang², Martin Saunders¹, Yujun Zhang³, Hui Tong Chua¹, and Jeffrey M. Gordon^{1,4,*}

¹ The University of Western Australia, Australia

² Taiyuan University of Technology, China

³ Shandong University, China

⁴ Ben-Gurion University of the Negev, Israel



The quest to synthesize boron nitride (BN) nanostructures stems from their exhibiting a host of extraordinary chemical and physical properties, with the hollow closed-cage nanoparticles (nano-onions) having proved particularly elusive. Here, we report how the novel procedure of lamp ablation produces a variety of BN nanostructures—most notably nano-onions, for which transmission electron micrographs are shown above—in a process that is rapid, free of toxic reagents, and scalable, thereby offering significant advantages relative to the alternative methods.

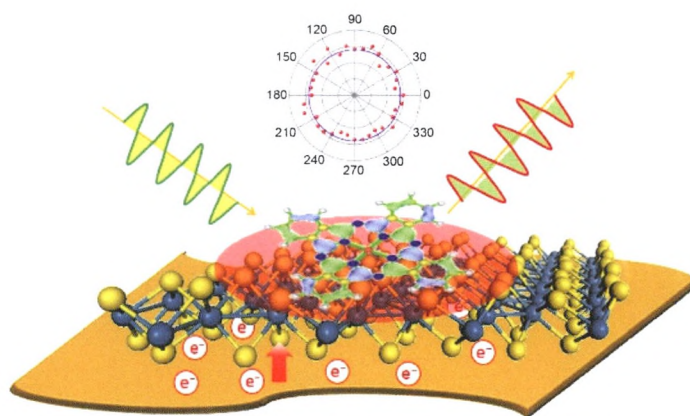
557–562

Doping modulated in-plane anisotropic Raman enhancement on layered ReS₂

Na Zhang¹, Jingjing Lin¹, Shuqing Zhang¹, Shishu Zhang¹, Xiaobo Li², Dongyan Liu², Hua Xu², Jin Zhang¹, and Lianming Tong^{1,*}

¹ Peking University, China

² Shaanxi Normal University, China



Layered ReS₂ can be doped by gold film, and electrons are injected into the conduction band of ReS₂. The doping level is layer-number dependent and can be probed by the change of enhancement factor and the degree of anisotropy in enhanced Raman intensities of copper phthalocyanine (CuPc) probe molecules.

563–568

Formation mechanism of twin domain boundary in 2D materials: The case for WTe_2

Guan-Yong Wang¹, Weiyu Xie^{2,3}, Dan Xu¹, Hai-Yang Ma¹,
Hao Yang¹, Hong Lu⁴, Hao-Hua Sun¹, Yao-Yi Li¹, Shuang Jia⁴,
Liang Fu⁵, Shengbai Zhang^{2,*}, and Jin-Feng Jia^{1,6,*}

¹ Shanghai Jiao Tong University, China

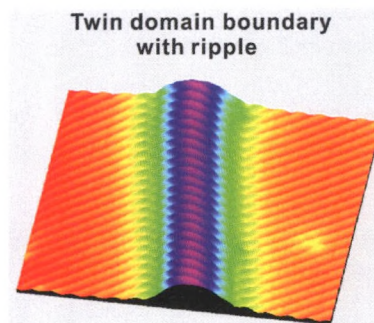
² Rensselaer Polytechnic Institute, USA

³ China Academy of Engineering Physics (CAEP), China

⁴ Peking University, China

⁵ Massachusetts Institute of Technology, USA

⁶ Tsung-Dao Lee Institute, China



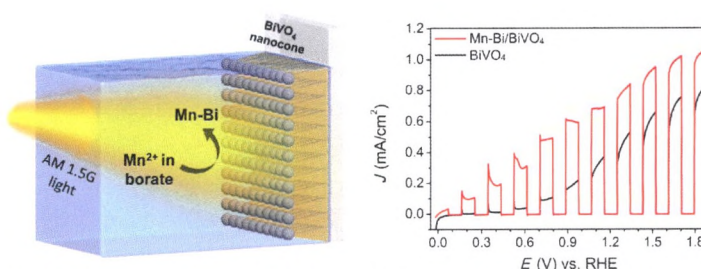
The formation mechanism of twin domain boundary in WTe_2 is revealed by high-resolution scanning tunneling microscopy (STM) combined with density functional theory calculations.

569–573

Hierarchical growth of a novel Mn-Bi coupled BiVO_4 arrays for enhanced photoelectrochemical water splitting

Lu Wang, Jinzhan Su*, and Liejin Guo*

Xi'an Jiaotong University, China



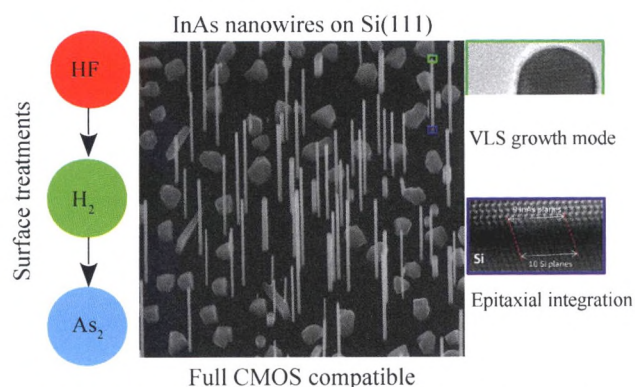
Due to the spontaneous photo-electric-field-enhancement effect in nanocone structure, Mn-Bi oxygen evolution catalyst was selectively deposited at the apex of BiVO_4 nanocone by photodeposition. The obtained novel structure shows significant improvement of photocurrent as a result of enhanced surface charge injection efficiency.

575–580

Insight of surface treatments for CMOS compatibility of InAs nanowires

Daya S. Dhungana, Anne Hemeryck, Nicolo Sartori, Pier-Francesco Fazzini, Filadelfo Cristiano, and Sébastien R. Plissard*

Université de Toulouse, France



Full CMOS compatible InAs nanowires on Si(111) have been grown by Molecular Beam Epitaxy (MBE) without crossing the CMOS thermal budget at any point.

581–586

Water transport through subnanopores in the ultimate size limit: Mechanism from molecular dynamics

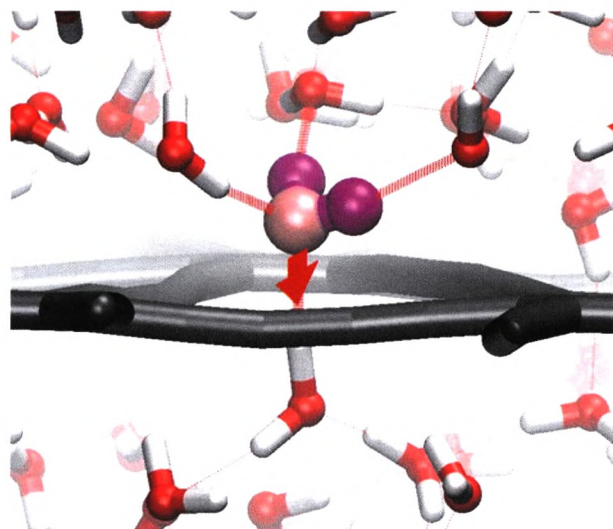
Jiyu Xu^{1,2}, Chongqin Zhu³, Yifei Wang^{1,2}, Hui Li^{1,4}, Yongfeng Huang^{1,2}, Yutian Shen^{1,2}, Joseph S. Francisco³, Xiao Cheng Zeng^{3,*}, and Sheng Meng^{1,2,*}

¹ Institute of Physics, Chinese Academy of Sciences, China

² University of Chinese Academy of Sciences, China

³ University of Nebraska, USA

⁴ Beijing University of Chemical Technology, China



Simulations show that water can transport through the 0.57-nm subnanopores via a chemical-reaction-like activated process.

587–592

All in one theranostic nanoplatform enables efficient anti-tumor peptide delivery for triple-modal imaging guided cancer therapy

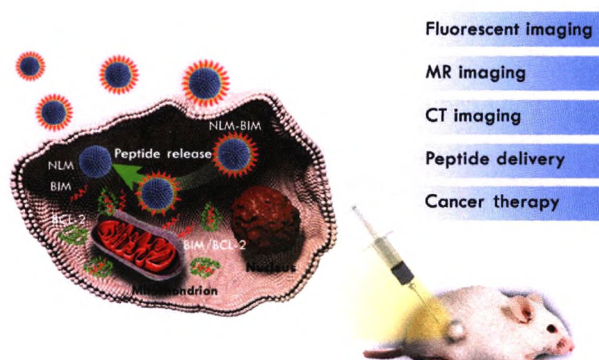
Xiaoyan Qu¹, Zhengqing Liu², Bohan Ma¹, Na Li^{1,4}, Hongyang Zhao¹, Tian Yang³, Yumeng Xue¹, Xiaozhi Zhang³, Yongping Shao¹, Ying Chang¹, Jun Xu², Bo Lei^{1,*}, and Yaping Du^{2,*}

¹ Xi'an Jiaotong University, China

² Nankai University, China

³ The First Affiliated Hospital of Xi'an Jiaotong University, China

⁴ Brookhaven National Laboratory, USA



A multifunctional nanoplatform based on porous europium/gadolinium (Eu/Gd)-doped $\text{NaLa}(\text{MoO}_4)_2$ nanoparticles was constructed to deliver antitumor peptide of B-cell lymphoma/leukemia-2-like protein 11 (BIM) for cancer therapy. Importantly, the BIM peptide was efficiently delivered into the tumor cells, and then inhibited the growth and promoted the apoptosis of cancer cells *in vitro*.

593–599

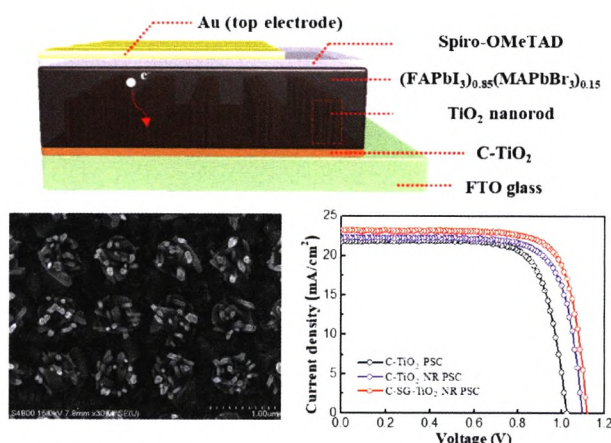
Selectively patterned TiO_2 nanorods as electron transport pathway for high performance perovskite solar cells

Daihong Huh¹, KyoungSuk Oh^{1,2}, Minjin Kim^{1,2}, Hak-Jong Choi^{1,3}, Dong Suk Kim^{2,*}, and Heon Lee^{1,*}

¹ Korea University, Republic of Korea

² Korea Institute of Energy Research (KIER), Republic of Korea

³ University of Pennsylvania, USA



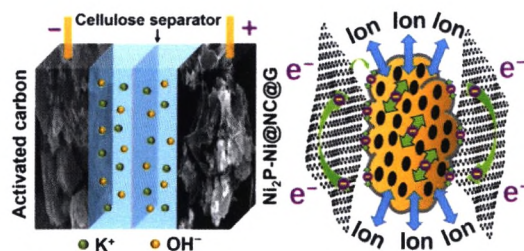
By using selectively patterned TiO_2 nanorod as an electron transport layer, the optical and electrical properties improvement of the perovskite solar cell was confirmed. In this study, fabricated perovskite solar cells (PSCs) have a conversion efficiency of 19.86%.

601–606

N-doped-carbon coated $\text{Ni}_2\text{P-Ni}$ sheets anchored on graphene with superior energy storage behavior

Yuanxing Zhang, Li Sun*, Liqi Bai, Haochen Si, Yu Zhang, and Yihe Zhang*

China University of Geosciences, China



A $\text{Ni}_2\text{P-Ni@NC@G}$ composite was fabricated as electrodes for asymmetric supercapacitors and lithium ion batteries, demonstrating outstanding pseudocapacitive characteristics and excellent lithium storage behavior.

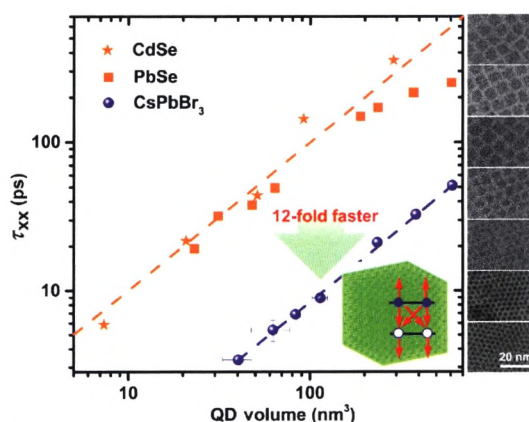
607–618

Biexciton Auger recombination in mono-dispersed, quantum-confined CsPbBr_3 perovskite nanocrystals obeys universal volume-scaling

Yulu Li^{1,2}, Tao Ding², Xiao Luo², Zongwei Chen², Xue Liu², Xin Lu^{1,*}, and Kaifeng Wu^{2,*}

¹ Xiamen University, China

² Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China



Biexciton Auger recombination lifetime in mono-dispersed, quantum-confined CsPbBr_3 perovskite nanocrystals was found to obey the universal volume scaling, but with a scaling factor 12-fold faster than conventional quantum dots.

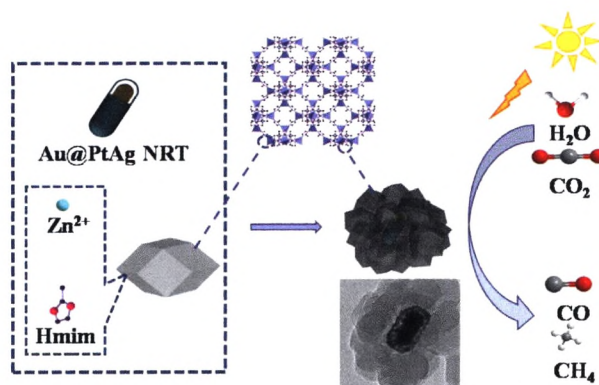
619–623

Nanorattle Au@PtAg encapsulated in ZIF-8 for enhancing CO_2 photoreduction to CO

Yuqun Su¹, Haitao Xu^{1,*}, Jiajia Wang¹, Xikuo Luo¹, Zhen-liang Xu¹, Kefu Wang², and Wenzhong Wang²

¹ East China University of Science and Technology (ECUST), China

² Shanghai Institute of Ceramics, Chinese Academy of Sciences, China



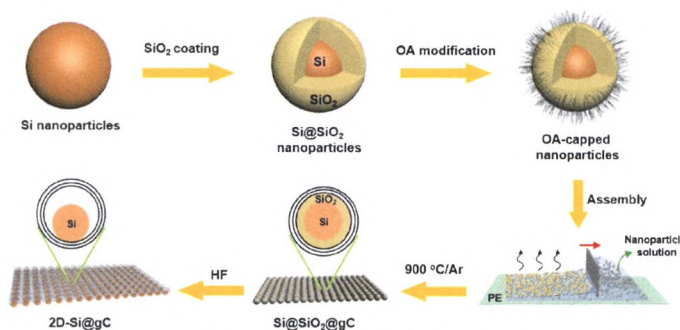
A zeolitic imidazolate-based metal-organic framework (MOF) catalyst Au@PtAg@ZIF-8 was assembled. The monodisperse bimetallic core-shell nanorods Au@Ag were employed and reacted with K_2PtCl_4 aqueous solution, which yielded rod-like nanorattles Au@PtAg via galvanic replacement. Au NRs, Au@Ag NRs, and Au@PtAg NRTs (NR = nanorod, NRT = nanorattle) were encapsulated into ZIF-8. Their catalytic effectiveness was investigated for the gas-phase CO_2 photoreduction with H_2O .

625–630

Exploiting oleic acid to prepare two-dimensional assembly of Si@graphitic carbon yolk-shell nanoparticles for lithium-ion battery anodes

Xiao Chen, Chen Chen, Yu Zhang, Xianfeng Zhang, Dong Yang*, and Angang Dong*

Fudan University, China



Oleic acid, a conventional ligand for colloidal nanocrystal synthesis, has been exploited as a versatile ligand and carbon precursor for the scalable production of two-dimensional (2D) assemblies of interconnected Si@graphitic carbon yolk-shell nanoparticles (2D-Si@gC) from commercial Si powders. Benefiting from its unique architecture, the resulting 2D-Si@gC exhibits excellent rate capability and cycling stability when used as anode materials for lithium-ion batteries.

631–636

Efficient renal clearance of DNA tetrahedron nanoparticles enables quantitative evaluation of kidney function

Dawei Jiang^{1,2}, Hyung-Jun Im^{1,3}, Madeline E. Boleyn¹, Christopher G. England¹, Dalong Ni¹, Lei Kang^{1,4}, Jonathan W. Engle¹, Peng Huang^{2,*}, Xiaoli Lan^{5,*}, and Weibo Cai^{1,*}

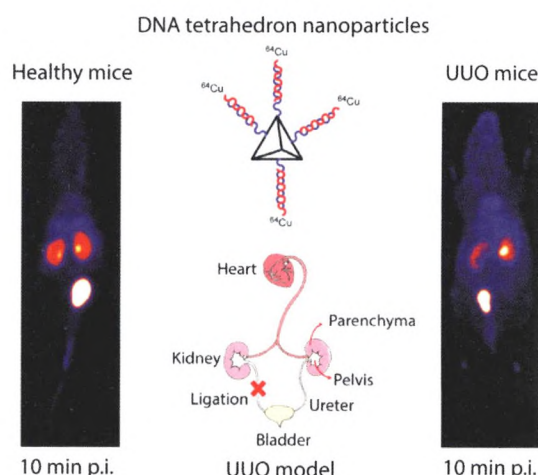
¹ University of Wisconsin-Madison, USA

² Shenzhen University, China

³ Seoul National University, Republic of Korea

⁴ Peking University First Hospital, China

⁵ Huazhong University of Science and Technology; Hubei Key Laboratory of Molecular Imaging, China



Radiolabeled DNA tetrahedron nanostructures (⁶⁴Cu-DTN) navigate throughout kidneys in healthy mice and mice with nephropathy, which was analyzed by dynamic positron emission tomography (PET) imaging and a cohesive mathematical model for kidney function evaluation.

637–642

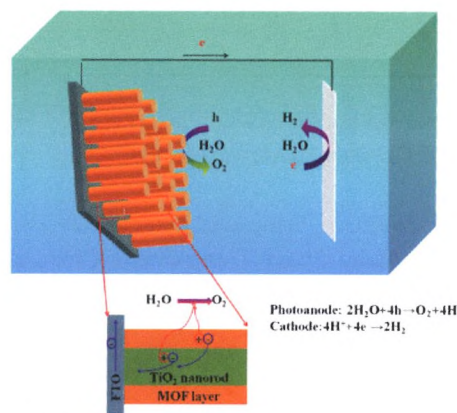
Metal-organic framework coated titanium dioxide nanorod array p-n heterojunction photoanode for solar water-splitting

Hui Yang¹, Joeseeph Bright¹, Sujun Kasani¹, Peng Zheng¹, Terence Musho¹, Banglin Chen², Ling Huang^{3,*}, and Nianqiang Wu^{1,*}

¹ West Virginia University, USA

² University of Texas at San Antonio, USA

³ Nanjing Tech University (NanjingTech), China



A metal-organic framework (MOF) is coated on titanium dioxide nanorod array via a layer-by-layer self-assembly method, which forms a p-n heterojunction photoanode for photoelectrochemical water splitting. The p-n junction improves the extraction of photogenerated electrons and holes out of the TiO₂ nanorods. The MOF coating significantly improves the efficiency of charge injection at the photoanode/electrolyte interface.

643–650

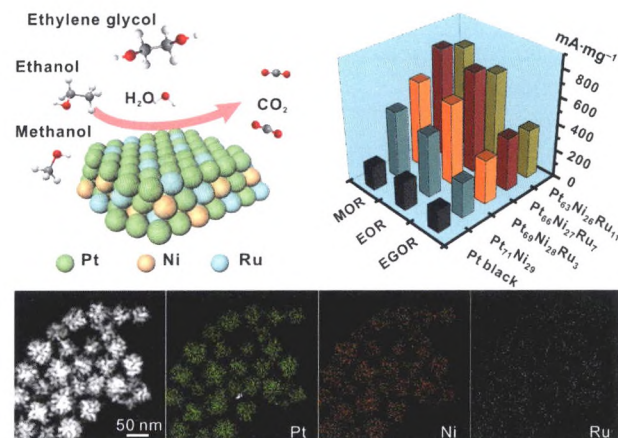
Composition optimized trimetallic PtNiRu dendritic nanostructures as versatile and active electrocatalysts for alcohol oxidation

Yan Lu¹, Wei Wang^{1,2,3}, Xiaowei Chen¹, Yuhui Zhang¹, Yanchen Han¹, Yong Cheng², Xue-Jiao Chen¹, Kai Liu¹, Yuanyuan Wang¹, Qiaobao Zhang², and Shuifen Xie^{1,3,*}

¹ Huaqiao University, China

² Xiamen University, China

³ Shenzhen Research Institute of Xiamen University, China



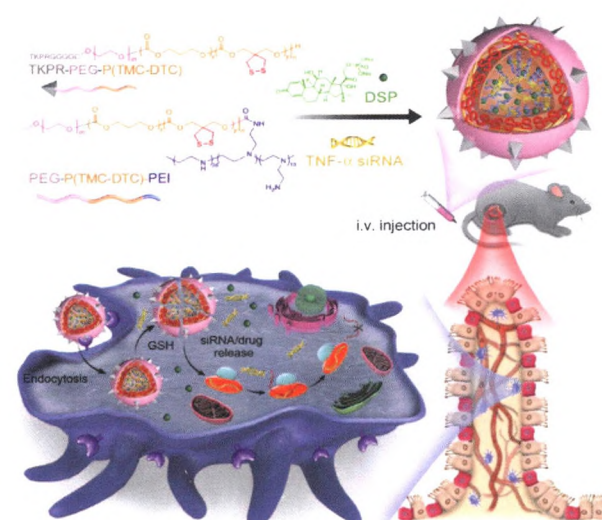
Trimetallic PtNiRu dendritic nanostructures with precisely optimized compositions can serve as versatile and active catalysts towards diverse alcohol electrooxidations for fuel-flexible fuel cell applications.

651–657

Efficient and targeted drug/siRNA co-delivery mediated by reversibly crosslinked polymersomes toward anti-inflammatory treatment of ulcerative colitis (UC)

Xin Xu, Weijing Yang, Qiujun Liang, Yanan Shi, Wenxin Zhang, Xiao Wang, Fenghua Meng, Zhiyuan Zhong*, and Lichen Yin*

Soochow University, China



Macrophage-targeting and reversibly crosslinked polymersomes (TKPR-RCP) were developed to efficiently co-deliver both TNF- α small interfering RNA (siRNA) and dexamethasone sodium phosphate (DSP), which afforded potent and cooperative anti-inflammatory effect toward the treatment of ulcerative colitis (UC).

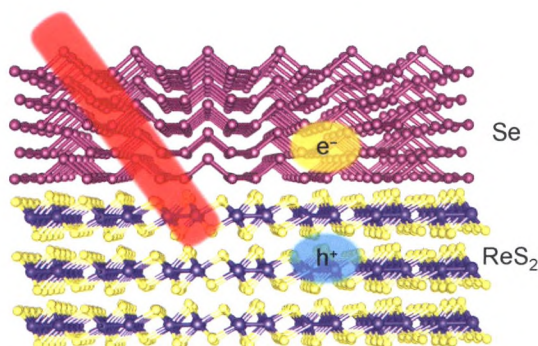
659–667

Hybrid dual-channel phototransistor based on 1D t-Se and 2D ReS₂ mixed-dimensional heterostructures

Jingkai Qin^{1,2}, Hang Yan¹, Gang Qiu², Mengwei Si², Peng Miao¹, Yuqin Duan², Wenzhu Shao³, Liang Zhen¹, Chengyan Xu^{1,*}, and Peide D Ye^{2,*}

¹ Harbin Institute of Technology, China

² Purdue University, USA



This work highlights that t-Se/ReS₂ hybrid structure might be a promising candidate for future high-performance optoelectronic devices.

669–674

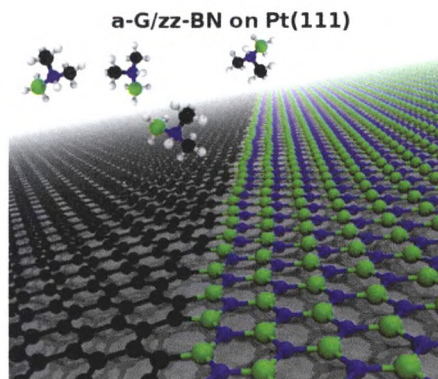
Microscopic insight into the single step growth of in-plane heterostructures between graphene and hexagonal boron nitride

Thanh Hai Nguyen¹, Daniele Perilli², Mattia Cattelan^{1,3}, Hongsheng Liu², Francesco Sedona¹, Neil A. Fox³, Cristiana Di Valentin², and Stefano Agnoli^{1,*}

¹ University of Padova, Italy

² Università di Milano-Bicocca, Italy

³ University of Bristol, UK



A variety of h-BN/graphene nanostructures can be obtained by the controlled decomposition of dimethylamino borane complex on the Pt(111) surface at different temperatures, which encompass B and N doped graphene layers, h-BN/graphene two-dimensional (2D) Janus quantum dots, and h-BN/graphene patchy layers. For the first time we report a quite unique 2D heterostructure where the graphene armchair edges are seamlessly connected to the h-BN zigzag edges.

675–682

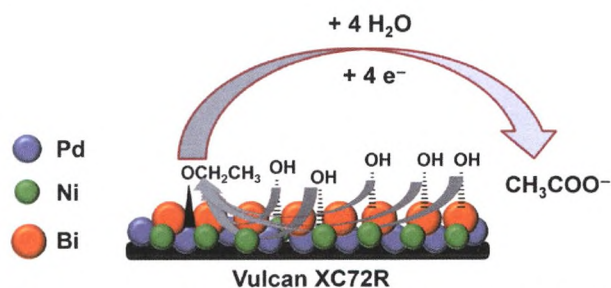
Novel highly active carbon supported ternary PdNiBi nanoparticles as anode catalyst for the alkaline direct ethanol fuel cell

Bernd Cermenek^{1,*}, Johanna Ranninger¹, Birgit Feketeöldi², Ilse Letofsky-Papst¹, Norbert Kienzl³, Brigitte Bitschnau¹, and Viktor Hacker^{1,*}

¹ Graz University of Technology, Austria

² JOANNEUM RESEARCH Forschungsgesellschaft mbH/Materials, Austria

³ Bioenergy 2020+ GmbH, Austria



The Ni-OH_{ads} and Bi-OH_{ads} species on carbon supported Pd₇₀Ni₂₀Bi₁₀ nanocatalyst facilitate the ethanol oxidation reaction (EOR) process to CH₃COO⁻ by bifunctional mechanism and also by oxidative removal of poisonous ethanol species from the catalyst surface. This results in a catalytic activity enhancement of Pd₇₀Ni₂₀Bi₁₀/C with lower onset potential (0.236 V) for alkaline EOR compared to Pd/C (0.280 V) and Pd₆₀Ni₄₀/C (0.290 V) nanocatalysts.

683–693

Spindle-like Fe₇S₈/N-doped carbon nanohybrids for high-performance sodium ion battery anodes

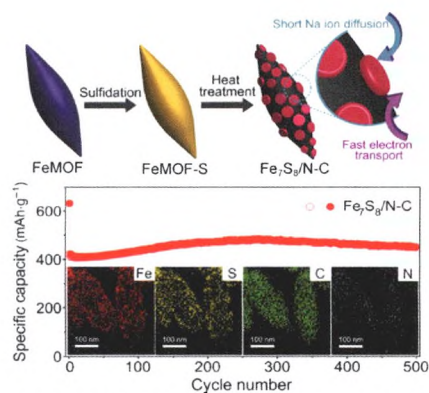
Aihua Jin^{1,2}, Mi-Ju Kim^{1,2}, Kug-Seung Lee³, Seung-Ho Yu^{1,2,†,*}, and Yung-Eun Sung^{1,2,*}

¹ Institute for Basic Science (IBS), Republic of Korea

² Seoul National University, Republic of Korea

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Spindle-like Fe₇S₈ with nitrogen-doped carbon (Fe₇S₈/N-C) nanohybrids are synthesized by using a metal organic framework and exhibit extremely high electrochemical properties as anode materials for sodium ion batteries. The reversible conversion reaction and surface reaction have been studied by X-ray absorption spectroscopy and X-ray photoelectron spectroscopy analyses.

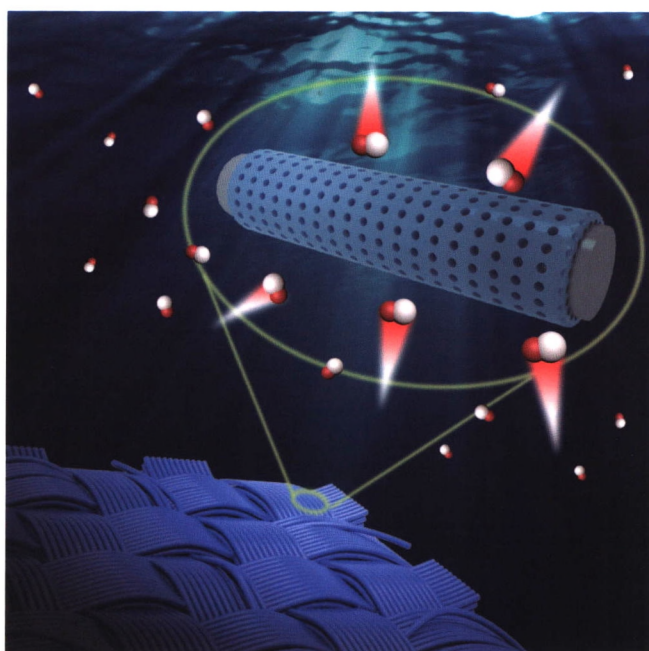
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