HARBIN INSTITUTE OF TECHNOLOGY
NEWSLETTER 2022 ISSUE 1

HIT TIMES

ACADEMICIAN LENG JINSONG'S RESEARCH ACHIEVEMENT SELECTED AS TEN MAJOR SCIENTIFIC AND TECHNOLOGICAL PROGRESS OF CHINA'S COLLEGES AND UNIVERSITIES

CHINA SPACE DAY 2022

HIT TIMES

Harbin Institute of Technology Newsletter
2022 ISSUE 1

HIT TIMES is a publication for alumni and friends of Harbin Institute of Technology, which is produced by the HIT Editorial Department of Journal. If you have any suggestions, please do not hesitate to contact us. We sincerely appreciate your wholehearted support.

Contents

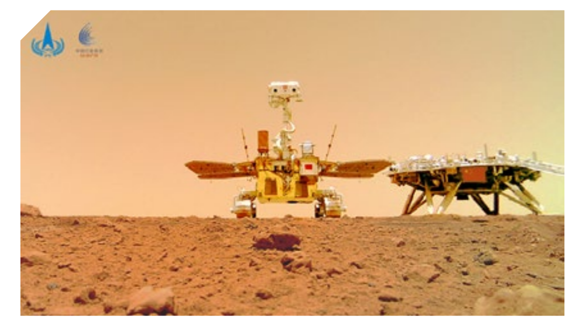
AWARDS & HONORS

ACADEMICIAN LENG JINSONG'S RESEARCH ACHIEVEMENT SELECTED AS TEN MAJOR SCIENTIFIC AND TECHNOLOGICAL PROGRESS OF CHINA'S COLLEGES AND UNIVERSITIES

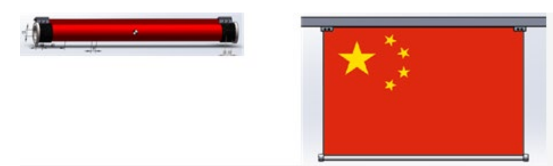
Recently, the list of Ten Major Scientific and Technological Progress of China's Colleges and Universities was announced by the Science and Technology Committee of the Ministry of Education. The "Shape-Memory Intelligent Deployment Structure Technology of Tianwen-1 Mars Probe" led by Harbin Institute of Technology was on the list.

The locking-deploying mechanism developed by Academician Leng Jinsong's team successfully completed the controlled dynamic deployment of China's national flag on the Tianwen-1 lander on May 15th, 2021, after a 202-day Earth-Mars transfer orbit flight and a 93-day Mars orbit exploration, making China the first country in the world to apply the intelligent structure based on shape memory polymer composites to deep space exploration projects.

In the future, the shape-memory intelligent deployable structure technology is expected to be applied to the space station, the lunar exploration project, the manned lunar landing, deep space exploration and other aerospace fields. It also has broad application prospects in the fields of aviation, robotics, intelligent manufacturing, medical devices, and transportation.



Picture from China National Space Administration



The locking-deploying mechanism releases and deploys China's national flag; the left picture shows the locking state, and the right picture shows the deploying state.

PROFESSOR HUANG YUDONG WON THE GUANGHUA ENGINEERING SCIENCE AND TECHNOLOGY PRIZE

On May 30th, the 16th Academician Conference of the Chinese Academy of Engineering was held in Beijing, at which the list of winners of the 14th Guanghua Engineering Science and Technology Prize was announced. Professor Huang Yudong from the School of Chemistry and Chemical Engineering was on the list.

Professor Huang has been engaged in the research of composite material, chemical engineering, ultimate tensile strength, epoxy, and fiber. His team has broken through a series of key core technologies, developed a number of new chemical materials, and won two second prizes of the National Technological Invention Award and four first prizes of the provincial and ministerial Science and Technology Award, etc.

The Guanghua Engineering Science and Technology Prize was initiated by the Chinese Academy of Engineering, approved by the National Science and Technology Award Office, and managed by the Guanghua Engineering Science and Technology Prize Foundation. It is an important award in China's engineering science and technology industry. It aims to reward Chinese engineers and scientists who have made important contributions in the field of engineering science and technology and encourages enthusiasm and creativity in engineering science and technology research, development, and application. Since 1996, more than 300 experts and one group in different engineering disciplines have won this award.

Picture from Xinhua News

HIT STUDENT WON AWARD IN BEIJING WINTER OLYMPICS AND PARALYMPICS REVIEW AND AWARDS CEREMONY

On April 8th, a ceremony was held in Beijing at the Great Hall of the People to honour those who have made outstanding contributions to the Beijing 2022 Winter Olympics and Paralympics. President Xi Jinping, also general secretary of the Communist Party of China (CPC) Central Committee and chairman of the Central Military Commission, delivered a speech.

Xi said that a great cause nurtures a great spirit, and a great spirit promotes a great cause. The participants in the Games cherished the opportunity presented by

Picture from Xinhua News: The first recipient is HIT's PhD student Qi Guangpu.

HIT's PhD student Qi Guangpu, HIT's PhD student Jia Zongyang and their teammate Xu Mengtao won the silver medal in the freestyle skiing air skills mixed team.

HIT's PhD student Qi Guangpu won the championship in the men's air skills final of freestyle skiing.

the great era, and in the process of bidding, organizing and hosting the Games, they have created the spirit of bearing in mind the big picture, being confident and open, rising to the challenges, pursuing excellence, and creating a better future together. Xi called for carrying forward the spirit of the Games and forging ahead more confidently and more determinedly toward the second centenary goal and toward the Chinese Dream of national rejuvenation.

The CPC Central Committee and the State Council decided to award 148 groups and 148 individuals for their outstanding contributions to the Beijing Winter Olympics and Paralympics.

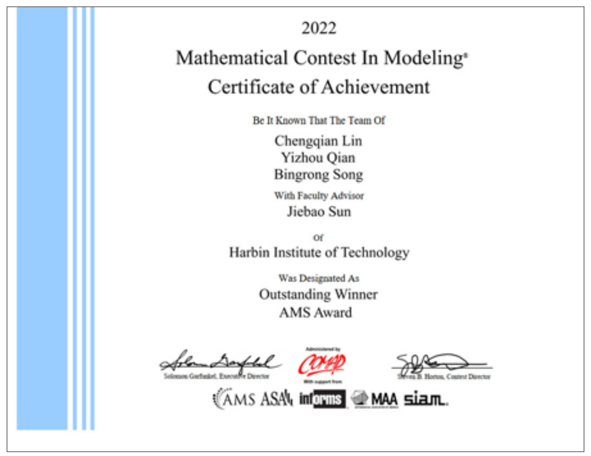
PhD student Qi Guangpu from the School of Astronautics, athlete of the national freestyle skiing aerial skills team, won the outstanding contribution award for individuals. On the evening of February 16th, in the men's air skills final of freestyle skiing at the Beijing Winter Olympic Games, Qi Guangpu, who had competed four times in the Winter Olympic Games, won the gold medal with a score of 129.00, realizing his goal as "Grand Slam".

Awards & Honors
HIT TIMES 2022

HIT STUDENTS WON OUTSTANDING ACHIEVEMENTS IN MCM/ICM 2022

Recently, the results of the 2022 Mathematical Contest in Modeling / The Interdisciplinary Contest in Modeling (MCM/ICM) were announced. HIT students won one special prize in the competition (the winning rate in 2022 is about 0.16%), six nominations for special prizes, 19 first prizes, and 69 second prizes, a total of 95 winners, creating our best performance in this competition in history.

A total of 27,205 teams from 22 countries and regions participated in the competition. The content of the competition involves scientific research, engineering application, and hot issues in real life and has a wide range of practical background and application value. The HIT team that won the special prize was composed of three sophomores, Lin Chengqian from the Honors School of HIT, Qian Yizhou from the School of Environment, and Song Bingrong from the School of Astronautics. The faculty advisor was Professor Sun Jiebao from the School of Mathematics.


2022
Mathematical Contest In Modeling®
Certificate of Achievement
Be It Known That The Team Of
Chengqian Lin
Yizhou Qian
Bingrong Song
With Faculty Advisor
Jiebao Sun
of
Harbin Institute of Technology
Was Designated As
Outstanding Winner
AMS Award

Before the competition, the School of Mathematics set up a special group of instructors and held several special lectures and training sessions to explain in detail the construction and solution methods of various basic models, the programming application of open source computing software and the key points for participation, which provided important support for students.

A VISCOELASTIC CONSTITUTIVE MODEL FOR SHAPE MEMORY POLYMER COMPOSITES: MICROMECHANICAL MODELING, NUMERICAL IMPLEMENTATION AND APPLICATION IN 4D PRINTING

Academician Leng Jinsong's team, from the Center for Composite Materials and Structures at Harbin Institute of Technology, published a research paper titled "A Viscoelastic Constitutive Model for Shape Memory Polymer Composites: Micromechanical Modeling, Numerical Realization and Application in 4D Printing" in *Mechanics of Materials*, an internationally renowned journal in the field of mechanics. The research team proposed a novel micromechanics-based thermo-viscoelastic constitutive model for shape memory polymer composites (SMPCs), which was implemented in the finite element software ABAQUS to enable mechanical simulations of 4D printed fiber-reinforced composites.

Thermotropic shape memory polymers (SMPs) are a kind of active materials that can sense external temperature changes and produce an autonomous deformation response, which are characterized by severe deformability, variable stiffness, and shape memory effects. SMPC, composed of SMP and other reinforcing phases such as carbon nanotubes, metal micro-nanoparticles, chopped fibers, or long fibers, tends to exhibit extreme anisotropic thermodynamic behavior, prompting researchers to seek new modeling approaches to describe this anisotropic behavior of SMPCs. However, in most of the constitutive models, the contributions of the reinforcing phases to the thermodynamic properties of SMPCs are considered simply by the volume averaging method, failing to model the interactions and interfacial effects between the matrix and the reinforcing phases.

In this study, a viscoelastic constitutive model based on micromechanics is derived for SMPC composed of SMP matrix and elliptical inclusions. For the composite composed of the matrix and multiple inclusions, we assume that the interface between each type of inclusion and the matrix is imperfect. The imperfect interface is simulated as a linear spring layer with no thickness, which has continuous traction but discontinuous displacement field (Figure 1). The multi-branch constitutive model is used to simulate the time- and temperature-dependent mechanical behavior of SMP matrix. According to the elastic–viscoelastic correspondence principle, the equivalent viscoelastic stiffness tensor of the composite is obtained in the micromechanics framework of energy-based effective strain theory and the Mori-Tanaka homogenization scheme.

The numerical integration scheme for the viscoelastic constitutive model of SMPCs is presented, and the finite element application is implemented by writing a user material (UMAT) subroutine of ABAQUS. After identifying the model parameters with experimental data, the tensile stress-strain curves and stress relaxation phenomena of 4D printed unidirectional SMPCs are successfully described by theoretical simulations. These theoretical simulations also adequately predict the shape memory behavior of 4D printed composites and complex members (Figure 2).■

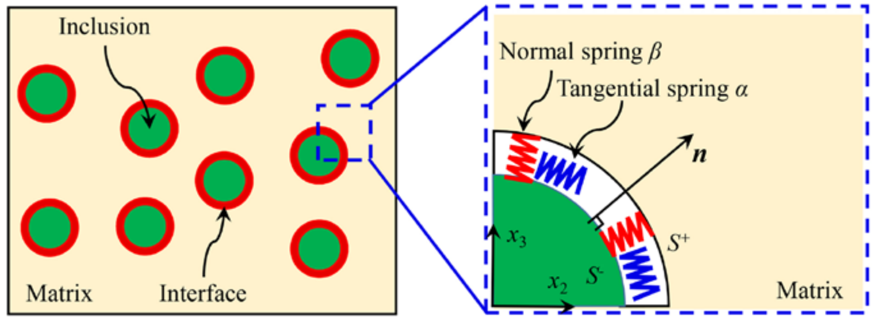


Figure 1 Schematic of the interface spring model

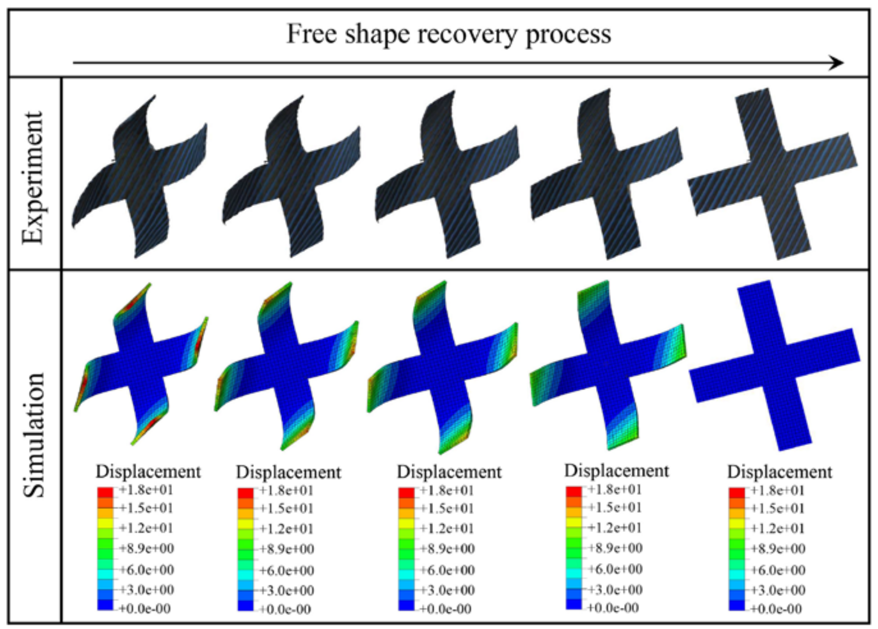


Figure 2 Experiments and theoretical simulations for the free shape recovery process of 4D printed cross-shaped SMPC member

REFERENCE

Chengjun Zeng, Liwu Liu, Yunqiang Hu, Wenfeng Bian, Jinsong Leng, Yanju Liu. A viscoelastic constitutive model for shape memory polymer composites: micromechanical modeling, numerical implementation and application in 4D printing. Mechanics of Materials, 2022, 169: 104301. DOI: 10.1016/j.mechmat.2022.104301

Research & Academia
HIT TIMES 2022

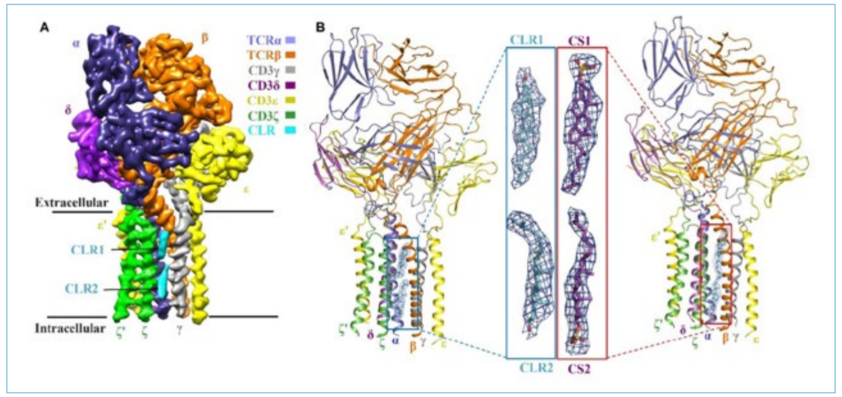
CHOLESTEROL INHIBITS TCR SIGNALING BY DIRECTLY RESTRICTING TCR-CD3 CORE TUNNEL MOTILITY

Recently, Professor Huang Zhiwei's group from the HIT Center for Life Sciences, revealed the Cryo-EM structures of cholesterol-inhibited and auto-active TCR-CD3. This work provides a structural basis for understanding the inhibition mechanism of TCR and cholesterol. The related research article titled "Cholesterol Inhibits TCR Signaling by Directly Restricting TCR-CD3 Core Tunnel Motility" was published in *Molecular Cell*.

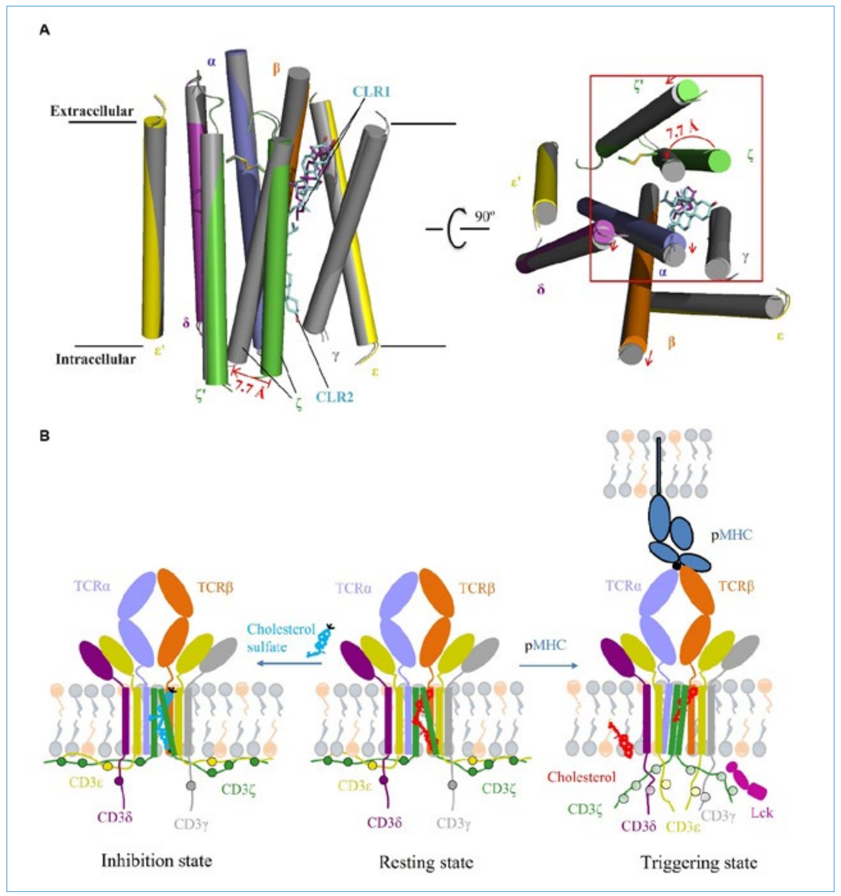
T cells are important cells of vertebrate adaptive immunity and play key roles in viral infections, cancer, and autoimmune diseases. T cells specifically recognize antigens through their T cell receptor complexes (TCR-CD3) and then transmit extracellular antigen recognition signals across the membrane to activate intracellular immune signaling pathways, thereby initiating immune responses. In 2019, Huang's group published a paper titled "Structural Basis of Assembly of the Human TCR-CD3 Complex" in *Nature*. The research article analyzed the high-resolution cryo-electron microscope (cryo-EM) structure of the human T cell receptor complex (including all 8 subunits) for the first time, revealing that the molecular mechanism of the TCR-CD3 subunit recognizes and assembles into functional complexes outside and inside the membrane. But until now, the mystery of the structural basis behind the key mechanism by which T cell receptors transmit extracellular antigen signals into the cell and activate T cells has not been solved.

In this work, Huang's team presents cryo-EM structures of cholesterol (CLR)- and cholesterol sulfate (CS)-inhibited TCR-CD3 complexes and an auto-active TCR-CD3 variant. The structures reveal that cholesterol molecules act like a latch to lock CD3ζ into an inactive conformation in the membrane. Mutations impairing binding of cholesterol molecules to the tunnel result in the movement of the proximal C terminus of the CD3ζ transmembrane helix, thereby are activating the TCR-CD3 complex in human cells. This work provides a structural basis for understanding the inhibition mechanism of TCR by CLR. More importantly, capturing an active conformation of full-length TCR-CD3 for the first time provides important insights into TCR triggering. The information would be valuable for the development of effective immunotherapies against the TCR-CD3 complex through the direct modulating of its activity.

This research was financially supported by the National Natural Science Foundation of China and the Heilongjiang Touyan Innovation Team Program.



Cryo-EM structure of the CS-bound TCR-CD3 complex



Structural comparison of auto-active TCR-CD3 with wild type TCR-CD3 (A) and the working model for TCR-CD3 triggering (B).

REFERENCE

Yan Chen, Yuwei Zhu, Xiang Li, Wenbo Gao, Ziqi Zhen, De Dong, Buliao Huang, Zhuo Ma, Anqi Zhang, Xiaocui Song, Yan Ma, Changyou Guo, Fan Zhang, Zhiwei Huang. Cholesterol inhibits TCR signaling by directly restricting TCR-CD3 core tunnel motility. Molecular Cell, 2022, 82(7):1278-1287. DOI: 10.1016/j.molcel.2022.02.017

Research & Academia
HIT TIMES 2022

A 2-YEAR LOCOMOTIVE EXPLORATION AND SCIENTIFIC INVESTIGATION OF THE LUNAR FARSIDE BY THE YUTU-2 ROVER

Recently, Professor Ding Liang, from the Key State Laboratory of Robotics and System, Harbin Institute of Technology, collaborating with researchers from the Beijing Aerospace Control Center, the State Key Laboratory of Remote Sensing Science, Aerospace Information Research Institute, Chinese Academy of Sciences, the China Academy of Space Technology, the Ryerson University, etc., published a paper titled "A 2-Year Locomotive Exploration and Scientific Investigation of the Lunar Farside by the Yutu-2 Rover" in the high impact international journal *Science Robotics* and was selected as the cover story.

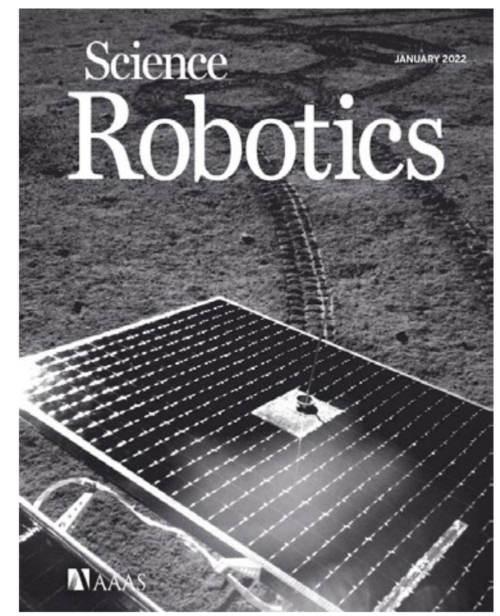


Figure 1 Wheel imprints of the Yutu-2 rover (the cover of the *Science Robotics*)

The lunar nearside has been investigated by many unmanned and manned missions, but the farside of the Moon remains poorly known. Lunar farside exploration is challenging because maneuvering rovers with efficient locomotion in harsh extraterrestrial environments is necessary to explore geological characteristics of scientific interest. Chang'e-4 mission successfully targeted the Moon's farside and deployed a teleoperated rover (Yutu-2) to explore inside the Von Kármán crater, conveying rich information regarding regolith, craters, and rocks.

In this work, researchers report mobile exploration on the lunar farside with Yutu-2 over the initial two years. During its journey, Yutu-2 has experienced varying degrees of mild slip and skid, indicating that the terrain is relatively flat at large scales but scattered with local gentle slopes. Cloddy soil sticking on its wheels implies a greater cohesion of the lunar soil than encountered at other lunar landing sites. Further identification results indicate that the regolith resembles dry sand and sandy loam on Earth in bearing properties, demonstrating greater bearing strength than that identified during the Apollo missions. In sharp contrast to the sparsity of rocks along the traverse route, small fresh craters with unilateral moldable ejecta are abundant, and some of them contain high-reflectance materials at the bottom, suggestive of secondary impact events.

These findings hint at notable differences in the surface geology between the lunar farside and nearside. Experience gained with Yutu-2 improves the understanding of the farside of the Moon, which, in return, may lead to locomotion with improved efficiency and larger range.

Professors Ding Liang, Gao Haibo from HIT, and Yu Tianyi from BACC are the corresponding authors. This work was financially supported by the National Natural Science Foundation of China and the National Key Research and Development Program of China.

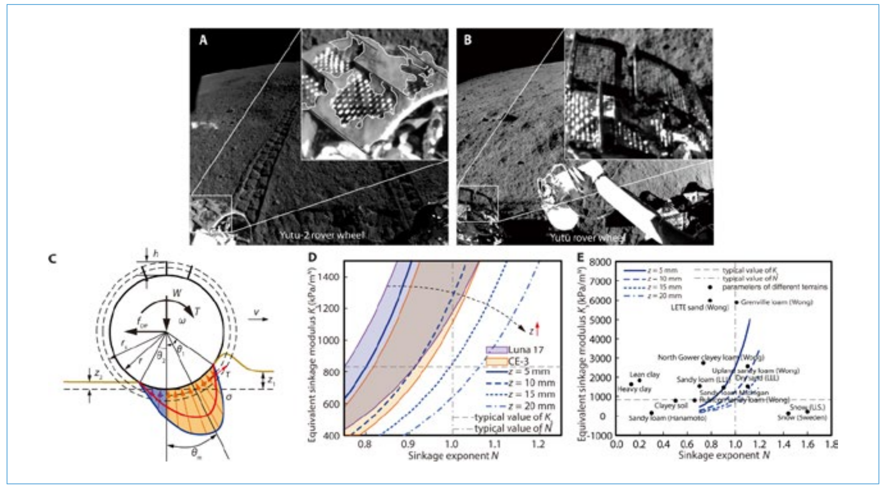


Figure 2 Mechanical property analysis of the lunar regolith based on the wheel-terrain interaction of the Yutu-2 rover

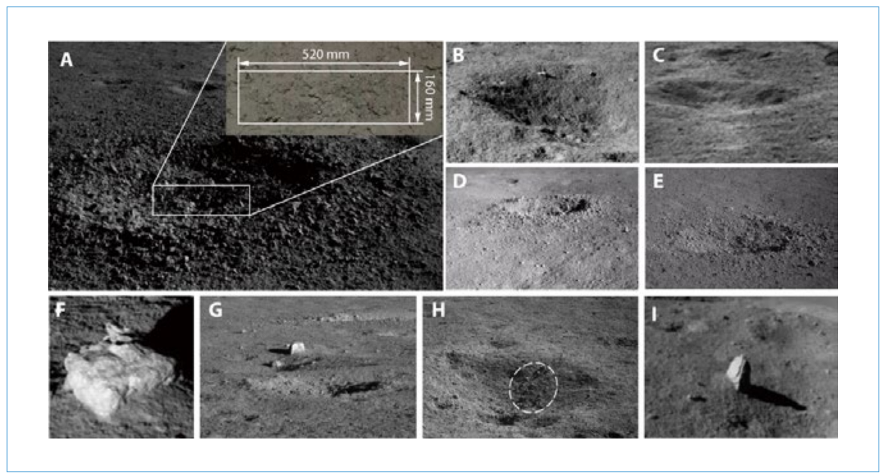


Figure 3 Craters and rocks encountered by Yutu-2 along the traversed route

REFERENCE

Liang Ding, Ruyi Zhou, Ye Yuan, Huaiguang Yang, Jian Li, Tianyi Yu, et al. A 2-year locomotive exploration and scientific investigation of the lunar farside by the Yutu-2 rover. Science Robotics, 2022, 7, abj6660. DOI: 10.1126/scirobotics.abj6660

Research & Academia
HIT TIMES 2022

FUNCTIONAL ARTIFICIAL TISSUES CAPABLE OF PRODUCING NO FOR VASODILATION

Professor Han Xiaojun's group from the State Key Laboratory of Urban Water Resource and Environment, the School of Chemistry and Chemical Engineering, has made significant progress on tissue mimics based on their strong background in artificial cells. The research article "High-Throughput Production of Functional Prototissues Capable of Producing NO for Vasodilation" was recently published in *Nature Communications*.

Natural tissues are composed of multiple cells, which exhibit collective behaviors by internal communications. The bottom-up construction of prototissues helps us understand the internal working mechanism of natural tissue and has potential in tissue repair. The construction of prototissues and their biomedical applications are still in their infancy stage,

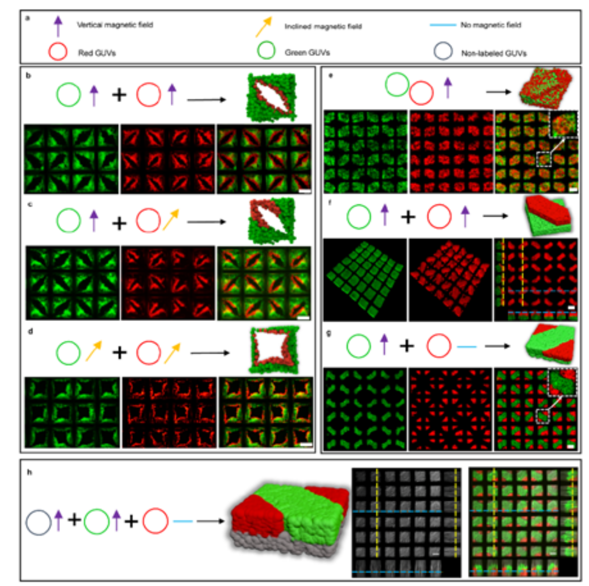


Figure 1 Diverse multicomponent spatial programmed prototissues

lacking high-throughput controllable preparation methods. Moreover, the existed prototissues lack physiological functions.

Targeting these challenges, Professor Han Xiaojun's group fabricated spatially coded prototissues using artificial cells (phospholipid vesicles) as assembly units based on the magnetic Archimedes effect in a high-throughput manner. The method is simple and efficient. More than 2,000 prototissues can be prepared within two hours. By varying the addition giant unilamellar vesicles order/number and the magnetic field distributions, a variety of prototissues with specific spatially coded structures were obtained (Figure 1). Prototissues have similar characteristics of collective behaviors and signal communications with natural tissues. Under hypotonic and hypertonic conditions, the prototissues exhibited collective expansion and contraction behaviors. Signals can be exchanged within the prototissues. Through the cascade reactions of glucose oxidase and horseradish peroxidase in artificial cells, binary and ternary signal communications were realized in the prototissues. The research group further prepared prototissues with the function of nitric oxide generation (Figure 2). Through the vascular ring experiments, the prototissues were proven to induce vasodilation and improve vascular function, which holds potential to treat cardiovascular diseases (Figure 3). This work may find great potential in biomedical fields, including tissue engineering.

The paper was financially supported by the National Natural Science Foundation of China.

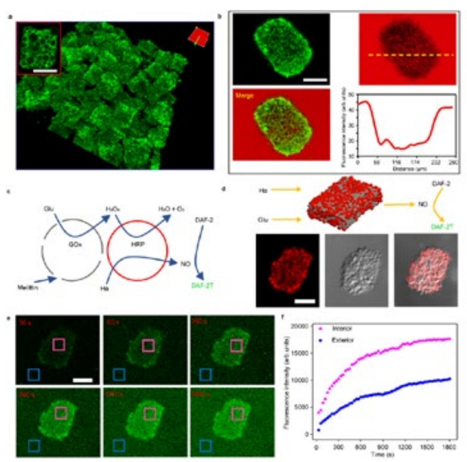


Figure 2 Prototissues capable of producing nitric oxide

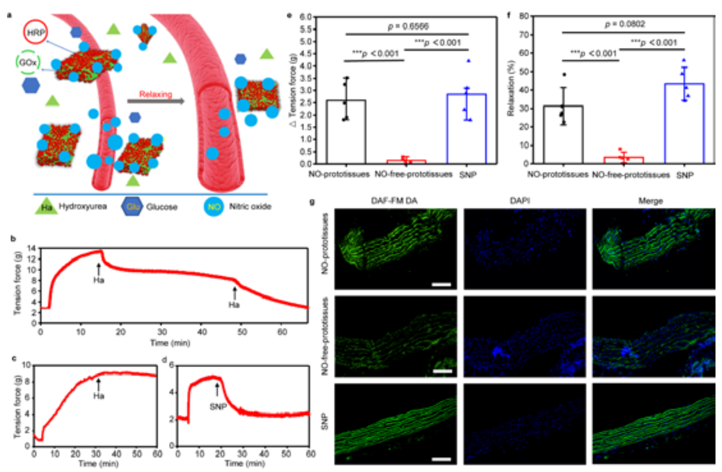


Figure 3 Nitric oxide generating prototissues for vasodilation

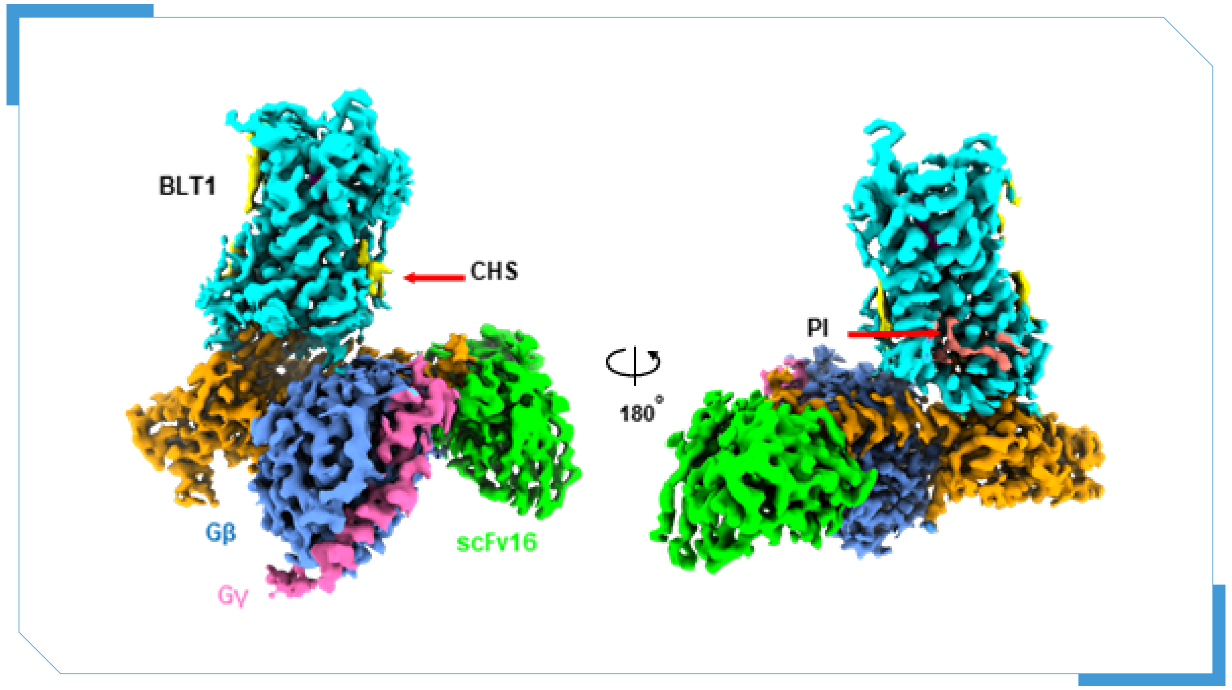
REFERENCE

Xiangxiang Zhang, Chao Li, Fukai Liu, Wei Mu, Yongshuo Ren, Boyu Yang, Xiaojun Han. High-throughput production of functional prototissues capable of producing NO for vasodilation. Nature Communications, 2022, 13, 2148. DOI: https://doi.org/10.1038/s41467-022-29571-3

HIT TEAM REVEALED MECHANISM OF LEUKOTRIENE RECEPTOR ACTIVATION VIA CRYO-EM

Dr. He Yuanzheng's group at the HIT Center for Life Science (HCLS) recently reported the cryo-electron microscopy (cryo-EM) structure of LTB4-bound human BLT1 in complex with a G_i protein in an active conformation at a resolution of 2.91 Å. This result was published in *Nature Communications*.

Leukotrienes, metabolic products of arachidonic acid, are key initiators of inflammatory response and play crucial roles in the immune defense system. Leukotrienes exert their physiological functions by binding and activating leukotriene receptors, which in turn start a series of signal transduction events to generate immune responses against outside invasion.



The cryo-EM structure of LTB4-bound BLT1 in complex with G_i protein.

Leukotrienes receptors are attractive targets for anti-inflammation treatments but the development of novel anti-leukotriene is heavily impeded by the lack of mechanistic insight into leukotriene receptor activation. For this reason, Dr. He's group resolved the cyro-EM structure of active leukotriene receptor in complex with a G_i protein. In combination of molecule dynamics (MD) simulation, docking, and site-directed mutagenesis, the structure reveals the molecular determinant of LTB4 binding and the key mechanism of receptor activation. In addition, the structure also reveals a novel allosteric binding site of phosphatidylinositol (PI) and discovers that the widely open ligand binding pocket may contribute to the lack of specificity and efficacy of current BLT1-targeting drug design. To summarize, the structural analysis provides a scaffold for understanding BLT1 activation and a rational basis for designing anti-leukotriene drugs.■

REFERENCES

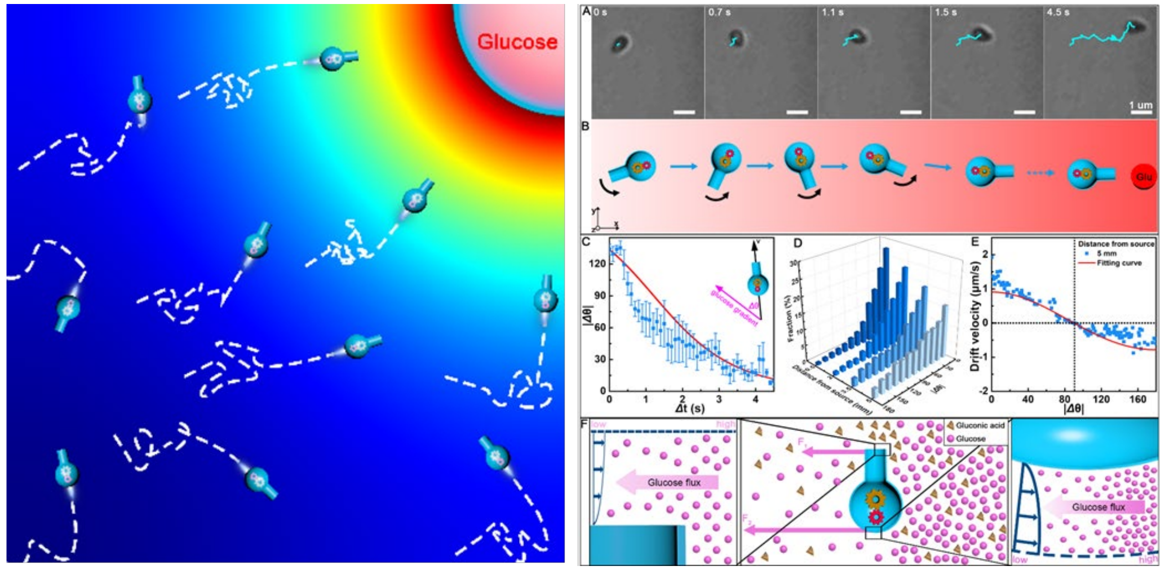
Wang N, He X, Zhao J, Jiang H, Cheng X, Xia Y, Eric Xu H, He Y. Structural basis of leukotriene B4 receptor 1 activation. Nature Communications, 2022, Mar 3;13(1):1156.

NEW PROGRESS ON THE BIOINSPIRED CHEMOTACTIC COLLOIDAL MOTORS

Professor He Qiang and Professor Wu Yingjie, from the Key Laboratory of Microsystems and Microstructures Manufacturing (Ministry of Education), School of Medicine and Health, in cooperation with Professor Yang Mingcheng from the Beijing National Laboratory for Condensed Matter Physics and Laboratory of Soft Matter Physics, Institute of Physics, Chinese Academy of Sciences, recently published a paper titled "Torque-Driven Orientation Motion of Chemotactic Colloidal Motors" in the journal of *Angewandte Chemie International Edition*.

Chemotactic motion plays an important role in the natural world of biological systems. For example, the microorganisms, such as *Escherichia coli*, can sense the glucose gradient in the solution and move towards the glucose-enriched area. Previous researches have theorized that the chemically driven colloidal motors can achieve true chemotaxis through self-orientational behavior just like the neutrophils, however, the existing experimental reports only showed the false chemotaxis, or aggregation, relying on the chemokinesis. At the same time, to realize the biomedical applications, such as active targeted delivery and cell surgery, colloidal motors must have the characteristics of a submicron scale, excellent fuel biocompatibility, and outstanding chemotactic ability. However, the motion behavior of colloidal motors with submicron scale is difficult to observe in real time, which limits the research on the mechanism of the chemotactic motion. Therefore, how to design and synthesize submicron colloidal motors with chemotactic ability that meets the future biomedical applications is still an urgent problem to be solved.

To overcome the above challenges, the research team designed and prepared bioinspired streamlined



colloidal motors with submicron scale and a round bottom flask shape inspired by the swimming and chemotaxis of the natural microorganisms. The flasklike colloidal motors can autonomously sense the glucose gradient and move toward the glucose-enriched area, showing the schooling chemotactic behavior similar to the bacterial colony. Based on the flasklike structure of the colloidal motors, the researchers tracked and recorded the whole process of the single flasklike colloidal motor sensing and orienting toward the glucose gradient and completing the positive chemotaxis under the optical microscope equipped with a high-speed camera. Combined with the physical analysis, theoretical calculation and mesoscale simulation of the experimental data, it is found that the gluconic acid produced by the enzyme catalyzed reaction in the flasklike colloidal motors dilutes the glucose gradient around the opening, and the resulted difference between the diffusiophoretic forces at the opening and bottom produced by the glucose gradient leads to the generation of a net self-diffusiophoretic torque. This torque can counteract the impact of molecular collision in the liquid and drive the colloidal motors complete the positive chemotaxis from the bottom to the opening.

This research has established the torque driven reorientation mechanism of the chemotaxis of the flasklike colloidal motors. Although it is different from the microscopic mechanism of chemotaxis of the natural bacteria, the flasklike colloidal motors can still imitate the chemotactic motion of the *Escherichia coli*, which provides an important theoretical and experimental basis for the design of chemically driven colloidal motors which can achieve directional motion. Furthermore, it also promotes the application of colloidal motors and swimming nanorobots in biomedical field.

REFERENCE

Chang Zhou, Changyong Gao, Yingjie Wu, Tieyan Si, Mingcheng Yang, Qiang He. Torque-driven orientation motion of chemotactic colloidal motors. Angewandte Chemie International Edition, 2022, 61, e202116013. DOI: 10.1002/anie.202116013

BREAKTHROUGH RESEARCH ON METAL-OXIDE CLUSTER MATERIALS

Recently, the research group of Professor Fang Xikui, from the School of Chemistry and Chemical Engineering at HIT, has developed innovative metal-oxide cluster materials that are tailored for different uses. In two papers published in the journal *Angewandte Chemie International Edition*, titled "Metal-Organic Cages with SiW_9Ni_4 Polyoxotungstate Nodes" and "Macrocyclic Polyoxometalates: Selective Polyanion Binding and Ultrahigh Proton Conduction", they designed two different sets of inorganic polyoxometalates and demonstrated their highly effective applications in photocatalytic CO_2 reduction and proton conduction. Both peer-reviewed articles were selected as hot papers by the journal.

To promote selective catalysis in confined space, the researchers designed a set of five discrete cage structures with defined interior voids (Figure 1). The design principle makes use of the directional, coordination-driven assembly of a tritopic polyoxotungstate cluster, $\{SiW_9Ni_4\}$, and rigid dicarboxylate linkers. This allows the shape/size of the internal cavities of these cages to be controlled by bend angles of the ditopic ligands. These porous molecular materials, when coupled with $[Ru(bpy)_3]Cl_2$ as a photosensitizer and triethanolamine as the electron donor, serve as highly effective catalysts for CO_2 reduction, with turnover numbers up to 328 and CO selectivity as high as 96.2%.

Apart from coordination assembly, the group

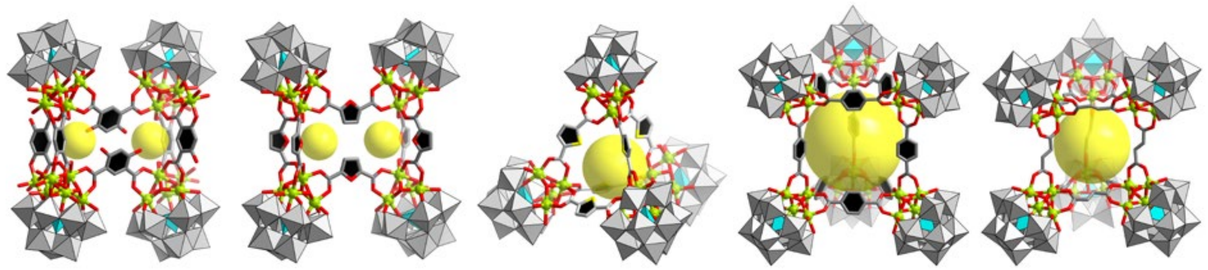


Figure 1 A set of five molecular cage structures that are highly effective catalysts for photocatalytic CO_2 reduction

also took advantage of the supramolecular interactions in their design of a $\{Mo_{22}Fe_8\}$ macrocycle by using a polyoxtungstate anion $\{P_5W_{30}\}$, as a supramolecular template via hydrogen bonds. The $\{Mo_{22}Fe_8\}$ macrocycle displays selective anion binding behavior in solution. In the solid state, the 1:2 host–guest complex $\{P_5W_{30}\}_2 \subset \{Mo_{22}Fe_8\}$ (Figure 2) very effectively transports protons through an extended hydrogen-bonding network. As a result, it displays ultrahigh proton conductivities, reaching 1.7×10^{-2} S cm^{-1} at 368 K and 90% RH.

The results highlight the great potential of inorganic metal-oxide clusters for applications in a wide range of areas, including photocatalysis, selective anion recognition, and proton conduction. Importantly, these molecular materials are high soluble, and thus they could be processed into different forms for diverse purposes.

Ph.D. students Chang Qing and Zhu Minghui from

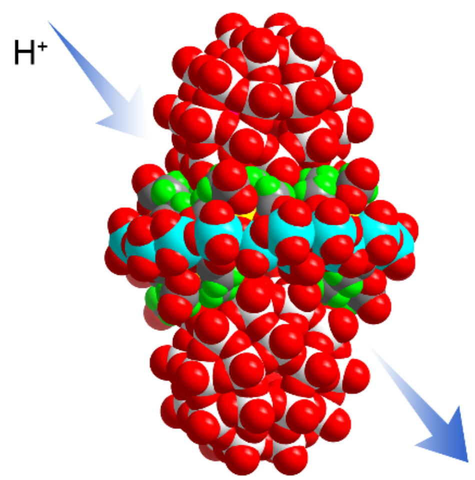


Figure 2 The 1:2 host–guest complex $\{P_5W_{30}\}_2 \subset \{Mo_{22}Fe_8\}$ displays ultrahigh proton conductivity in the solid state.

Professor Fang's group are the first authors of the two papers. The work was supported by the National Natural Science Foundation of China and the Heilongjiang Touyan Innovation Team Program.

REFERENCE

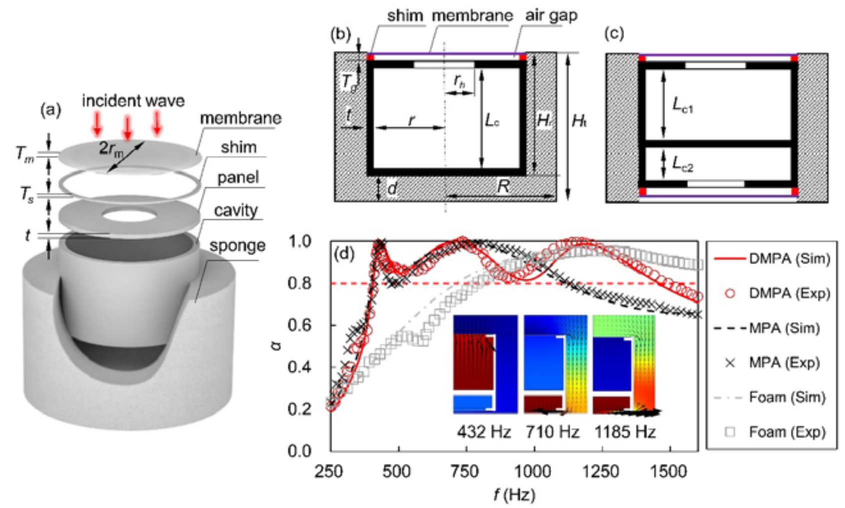
Chang Qing, Meng Xiangyu, Ruan Wenjun, Feng Yeqing, Li Rui, Zhu Jiayu, Dingyong, Lv Hongjin, Wang Wei, Chen Guanying, Fang Xikui. Metal-organic cages with SiW_9Ni_4 polyoxotungstate nodes. Angewandte Chemie International Edition, 2022, 61, e202117637.

Zhu Minghui, Iwano Tsukasa, Tan Mengjin, Akutsu Daiki, Uchida Sayaka, Chen Guanying, Fang Xikui. Macrocyclic polyoxometalates: selective polyanion binding and ultrahigh proton conduction. Angewandte Chemie International Edition, 2022, 61, e202200666.

MULTI SYNERGISTIC COUPLING DESIGN FOR BROADBAND SOUND ABSORPTION BASED ON COMPACT POROUS COMPOSITE EMBEDDED WITH MASSLESS MEMBRANE RESONATOR

In 2022, Professor Li Longqiu, from the State Key Laboratory of Robotics and System of Harbin Institute of Technology, published a paper titled "Multi Synergistic Coupling Design for Broadband Sound Absorption Based on Compact Porous Composite Embedded with Massless Membrane Resonator" in *Composite Structures*.

Broadband sound absorption within medium and low frequencies is of significant interest to scientific research and engineering applications. However, it is hard to achieve a broadband sound absorption within low-frequency range based on traditional porous materials. Aiming at the poor absorption of metaporous below the quarter-wavelength resonance frequency, a novel metaporous featuring with continuous high absorption within low-frequency range was proposed based on multi synergistic coupling



(a) 3D Perspective schematic of MPA
(b) 2D cross-sectional view of MPA
(c) 2D cross-sectional view of DMPA
(d) Absorption results of MPA, DMPA and the porous materials

effects in this work.

On account of abundant adjustable parameters and coupling effects with porous domain, the massless membrane resonator absorber was firstly designed as inclusion and embedded in polyurethane foam to form a metaporous absorber (MPA). Then, a developed metaporous absorber (DMPA) was designed step by step to achieve broadband absorption. The predicted and experimental results both indicate that an average absorption coefficient of 90% within 400-1500 Hz can be achieved, with the sample thickness of only 60 mm. Both weak and strong synergistic coupling between the porous materials and MMRA are found to form multi-wideband quasi-perfect absorption peaks. Broadband and low-frequency characteristics, as well as the flexible adjustability, make our design very promising in practical noise control engineering.

Professor Li Longqiu and Associate Professor Qiao Jing are the corresponding authors of this research paper; PhD student Xu Qishan is the first author. This research was supported by the National Natural Science Foundation of China, the Open Foundation from National Key Laboratory of Materials Behavior and the Evaluation Technology in Space Environments and Postdoctoral Scientific Research Developmental Fund of Heilongjiang Province.

REFERENCE

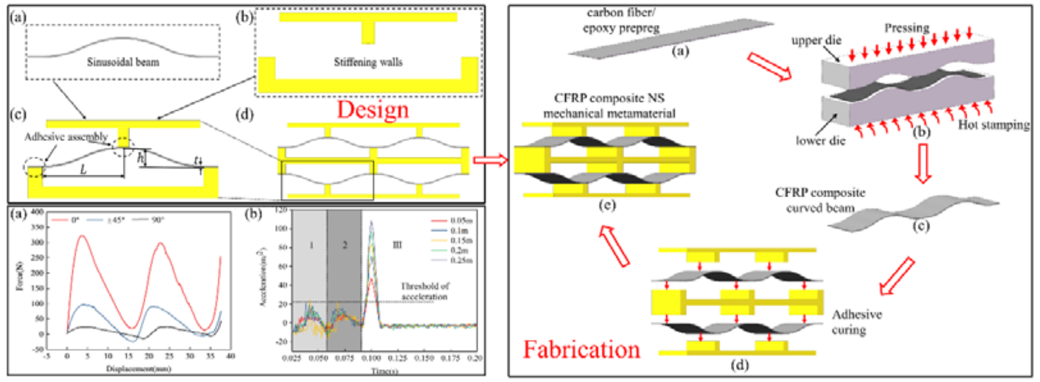
Qishan Xu, Jing Qiao, Zhuang Ren, Jiayue Sun, Guangyu Zhang, Longqiu Li. Multi synergistic coupling design for broadband sound absorption based on compact porous composite embedded with massless membrane resonator. Composite Structures, 2022, 286, 115312. DOI: https://doi.org/10.1016/j.compstruct.2022.115312

CONTINUOUS CARBON FIBER REINFORCED COMPOSITE NEGATIVE STIFFNESS MECHANICAL METAMATERIAL FOR RECOVERABLE ENERGY ABSORPTION

In 2022, Professor Wang Bing, from the Center of Composite Materials and Structures, Harbin Institute of Technology, and his Ph.D. student reported their recent progress on high-performance negative stiffness (NS) mechanical metamaterials and published a research paper titled "Continuous Carbon Fiber Reinforced Composite Negative Stiffness Mechanical Metamaterial for Recoverable Energy Absorption" in *Composite Structures*.

Considering the low specific energy absorption in traditional NS mechanical metamaterials, a team led by Professor Wang proposed and investigated a novel reusable composite negative stiffness structure made from continuous CFRP composite. A series of experimental specimens have been fabricated using a hot press molding method. The quasi-static mechanical characteristics of the CFRP composite NS mechanical metamaterial were investigated using experimental and finite element simulation approaches. The analysis indicates that the experimental measurements and numerical simulations exhibit a good quantitative agreement in terms of force-displacement curves and energy absorption, and the maximum energy absorption error of the CFRP composite NS mechanical metamaterial is no more than 25%. Besides, reusability of the CFRP composite NS mechanical metamaterial was also verified by 30 cyclic loading-unloading tests.

The results show that the proposed structure possesses good reusability because there is almost no unpredictable local plastic deformation throughout the whole loading process. The effect of the structural parameters on the mechanical properties of CFRP composite NS mechanical metamaterial was then investigated by using the experimentally verified numerical model. The numerical



Design, fabrication, and characterization of CFRP composite NS mechanical metamaterial for recoverable energy absorption

results reveal that the increase of *t* and *h* can improve the specific energy absorption of the structure, and the energy absorption per mass is more sensitive to the increase of *t*. The experimentally verified numerical model was also employed to investigate the mechanical properties of CFRP composite NS mechanical metamaterial with various stacking sequence, and the correctness of the curved beams adopted 0° stacking sequence in this paper was verified.

The cushion performance of the CFRP composite NS mechanical metamaterial was also explored by carrying out plate-impact tests. The results of impact tests indicate that the negative stiffness behavior of the curved beam in the uncompressed structure can effectively reduce the peak acceleration response and response time, thereby providing good cushioning performance. In short, the results of cushioning energy absorption verify the advantages of the CFRP composite NS mechanical metamaterial studied in this paper in terms of dynamics, showing an exciting engineering application prospect. Nevertheless, the asymmetric buckling of curved beams affects the energy absorption and cushion performance. Thus, there are still some challenges in the development of NS mechanical metamaterial. However, our work is helpful for promoting the NS mechanical metamaterial applications where excellent load-bearing and energy absorption capacities are simultaneously desired. Finally, the present work inspires a new strategy for the design of impact-resistant metamaterials.

Professor Wang Bing is the corresponding author. His Ph.D. student, Dr. Chen Shuai, is the first author. This work was supported by the National Natural Science Foundation of China.■

REFERENCE

Shuai Chen, Xiaojun Tan, Jiqiang Hu, Bing Wang, Lianchao Wang, Yajun Zou, Linzhi Wu. Continuous carbon fiber reinforced composite negative stiffness mechanical metamaterial for recoverable energy absorption. Composite Structures, 2022, 288:115411.

RESEARCHERS REVEAL 3D STRUCTURE AND EVOLUTION OF MAGNETIC ISLANDS IN A FAST MAGNETIC RECONNECTION

Magnetic reconnection is an important process of energy release on the Sun, which changes magnetic energy into heat, particle acceleration, and radiation energy. It exists universally in astrophysical, space, and laboratory plasma. However, the detailed process of magnetic reconnection is still not clear.

Recently, a collaborative team led by Yan Xiaoli, from Yunnan Observatories (corresponding author), and Jiang Chaowei, from Harbin Institute of Technology (corresponding author), with researchers from University of Potsdam, University of St Andrews, National Astronomical Observatories of CAS published a paper titled “Fast Plasmoid-Mediated Reconnection in a Solar Flare” in *Nature Communications*. For the first time, scientists found the formation of magnetic islands with the twisted structure in the current sheet during the fast magnetic reconnection of a solar flare.

Using high temporal and spatial resolution observations of the New Vacuum Solar Telescope (NVST), combined with UV and EUV images and vector magnetograms observed by SDO (Solar Dynamics Observatory), spectra from Hinode, as well as the X-ray data from RHESSI and GOES, scientists studied in detail the process of the

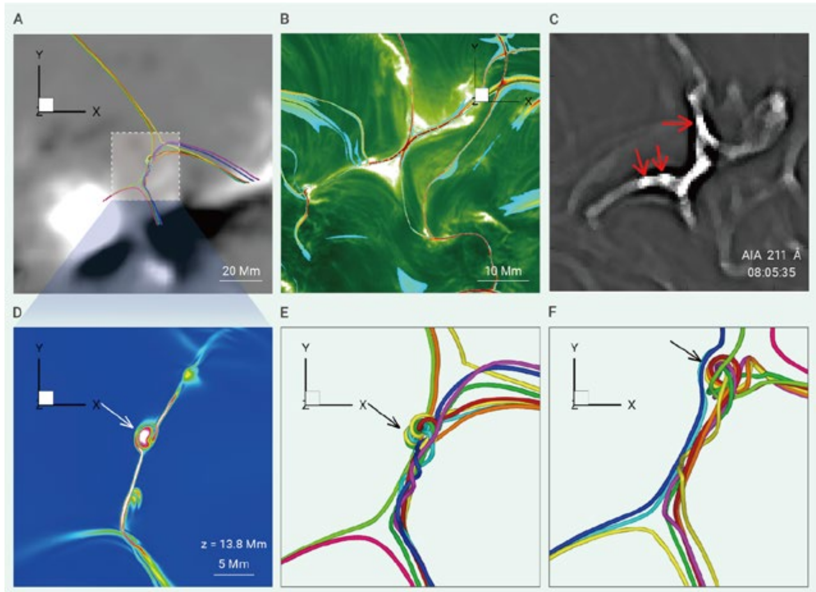


Figure 1 Detailed process of the fast magnetic reconnection revealed by the observations of NVST, SDO and data-driven simulation

magnetic reconnection during a confined solar flare in active region NOAA 11967 in early 2014. They found that the magnetic reconnection occurred between a twisted magnetic flux rope enveloping a filament and magnetic loops rooting in the near chromospheric fibrils. The most complete evidence of magnetic reconnection so far were observed in this event, including the reconnection inflows and outflows, the newly formed magnetic loops, current sheet, hot cusp-shaped structures, downflows, and so on. The estimated reconnection rate ranges from 0.01 to 0.03, which belongs to fast magnetic reconnection. From EUV observations, they found that the plasmoids formed in the current sheet and moved to the two ends of the current sheet (Figure 1A-C). By using vector magnetic fields from SDO/HMI, they also carried out a data-driven simulation of high resolution, which showed unambiguously that the plasmoids formed in the current sheet are mini twisted flux ropes (Figure 1D-F).

This research reveals the fine process of a fast magnetic reconnection, which greatly deepens the understanding of the basic process of magnetic reconnection. It is of great significance to the study of the physical characteristics and mechanisms of solar activities. Moreover, this study provides an important guideline for the research of eruptive activities stars and black holes.■

REFERENCES

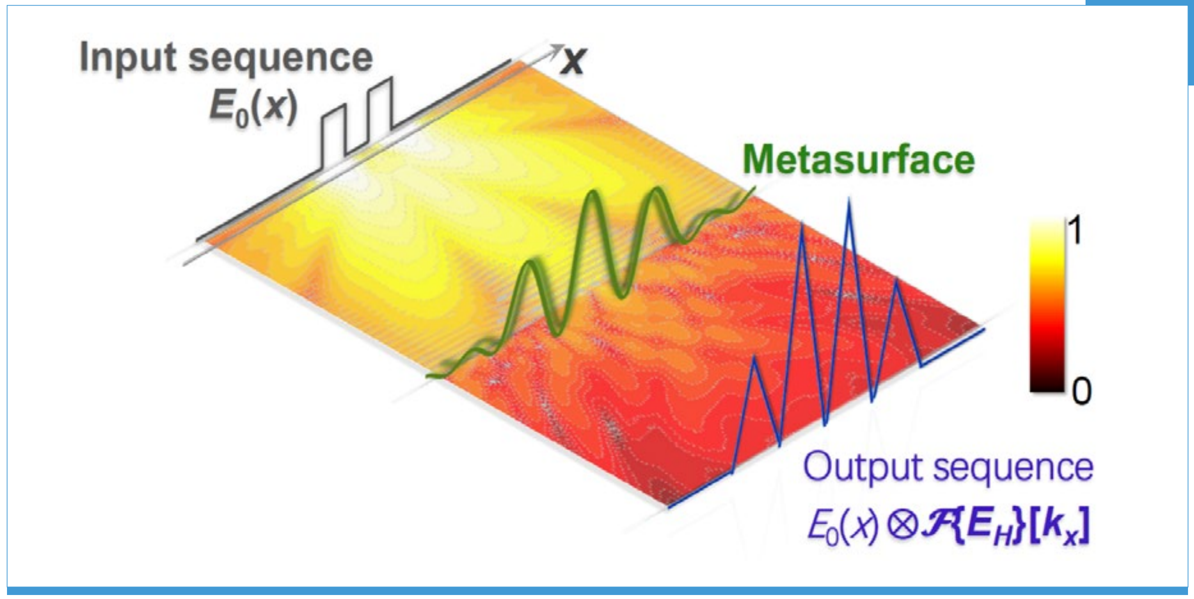
Yan, X., Xue, Z., Jiang, C., et al. Fast plasmoid-mediated reconnection in a solar flare. Nature Communications, 2022,13, 640.
DOI: 10.1038/s41467-022-28269-w

SINGLE-LAYER SPATIAL ANALOG META-PROCESSOR FOR IMAGING PROCESSING

In 2022, Associate Professor Ding Xumin's group from the Advanced Microscopy and Instrumentation Research Center, School of Instrumentation Science and Engineering, published a research paper titled "Single-Layer Spatial Analog Meta-Processor for Imaging Processing" in *Nature Communications*.

High-speed and high-efficiency computation is central in many modern technologies. The digital computation based on electron flows in microelectronic circuits relies on analog-to-digital conversions, which generally suffers from high energy consumption, low operation speed, and systematic complexity, making it challenging especially for massive data processing. Recently, all-optical analog computing provides an alternative computational platform at the speed of light with low power consumption and could be integrated into photonic chips with thin and planar profiles as well as enhanced compactness, which is thus widely explored as the next-generation computation tools. However, conventional physical architectures of spatial domain analog computers leverage upon the phase accumulation with stacked or series of optical elements, making the whole system bulky and lossy. Fourier optics method demands bulky and volumetric systems, while Green's function method relies on angle-dependent scattering spectrum which necessarily decreases the incident-angle range and operation diversity.

In order to address these issues, the researchers achieved a novel ultracompact analog processing system to overcome the speed and energy limitations of digital devices. By introducing specific phase factors into the complex wavefront profile on the interface, the single-layer meta-structure herein directly tailors the transverse wavevector exerted in spatial Fourier



spectrum and hence imposes the customized transfer function for analog image processing, which can essentially compress the typical 4f optical system to the 2f structure. Compared with reported state-of-the-art edge detectors, the proposed system demonstrates a relatively superior balance between the NA and device dimension, thanks to the on-demand electromagnetic control via Huygens' metasurfaces.

This work could enable the real-time and high-throughput parallel computing tasks, overcoming the existing integration issues of traditional bulky Fourier optical devices while performing diverse mathematical operations in contrast to GF kernels. Hence, the proposed miniaturized meta-processor revels high-performance computing and can be readily generalized for tremendous tasks in analog imaging processing and computations such as equation solvers, edge detection of patterns, optical memory, machine learning and others.

This work was financially supported by the National Key R&D Program of China.■

REFERENCE

Wang, Z., Hu, G., Wang, X., et al. Single-layer spatial analog meta-processor for imaging processing. Nature Communications, 2022, 13, 2188. DOI: https://doi.org/10.1038/s41467-022-29732-4

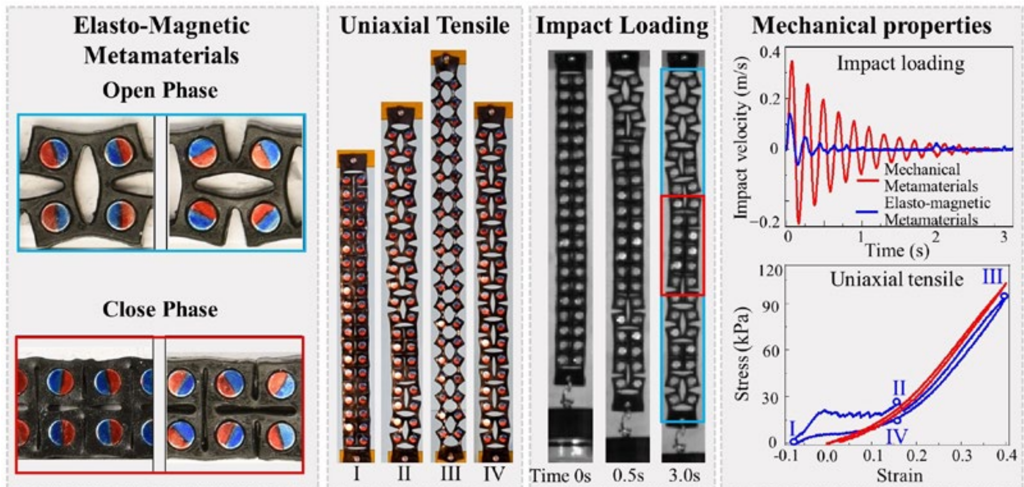
Research & Academia
HIT TIMES 2022

MAKING PHASE CHANGE MATERIALS TO RELEASE AND ABSORB A LARGE AMOUNT OF ENERGY WITH MAGNETS AND RUBBER

In 2022, Professor Liang Xudong, from the School of Science at Harbin Institute of Technology (Shenzhen), in collaboration with Professor Alfred Crosby from the University of Massachusetts, Amherst, reported their recent study on creating a material that can both absorb and release a large amount of energy and published a research article titled "Phase-Transforming Metamaterials with Magnetic Interactions" in *Proceedings of the National Academy of Sciences*.

Material phase transitions offer promise for driving motion and managing high-rate energy transfer events—for example, superelasticity in shape memory alloys and soft elasticity in liquid crystal elastomers. However, engineering conventional phase transitions based on atomic or molecular level thermodynamic and kinetic mechanisms is challenging.

The team developed elasto-magnetic metamaterials with two simple ingredients: magnets and rubber. The new material can display phase transformation behaviors due to nonlinear interactions between internal elastic structures and embedded, macroscale magnetic domains. The particular placement of the magnets is determined by the elastic properties of the rubber — and the geometry of the holes in the rubber strip. Together, the hole geometry, the elastic properties, and the magnetic strength determine where and how the phase transition could happen and provides a specific



Orienting the magnets in different directions within the metamaterials changes the static and dynamic mechanical properties

response. Like those in shape memory alloys and liquid crystal elastomers, these phase transitions have beneficial changes in strain state and mechanical properties that can drive actuations and manage overall energy transduction.

The constitutive response of the elasto-magnetic metamaterial changes as the phase transitions occur, resulting in a nonmonotonic stress-strain relation that can be harnessed to enhance or mitigate energy storage that release under high-strain-rate events, such as impulsive recoil and impact. Using a Landau free energy-based predictive model, the team develops a quantitative phase map that relates the geometry and magnetic interactions to the phase transformation. This framework, developed in the current study, creates new opportunities based on fundamental principles for using phase transitions to control engineering performance at high rates events.

With the ability to both drive high-power motion and quickly dampen impact-loading events, the material has a number of promising applications — from giving robots a boost to making helmets and protective equipment that dissipate energy quickly.■

REFERENCE

Xudong Liang, Hongbo Fu, Alfred J. Crosby. Phase-transforming metamaterial with magnetic interactions. Proceedings of the National Academy of Sciences, 2022, 119(1): e2118161119. DOI: https://doi.org/10.1073/pnas.2118161119

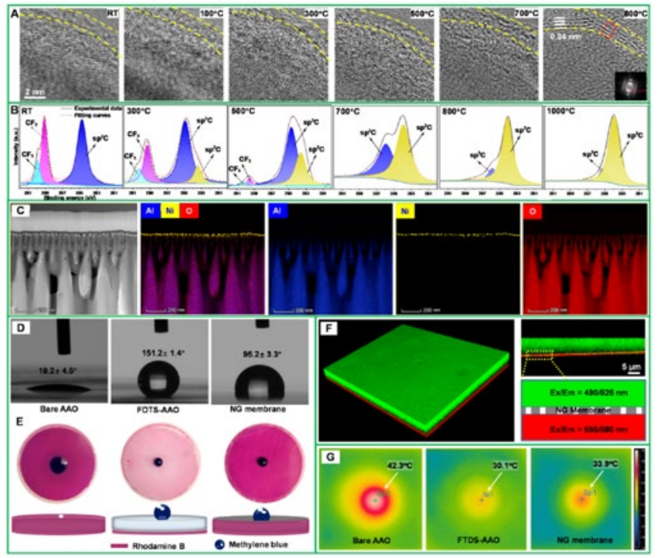
Research & Academia
HIT TIMES 2022

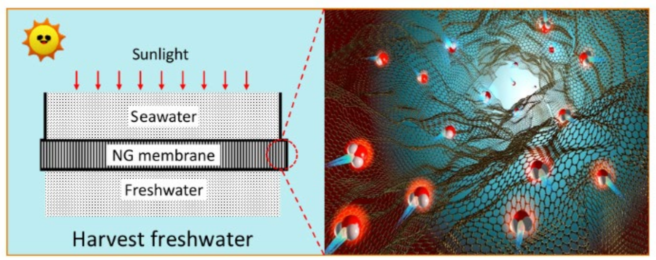
AN ULTRAHIGH-FLUX NANOPOROUS GRAPHENE MEMBRANE FOR SUSTAINABLE SEAWATER DESALINATION USING LOW-GRADE HEAT

Membrane distillation has attracted significant attention in developing sustainable desalination and zero-discharge processes. However, the conventional membrane structures and materials afford limited flux, thus obstructing its practical application. Recently, Associated Professor Lu Dongwei's research group from the School of Environment at Harbin Institute of Technology published the paper “An Ultrahigh-Flux Nanoporous Graphene Membrane for Sustainable Seawater Desalination Using Low-Grade Heat” in *Advanced Materials*.

In this study, ultrathin nanoporous graphene (NG) membranes are reported by selectively forming thin graphene layers on the top edges of a highly porous anodic alumina oxide support, and the graphene layer forms a hydrophobic gap and prevents the transport of liquid water, which creates short and fast transport pathways for water vapor but not liquid. The process avoids the challenging pore-generation and substrate-transfer processes required to prepare regular graphene membranes.

The test results show that in the direct-contact membrane distillation mode under a mild temperature pair of 65/25°C, the nanoporous graphene membranes show an average water flux of 421.7 L m^{-2} h^{-1} with over one 99.8% salt


Membrane preparation and characterization



rejection, which is an order of magnitude higher than any reported polymeric membranes. Detailed characterizations and theoretical modeling reveal the mechanism for high water flux. Compared with the conventional bare AAO membrane, the FSTS-AAO membrane highlights that the NG membrane has certain hydrophobicity and better water flux.

The average surface pore size and surface porosity of the NG membrane were ~26.8 nm and ~28%, respectively. NG-800 films have different contact angles on each side. The graphene surface contact angle is 95.2°, indicating slightly hydrophobic graphene. The contact angle of the backside is close to that of the AAO support, so it is hydrophilic. The water permeation behaviors of AAO, FDTS-AAO, and NG membranes showed that water could enter the channel from the hydrophilic AAO side but not from the hydrophobic graphene layer side. There is a fragile gap between the two streams of water. Dynamic salt diffusion tests show that the FDTS-AAO and NG membranes have good salt rejection. Outdoor field tests using water from the Red Sea heated under direct sunlight radiation show that the membranes have an average water flux of 86.3 L m−2 h−1 from 8 am to 8 pm. Based on the measured performance, it is expected that a 1 m2 NG membrane could theoretically produce enough fresh water every half a day to meet the daily water needs of a typical household, an order of magnitude higher flux than the MD membrane fluxes reported so far. At the same time, it can also meet the water needs of many zero-discharge processes to better achieve the need for environmental friendliness. This result shows the great potential of nanoporous graphene membranes for practical applications in seawater desalination.

REFERENCES

Lu, D., Zhou, Z., Wang, Z., Ho, D. T., Sheng, G., Chen, L., et al. An ultrahigh-flux nanoporous graphene membrane for sustainable seawater desalination using low-grade heat. Advanced Materials, 2022, 2109718.

Research & Academia
HIT TIMES 2022

BIOINSPIRED SOFT SWALLOWING GRIPPER FOR ADAPTABLE GRASPING

Professor Zhu Yanhe and his colleagues from the State Key Laboratory of Robotics and System, Harbin Institute of Technology, published a paper titled “A Bioinspired Soft Swallowing Gripper for Universal Adaptable Grasping” in *Soft Robotics*, the leading robotics journal publishing world-class peer-reviewed research on the emerging technologies and developments of soft and deformable robots.

This research presents the design, fabrication, modeling, and preliminary tests of a bloodworm-inspired soft gripper for universal grasping. The gripper was designed and fabricated based on a toy called water snake wiggly (WSW). The toroidal WSW can evert itself inside-out or outside-in, just like a bloodworm everting its teeth outside to hunt and inside to feed.

By driving a WSW rolling itself outside-in to wrap around the items, a bloodworm-inspired gripper was achieved with a flexible and passive form-fitting grasp. To enhance the capability of the gripper, two alternative detachable modules were added to the gripper—a vacuum suction cup for handling objects with smooth nonporous surfaces and an end-needle for taking in and expelling noncorrosive liquids like a syringe. The experiments indicate the gripper's good universal grasping capacity and reliability in handling a wide range of objects with different surface shapes, geometric dimensions, and stiffness. In addition, the gripper has the unique abilities to pick up more than one object during a maneuver, grasp multiple objects in a row without releasing the former ones, and even grasp powdered objects. These have presented a challenge for the existing robotic grippers. This soft gripper has potential use in deep water or outer space environments. ■

REFERENCE

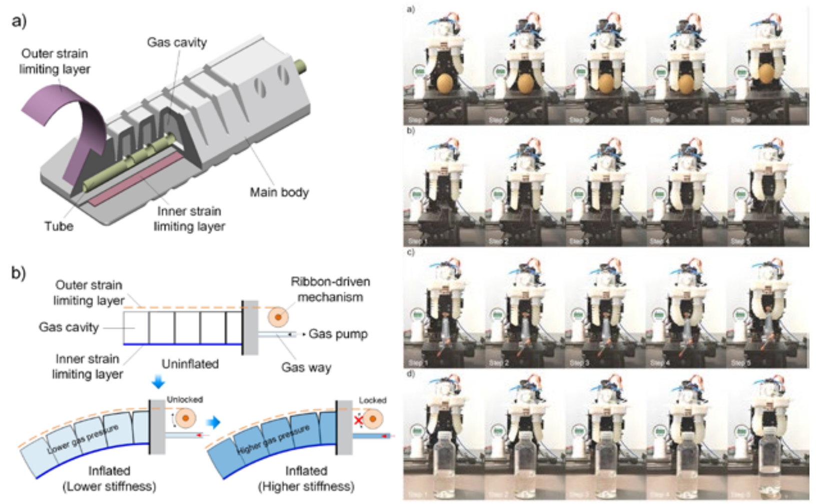
Dongbao Sui, Yanhe Zhu, Sikai Zhao, Tianshuo Wang, Sunil K. Agrawal, He Zhang, Jie Zhao. A bioinspired soft swallowing gripper for universal adaptable grasping. Soft Robotics, 2022, 9(1), 36-56. DOI: http://doi.org/10.1089/soro.2019.0106

GAS-RIBBON-HYBRID ACTUATED ACTIVE VARIABLE STIFFNESS MECHANISM FOR SOFT ROBOTIC FINGERS

Recently, Professor Zhang Xinbin's group, from the Laboratory for Space Environment and Physical Sciences, Harbin Institute of Technology, published a paper titled "A Gas-Ribbon-Hybrid Actuated Soft Finger with Active Variable Stiffness" in the journal of *Soft Robotics*.

Advances in soft robotics have greatly expanded our thinking about the development of new tools and devices for serving mankind. Soft robotic fingers, featuring high compliance and safe interactions, have received substantial attentions in recent years, which can be applied to fabricate grippers as end effectors to efficiently grab complex shaped or fragile targets or assemble robotic hands for artificial limbs or for rehabilitation. The key problems impeding the popularity of the soft robotic applications include sensing, control, and stiffening, etc. Grasping and manipulation are basic functional requirements for soft robotic fingers. Flexibility enables soft fingers with good capabilities of grasping objects with different shapes, sizes, and materials, while a higher stiffness is required for stable and correct manipulations. However, flexibility and stiffness are opposite to each other. To explore the full advantages of soft robotic fingers, it is of crucial importance to coordinate the logical relationships between the high flexibility and variable stiffness.

Variable stiffness has always been an important research issue for soft robotic fingers. An ideal variable stiffness mechanism should be



compatible with the high flexibility. That is, with the exception of some specific applications, on one hand, the stiffness modulation process should be uncoupled with the flexible deformation process; on the other hand, when grasping, the soft fingers should be in a high-flexibility mode, and when manipulating, the soft fingers should be in a high-stiffness mode. Therefore, the performance of soft robotic fingers not only depends on the structural design but is also closely related to control logic.

Herein, Professor Zhang and his group proposed a new hybrid actuated soft finger with active variable stiffness for the first time by integrating gas-driven and ribbon-driven mechanisms. By carefully coordinating the two mechanisms, the bending deformation and the stiffness modulation processes of the soft fingers can be uncoupled. The soft fingers, made entirely from flexible materials, works under a low and safe gas pressure difference of below 35 kPa, with the ratio of the maximum load to the mass of up to 33. For any bending angle, with the help of the ribbon-driven mechanism, the stiffness of the soft fingers can be increased by 3~6 times. Both the theoretical and experimental results indicate that the proposed gas-ribbon-hybrid actuated mechanism can effectively enhance the variable stiffness property of a soft finger while retaining its good compliance to surroundings. This work might provide some insight for the development of compact and cost-effective soft end effectors with active variable stiffness in future.

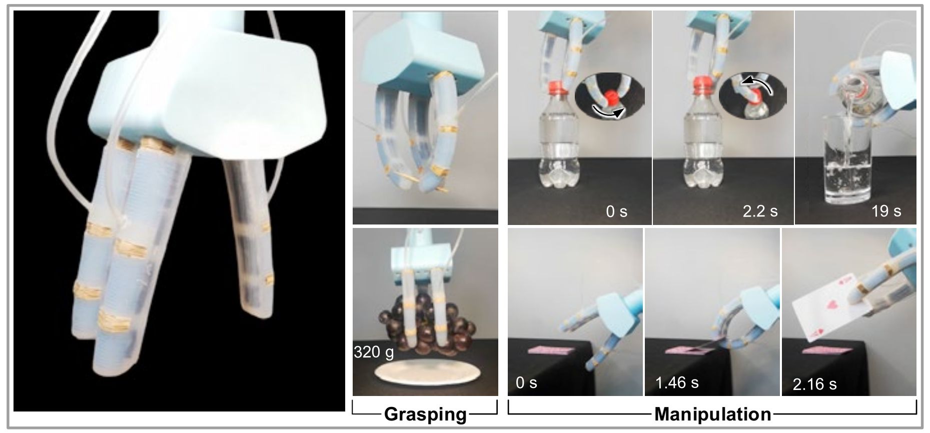
REFERENCE

Xinbin Zhang, Jihong Yan, and Jie Zhao. A gas-ribbon-hybrid actuated soft finger with active variable stiffness. Soft Robotics, 2022, 9(2): 250-265. DOI: http://doi.org/10.1089/soro.2020.0031

DUAL-MODE SOFT FINGER FOR SIMULTANEOUS COMPLIANCE, DEXTERITY, AND FAST VARIABLE STIFFNESS

In 2022, Professor Yan Jihong's group from the State Laboratory of Robotics and System published a research paper titled "A Human-Inspired Soft Finger with Dual-Mode Morphing Enabled by Variable Stiffness Mechanism" in *Soft Robotics*.

Biological fingers demonstrate compliant and dexterous morphing via soft tissues and salient structures. Compliance ensures adaptive and safe interaction, and dexterity manifests as delicate and dynamic manipulation. Bioinspired soft robotic fingers composed of flexible materials have attracted tremendous interests due to their large deformation, excellent adaptability, and infinite degrees of freedom. However, it is still challenging for soft fingers



Three-fingered soft gripper with dexterous grasping and manipulation capabilities

to simultaneously have compliance, dexterity, and fast, reversible stiffness switch.

Taking inspiration from the soft-rigid structure and drive mechanism of human fingers, a discrete-joint soft finger with dual-mode morphing was proposed. It can achieve fast transformation between human-like and deformable-phalanges articulate flexion through active and passive stiffness varying of lightweight CTPS-phalanges and compact Yoshimura-origami ligaments. This function makes it possess the advantage of multi-joint dexterous manipulation based on deformation and stiffness requirements of different tasks.

A three-fingered gripper can perform dexterous manipulations by independent dual morphing modes, including drawing a playing card, unscrewing a bottle cap, grasping a peeled egg, grapes, etc. Besides, it can hold a water bottle weighing 600 g, lift a dumbbell weighing 1460 g (load-weight ratio 7.6), as well as grasp large, or wide objects (Φ2~Φ122 mm) through dual-mode transformation, which is impossible for single mode.■

REFERENCE

Jihong Yan, Zhidong Xu, Peipei Shi, and Jie Zhao. A human-inspired soft finger with dual-mode morphing enabled by variable stiffness mechanism. Soft Robotics, 2022, Apr;9(2):399-411. DOI: 10.1089/soro.2020.0153

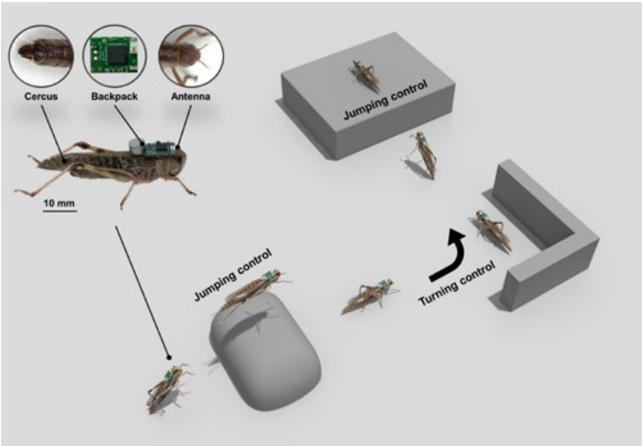
Research & Academia
HIT TIMES 2022

OMNIDIRECTIONAL JUMP CONTROL OF A LOCUST-COMPUTER HYBRID ROBOT

In 2022, the research team of Professor Li Bing and Associate Professor Li Yao, from the School of Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, published a paper titled "Omnidirectional Jump Control of a Locust-Computer Hybrid Robot" in *Soft Robotics*, a top robotics journal. The team demonstrated the first-ever insect-computer hybrid robot, which can perform high-accuracy directional jumping using collaborative neuron stimulation.

Micro jumping robots are necessary for conducting search-and-rescue missions in narrow and obstacle spaces. The excellent performance of the micro-jumping robot in complex terrain is more conducive to improving disaster relief and rescue capability. However, even state-of-the-art micro jumping robots are far from usable for real missions due to hindrance in power consumption and obstacle-crossing locomotion, such as an unadjustable take-off angle and unrepeatable leaps.

What if a living locust could be employed as a platform for micro jumping robots? The locusts show extremely strong explosive power due to a dexterous combination working of the flexor and the extensor muscles. Instead of the fabrication of the artificial micro structures, a locust-computer hybrid



A locust-computer hybrid robot with a remote-controlled electrical backpack demonstrated the consecutive turning and jumping controls following an obstacled path.

robot can easily preserve the complex biological structure and thus retain the locust's locomotor capabilities, while being able to perform tasks in complex environments.

In this study, the omnidirectional jumping control was achieved through the electrical stimulation of the antennae and cercus of the locust. By analyzing the locust's bio-neural signals and motor characteristics under kicking movements, the team determined the appropriate electrical stimulation parameters. With the electrical pulse conducted on the cercus, the locusts can be induced to jump with a height of ~111 mm and a distance of ~369 mm. Meanwhile, the locust exhibited contralateral steering with electrical stimulation of antennae, and the turning rate of locusts increased as the frequency of electrical pulses increased. A safe and efficient method was established to modulate locusts' heading direction according to the graded protocol, which is important for a precise jump. Meanwhile, the insect had the lowest response time of 0.14 s to initiate turning after stimulation. Finally, combining antennae and cercus electrical stimulation resulted in an omnidirectional jumping strategy.

Combining the biological control technique and a micro control system, the team designed a remote controlled jumping robot that retains the locust's locomotion ability. Moreover, a feedback control strategy was introduced to realize the omnidirectional consecutive jumps with high precision. The whole biohybrid jumping robot weighs 2.7 g in total (inclusive of the insect, backpack, and battery). With the ongoing improvements in electrode implantation and fixation, the locust-computer hybrid robot is becoming more reliable and stable and will be applicable in search and rescue missions in the future.

The postgraduate student Liu Peng is the first author of this paper, and Associate Professor Li Yao and Professor Li Bing are the corresponding authors. This study was financially supported by the National Natural Science Foundation of China.

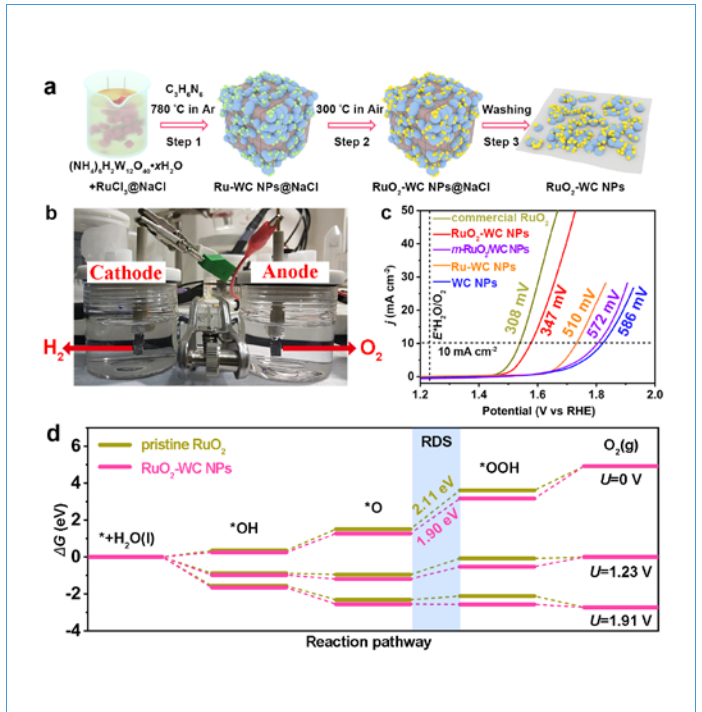
REFERENCE

Peng Liu, Songsong Ma, Shen Liu, Yao Li, and Bing Li. Omnidirectional jump control of a locust-computer hybrid robot. Soft Robotics, 2022.
DOI: 10.1089/soro.2021.0137

SUPPORT EFFECT ON ELECTROCATALYST FOR ACIDIC OVERALL WATER SPLITTING

Recently, Professor Song Bo from the Center for Composite Materials and Structures, Harbin Institute of Technology, in collaboration with Professor Xu Chengyan from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), published a research paper titled "Bifunctional WC-Supported RuO_2 Nanoparticles for Robust Water Splitting in Acidic Media" in *Angewandte Chemie International Edition*.

Electrochemical hydrogen evolution is among the most potential ways to produce high-purity hydrogen as renewable energy carrier for the conversion of electrical energy into sustainable fuels because of its high calorific value and zero emission. The proton exchange membrane (PEM) electrolyzer, with higher voltage efficiency, larger current density, and lower electrolyte resistance than conventional alkaline media, is regarded as a promising technology in the realization of industrial hydrogen production. However, the counter electrode performing oxygen evolution reaction (OER) is an up-hill reaction involving complex four-electron processes, leading to the sluggish reaction kinetics and large overpotential in acidic electrolyte. Therefore, developing high-efficient OER electrocatalyst with excellent activity, superior durability, and low cost is indispensable for constructing bifunctional



electrocatalyst for acidic overall water splitting (OWS).

Among all the alternatives, including precious metal oxides, RuO_2–with the cheapest price of 575 $^{-1} oz and moderate capacity of binding oxygen intermediates–is regarded as one of the most effective OER electrocatalysts in acidic electrolytes, even surpassing IrO_2. However, the lack of durability still hinders their applications in acidic solution. Considering aforementioned limitations, the catalytic metal oxides supported on durable substrates is an effective solution, which could yield intrinsic catalyst-support interaction driven by the different Fermi levels (E_F). Among all candidates, WC has been identified as suitable due to the excellent chemical corrosion stability and metal-like electrical conductivity in acidic media.

In this work, for the first time, WC support bonding with RuO_2 was designed as bifunctional electrocatalyst toward acidic OWS. The outstanding OER performance could be attributed to catalyst-support interaction between RuO_2 and WC support. It optimizes the surrounding electronic condition of Ru active sites, resulting in favorable adsorption energies of OER intermediates and decrease of reaction barrier. Simultaneously, the WC support contributes more electrons to catalyst surface to protect Ru active sites from overoxidation during acidic OER process. The RuO_2-WC NPs exhibit remarkable OER performance, requiring η_{10} of only 347 mV. Specifically, the mass activity of RuO_2-WC NPs reaches up to 1430 A g_{Ru}^{-1}, about eight-fold higher than commercial RuO_2 (176 A g_{Ru}^{-1}). Combining excellent HER performance with low η_{10} of only 58 mV, an acidic electrolyzer for OWS was constructed by bifunctional RuO_2-WC NPs, affording cell potential of only 1.66 V to achieve 10 mA cm^{-2} and excellent long-term stability.

This work demonstrated that WC is a suitable support for precious metal oxides, providing an innovative guideline to tradeoff weak catalytic activity and high precious metal cost to accelerate practical application for acidic water splitting.■

REFERENCE

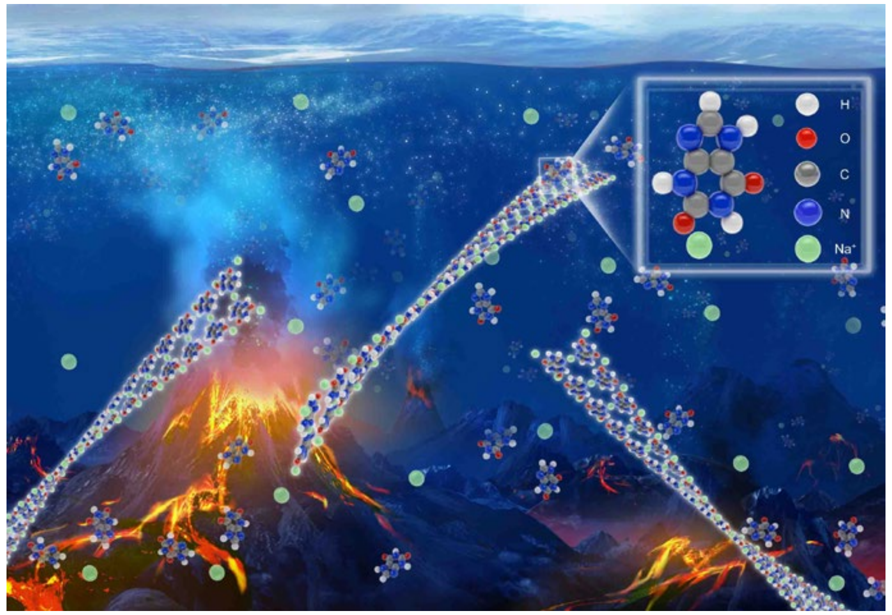
Shu-Chao Sun, Hao Jiang, Zi-Yao Chen, Qing Chen, Ming-Yuan Ma, Liang Zhen, Bo Song and Cheng-Yan Xu. Bifunctional WC-supported RuO_2 nanoparticles for robust water splitting in acidic media. Angewandte Chemie International Edition, 2022. DOI: 10.1002/anie.202202519

SUPER-ROBUST XANTHINE-SODIUM COMPLEXES ADDRESSING PUZZLES FOR PRIMORDIAL SUBMARINE SYNTHESIS

Professor Yu Miao, from the School of Chemistry and Chemical Engineering, recently published an article titled "Super-Robust Xanthine-Sodium Complexes on Au(111)" in *Angewandte Chemie International Edition*.

Being the most decisive process in the origin of life, the evolution from individual biomolecules to functional oligomers/polymers and hence to primitive forms of life has remained particularly intriguing yet mysterious over the centuries. A widely accepted theory is that life originated from the hydrothermal environment [550–670 K][3] that was induced by volcano eruption in the primordial ocean. Nevertheless, certain seemingly contradictory findings make this point puzzling: The accumulation hence polymerization of biomolecules on inorganic substrates is regarded to be crucial for the evolution of biomolecular systems, whereas the reported desorption temperatures of the DNA bases are far less than 550 K. Moreover, although molecular recognition based on hydrogen bonding (the most primary interaction between nucleobases) can already occur at room temperature, such bonding can easily be broken even at 483 K. How could the high-temperature submarine environment be appropriate and indispensable for the synthesis of initial form(s) of life then?

Although it is highly difficult to restore the actual picture of primordial submarine synthesis, shedding light on this puzzle through simplified cases is feasible. In this work, Professor Yu's group investigates the complexes of xanthine (3,7-dihydro-purine-2,6-dione, $C_5H_4N_4O_2$) and sodium (Na) on the Au(111) surface. Xanthine is a typical purine base, prevailingly distributed not only in human tissues and fluids but also in prokaryote and eukaryote cells–the earliest life forms on the earth. This compound was present in the ancient solar system and found in high concentrations in extraterrestrial meteorites. Moreover,



xanthine has been recognized as one of the original exogenous nucleobases abundant on the prebiotic Earth, serving as one of the precursors for primitive nucleic acids. Na is a vital element in animals and plants. Concentration of Na ions in the primitive ocean was proposed to be 1.5–2.0 folds as that in the modern ocean. It has been suggested that the presence of Na is capable of accelerating the self-assembly of nucleobases at the liquid-solid interfaces and improving the stability of DNA duplex oligomers.

In this work, the authors demonstrate that the well-defined xanthine-Na complexes on Au(111) can be only fabricated at elevated temperatures: forming one-dimensional (1D) chain at ~430 K and converting into a close-packed two-dimensional (2D) polymer at ~650 K. The 2D complex keeps adsorbing on Au(111) even at ~720 K, presenting as the most thermally stable organic polymer ever reported on Au(111). Besides justifying the necessity of high-temperature, Na-rich environment for the prebiotic biosynthesis and the robustness of the polymer upon the harsh environment, this work further reveals the ability of the xanthine-Na complexes to induce significant electron transfer with the metal as inert as Au, lifting up Au atoms from the substrate by the strong interaction. This work not only addresses the puzzles about the thermochemical synthesis in primordial oceans, but also proposes that the complexes of biomolecules and Na atoms formed in the synthesis may act as the primitive metalloenzyme to trigger the initial redox reactions promoting the origin and evolution of life.

REFERENCE

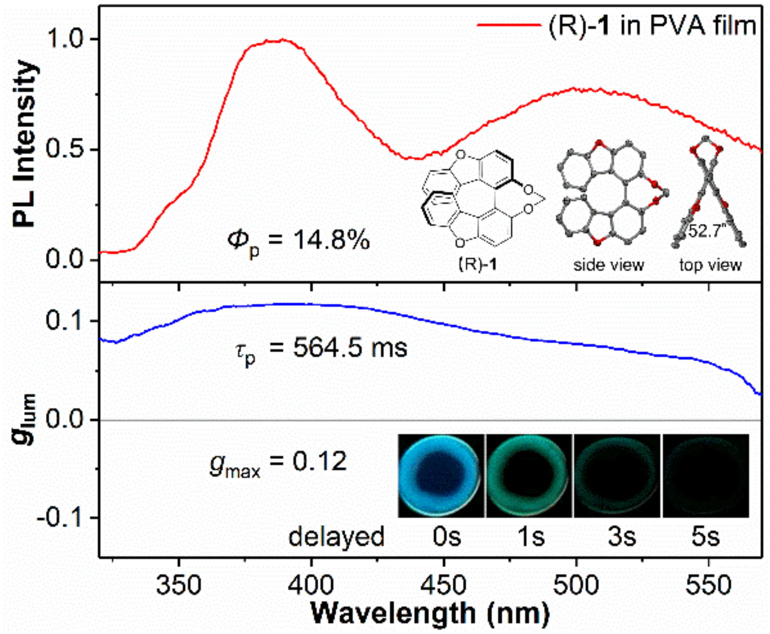
Chong Chen, Pengcheng Ding, Zhuo Li, Guoqiang Shi, Ye Sun, Lev N. Kantorovich, Flemming Besenbacher, and Miao Yu. Super-robust xanthine-sodium complexes on Au(111). Angewandte Chemie International Edition, 2022, DOI: https://doi.org/10.1002/anie.202200064

STRONG CIRCULARLY-POLARIZED ROOM-TEMPERATURE PHOSPHORESCENCE ACHIEVED IN LOCKED AXIAL CHIRAL STRUCTURE

Recently, a group led by Professor He Zikai from the School of Science, Harbin Institute of Technology (Shenzhen), published a research paper titled "Strong Circularly-Polarized Room-Temperature Phosphorescence from a Feasibly Separable Scaffold of Bidibenzo[b,d]furan with Locked Axial Chirality" in *Angewandte Chemie International Edition*.

Organic circularly-polarized phosphorescence materials have attracted significant attention because of their fascinating photophysical properties and potential applications in optoelectronic devices, three-dimensional displays, biological sensors, optical information storage, asymmetric photocatalysis, etc. Due to the weak spin-orbit coupling, quick deactivation of triplet excitons, and insufficient chiral characteristics, organic room temperature circularly-polarized phosphorescence materials have rarely been obtained. Subsequent studies mainly focus on enhancing the chirality of structure to obtain excellent dissymmetry factor, increase quantum yield, and prolong the phosphorescence lifetime to achieve a reliable performance and address actual needs.

In this study, a novel feasibly separable scaffold of bidibenzo[b,d]furan, with strong circularly-polarized room-temperature phosphorescence, was developed.



Through a simple coupling reaction and NHC-catalyzed kinetic resolution, the absolute chiral bidibenzo[b,d]furan derivate (R)-1 with locked conformation was obtained, which was verified by the single-crystal structure analysis and chiral high-performance liquid chromatography. After doped into PVA films and induced by thermal-annealing and photoirradiation, excellent performance was achieved with a persistent lifetime of 0.56 s, RTP quantum yield of 0.15, and dissymmetry factor of 0.12. The performance is strongly affected by non-radiative deactivation, which could be weakened by thermal-annealing to reduce water content and photoirradiation to achieve cross-linked networks. Based on photothermal-responsive circularly polarized phosphorescence, (R)-1 films are expected to play a role in optical sensing and anti-counterfeiting.

This work was financially supported by the National Natural Science Foundation of China, the Natural Science Foundation of Guangdong Province, and the Shenzhen Fundamental Research Program.

REFERENCES

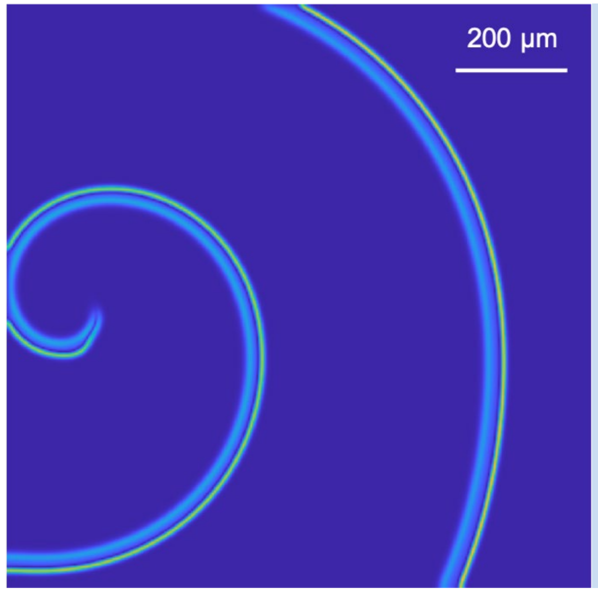
Wenbin Huang, Chunya Fu, Zhiwei Liang, Kang Zhou, Zikai He. Strong circularly-polarized room-temperature phosphorescence from a feasibly separable scaffold of bidibenzo[b,d]furan with locked axial chirality. Angewandte Chemie International Edition, e202202977. DOI: https://doi.org/10.1002/anie.202202977

UNRAVELING THE SECRETS FOR MICROMACHINES TO SWARM

Recently, Professor Wang Wei from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), has made important progress in understanding the collective behaviors of micromachines. This was published in *Science Advances* with the title “Unraveling the Physiochemical Nature of Colloidal Motion Waves among Silver Colloids”.

Micromachines are a unique type of biomimetic device and have received mounting interest due to their potential applications in biomedicine, environmental remediation, and micro-assembly. One of the key challenges of using micromachines is the swarm control in large populations. Because conventional control strategies fail at such small scales and for large populations, new strategies are being sought. One way is to draw inspiration from biology such as methods of communication used by bacteria or cells.

In this article, Professor Wang Wei’s team has focused on silver-coated micromachines that spontaneously oscillate under ultra-violet light and in aqueous solutions. What is special



with these micromachines is that they exhibit periodic motion waves similar to the Mexican waves circulating in a football stadium. To understand the physio-chemical nature of these fascinating waves, Professor Wang's team first identified the presence of traveling waves of OH^- among oscillating micromachines with pH-sensitive fluorescent dyes. Working in collaboration, Professor Zhang Hepeng's team from Shanghai Jiaotong University developed a theoretical model that predicted chemical waves with key features matching experiments. As the final piece of the puzzle, colloidal electrokinetics was used to explain how these micromachines move in chemical waves.

In addition to unraveling the underlying physio-chemical nature of motion waves, the findings of this study are also significant for other research topics. For example, the silver coating on these micromachines is responsible for chemical oscillation and could be potentially applied to nonlinear catalysis. Moreover, motion waves traveling across micromachines can be developed into a biomimetic strategy to transmit information in a large population. Finally, the research field of complex systems and active matter could benefit from a good model system such as oscillating micromachines.■

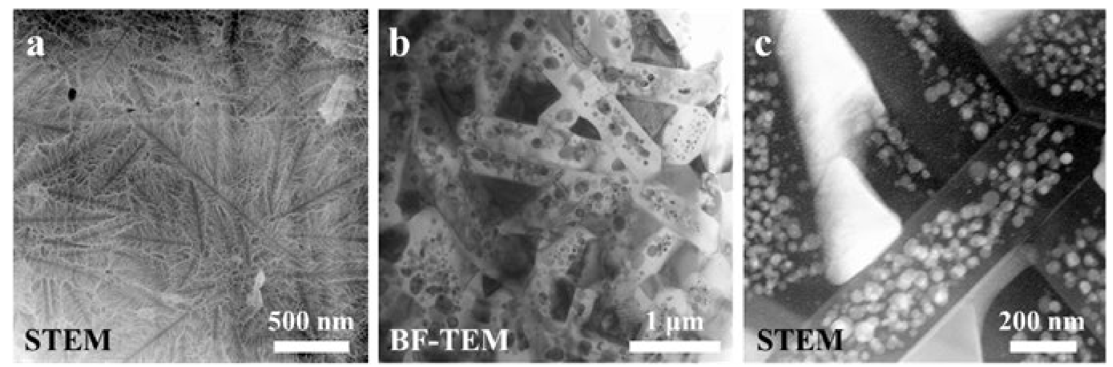
REFERENCE

Xi Chen, Yankai Xu, Chao Zhou, Kai Lou, Yixin Peng, Hepeng Zhang, Wei Wang. Unraveling the physiochemical nature of colloidal motion waves among silver colloids. Science Advances, 2022, 8, eabn9130. DOI: 10.1126/sciadv.abn9130

MAKING ULTRA-TOUGH NANOCERAMICS BY COLUMNAR SUBMICROCRYSTALS WITH THREE-LEVEL MICRO-NANO STRUCTURES

In 2022, the laboratory of Professor Zheng Yongting, from the Center for Composite Materials and Structures at Harbin Institute of Technology, achieved important progress in the field of "columnar crystal Al_2O_3-based nanoceramics with ultra-high toughness" and published a research paper titled "Making Ultra-Tough Nanoceramics by Columnar Submicrocrystals with Three-Level Micro-Nano Structures" in *Small*.

The team pioneered the method of "Al-O_2 ultrahigh-temperature combustion synthesis + melt rapid water cooling" to synthesize Al_2O_3/ZrO_2 metastable micro-powders (Fig. a) with special microstructures (Fig. b). In the sintering densification process, this kind of powder induces columnar Al_2O_3-based submicrocrystal ceramics with high-density multistage nanostructures by in-situ (Fig. c, d), which can realize the synergistic toughening of



multistage nanostructures, columnar crystals, t-m phase transitions of zirconia and other factors, thus greatly improving the mechanical properties of nanoceramics. The bending strength of ceramics was up to ~ 1300 MPa, the fracture toughness of ceramics with U-notch up to ~ 16 MPa·m$^{1/2}$, and fracture toughness of ceramics with ultra-sharp V-notch up to ~ 7 MPa·m$^{1/2}$, which made their mechanical properties reach world leading levels. This method is beneficial to the microstructural design of high-performance ceramics and can be widely applied to various ceramic systems, which when coupled with simplicity, low-cost, and high-efficiency make it suitable to industrially produce large-sized nanoceramics with specific grain geometry in large quantities.

Alumina and zirconia are widely used advanced ceramics, which have important applications in many fields. This research provides a new scientific principle and technical approach to produce new generation ultra-tough ceramic products, such as cutting tools, high-speed ceramic cutting tools, bioceramics, high-end ceramic bearings, wear resistance ceramic parts etc. Compared with the traditional process methods of nanocomposite ceramics, this research results have the following advantages:

(1) Economic efficiency and low-cost;

(2) Multistage high-density, fine and uniform nanostructure, the grain size about 500 nm, and the nanoenhancement phases in the grain is about 50 nm;

(3) The spontaneous growth of a large number of columnar submicrocrystals in the ceramic, the columnar crystals closely combined with the matrix at the atomic level, and the significantly improved strengthening and toughening effects;

(4) No pollution, green environmental protection, avoiding the pollution problems caused by the mainstream liquid phase production process of nanopowder;

(5) The raw material for preparing nanoceramics is spherical solid solution micro-powder, which avoids the problems of easy agglomeration, difficult dispersion, and difficult forming of nanopowders, greatly reducing the difficulty and cost of the forming process.

In addition, the team has achieved a number of research achievements in "ultrahigh-temperature combustion synthesis + melt rapid water-cooled atomization technology". The previous work of the team has successfully prepared Al_2O_3/ZrO_2 supersaturated solid solution micro-powder and nano-eutectic powder. These powders were sintered to prepare equiaxed nanocrystalline nanoceramics with high-density nanostructures. In the process of nonlinear phase transformation far from equilibrium, the precise regulation of the microstructure of advanced ceramics was realized. Relevant research was published in the international famous journal of *J. Eur Ceram. Soc.* (2019, 39: 4313-4321; 2021, 41: 5269-5279) and *J. Am. Ceram. Soc.* (2019, 102:7689-7698). In addition, nine national invention patents have been authorized for relevant research results, and one international patent has been authorized by the United States and Japan.

This work was supported by the R&D projects entrusted by enterprise and the National Natural Science Foundation of China. Professor Zheng Yongting is the corresponding author and PhD Yu Yongdong is the first author of this paper.

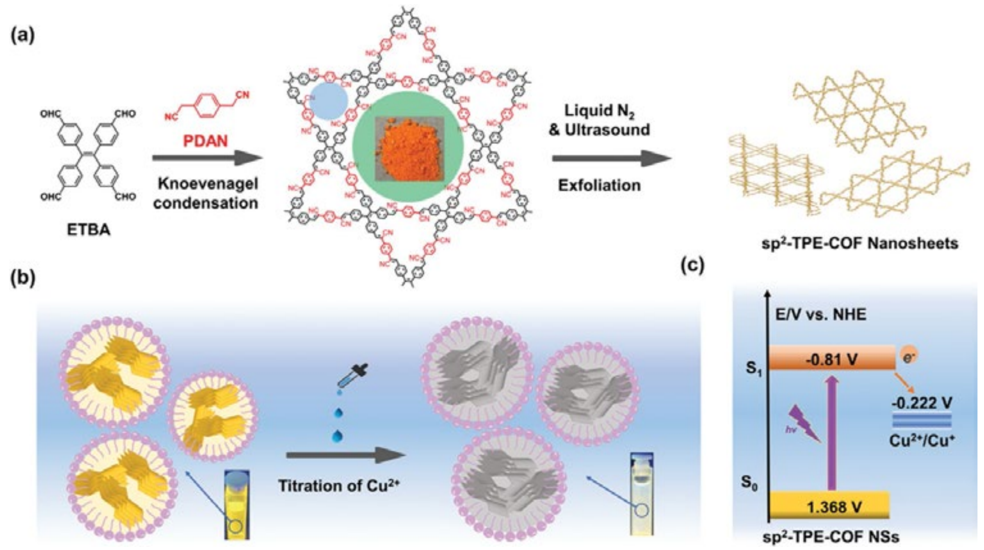
REFERENCE

Yu, Y., Zheng, Y., Liu, X., Yuan, Y., He, X. Making ultra-tough nanoceramics by columnar submicrocrystals with three-level micro-nano structures. Small, 2022, 18, 2105367. DOI: https://doi.org/10.1002/smll.202105367

A HIGHLY SENSITIVE FLUORESCENT PROBE WITH SURFACTANT-MODULATED CONJUGATED COVALENT ORGANIC NANOSHEETS FOR DETECTING COPPER IONS IN AQUEOUS SOLUTION

Efficient detection of aqueous copper ions is of high significance for environmental and human health, since copper is involved in potent redox activity in physiological and pathological processes. A team led by Dr. Guo Bing from the School of Science, Shenzhen Key Laboratory of Flexible Printed Electronics Technology, Harbin Institute of Technology (Shenzhen), recently published a research paper titled "Surfactant-Modulated a Highly Sensitive Fluorescent Probe of Fully Conjugated Covalent Organic Nanosheets for Detecting Copper Ions in Aqueous Solution" in *Small*.

Covalent organic frameworks (COFs) have shown advantages in efficient capturing and detecting of copper ions due to their large surface area, robust chemical stability, and high sensitivity, but most of them are hydrophobic, leading to the limitation in sensing copper ions in aqueous media. To this end, the research team reported the design and synthesis of a sp^2-carbon conjugated COF (sp^2-TPE-COF) with surfactant-assisted water dispersion for detecting traces of copper ions based on the photo-induced electron transfer (PET) mechanism. The design principle was based on the following considerations: (1) Fully sp^2-carbon-linked framework was constructed by Knoevenagel condensation. Such olefin linkage ensures better chemical stability and is more efficient in π-conjugation transmission compared to common imine and boronate ester linkages. Also, stronger π-electron delocalization always means stronger light-harvesting ability and enhanced fluorescence emission efficiency owing to narrowed LUMO-HOMO gap. Apart from that, fully conjugated COFs as robust signal transducers can exhibit excellent signal amplification according to "molecular wire effect". (2) A characteristic AIE-active unit, ETBA, was chosen to construct the COF skeleton, which was expected to represent high



(a) Synthesis of sp^2-TPE-COF by Knoevenagel Condensation between ETBA and PDAN and following exfoliation treatment
(b) The diagram of titration experiment for copper ion detection
(c) Electron transfer process during copper ion sensing with sp^2-TPE-COF NSs

fluorescence quantum yields because of intralayer covalent link and interlayer noncovalent π-π interaction in COF skeleton working together to hinder rotation induced energy dissipation. Importantly, the olefin-linked conjugated backbone of sp^2-TPE-COF worked as a signal amplified transducer for metal ion sensing. It was noticeable that a surfactant-assisted strategy could greatly enhance COF's dispersion in aqueous solution and finely modulate their sensitivity with a significantly improved KSV to 15.15 Å × 10^4 M^{-1} in SDBS (sodium dodecyl benzene sulfonate) solution, the value of which was larger than that of a majority of COF/MOF based sensors for copper ions. In short, this research demonstrates the promise of surfactant modulated fully π-conjugated COFs for sensing applications.

This work was supported by the Shenzhen Excellent Science and Technology Innovation Talents Training Project, the Special Foundation for General Basic Research Program of Shenzhen, the Start-Up Grant Harbin Institute of Technology (Shenzhen), the Start-Up Talent Grant at Harbin Institute of Technology (Shenzhen), Guangdong Basic and Applied Basic Research Foundation, and the General Project of Guangdong Natural Science Foundation.

REFERENCE

Zifeng Yan, Long Fang, Zhiguo He, Hui Xie, Binbin Liu, Bing Guo, and Youwei Yao. Surfactant-modulated a highly sensitive fluorescent probe of fully conjugated covalent organic nanosheets for detecting copper ions in aqueous solution. Small, 2022, 2200388. DOI: https://doi.org/10.1002/smll.202200388

HIGHLY STRENGTHENED AND TOUGHENED ZN-LI-MN ALLOYS AS LONG-CYCLING LIFE AND DENDRITE-FREE ZN ANODE FOR AQUEOUS ZINC-ION BATTERIES

Recently, binary Zn alloys such as Zn-Al, Zn-Ag and Zn-Ni alloys have been probed to protect Zn anode from dendrite growth and side reactions. Compared with pure Zn, these alloys have distinct features, like higher ionic conductivity, lower surface energy, better wettability, and higher resistance to the presence of oxygen. On the other hand, as structural materials, it was found that alloying Zn with a low amount of low-cost Li or Mn can enhance the mechanical properties of pure Zn. Compared with Ag and Ni, Li/Mn are more cost-effective and environmentally friendly. However, the electrochemical anode performances of Zn-Li-Mn based alloys have not been explored.

Herein, a group led by Professor Qiu Hua-Jun and Xie Guoqiang, from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), published the article "Highly Strengthened and Toughened Zn-Li-Mn Alloys as Long-Cycling Life and Dendrite-Free Zn Anode for Aqueous Zinc-Ion Batteries" in *Small*.

ZnLiMn ternary alloy is developed to inhibit the dendrite formation by comprehensively adjusting the spatial movement of Zn^{2+} and electrons. The formed Li/Mn-based cationic ions can inhibit the accumulation of Zn^{2+} via electrostatic shield mechanism. As a result, alloying Li/Mn greatly lowers the overpotential of Zn stripping-plating process, prevents the formation of Zn dendrites, and greatly extends the cycling life of ZIBs. When pairing the Zn-0.4Li-1.0Mn anode with the MnO_2 nanofiber cathode, the as-assembled ZnLiMn/MnO_2 full cell exhibits outstanding electrochemical properties, delivering a high specific capacity of 250 mAh g^{-1} with near 100% coulombic efficiency and no significant capacity fading after 400 cycles at a current density of 1 C. In comparison, Zn/MnO_2 shows a rapid decline of capacity after only 100 cycles. These results further verify the significance of solving the growth of dendrite and Zn passivation for better ZIB performance.■

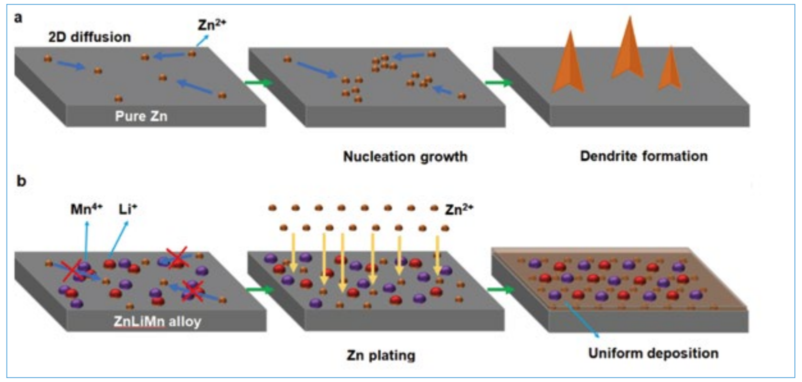


Figure 1 (a) Schematic illustration of the dendrite suppression mechanism by pure Zn (b) ZnLiMn alloy

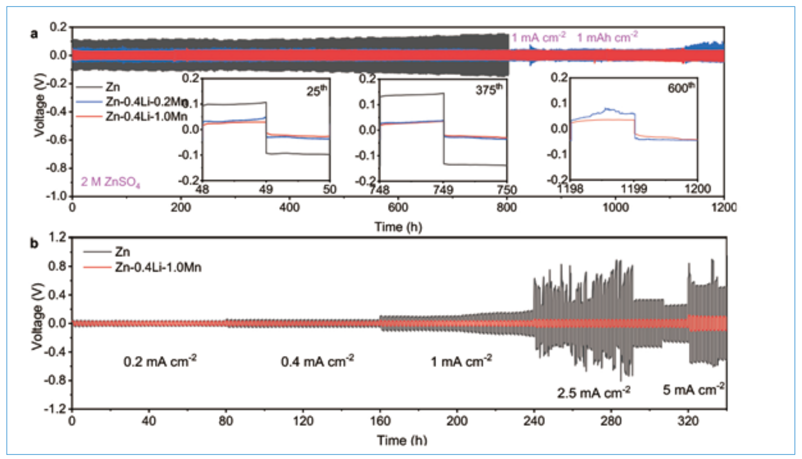


Figure 2 (a)Long-term Zn stripping/plating cycling profiles for pure Zn, Zn-0.4Li-0.2Mn and Zn-0.4Li-1.0Mn ymmetric cells (b)Comparison of voltage profiles for symmetric cells cycled at various current densities

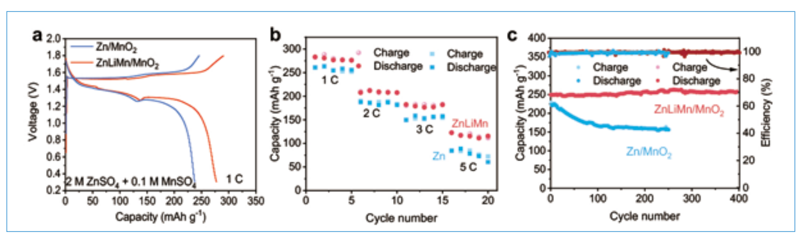


Figure 3 (a) Typical voltage profiles (b) Rate performance from 1 to 5 C (c) Capacity stability and coulombic efficiency of the ZnLiMn based ZIBs

REFERENCE

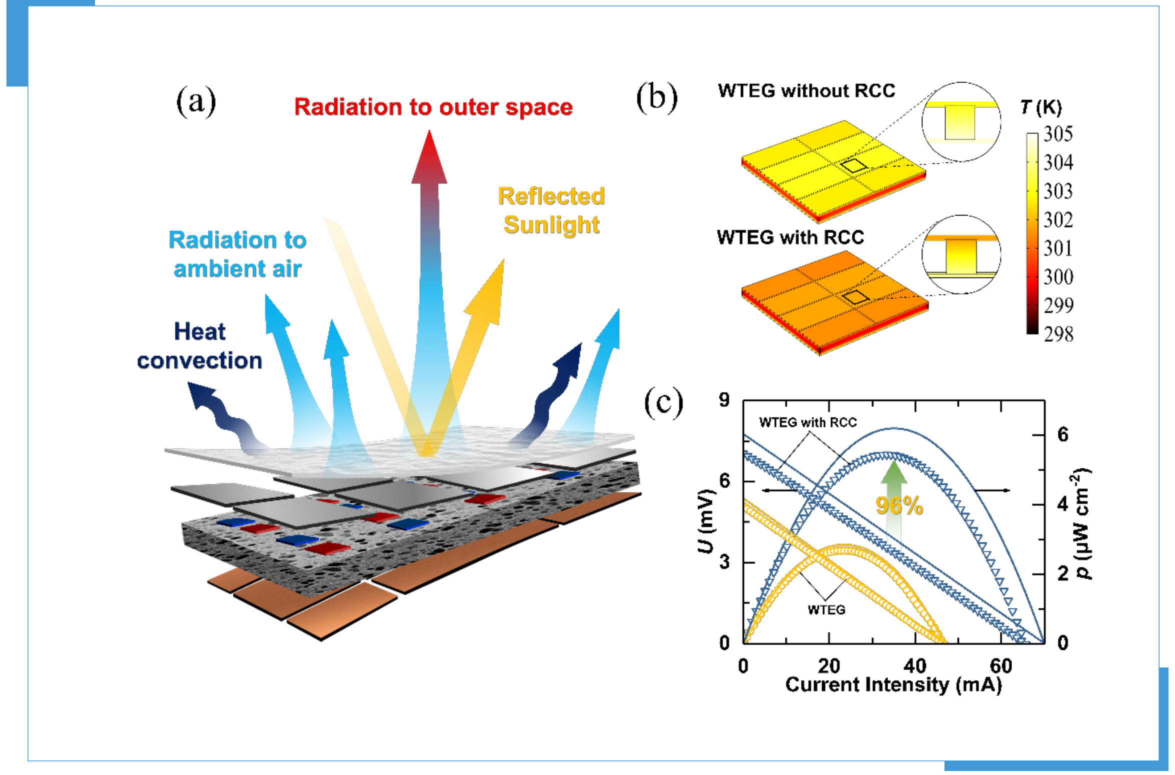
Zhang, Y., Yang, X., Hu, Y., Hu, K., Lin, X., Liu, X., Reddy, K. M., Xie, G., Qiu, H.-J. Highly strengthened and toughened Zn–Li–Mn alloys as long-cycling life and dendrite-free Zn anode for aqueous zinc-ion batteries. Small, 2022, 18, 2200787. DOI: https://doi.org/10.1002/smll.202200787

PASSIVE RADIATIVE COOLING ENABLES IMPROVED PERFORMANCE IN WEARABLE THERMOELECTRIC GENERATORS

In 2022, Associate Professor Cao Feng from the School of Science at Harbin Institute of Technology (Shenzhen), and Professor Liu Zhiguo from the School of Physics at Harbin Institute of Technology, published a paper titled "Passive Radiative Cooling Enables Improved Performance in Wearable Thermoelectric Generators" in *Small*.

With the development of wearable electronic devices and the "Internet of Things", designing a wearable self-powered generator is an urgent task. Wearable thermoelectric generators have great potential to be utilized as the power supply for these devices. However, the limited temperature difference across the thermoelectric generators significantly degrades the output performance.

In this work, they simulated the impact of thermal radiation on the performance of thermoelectric generators in different environments and experimentally verified the



(a) The schematic of WTEG with RCC
(b) The temperature distribution of the WTEG with and without RCC
(c) The comparison of voltage (*U*) and power density (*p*)

enhanced performance in a wearable thermoelectric generator combined with a radiative cooling coating. Compared with the pristine device, the wearable thermoelectric generator with radiative cooling coating (RCC) can not only achieve a ~128% improvement of output power in exposed environments but also exhibit a ~96% improvement of output power in non-exposed environments. They extensively investigated the indoor output performance of the wearable thermoelectric generator with a radiative cooling coating due to its stable voltage output, which shows an output power density of ~5.5 W cm^{-2} at the indoor temperature of 295 K, doubled without a radiative cooling coating. This effect resulted from RCC is equivalent to a ~1.75-fold improvement in *ZT*, which is extremely challenging if only optimizing TE materials. This work paves a new way for further enhancing the performance of thermoelectric generators via passive radiative cooling.

REFERENCE

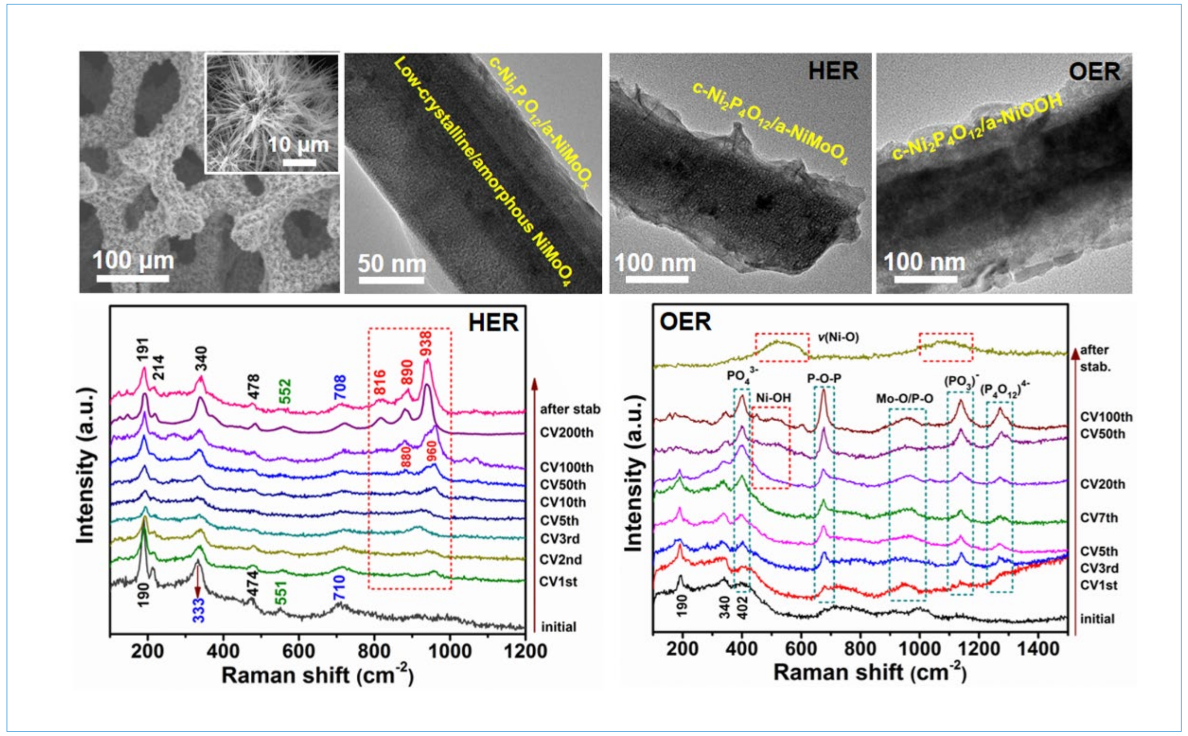
Yijie Liu, Shuaihang Hou, Xiaodong Wang, Li Yin, Zuoxu Wu, Xinyu Wang, Jun Mao, Jiehe Sui, Xingjun Liu, Qian Zhang, Zhiguo Liu, Feng Cao. Passive radiative cooling enables improved performance in wearable thermoelectric generators. Small, 2022, 18(10): e2106875.

CRYSTALLINE-AMORPHOUS $Ni_2P_4O_{12}$/$NiMoO_X$ NANOARRAYS FOR EFFICIENTLY ALKALINE WATER ELECTROLYSIS

Water electrolysis, powered by renewable electricity, affords a promising approach to large-scale hydrogen yield, but its efficiency is restrained by the sluggish water dissociation kinetics. It is vital to develop electrocatalysts with efficient and robust activity to facilitate the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) processes. Nonetheless, there are still challenges in preparing non-noble metal-based catalysts with excellent activity and stability for both HER and OER. It has been shown that in-situ surface reconstruction can contribute to the change of the intrinsic properties of catalysts (such as microstructure, composition, etc.), thus leading to the variation of energy barrier and kinetics of the catalytic reaction. Therefore, monitoring the dynamic surface reconstruction and intermediates of catalysts during the reaction process, so as to explore the real active site, is conducive to the rational design and synthesis of efficient non-noble metal-based catalysts.

Recently, Professor Xu Ping's group, from the School of Chemistry and Chemical Engineering at Harbin Institute of Technology, published a research paper titled "Crystalline-Amorphous $Ni_2P_4O_{12}$/$NiMoO_x$ Nanoarrays for Alkaline Water Electrolysis: Enhanced Catalytic Activity via In-situ Surface Reconstruction" in *Small*, a top journal in the field of engineering technology.

By in-situ forming crystalline $Ni_2P_4O_{12}$



($c-Ni_2P_4O_{12}$) on amorphous $NiMoO_x$ ($a-NiMoO_x$) nanoarrays supported on nickel foam via a facile one-step phosphorization process, $c-Ni_2P_4O_{12}/a-NiMoO_x/NF$ was prepared. Benefiting from the crystalline-amorphous nanostructures, the obtained catalyst exhibited excellent catalytic performances with a low overpotential of 78 mV at 10 mA/cm^2 for alkaline HER and 250 mV at 20 mA/cm^2 for alkaline OER, respectively. Besides, using $c-Ni_2P_4O_{12}/a-NiMoO_x/NF$ as both the anode and cathode, the electrolyzer displayed an excellent catalytic property with a cell voltage of 1.545 V to deliver a current density of 10 mA cm^{-2} and stable durability over 84 h. Moreover, various spectroscopic studies revealed that in-situ surface reconstruction of $c-Ni_2P_4O_{12}/a-NiMoO_x/NF$ was crucial for the enhanced catalytic activity. It was found that the $c-Ni_2P_4O_{12}/a-NiMoO_x/NF$ would adaptively rebuild into $c-Ni_2P_4O_{12}/a-NiMoO_4$ during the HER process and into $c-Ni_2P_4O_{12}/a-NiOOH$ during the OER process. This work may provide a new understanding on the design of crystalline-amorphous catalyst for efficient water electrolysis.

This work was financially supported by the National Natural Science Foundation of China.■

REFERENCE

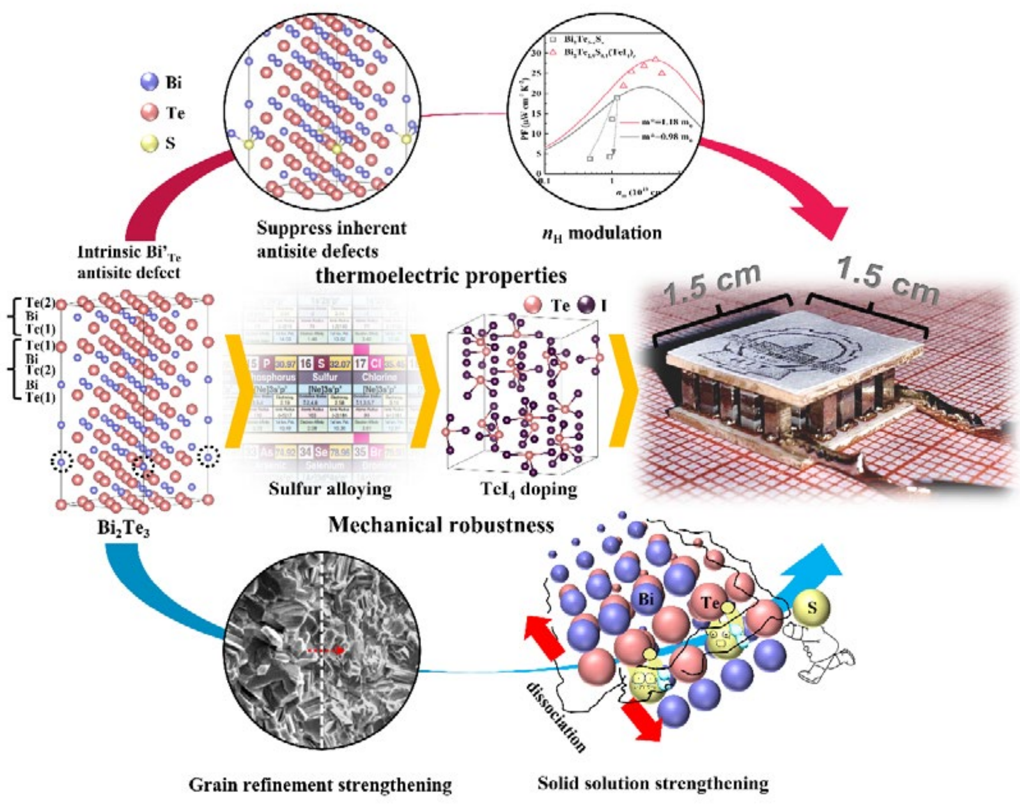
Jing Wang, Jing Hu, Ping Xu. Crystalline-amorphous $Ni_2P_4O_{12}/NiMoO_x$ nanoarrays for alkaline water electrolysis: enhanced catalytic activity via in-situ surface reconstruction. Small, 2022, 18(10): 2105972.

MEDIATING POINT DEFECTS ENDOWS N-TYPE Bi_2Te_3 WITH HIGH THERMOELECTRIC PERFORMANCE AND SUPERIOR MECHANICAL ROBUSTNESS FOR POWER GENERATION APPLICATION

In 2022, Professor Sui Jiehe's group from the State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, reported their new progress titled "Mediating Point Defects Endows N-Type Bi_2Te_3 with High Thermoelectric Performance and Superior Mechanical Robustness for Power Generation Application" in *Small*.

Extremely huge amounts of waste heat energy are distributed in the range of 300-600 K as low-grade resources. Regarding waste heat harvesting, in the context of the economic and environmental impact, thermoelectric technology is believed to be the next-generation promising approach when taking the maintenance cost, environment protection, and service stability into consideration.

In this work, point defect configuration by S/Te/I defects engineering was engaged to synergistically boost thermoelectric and mechanical properties of n-type Bi_2Te_3 alloy, leading to an advanced average ZT of 1.05 with ultrahigh compressive strength of 230 MPa, both of which are significantly superior to the commercial Bi_2Te_3. Based on the optimum composition, a fabricated 17-pair power generation module demonstrates a high



conversion efficiency of 5.37% under the temperature difference of 250 K that rivals the current state-of-the-art Bi_2Te_3 modules. This work proposes a new path of simultaneous optimization of thermoelectric and mechanical properties by point defect reconfiguration that can be potentially applied in other thermoelectric systems.

Professor Sui Jiehe and Professor Liu Zihang are the corresponding authors of this research paper, and Ph.D. student Zhu Yuke is the first author. This work was supported by the National Natural Science Foundation of China, the Natural Science Foundation of Heilongjiang Province, and Heilongjiang Touyan Team.

REFERENCE

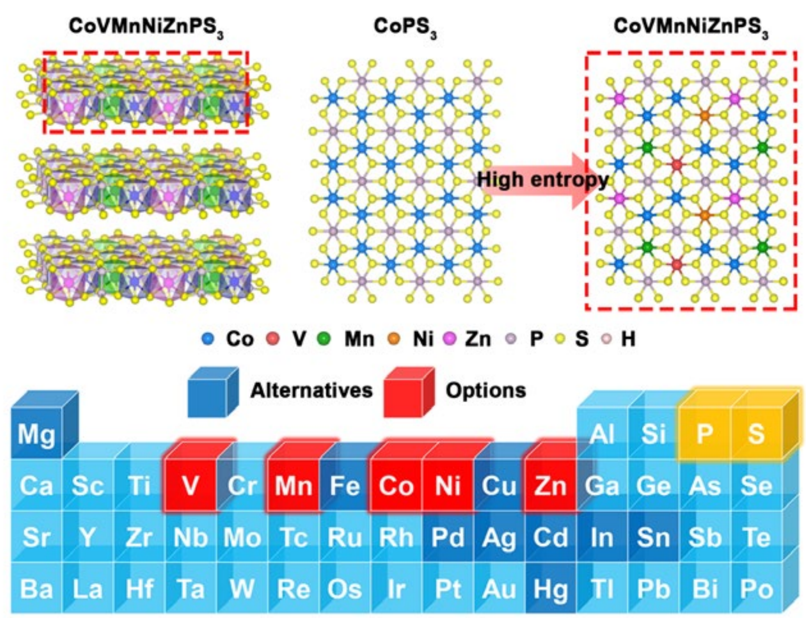
Yu-Ke Zhu, Zihang Liu, Jiehe Sui, et al. Mediating point defects endows n-type Bi_2Te_3 with high thermoelectric performance and superior mechanical robustness for power generation application. Small, 2022, 2201352.

TWO-DIMENSIONAL HIGH-ENTROPY ELECTROCATALYST FOR HYDROGEN EVOLUTION REACTION

Recently, Professor Song Bo, from the Center for Composite Materials and Structures, reported the progress on developing two-dimensional (2D) high-entropy electrocatalyst for efficient hydrogen evolution reaction (HER). The article titled "Two-Dimensional High-Entropy Metal Phosphorus Trichalcogenides for Enhanced Hydrogen Evolution Reaction" was published in *ACS Nano*.

Hydrogen is a carbon-neutral fuel that promises to replace traditional fossil fuels to cope with the increasing greenhouse effect. Hydrogen evolution reaction (HER) in the cathode plays a key role in electrocatalysis water splitting, which can effectively convert green electricity into renewable hydrogen energy. Although noble metals have impressive HER activities, their large-scale application is limited by high cost and low elemental abundance. Developing high-performance with cost-effective HER catalysts based on nonnoble elements is highly desirable.

High-entropy alloys (HEAs) are attracting increasing interests in both the materials and chemistry community, which also have been recognized to be a promising strategy to optimize the electrocatalytic performance of the catalysts. However, currently the limited preparation methods are not sufficient to provide HEA samples with well-defined morphology, which is actually an important platform to study the intrinsic activity and reveal the enhancement mechanism of high-entropy strategy. 2D high-entropy metal phosphorus trichalcogenides ($MPCh_3$) have the advantages of both near-continuous adsorption energies of HEAs and large specific surface area of 2D materials, which are excellent catalytic platforms. Combining high-entropy and 2D material concepts, $Co_{0.6}(VMnNiZn)_{0.4}PS_3$ nanosheets with high-concentration active sites show an overpotential of 65.9 mV at a current density of 10 mA cm^{-2} and a



Tafel slope of 65.5 mV dec^{-1}, making them an efficient electrocatalysts for HER.

Decent characterizations are applied to reveal lattice expansion and tensile strains in the high-entropy $MPCh_3$ that are endowed by the highly-random distribution of multi metals, which further leads to the charge redistribution and optimizes the adsorption properties of the active site. The structure features of the most active high-entropy $Co_{0.6}(VMnNiZn)_{0.4}PS_3$ obtained from the Rietveld refinement of powder X-ray diffraction pattern are used to build the catalyst model for density function theory calculation, which can strengthen the connections between experimental and theoretical results, thus improving the reliability and integrity of the conclusion. It suggests that the high-entropy strategy triggers the charge redistribution and increases the abundance of active sites by optimizing the S site at the edge, activating the P sites on the basal plane and introducing more metal sites to promote the water dissociation and improving the alkaline HER performance significantly.

This work not only demonstrates the successful application of the HEA concept in phosphosulfide material systems but also provides a strategy to enhance the electrocatalytic activity for 2D catalysts.■

REFERENCE

Ran Wang, Jinzhen Huang, Xinghong Zhang, Jiecai Han, Zhihua Zhang, Tangling Gao, Lingling Xu, Shengwei Liu, Ping Xu, and Bo Song. Two-dimensional high-entropy metal phosphorus trichalcogenides for enhanced hydrogen evolution reaction. ACS Nano, 2022, 16, 3, 3593-3603. DOI: 10.1021/acsnano.2c01064

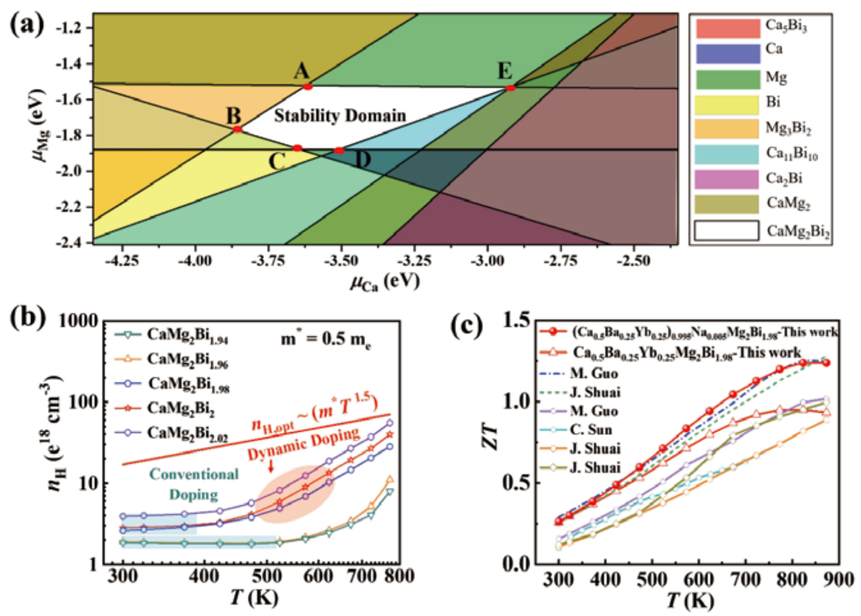
HIGH THERMOELECTRIC PERFORMANCE OF $CaMg_2Bi_2$ ENABLED BY DYNAMIC DOPING AND ORBITAL ALIGNMENT

In 2022, Professor Sui Jiehe's group from the State Key Laboratory of Advanced Welding and Joining published a research paper titled "High Thermoelectric Performance of $CaMg_2Bi_2$ Enabled by Dynamic Doping and Orbital Alignment" in *Advanced Functional Materials*.

Exploring new energy sources or improving energy utilization patterns has become a long-term effective means to cope with the ever-increasing demands for energy. Over the last few decades, we have witnessed the prosperity of energy technology in many areas. Thermoelectric technology, particularly, as a renewable energy utilization technology has sprung up in recent years, which allows the direct conversion of electricity from the harvesting of waste heat. For a given material, its thermoelectric conversion efficiency depends on a dimensionless figure of merit *ZT*.

P-type $CaMg_2Bi_2$-based thermoelectric materials, as a crucial subgroup of 1-2-2 type Zintl phase with "phonon-glass electron-crystal" concept, have attracted extensive attention in recent years. The high *ZT* values have been obtained so far via various valid strategies, but there is an essential topic that has been neglected for a long time: since the Bi second phase is inevitably formed due to the volatilization of cation Mg during the preparation process, how does the Bi second phase evolve with temperature, and how does it affect the thermoelectric properties? Therefore, to clarify these basic scientific issues, the phase structure is explored by adjusting the initial Bi content, its influence on the intrinsic microstructure and thermoelectric properties studied deeply in this work. The first-principles calculation shows that a more Bi-rich condition through the increase of initial Bi content provides a driving force to reduce the cation vacancy formation energy and then increase the carrier concentration. Specially, there is a dynamic doping behavior in the samples with high content of Bi second phase, making the carrier concentration meeting the requirement for temperature-dependent optimal carrier concentration and realizing a *ZT* of 6.5 times as high as that of the single-phase.

Based on the optimized matrix, a delicate design of orbital alignment, i.e., $\Delta E = 0$ eV, is successfully realized by Yb/Ba co-doping to maximize the band degeneracy (N_v) then optimizing the electrical transport



The calculated effective stability domain of $CaMg_2Bi_2$ under equilibrium situation and the optimized thermoelectric performance

properties. Meanwhile, the substitution of Yb/Ba can enhance phonon scattering and largely reduce the lattice thermal conductivity. Benefitting from the synergistical modulation of electrical and thermal transportation, the $(Ca_{0.5}Yb_{0.25}Ba_{0.25})_{0.995}Na_{0.005}Mg_2Bi_{1.98}$ sample shows a highest *ZT* of 1.24 at 873 K and a record ZT_{ave} of 0.86 between 300 K and 873 K. This work not only provides a new understanding of the dynamic doping behavior of Bi second phase, which is a prerequisite for high *ZT* values of $CaMg_2Bi_2$ system, but also offers an effective strategy to tune the band structure by manipulating the crystal field splitting energy.

Professor Sui Jiehe, Professor Cai Wei, and Dr. Guo Fengkai are the corresponding authors of this work. The Ph.D. student Guo Muchun is the first author. The Ph.D. student Zhai Wenya is an equal contributor. This work was financially supported by the National Natural Science Foundation of China, the Natural Science Foundation of Heilongjiang Province of China, and the Heilongjiang Touyan Innovation Team Program. This work also thanked the support from the Fundamental Research Funds for the Central Universities.■

REFERENCE

Guo Muchun, Zhai Wenya, Li Jingyu, Zhu Jianbo, Guo Fengkai, Liu Zihang, Liu Ming, Zhu Yuke, Dong Xingyan, Zhang Yongsheng, Zhang Qian, Cai Wei, and Sui Jiehe. High thermoelectric performance of $CaMg_2Bi_2$ enabled by dynamic doping and orbital alignment. Advanced Functional Materials, 2022, 2200407. DOI: 10.1002/adfm.202200407

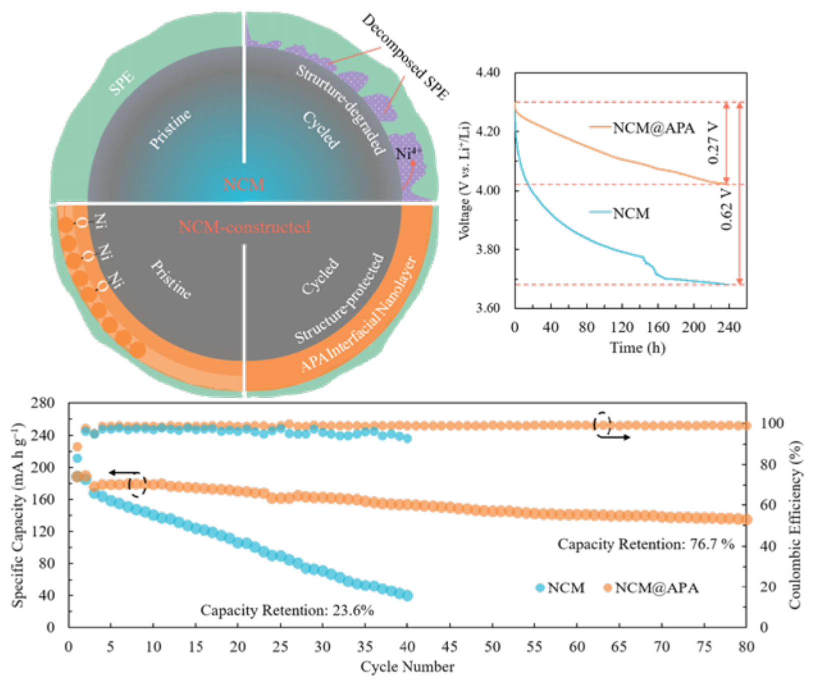
CONSTRUCTING INTERFACIAL NANOLAYER STABILIZES 4.3 V

HIGH-VOLTAGE ALL-SOLID-STATE LITHIUM BATTERIES WITH PEO-BASED SOLID-STATE ELECTROLYTE

In 2022, Professor Wang Jiajun's group from the School of Chemistry and Chemical Engineering published a research paper titled "Constructing Interfacial Nanolayer Stabilizes 4.3 V High-Voltage All-Solid-State Lithium Batteries with PEO-Based Solid-State Electrolyte" in *Advanced Functional Materials*.

Complicated interfacial problems of poly(ethylene oxide) (PEO)-based solid polymer electrolyte (SPE) at high voltages severely hinder its practical applications for high-energy-density all-solid-state lithium batteries (ASSLBs). Herein, the failure mechanisms of ASSLBs with $LiNi_{0.6}Co_{0.2}Mn_{0.2}O_2$ (NCM)-PEO are studied. It is found that the ASSLBs after charging generated a sharp drop of 0.62 V for 10-day storage. This phenomenon can be explained as follows: when NCM||SPE||Li ASSLBs are charged at a high cut-off voltage, both high-valent nickel ions on the surface of the NCM active material and Super P in the cathode will accelerate the oxidative decomposition of PEO, and PEO with ether groups tends to lose electrons. In order to remain charge balance, accompanied by Li^+ inserted into NCM, the voltage of ASSLBs rapidly dropped accompanied by Li^+ inserted into NCM. The failure of NCM active materials and the increase of the interfacial resistance on the cathode side are responsible for the performance degradation of NCM||SPE||Li ASSLBs.

To mitigate interfacial side reactions between NCM and SPE, we constructed an interfacial nanolayer with aromatic polyamide (APA) on the surface of NCM active particles (NCM@APA). The strong interaction between NCM and APA interfacial nanolayer is attributed to O atoms in APA being able to combine with Ni atoms on the NCM particle



Interfacial nanolayer strategy for solid-state lithium batteries

surface. Robust interfacial nanolayers not only effectively protect the crystal structure of NCM but also provide a steady interfacial environment for Li^+ diffusion kinetics. Accordingly, NCM@APA||SPE||Li ASSLBs exhibit an acceptable voltage drop of 0.27 V after 10-day storage and a substantially improved electrochemical performance with an average coulombic efficiency of 99.1% and capacity retention of 76.7% after 80 cycles.

This work was supported by the National Natural Science Foundation of China, the Chinesisch-Deutsches Mobilitätspropgamm, the Fundamental Research Funds for the Central Universities, the Natural Science Funds of Heilongjiang Province, the Heilongjiang Touyan Innovation Team Program, the "Young Scientist Studio" of Harbin Institute of Technology (HIT), and funds from the Chongqing Research Institute of HIT, China Aerospace Science and Technology, the Corporation-Harbin Institute of Technology Joint Center for Technology Innovation Fund, the Cultivation Plan of Major Scientific Research Projects of HIT.■

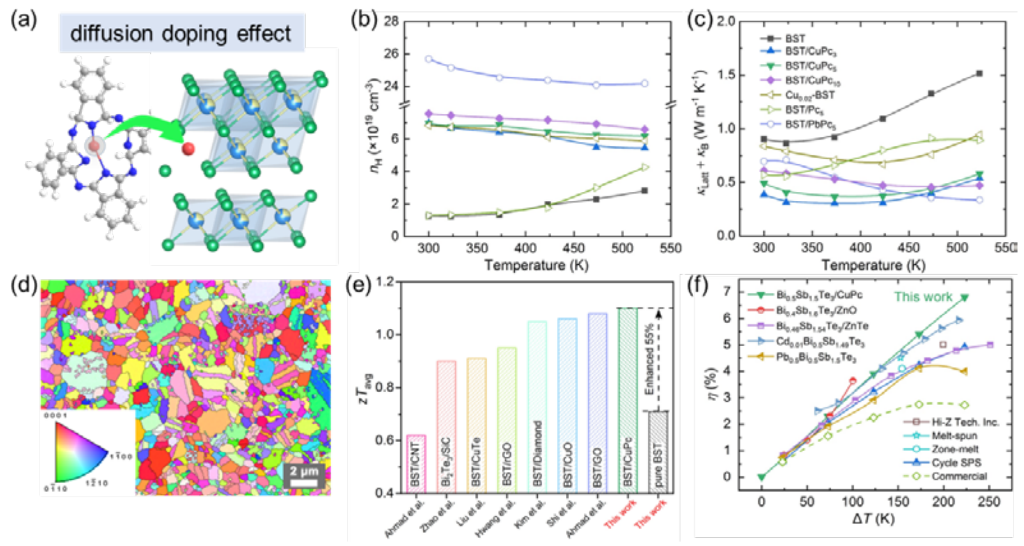
REFERENCE

Xufeng Wang, Yajie Song, Xin Jiang, Qingsong Liu, Jidong Dong, Jian Wang, Xin Zhou, Bing Li, Geping Yin, Zaixing Jiang, Jiajun Wang. Constructing interfacial nanolayer stabilizes 4.3 V high-voltage all-solid-state lithium batteries with PEO-based solid-state electrolyte. Advanced Functional Materials, 2022, 2113068. DOI: 10.1002/adfm.202113068

ORGANIC/ INORGANIC HYBRID DESIGN AS A ROUTE FOR PROMOTING THE HERMOELECTRIC PERFORMANCE

Recently, a team led by Professor Zhang Qian, from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), published a research paper titled "Organic/Inorganic Hybrid Design as a Route for Promoting the $Bi_{0.5}Sb_{1.5}Te_3$ for High-Performance Thermoelectric Power Generation" in *Advanced Functional Materials*.

Bismuth telluride (Bi_2Te_3) and its alloys are state-of-the-art room-temperature thermoelectric materials and are quite promising for low-grade waste heat recovery. However, the primary research focus has been on improving the peak zT by manipulating electron and phonon transport properties, which does not assure high conversion efficiency of TE generator mainly due to the low zT_{avg}. Copper(II) Phthalocyanine (CuPc) is one of the most studied metal-organic complex, exhibiting the characteristics of both metal and organic porous frame. It can be potentially applied in thermoelectric fields due to its ultra-low thermal conductivity, high carrier mobility, and high thermal stability.



In this work, researchers demonstrate a synergistic optimization for $Bi_{0.5}Sb_{1.5}Te_3$ by incorporating the CuPc, which is preferentially distributed at the grain boundary of $Bi_{0.5}Sb_{1.5}Te_3$ after the spark plasma sintering process and suppresses the grain growth of $Bi_{0.5}Sb_{1.5}Te_3$. The lattice thermal conductivity of composites is then extensively reduced by the multiscale scattering induced by the CuPc. In addition, the Cu atoms diffuse into the lattice of $Bi_{0.5}Sb_{1.5}Te_3$ and increase the hole concentration, thus suppressing the bipolar effect. As a result, the average zT value is effectively enhanced from 0.7 to 1.1 in the temperature range between 300 and 523 K. A high conversion efficiency of 6.8% is achieved in a single $Bi_{0.5}Sb_{1.5}Te_3/CuPc_5$ leg, which is 41.7% higher than that of $Bi_{0.5}Sb_{1.5}Te_3$ at temperature difference ΔT = 223 K. This result proves that the organic/inorganic hybrid design is a promising strategy to improve the performance of Bi_2Te_3-based TE modules.

The first author Wang Xiaodong is a post-doctoral in Professor Zhang Qian's group. This research was financially supported by the National Natural Science Foundation of China.■

REFERENCE

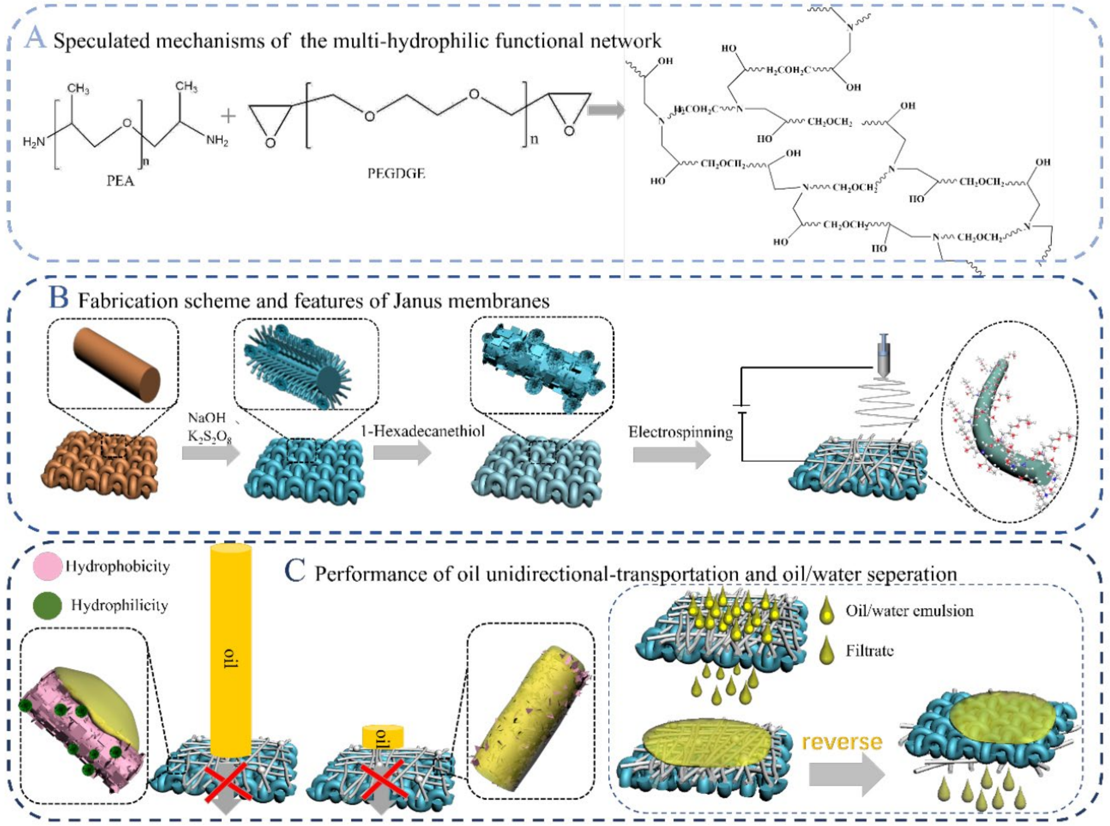
Xiaodong Wang, Jinxuan Cheng, Qian Zhang, et al. Organic/inorganic hybrid design as a route for promoting the $Bi_{0.5}Sb_{1.5}Te_3$ for high-performance thermoelectric power generation. Advanced Functional Materials, 2022, 202200307. DOI: 10.1002/adfm.202200307

NOVEL "OIL-DIODE" JANUS MEMBRANE FOR OIL/WATER SEPARATION

Recently, a team led by Associate Professor Cheng Xiquan, from the School of Marine Science and Technology, State Key Laboratory of Urban Water Resource and Environment (SKLUWRE), Harbin Institute of Technology (Weihai), published a research paper titled "Constructing Environmental-Friendly 'Oil-Diode' Janus Membrane for Oil/Water Separation" in *ACS Nano*.

Due to the frequency of oil leakage and the increasement of industrial oily water, there is an urgent need to fabricate advanced materials to solve oil/water separation efficiently. With unidirectional oil transportation performance, "oil-diode" Janus membranes are applied in oily wastewater treatment. However, the hydrophobic side of traditional "oil-diode" Janus membrane is completely hydrophobic, resulting in an easy permeation of oil, which hampers light oil recycling.

In current study, we fabricated an environmental-friendly "oil-diode" Janus membrane with special wettable structure for oil unidirectional transportation and oil/water separation. On the one hand, some micro-nano structure area with partially hydrophilic surface on the hydrophobic side of the membrane is the key to increasing Laplace pressure. On the other hand, experimental and theoretical studies show that surface wettability and material characters that generate superimposed efforts act significant parts in achieving oil unidirectional transportation performance. The fabricated membranes with relatively thin underwater superoleophobic PLA nanofiber membrane and relatively thick hydrophobic copper mesh underneath show an ultra-high oil intrusion pressure, an excellent



permeability and an extra-high separation efficiency of the water-in-oil stable emulsion containing surfactants. Besides, the finely designed membrane exhibits extra-high oil intrusion pressure up to 12 kPa which is higher than that of the state-of-art membranes. Meanwhile, the fabricated membranes show an outstanding separation performance for stable oil-water emulsions containing surfactants with permeance about 2993 L m^{-2} h^{-1} bar^{-1} and separation efficiency up to 99.6% superior to that of the state-of-art membranes. Additionally, the PLA nanofiber membrane is biodegradable and the copper network is recyclable, which is highly consistent with the concept of green development. Taken together, with membrane's specifically designed structure, its thickness, high permeance and high separation efficiency, and excellent liquid unidirectional transportation performance, the environmental-friendly Janus membranes show a strong promise in separating stable water-oil emulsion, recycling of offshore oil slick, liquid manipulation and other fields.■

REFERENCE

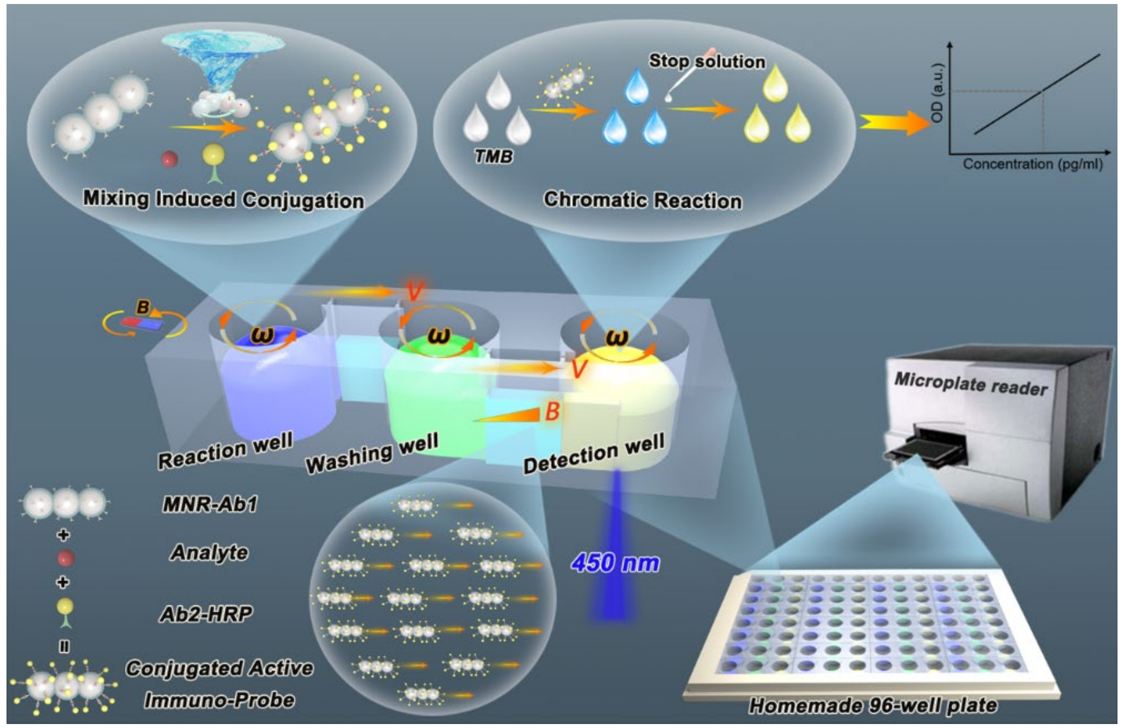
Xiquan Cheng, Yanyan Ye, Zhixing Li, Xueying Chen, Qing Bai, Kai Wang, Yingjie Zhang, Enrico Drioli, Jun Ma. Constructing environmental-friendly "oil-diode" Janus membrane for oil/water separation. ACS Nano, 2022. DOI: 10.1021/acsnano.1c11388

MAGNETIC NANO-ROBOTS AS MANEUVERABLE IMMUNOASSAY PROBES FOR AUTOMATED AND EFFICIENT ENZYME LINKED IMMUNOSORBENT ASSAY

Recently, the maneuverable immunoassay probe based on an micro/nano motor was proposed by Professor Ma Xing's team from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), and the results titled "Magnetic Nano-Robots as Maneuverable Immunoassay Probes for Automated and Efficient Enzyme Linked Immunosorbent Assay" was published in *ACS Nano*.

As a typical, classical, but powerful biochemical sensing technology in analytical chemistry, enzyme-linked immunosorbent assay (ELISA) shows excellence and wide practicability for quantifying analytes of ultralow concentration. However, long incubation times and burdensome laborious multi-step washing processes make it inefficient and labor-intensive for conventional ELISA.

Here, we propose rod-like magnetically-driven nano-robots (MNRs) for use as maneuverable immunoassay probes that facilitate a strategy for an automated and highly efficient ELISA analysis, termed nano-robots enabled ELISA (nR-ELISA). To automate the analysis process, we designed and fabricated a 3-D printing of a detection unit consisting of three



function wells. The MNR-Ab1s can be steered into different function wells for required reaction or wishing process. The actively rotating MNR-Ab1s can enhance the binding efficacy with target analytes at micro-scale and greatly decreased incubation time. The integrated nR-ELISA system can significantly reduce the assay time, during which process manpower input is greatly minimized. This work of taking magnetic micro/nano-bots as active immunoassay probes for automatic and efficient ELISA not only holds great potential for point-of-care testing (POCT) in the future but also extends the practical applications of self-propelled micro/nano-robots into the field of analytical chemistry.

This research was financially supported by the National Natural Science Foundation of China.■

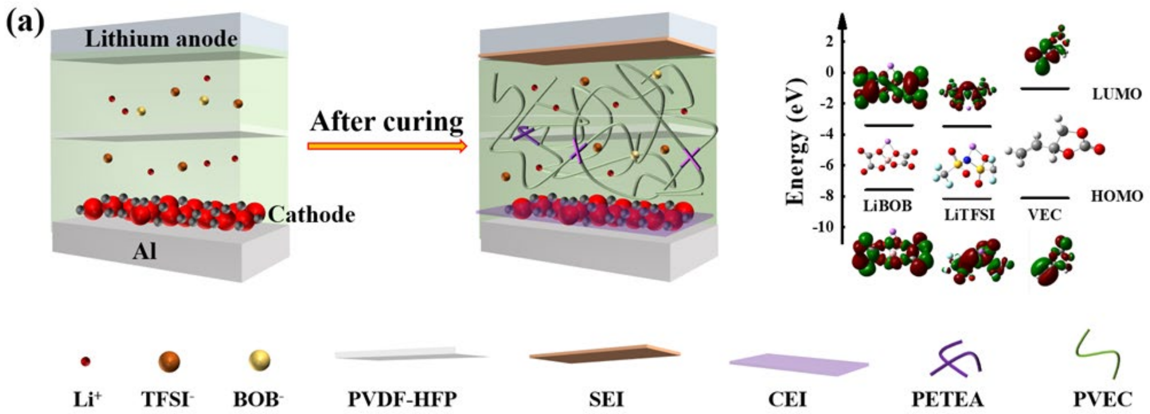
REFERENCE

Yong Wang, Liaoxia Liu, Xing Ma, et.al. Magnetic nano-robots as maneuverable immunoassay probes for automated and efficient enzyme linked immunosorbent assay. ACS Nano, 2022, 16, 1, 180–191. DOI: 10.1021/acsnano.1c05267

POLY (VINYL ETHYLENE CARBONATE)-BASED DUAL-SALT GEL POLYMER ELECTROLYTE ENABLING HIGH VOLTAGE LITHIUM METAL BATTERIES

Rechargeable lithium metal batteries (LMBs) have been regarded as one of the most promising next-generation energy storage systems due to their high theoretical energy density. However, the practical application of LMBs is greatly impeded by poor high-voltage tolerance and safety concerns originating from flammable organic carbonate-based liquid electrolytes. The polymer electrolytes are considered as a promising strategy to improve the safety of LMBs. But the polymer electrolytes usually exhibit low compatibility with the high voltage cathode, resulting in continuous electrolyte decomposition and poor cycle life. Therefore, it is urgent to develop suitable polymer electrolytes for high-voltage lithium metal batteries.

Recently, Professor Zuo Pengjian's group from the School of Chemistry and Chemical Engineering at Harbin Institute of Technology published a paper titled "Poly (Vinyl Ethylene Carbonate)-Based Dual-Salt Gel Polymer Electrolyte Enabling High Voltage Lithium Metal Batteries" in *Chemical Engineering Journal*.



Schematic illustration of the design strategy of DS-GPE and the LUMO and HOMO energy values of the solvent components

In this work, a novel poly (vinyl ethylene carbonate)-based dual-salt gel polymer electrolyte (DS-GPE) was reported for high-voltage LMBs. Vinyl ethylene carbonate (VEC) shows high dielectric constant and excellent compatibility with Li metal. Meanwhile, the VEC with unique framework can be polymerized with C=C bonds to improve the safety of LMBs. The weaker complexation between C=O bonds and Li^+ can facilitate ion transport and enable high ionic conductivity. Moreover, the lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) has been the widely used in GPEs, owing to the high solubility, chemical stability, and stable cycling efficiency. However, LiTFSI can induce severe corrosion of the electrode current collector, which can be suppressed by the addition of lithium bis(oxalato)borate (LiBOB) salt to effectively passivate the Al current collector. Remarkably, the high-voltage Li|DS-GPE|$LiCoO_2$ cells deliver an outstandingly long lifespan with high-capacity retention of 83.42% after 100 cycles at 1 C with an average Coulombic efficiency of 99.86%. ■

REFERENCE

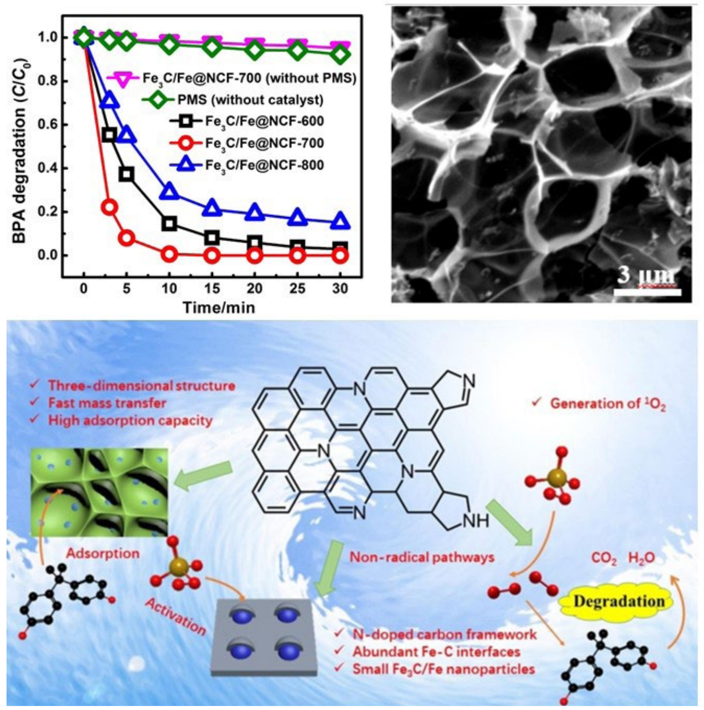
Q. Zhou, C. Fu, R. Li, X. Zhang, B. Xie, Y. Gao, G. Yin, P. Zuo. Poly (vinyl ethylene carbonate)-based dual-salt gel polymer electrolyte enabling high voltage lithium metal batteries. Chemical Engineering Journal, 2022, 437, 135419.

THREE-DIMENSIONAL MACROPOROUS CARBON-BASED CATALYST FOR WASTEWATER REMEDIATION

Professor Du Yunchen, from the School of Chemistry and Chemical Engineering, recently published a research paper titled "Fe_3C/Fe Nanoparticles Decorated Three-Dimensional Nitrogen-Doped Carbon Foams for Highly Efficient Bisphenol: A Removal through Peroxymonosulfate Activation" in *Chemical Engineering Journal*.

With the development of industrialization and society, a large amount of industrial wastewater and domestic sewage is discharged into natural water bodies, which aggravates the amount of pollution of water environments. Advanced oxidation processes (AOPs) with generated free radicals as powerful oxidative species have been proven to be one of the most promising technologies for organic pollutant removal. Different from conventional Fenton reaction, peroxymonosulfate (PMS) receives much attention as a candidate for H_2O_2, because the resultant sulfate radicals have higher oxidative potential, longer half-life period, and more flexible pH range than hydroxyl radicals. The development of highly efficient catalysts to activate PMS is an attractive topic in this field.

In this study, we demonstrated a direct synthesis of 3D nitrogen-doped carbon foams decorated with Fe_3C/Fe nanoparticles (Fe_3C/Fe@NCFs) by pyrolyzing the mixture of polyvinyl pyrrolidone



(PVP) and ferric nitrate nonahydrate. The formation of carbon foams is benefited from the blowing process of PVP during the decomposition of ferric nitrate nonahydrate. The synergistic effect between highly dispersed Fe_3C/Fe nanoparticles and N-doped carbon frameworks are greatly helpful for BPA removal through PMS activation. The contribution of 3D macroporous structure was also verified by comparing with a counterpart from the pyrolysis of PVP/ferric chloride. Besides, the oxidative reactive species were determined through elaborate quenching experiments and electron paramagnetic resonance analysis, and the mechanism of PMS activation was tentatively proposed based on detailed structure and performance characterizations. We believe that this study is expected to provide some new ideas for the development of efficient and stable green heterogeneous catalysts as PMS activators.

This work was financially supported by the National Natural Science Foundation of China.■

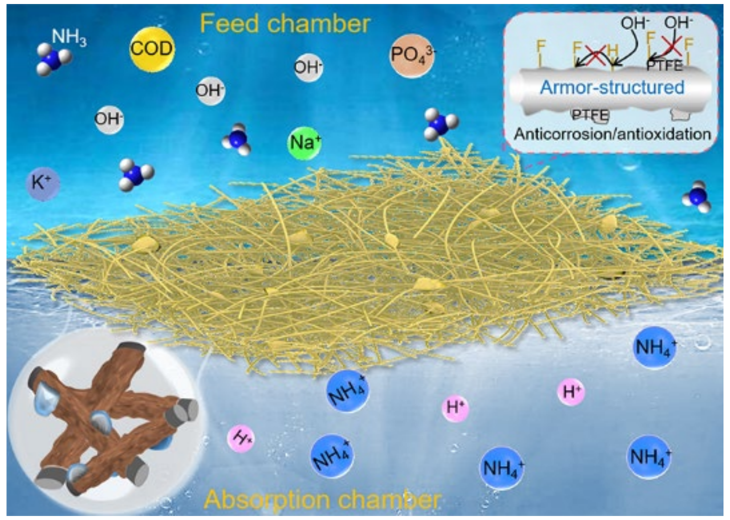
REFERENCE

Zhang L, Wang B, Ma W, et al. Fe_3C/Fe nanoparticles decorated three-dimensional nitrogen-doped carbon foams for highly efficient bisphenol A removal through peroxymonosulfate activation. Chemical Engineering Journal, 2022, 437, 135472. DOI: 10.1016/j.cej.2022.135472

ARMOR-STRUCTURED INTERCONNECTED-POROUS MEMBRANES FOR WASTE AMMONIUM RESOURCE RECYCLING

Professor Wang Wei and Professor Ma Jun, from the State Key Laboratory of Urban Water Resource and Environment, recently published a paper titled "Armor-Structured Interconnected-Porous Membranes for Corrosion-Resistant and Highly Permeable Waste Ammonium Resource Recycling" in *Environmental Science & Technology*. The first author is Liu Dongqing.

Gas-permeable membrane ammonium recovery (GMAR), which is driven by a partial pressure gradient of ammonia between the feed and collected side, is quite promising for sustainable development to recycle ammonium as a precious resource from wastewater. Maintaining the chemical stability and high ammonia permeability of membrane is critical for the success of the GMAR process. Conventional chemical-resistant membranes display modest permeability due to the poor solubility and processibility; chemical-active membranes are more easily endowed with better permeability however are hindered by instability. To overcome this tradeoff, the research



group developed a novel membrane configuration via one-step solution-electrospinning, with the chemical-active component (low-strength fluorine polymer) as the inner skeleton to construct interconnected porous structures, and the chemical-resistant component (high-strength fluorine polymer) as the outer armor to serve as a protective layer. The unique armored construction enables the membrane to operate stably under harsh conditions, and the interconnected porous structure greatly improves the ammonia mass transfer efficiency.

Through long-term intermittent and consecutive operation, the armor-structured nanofibrous membrane exhibited outstanding reusability and durability. More significantly, when treating actual piggery wastewater with complicated water quality, the armor-structured nanofibrous membrane also displayed a robust stable performance with excellent anti-wettability.

This work was financially supported by the National Natural Science Foundation of China and the Natural Science Foundation of Heilongjiang Province.

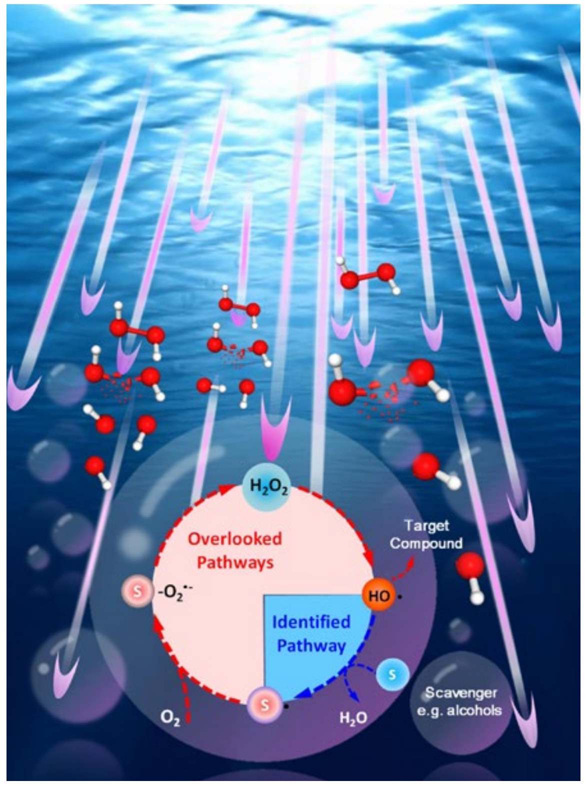
REFERENCE

Dongqing Liu, Fuyun Yu, Lingling Zhong, Tao Zhang, Ying Xu, Yingjie Qin, Jun Ma, and Wei Wang. Armor-structured interconnected-porous membranes for corrosion-resistant and highly permeable waste ammonium resource recycling. Environmental Science & Technology, 2022. DOI: 10.1021/acs.est.2c00737

THINK BEFORE USE: HOW TO DETERMINE RADICALS WHEN USING ALCOHOLS AS SCAVENGERS?

In 2022, Professor Chen Baiyang's group from Harbin Institute of Technology (Shenzhen) published a research paper titled "Overlooked Formation of H_2O_2 during the Hydroxyl Radical-Scavenging Process When Using Alcohols as Scavengers" in *Environmental Science & Technology*.

This study challenges a traditional method for hydroxyl radical (•OH) determination in the presence of other reactive species when using alcohols as scavengers. Although alcohols are currently widely applied in environmental, agricultural, biochemical, and biomedical areas now, adding different types of alcohols in •OH scavenging processes can result in formation of substantial levels of H_2O_2, which is a known •OH precursor. This means that adding alcohols may trigger formation of more •OH and therefore bring risk to the quantification of •OH. From the tested alcohols, n-butanol is the best scavenger, because



Due to the overlooked H_2O_2 formation, which was proven in this study, conventional •OH determination method using alcohols is likely unreliable or misleading.

it quenches •OH rapidly but forms little H_2O_2. In addition, the study also clarified the roles of oxygen, pH, and scavenger dosage on the H_2O_2 formation, proving that they can also alter •OH determination results as well.

Overall, this study identified considerable uncertainties in determining •OH in previous approaches (i.e., using alcohols as scavengers) and provided theoretical insights on how to choose and use appropriate scavengers to enable reliable •OH determination. Notably, these uncertainties are present not only in ultraviolet-based advanced oxidation processes but also likely to be present in other •OH-related processes. Taken together, three things need to be done to avoid scavenger misuse: (1) choosing an appropriate type of alcohol, (2) using an excessive amount of alcohol, and (3) conducting tests under proper pH and oxygen conditions.

The first author is Dr. Wang Lei, who graduated from Professor Chen Baiyang's group. This work was financially supported by the Shenzhen Science and Technology Innovation Commission and the National Natural Science Foundation of China.■

REFERENCE

Wang, L., Li, B., Dionysiou, D. D., Chen, B., Yang, J., Li, J. Overlooked formation of H_2O_2 during the hydroxyl radical-scavenging process when using alcohols as scavengers. Environmental Science & Technology, 2022, 56(6), 3386-3396. DOI: https://doi.org/10.1021/acs.est.1c03796

Research & Academia
HIT TIMES 2022

STRENGTHENING HIGH ENTROPY ALLOY VIA LASER SHOCK PEENING

In 2022, a group led by Dr. Huang Yongjiang, from the School of Materials Science and Engineering at Harbin Institute of Technology, published a research paper titled "Strengthening $CrFeCoNiMn_{0.75}Cu_{0.25}$ High Entropy Alloy via Laser Shock Peening" in the journal of *International Journal of Plasticity*.

For most metallic materials, surface hardening via modifying the near-surface microstructure has been considered an effective method for improving mechanical properties. Among these processes, laser shock peening (LSP), which is versatile and nondestructive to the fabricated product shape, has received considerable attention. LSP can produce a severe plastic deformation with a strain rate excess 10^6 s^{-1} in the surface of alloys to enhance mechanical properties, which has been widely used in the aerospace industry. However, the response of face centered cubic (*fcc*) high entropy alloys (HEAs) in terms of mechanical properties and deformation mechanism to LSP impacts remains a mystery. Besides, it is also significant to investigate the microstructural evolution and redistribution of strain in soft to hard regions of LSP-processed

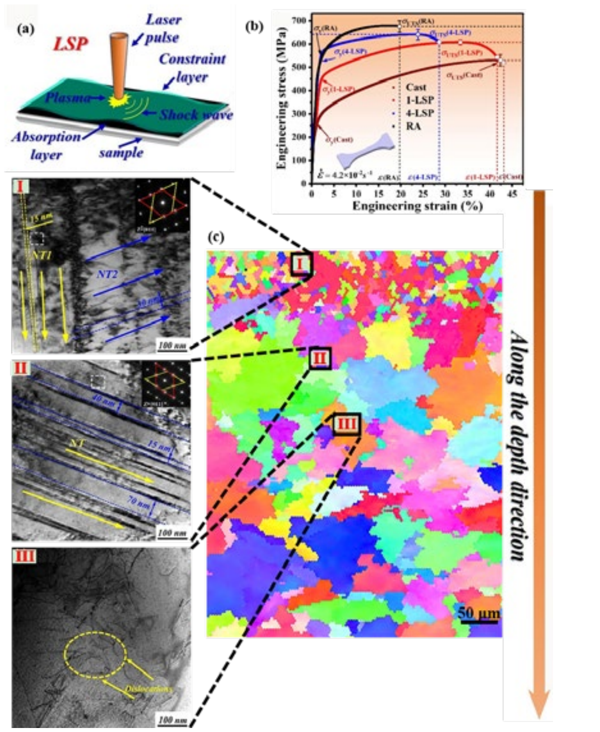


Figure 1
(a) Schematic of LSP processing
(b) A typical engineering stress-strain curve of HEA at different conditions
(c) Micro-structures of 4-LSP-treated HEA along the different depths

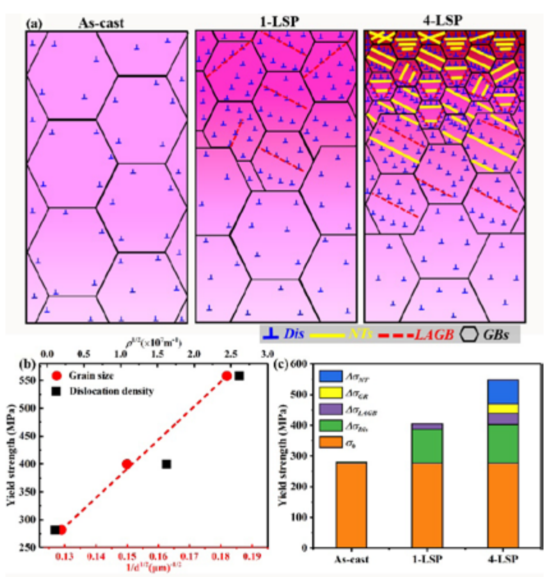


Figure 2 The schematic illustrations of the strengthening mechanisms for the as-cast, 1-LSP and 4-LSP processed HEAs

HEAs in relation to the deformation behaviors upon loading.

The present work has shown that the mechanical properties of a single *fcc* phase CoNiMn$_{0.75}$Cu$_{0.25}$ HEA have significantly improvement after LSP treatment. Yield strength more than two times of the as-cast alloy is achieved in HEA treated by LSP for 4 cycles, due to the introduction of a gradient microstructure comprising subgrains, dense dislocations and nano-twins near the treated surface. The combination of dislocation hardening and mechanical twinning improves the strain hardening ability for the LSP-treated HEA, leading to its excellent plasticity during tensile loading. Grain refinement also takes place via a faulting process of dislocation dissociation on nearly every {111} plane. Combining transmission electron microscope observations and finite element modeling of the LSP processed HEA samples after different levels of accumulated strain yield that further tensile deformation is mainly accommodated by dislocations in the core region of the HEA sample unaffected by the LSP, while the top LSP-affected layer accommodates little further plasticity as it is sufficiently hardened by the LSP. The present results indicate the possibility to explore gradient-structured HEAs with excellent mechanical properties using laser shock peening.

Professor Alfonso H.W. Ngan from the University of Hong Kong, Fellow of the Royal Academy of Engineering, is the co-corresponding author of this research paper. This work was financially supported by the National Natural Science Foundation of China, the National Key Research and Development Programs of China, the Guangdong Province Basic and Applied Research Key Projects, and the National Key R&D Programme, Ministry of Science and Technology of China.

REFERENCE

Wujing Fu, Yongjiang Huang, Jianfei Sun, Alfonso H.W. Ngan. Strengthening CrFeCoNiMn$_{0.75}$Cu$_{0.25}$ high entropy alloy via laser shock peening. International Journal of Plasticity, 2022, 15: 103296. DOI: https://doi.org/10.1016/j.ijplas.2022.103296

NEWS & EVENTS

HIT Party Secretary Xiong Sihao

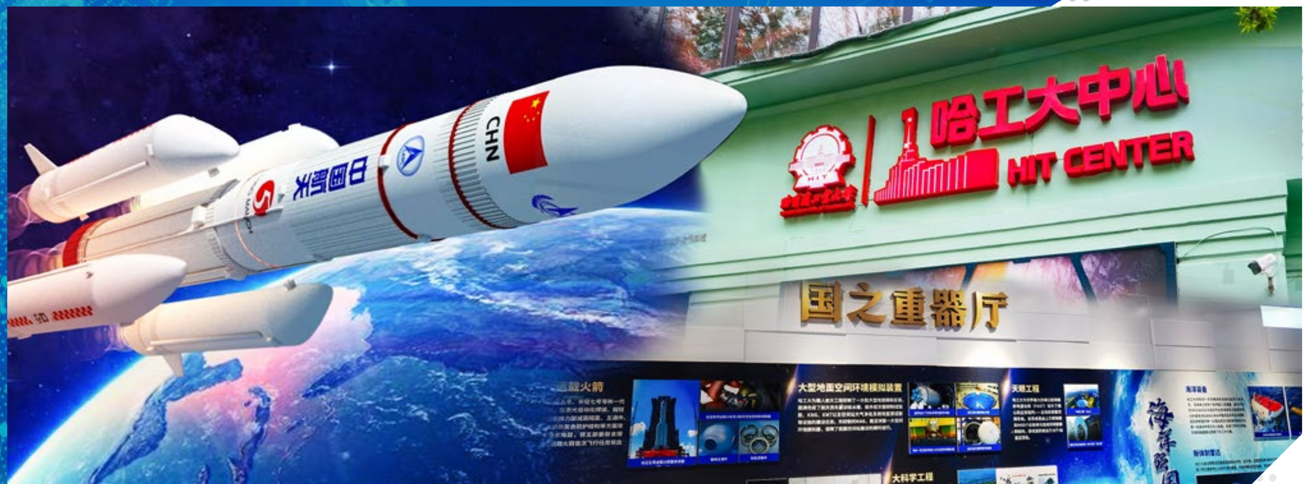
HIT President Han Jiecai

FLAG RAISING CEREMONY FOR COMMEMORATING HIT'S 102ND ANNIVERSARY

On June 7th, 2022, a flag-raising ceremony for commemorating HIT's 102nd anniversary was held on three campuses, Harbin, Weihai, and Shenzhen. HIT Party Secretary Xiong Sihao attended and delivered a speech. HIT President Han Jiecai chaired the ceremony.

Xiong Sihao reviewed the excellent achievements of the university under the guidance of the spirit of Chinese President Xi Jinping's congratulatory letter in the past two years. He also put forward three plans: explore a road of self-reliance and self-improvement in advance; based on China's situation, solve the country's problems and run satisfactory higher education; summarize the experience of reform, bravely face the difficulties of reform and development, and comprehensively enhance our strategic implementation.

HIT President Han Jiecai pointed out that we should promote the implementation of the measures and arrangements of the 13th HIT's Party Congress, and continue to establish a world-class university with Chinese characteristics in the new century.■



HIT CENTER FOUNDED

On the morning of May 11th, the HIT Center held a launching ceremony, which is also the first brand store of a university built in the central business district of a major metropolitan area in China

Harbin Party Secretary Zhang Anshun and HIT Party Secretary Xiong Sihao inaugurated the center and delivered speeches. HIT President Han Jiecai, Secretary General of the municipal Party committee Feng Yanping, Head of the Heilongjiang Central Station of China Central Radio, and Television Feng Xuesong attended the launching ceremony.

HIT Center, located at No.134, Zhongyang Street, comprehensively and vividly displayed HIT's development history, outstanding talents, major scientific and technological projects, key core technological achievements, and other contents in multimedia format. At the same time, a series of exhibitions and interactive activities were creatively planned.

CHINA SPACE DAY 2022

April 24th witnessed the 7th Space Day of China. Harbin Institute of Technology held a flag-raising ceremony on three campuses, Harbin, Weihai, and Shenzhen, as well as a carnival, a painting activity, a flight performance, and a quiz competition.

CONTACT US:

Address: Editorial Department of Journal of Harbin Institute of Technology,
Room 402-2, School of Management, 92 West Dazhi Street, Nan Gang
District, Harbin, Heilongjiang Province, China
Post Code: 150001
Email: hit-times@hit.edu.cn

HIT TIMES ONLINE:

The HIT TIMES can be read online at http://hit-times.hit.edu.cn
The views expressed in this publication are the views of the authors and do not necessarily reflect the views of the Harbin Institute of Technology.

Please scan the QR code to read on your phone:

Please scan the QR code to subscribe our WeChat public account: