HARBIN INSTITUTE OF TECHNOLOGY
NEWSLETTER 2023 ISSUE 1

HIT TIMES

CHINA SPACE DAY 2023

HIT TIMES

Harbin Institute of Technology Newsletter
2023 ISSUE 1

Contents

Awards & Honors

Research & Academia

News & Events

Editorial Team:
Editor-in-chief: Han Jiecai
Editors: Li Longqiu
Yue Huimin
Xiong Jian
Li You

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.

AWARDS & HONORS

Academician Cao Xibin

ACADEMICIAN CAO XIBIN WON HO LEUNG HO LEE FOUNDATION AWARD

On February 17, 2023, the 2021 and 2022 Ho Leung Ho Lee Foundation (HLHL) Award Ceremony was held in Beijing. Academician Cao Xibin won the HLHL Science and Technology Progress Award for 2021. Professor Wang Aijie won the HLHL Science and Technology Innovation Award for 2022.

The HLHL was founded in 1994 by four philanthropists from Hong Kong: Ho Sin Hang, Leung Kau Kui, Ho

Tim, and Lee Kuowei. The annual award recognizes outstanding scientific and technological professionals in China. Since its establishment, it has been awarded to 1,526 outstanding science and technology workers, enjoyed a high reputation, and played an active role in inspiring innovation talent.

The 2021 and 2022 Ho Leung Ho Lee Foundation Science and Technology Awards were awarded to 112 scientists. In 2022, there was one winner of the Scientific and Technological Achievement Award, 33 winners of the Science and Technology Progress Award, and 22 winners of the Science and Technology Innovation Award.

PROFESSOR XIAO SHUMIN WON CHINESE YOUNG WOMEN IN SCIENCE AWARD

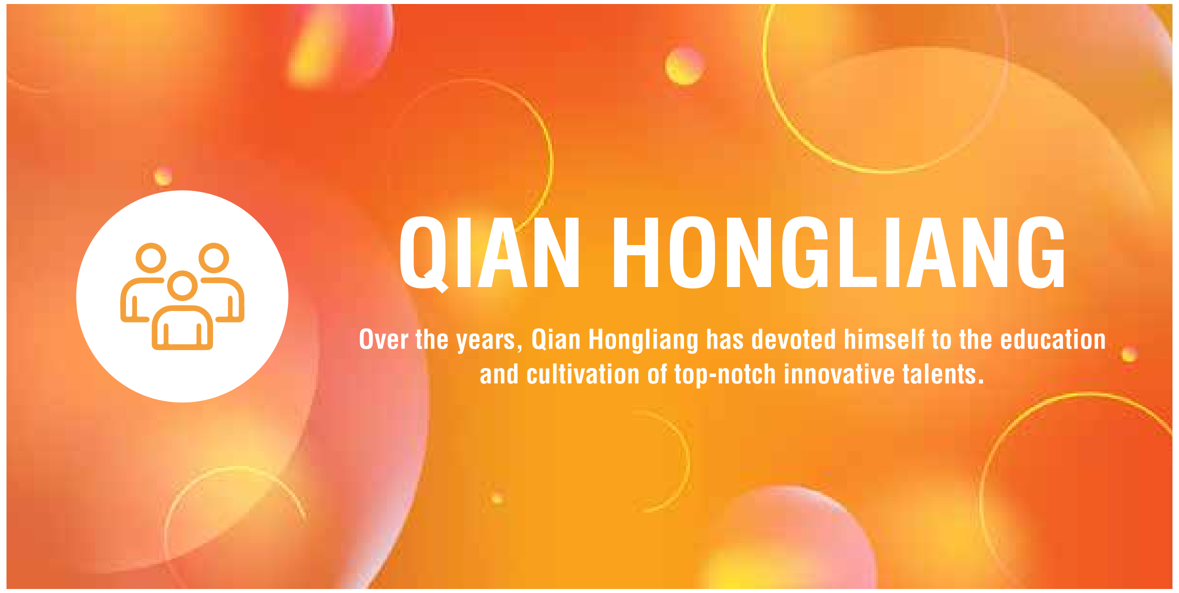
On April 22, 2023, the ceremony of the 18th Chinese Young Women in Science Award was held in Beijing. A total of 20 young female scientists and five scientific teams won. Professor Xiao Shumin, from the School of Materials Science and Engineering at Harbin Institute of Technology (Shenzhen), was on the winners list.

Professor Xiao Shumin (third from the right) receiving the award

Professor Xiao received a Ph.D. from the Department of Electrical Engineering and Computer Science, Purdue University, West Lafayette, IN, USA, in 2010. In 2011, she joined Harbin Institute of Technology; her current research interests include integrated optoelectronics, semiconductor devices, metamaterials, plasmonic physics and devices, nonlinear optics, and nanophotonics.

The Chinese Young Women in Science Award was jointly established by the All-China Women's Federation, the China Association for Science and Technology, the Chinese National Commission for UNESCO, and L'Oréal China in 2004. It aims at recognizing and rewarding young female scientists who have made groundbreaking discoveries in sciences and empowering more female scientists to achieve scientific excellence. To date, a total of 184 women have been awarded this honor. ■

PROFESSOR QIAN HONGLIANG AWARDED THE NATIONAL MAY DAY LABOUR MEDAL

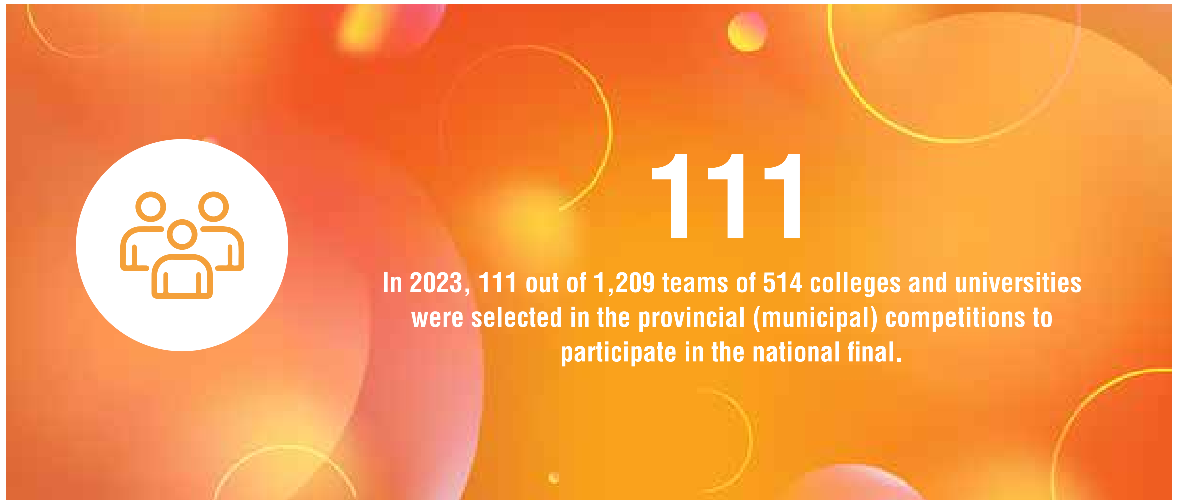


On April 27, 2023, the "National May Day Labour Award and the National Workers' Pioneer Award Commendation Conference" was held in Beijing. Professor Qian Hongliang, dean of the School of Ocean Engineering at Harbin Institute of Technology (Weihai), was awarded the National May Day Labour Medal.

Over the years, Qian Hongliang has devoted himself to the education and cultivation of top-notch innovative talents. As a member of the HIT spiritual propaganda group, his lecture on the theme of patriotic striving was selected as one of the lectures in Shandong Province. As the first dean of the School of Ocean Engineering at Harbin Institute of Technology, he focused on the major needs of the nation and Shandong's marine strategy and the key scientific research directions in ocean engineering. As the deputy chief engineer of the structural system of the Five-hundred-meter Aperture Spherical radio Telescope (FAST), he was involved in proposing the active dislocation cable network structural scheme and a number of key technologies, making a significant contribution to the successful implementation of the project.■

HIT STUDENTS WON AWARDS IN THE 15TH NATIONAL STRUCTURE DESIGN CONTEST FOR COLLEGE STUDENTS

Recently, the 15th National Structure Design Contest for College Students was held. Under the guidance of Professor Shao Yongsong from the School of Civil Engineering at Harbin Institute of Technology, the work designed by undergraduate students He Taipeng, Li Jie, and Xiao Hongshuo from the School of Civil Engineering won the first prize. Under the guidance of Associate Professor Wang Huajie, Engineer Zhang Tianwei, and Associate Professor Chen Deshen from the School of Ocean Engineering at HIT Weihai campus, the



work designed by undergraduate students Zhang Jiahao, Wang Yankai, and Wu Haoran from the School of Ocean Engineering won second prize. Harbin Institute of Technology won the "Excellent Organization Award," and Professor Shao Yongsong won the "Outstanding Contribution Award."

Launched in 2005, the contest was one of the first nine funded programs of national discipline competitions for college students jointly approved by the Ministry of Education and the Ministry of Finance. It is China's highest and largest comprehensive discipline competition in civil engineering. It aims to improve college students' innovative design and practical ability, comprehension, while strengthening exchanges and cooperation among colleges and universities. A two-level competition system is adopted. In 2023, 111 out of 1,209 teams of 514 colleges and universities were selected in the provincial (municipal) competitions to participate in the national final.

The School of Civil Engineering has attached great importance to students' practical innovative activities for many years and helped its teams win the first prize six consecutive times by providing an innovative practice platform, holding a school-level structure design competition, strengthening training guidance, etc.

RESEARCH & ACADEMIA

A 4D PRINTED PROGRAMMABLE SOFT NETWORK WITH FRACTAL DESIGN AND ADJUSTABLE HYDROPHOBIC PERFORMANCE

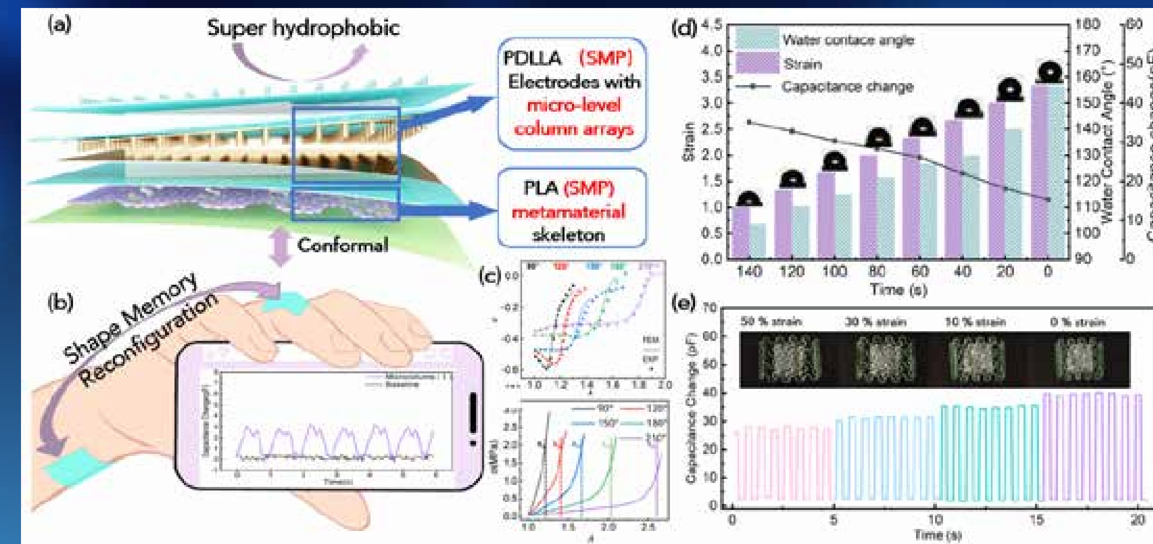


Figure 1 The constituent part and functions of the sensor. (a) Constituent parts, (b) Multi-scene function, (c) Experimental and FEA results of the metamaterial skeleton, (d) Mechanical and electrical properties in the shape memory circle, (e) Capacitance change and optical image

Flexible sensors and their derived wearable electronic devices have broad application prospects in human-computer interaction, the Internet of Things, and other fields. However, flexible sensing and wearable devices of inorganic materials are currently faced with limitations such as manufacturing technique, sensitivity, and flexibility. This is in particular due to the fact that the configuration and function of the device cannot be adjusted after manufacturing, leading to mechanical incompatibility when faced with different target sites. Therefore, shape memory polymer (SMP) becomes an ideal candidate in the flexible electronic field by virtue of its environmentally responsive ability. Recently, a group led by Professor Leng Jinsong from the Center for Composite Materials and Structures at Harbin Institute of Technology proposed a shape memory flexible sensor with environmentally responsive electrical and mechanical properties and the work was published in *Matter*.

The sensor was fabricated based on lotus-inspired super-hydrophobic surface and metamaterials as Figure 1 (a) shows. It can accurately perceive tactile signals generated by physical contact with the skin's surface meanwhile maintaining high flexibility and compliance with detected sites. By reconfiguring the metamaterial skeleton, the sensor can switch between high-sensitivity modes (corresponding to small ranges, microscopic action signals) and low-sensitivity modes (corresponding to large ranges, macroscopic action signals) under environmental stimulation according to the needs of users as shown in Figure 1 (b).

They design a fractal-inspired 4D printed metamaterial sensor skeleton to realize its mechanical and electrical reconfiguration function. A finite-deformation theoretical model is established to serve as a guideline to precisely tune the mechanical properties of auxetic mechanicals. Under large deformation, the metamaterial exhibits biomimetic non-linear "J-shape" σ-λ curve which indicates its ability to improve the flexibility and compliance in healthy monitoring devices as shown in Figure 1 (c). Moreover, the auxetic metamaterial exhibited the negative Poisson's ratio with larger values than existing works, which widened the working domain of the shape memory biomimetic sensor and enhanced its adaptability with human skin.

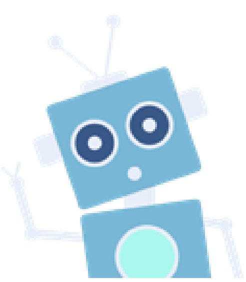
Furthermore, sensors with super-hydrophobic surface display ≈10 times and ≈4 times improvement in signal-to-noise ratio and sensitivity respectively compared to flat electrodes, showing remarkable practical and scientific research prospects. Finally, due to the shape memory effects of both the skeleton and electrodes, the sensor possesses reconfigurable properties in both mechanical and electronic functions corresponding to external stimuli as shown in Figure 1 (d)-(e).

REFERENCE

Nan Li, Wei Zhao, Fengfeng Li, Liwu Liu, Yanju Liu, and Jinsong Leng. A 4D printed programmable soft network with fractal design and adjustable hydrophobic performance. Matter, 2023, 6(3), 940-962. DOI: https://doi.org/10.1016/j.matt.2022.12.010

NEW PROGRESS IN BIONIC MULTIFUNCTIONAL SOFT STACKABLE ROBOTS

Soft robots equipped with multifunctionalities are increasingly in demand for secure, adaptive, and autonomous operations in unknown and unpredictable environments. Robotic stacking emerges as a promising solution to enhance the functional diversity of soft robots, enabling safe human-machine interactions and adaptability in unstructured surroundings. However, existing multifunctional soft robots often exhibit limited capabilities or fail to fully exploit the advantages of the robotic stacking approach. Recently, a team led by Professor Leng Jinsong from the Center for Composite Materials and Structures at Harbin Institute of Technology published a paper titled "Multifunctional Soft Stackable Robots by Netting–Rolling–Splicing Pneumatic Artificial Muscles" in *Soft Robotics*.



This work introduced a novel strategy for robotic stacking called Netting-Rolling-Splicing (NRS) stacking, which leverages a dimensional raising method 2D-to-3D rolling-and-splicing of netted stackable pneumatic artificial muscles (PAMs). The approach allows for the rapid and efficient fabrication of multifunctional soft robots using simple, cost-effective components. To validate their approach, the researchers developed a TriUnit robot capable of crawling at a speed of 0.46 ± 0.022 body length per second and climbing at a rate of 0.11 body length per second, with the ability to carry a 3 kg payload while climbing. Additionally, the TriUnit robot demonstrated novel omni-directional pipe climbing capabilities, including rotating climbing, as well as bionic swallowing-and-regurgitating and multi-degree-of-freedom manipulation through multimodal combinations.

Furthermore, by employing a pentagon unit, the researchers achieved steady rolling at a speed of 0.19 body length per second. They also showcased the adaptability of the TriUnit pipe climbing robot in panoramic shooting and cargo transferring applications, highlighting its versatility for various tasks. The NRS stacking approach utilized in this soft robot design exhibited superior overall performance compared to existing stackable soft robots, thus presenting an innovative and effective means of constructing multifunctional and multimodal soft robots in a cost-effective and efficient manner.

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

REFERENCE

Qinghua Guan, Liwu Liu, Jian Sun, Jiale Wang, Jianglong Guo, Yanju Liu, Jinsong Leng. Multifunctional soft stackable robots by Netting–Rolling–Splicing pneumatic artificial muscles. Soft Robotics, 2023. DOI: 10.1089/soro.2022.0104

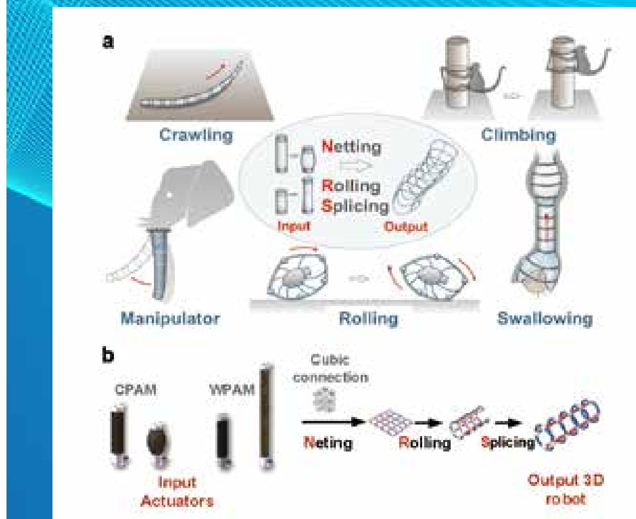


Figure 1 Multifunctional soft bioinspired robots enabled by the NRS method. (a) Multi-functions inspired by animals and realized by NRS stacked PAMs. (b) The NRS design framework for designing soft robots with diverse functions and modalities

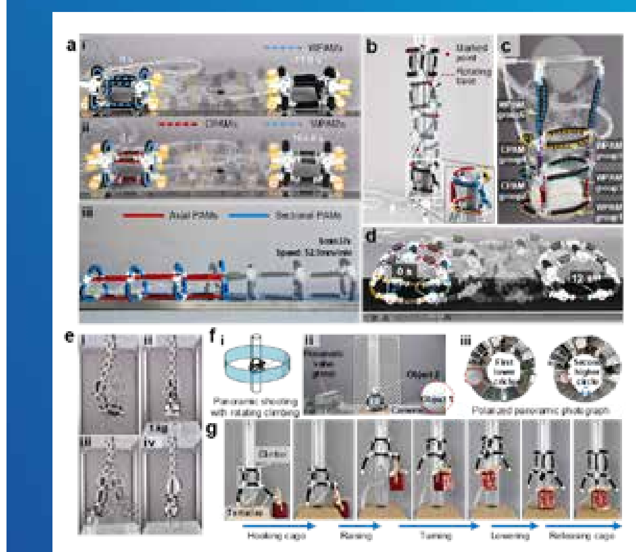


Figure 2 Modular soft robots with various modalities and locomotion, (a) Crawling robots based on mono-oscillation (i&ii) and wave-crawling (iii), (b) Anticlockwise rotating climbing of the omnidirectional pipe climbing robots, (c) A swallowing robot based on CPAMs and WPAMs, (d) A rolling robot based on the variable stiffness of CPMS, (e) 28-DOF soft manipulator based on CPAMs and WPAMs, (i) Multi-DOF bending, (ii) Vertical gripping, (iii) Pick-and-place. (iv) Swallowing and transporting, (f) A soft panoramic shooting robot based on a 9-DOF Tri-unit, (i) The diagram panoramic shooting, (ii) The scenery, (iii) The first (left) and second (right) rotating climbing circle, (g) Cargo transferring by the Tri-unit robot with tentacles based on helical PAMs

SUPER-TOUGH, SELF-SENSING AND SHAPE-PROGRAMMABLE POLYMERS VIA TOPOLOGICAL STRUCTURE CROSSLINKING NETWORKS

Shape-memory polymers (SMPs) are smart materials capable of deforming under external excitations. Owing to their characteristics, SMPs and their composites have been extensively developed to provide materials for applications in aerospace engineering, biomedicine, flexible electronics, and soft robotics. Recently, a team led by Professor Leng Jinsong from the Center for Composite Materials and Structures at Harbin Institute of Technology published a paper titled "Super-Tough, Self-Sensing and Shape-Programmable Polymers via Topological Structure Crosslinking Networks" in *Chemical Engineering Journal*.

This study developed a molecular engineering strategy based on a topological cross-linking network, which forms quadruple hydrogen bonds, hyperbranching, ring network structure, etc. to obtain SMEP with super toughness, high-temperature resistance, and triple shape memory effect (TSME). The internal relationship between the molecular network structure and material performance is simulated by molecular dynamics. It has super toughness (1,288%) and high impact energy (216MJ/m^3) above the transition temperature, breaking through the thermosetting resin that has been reported so far (Figure 1a~d). Critically, the developed system of SMPs exhibits outstanding fatigue resistance and can be loaded repeatedly for more than 100 cycles (Figure 1e~g), allowing the application of these materials in engineering applications such as aerospace, smart furniture, and soft robotics.

Owing to its excellent super stretching properties, Bi-EP can be used in wearable electronic devices, artificial muscles, strain monitoring, and stretchable devices (Figure 2a). Owing to its high-temperature resistance, the Tri-EP system can also be used in lock release mechanisms (Figure 2b). The satellite orbit entry mode was simulated, and when heated to 200℃, the solar array gradually transits from temporary shape II to temporary shape I (Figure 2c). Compared with the reported comprehensive properties of thermosetting resins. This work has made breakthrough progress in both tensile strain and heat resistance compared to Figure 2d.

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

REFERENCE

Luo Lan, Zhang Fenghua, Liu Yanju, Leng Jinsong. Super-tough, self-sensing and shape-programmable polymers via topological structure crosslinking networks. Chemical Engineering Journal, 2023, 457, 141282. DOI: https://doi.org/10.1016/j.cej.2023.141282

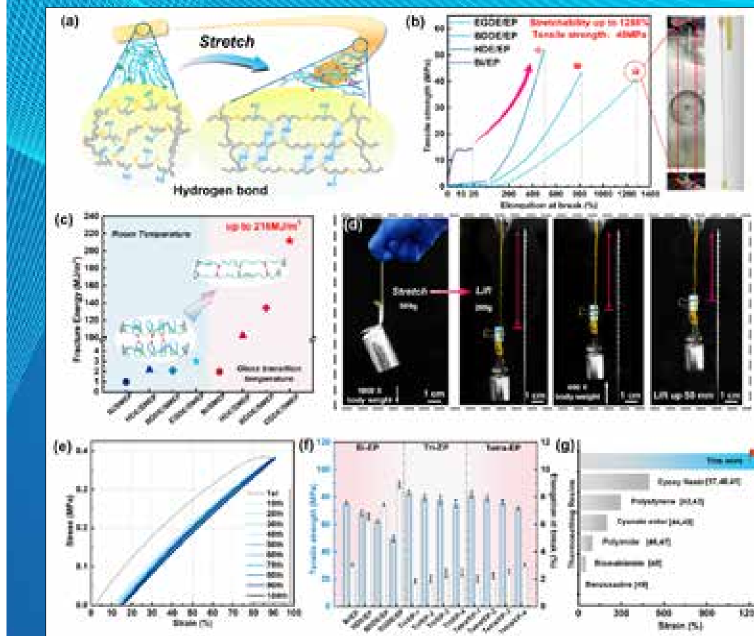


Figure 1 Mechanical properties of SMEPs with different crosslinked network structures, (a) Molecular schematic diagram of the mechanism; (b) Tensile stress-strain curves of systems at Tg; (c) The fracture energy of ystem; (d) Lifted 5 cm under the recovery driving force; (e) Systems undergoes 100 tension load/unload cycles; (f) Fracture elongation and tensile strength of all samples; (g) Our work studies the tensile properties of SMEP, compared with other reports.

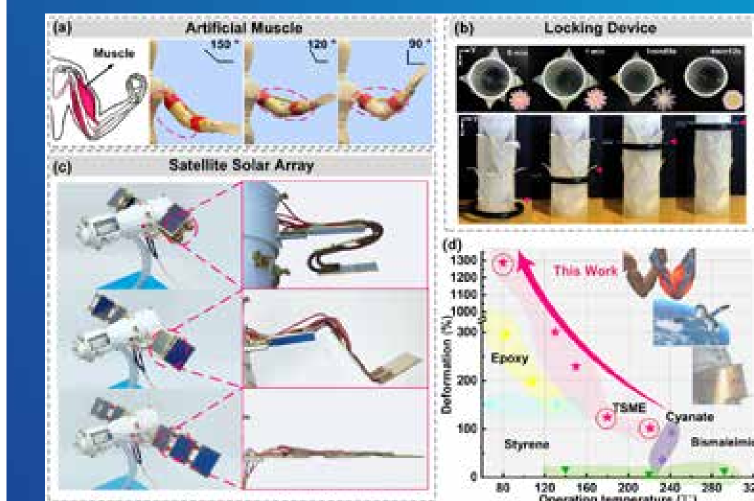


Figure 2 Application verification of SMEPs with different cross-linked network structures, (a) Mimicking the lifting behavior exhibited by artificial muscles; (b) Simulation of "Lotus" locking structure; (c) Satellite solar wing unfolding structure; (d) Comparison chart with other reported thermosetting resins

MICRO/NANO FUNCTIONAL DEVICES FABRICATED BY ADDITIVE MANUFACTURING

A team led by Professor Li Longqiu from the School of Mechatronics Engineering at HIT recently published a review titled "Micro/Nano Functional Devices Fabricated by Additive Manufacturing" in *Progress in Materials Science*, a top international review journal in the field of material science. Two PhD candidates Huang Zhiyuan and Shao Guangbin are first authors of the paper.

Micro/nano functional devices (MNFDs) featuring deep integration, intelligence, and miniaturization have attracted much attention recently. However, traditional micro/nano fabrication techniques, such as lithography, electrodeposition, or etching, show inferior capability in manufacturing micro/nano structures with sophisticated geometries and multiple materials. Additive manufacturing (AM) is an advanced manufacturing process that offers great flexibility in fabricating highly sophisticated structures over a wide length scale (nm ~ mm) and provides multi-scale, multi-material, and multi-dimensional manufacturing capabilities.

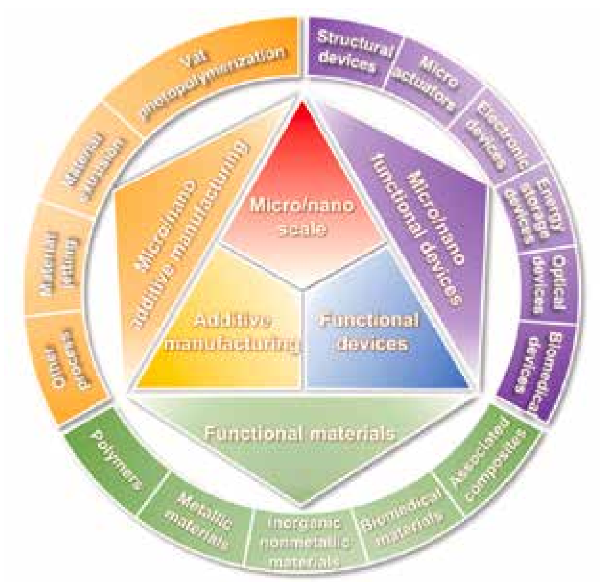


Figure 1 Framework of the paper

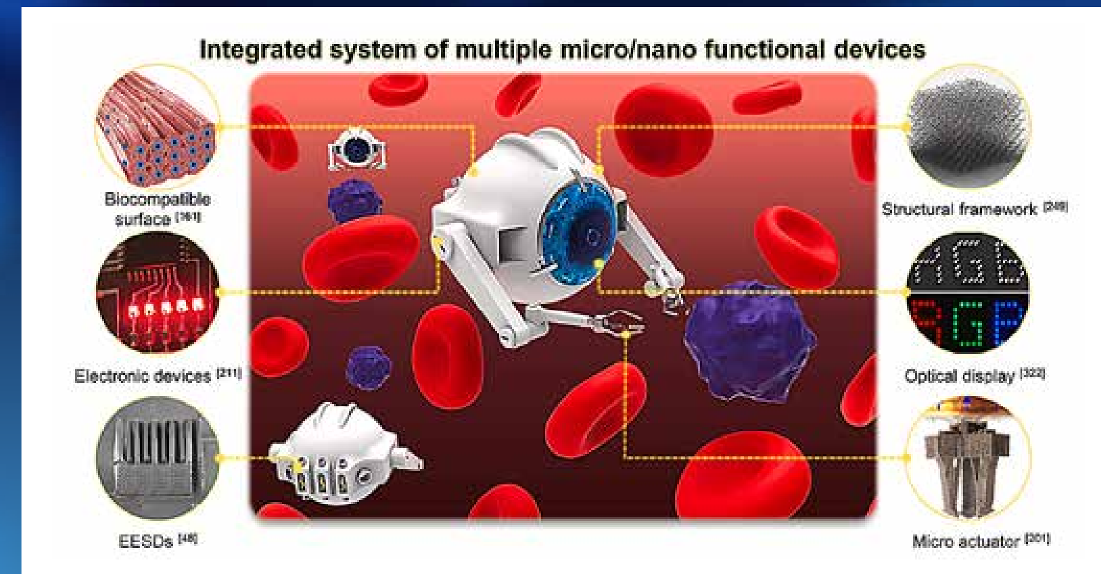


Figure 2 Illustration of integrated system of multiple micro/nano functional devices (MNFDs)

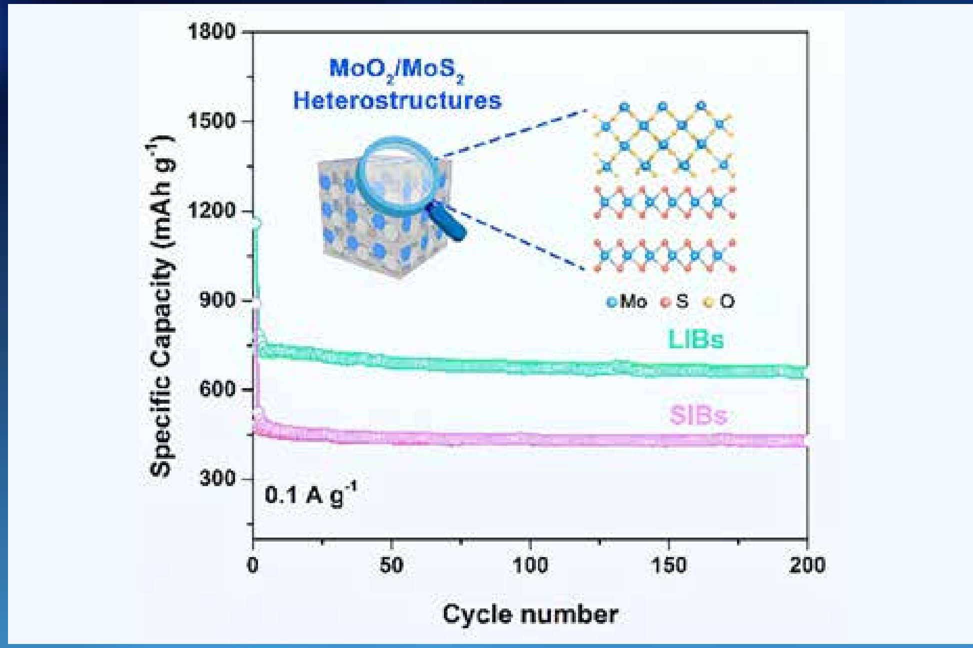
This paper reviews MNFDs fabricated by AM, including MNAM (micro/nano additive manufacturing) processes, MNAM functional materials, and applications of MNFDs in structural devices, micro actuators, electronic devices, electrochemical energy storage devices, optical devices and so on. In addition, the functional materials used are summarized. Although MNFDs fabricated using MNAM are rapidly evolving, there still exist many significant challenges. Finally, this paper discusses the current limitations and prospective future trends. An integrated system of multiple MNFDs is proposed as a prospect, and the future trends of MNFDs and MNAM are discussed in terms of design, manufacture, and evaluation. The summary, discussion, and future trends of this review should greatly promote further development of MNFDs and MNAM.

This work was supported by the National Natural Science Foundation of China and the Key-Area Research and Development Program of Guangdong Province.

REFERENCE

Zhiyuan Huang, Guangbin Shao, Longqiu Li. Micro/nano functional devices fabricated by additive manufacturing. Progress in Materials Science, 2023, 131.101020. DOI: https://doi.org/10.1016/j.pmatsci.2022.101020

DUAL INTERFACES DESIGN OF ELECTRODE MATERIALS FOR SODIUM/LITHIUM ION BATTERIES



Recently, Professor Song Bo's group from the Center for Composite Materials and Structures published a research paper titled "Synergistically Designed Dual Interfaces to Enhance the Electrochemical Performance of MoO_2/MoS_2 in Na- and Li-Ion Batteries" in *Small*.

It is imperative to develop and design electrodes materials with high capacity, high rate performance, long cycling life, and low-cost for lithium-ion batteries (LIBs) and sodium-ion batteries (SIBs). Mo-based monoclinic MoO_2 with a tunnel framework and MoS_2 with large interlayer spacing, which are typical transition metal compounds (TMCs), have been extensively investigated due to their high theoretical capacity and low metallic electrical resistivity. However, the development of these materials is hindered by sluggish electrochemical reaction kinetics and poor cycling stability, caused by inadequate conductivity and unstable structure.

In this work, the structural stability and reaction kinetics of MoO_2 and MoS_2 electrodes are enhanced through an ingenious design by employing 3D dual heterogeneous interfaces, including TMCs heterojunctions and carbon-based support. Benefitting from the unique features of dual heterogeneous interfaces: i) the built-in electric field in MoO_2/MoS_2 heterogeneous interface accelerated the 3 electrochemical reaction kinetics, ii) the robust Mo-S, C-S, and C-O in the heterojunction formed by MoO_2/MoS_2 and carbon enhanced the structural stability and electron transport, iii) the carbon acted as a conductive interconnected 3D frame provided the paths for electrons/ions diffusion, besides prevent MoO_2/MoS_2 agglomeration and buffer volume from expanding. Consequently, the MoO_2/MoS_2@C electrode exhibited significantly enhanced electrochemical performances (324 mAh g^{-1} for SIB at 1 A g^{-1} after 1,000 cycles and 500 mAh g^{-1} for LIBs at 1A g^{-1} after 500 cycles). Furthermore, the positive effect of dual heterogeneous interfaces on electrochemical reaction kinetics has also been analyzed thoroughly both in experiments and theory. The reaction mechanism and phase evolution of MoO_2/MoS_2/C during the electrochemical cycling have been further investigated.

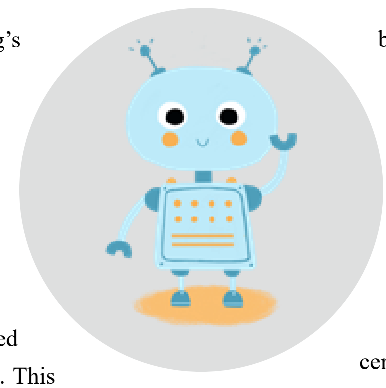
The current work not only illustrates the synergistic effect of dual heterogeneous interfaces on the enhanced electrochemical reaction kinetics and structure stability, but also presents a simple, useful, and cost-effective route to design high-quality electrodes via interfacial engineering.

REFERENCE

Xiaofeng Li, Ran Wang, Qing Wu, Yonghao Yu, Tangling Gao, Tai Yao, Xianjie Wang, Jiecai Han, Bo Song. Synergistically designed dual interfaces to enhance the electrochemical performance of MoO_2/MoS_2 in Na- and Li-ion batteries. Small, 2023, 19, 2206940. DOI: https://doi.org/10.1002/smll.202206940

PIEZOELECTRIC ROBOTIC HAND FOR MOTION MANIPULATION FROM MICRO TO MACRO

Recently, Professor Liu Yingxiang's group, from the State Key Laboratory of Robotics and System at Harbin Institute of Technology, published a research paper titled "Piezo Robotic Hand for Motion Manipulation from Micro to Macro" in the high impact international journal *Nature Communications*, and it was selected as a featured article focusing on "devices". This study innovatively proposed and developed a four-finger robotic hand constructed on functional piezoelectric ceramic.

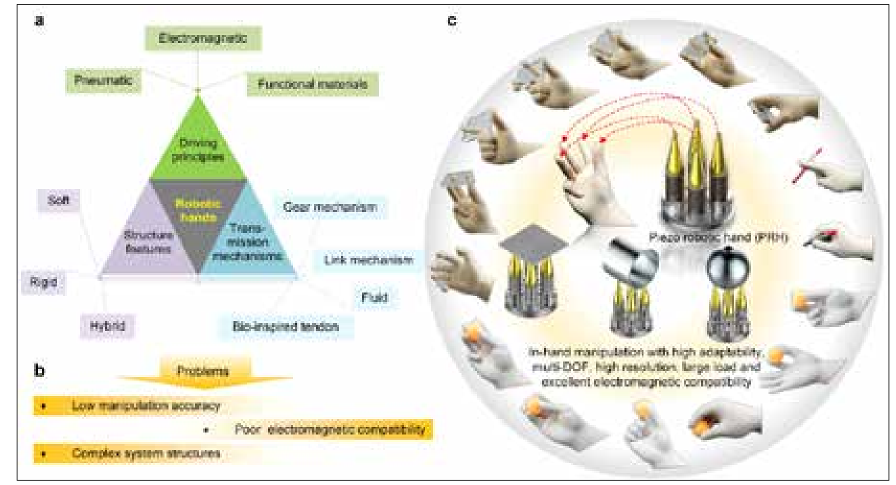


As a robot system that replaces or assists human hands to achieve agile manipulations, the robotic hand plays a crucial role in the field of robot assisted manipulation, and its functions and performance often determine the overall service level of the system. There are various types of existing robotic hands, mainly reflected in their different structural features, energy conversion principles, and transmission mechanisms, most existing robotic hands are facing the limitations in motion accuracy, electromagnetic compatibility, and structure compactness. Therefore, how to find new energy conversion principles for the actuation mode of robotic hands, how to design more efficient and precise transmission mechanisms, and even completely abandon transmission mechanisms have become new focuses and challenges in the field of robotics.

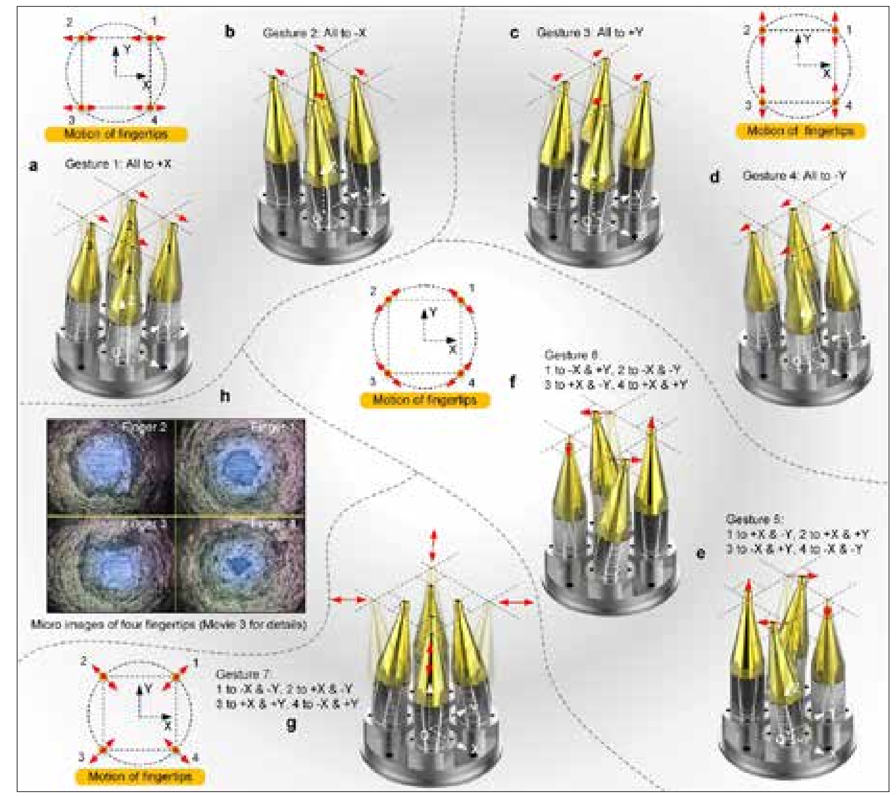
Inspired by the manipulation of human hand, this work proposes the first four-finger robotic hand constructed on functional piezoelectric ceramics. It adopts a four-finger array uniformly distributed configuration, and its piezoelectric fingers utilize a four-zone annular piezoelectric ceramic integrated structure. The electrical energy can be converted to mechanical energy by using the inverse piezoelectric effect, resulting in the conversion of the multi-dimensional micro deformations of piezoelectric ceramics into the multi-dimensional motions of the piezoelectric finger. More than ten functionalized hand gestures are planned by utilizing the idea of four-finger cooperation manipulation, and the multi-DOF and cross-scale motion manipulation of the flatbed, cylindrical and spherical objects are achieved by using the alternation dynamic and static frication manipulation method. The detailed experiments are carried out to study fundamental characteristics of the piezoelectric robotic hand, including response hysteresis (<3.95%), motion resolution (15 nm), response time (0.5 ms) and natural frequency (4.1 kHz). The motion manipulation characteristics of the piezoelectric robotic hand are also evaluated in detail. A series of experiments successfully demonstrate the high adaptability, multi-DOF, and cross-scale motion manipulation ability of the piezoelectric robotic hand for diverse objects. A series of application exploration experiments are conducted in this study, which successfully confirms great application potentials of the piezoelectric robotic hand in manipulating diverse objects to construct multi-DOF manipulation devices and to integrate robotic arm as end effectors.

In summary, this work adopts the inverse piezoelectric effect of the piezoelectric ceramic as the new energy conversion principle and actuation mode of the robotic hand, with the integrated configuration of no transmission and high rigidity functional ceramics as the core, demonstrating the feasibility of using micro deformation of piezoelectric ceramics to achieve cross-scale motion manipulation of various objects. The relevant multi-DOF motion generation methods and functionalized hand gesture collaborative manipulation idea of the piezoelectric robotic hand provide a new design and development approach for robotic hands. The unique macro/micro motion manipulation ability of the piezoelectric robotic hand is expected to solve the cross-scale motion manipulation problems faced by many advanced technology fields in the future.

This study was supported by the National Natural Science Foundation of China and the Interdisciplinary Research Foundation of HIT.■



Classifications and problems of the existing robotic hands, as well as the piezo robotic hand inspired by in-hand motion manipulation



Typical functionalized hand gestures of the piezoelectric robotic hand

REFERENCE

Shijing Zhang, Yingxiang Liu, Jie Deng, Xiang Gao, et al. Piezo robotic hand for motion manipulation from micro to macro. Nature Communications, 2023, 14, 500. DOI: https://doi.org/10.1038/s41467-023-36243-3

Research & Academia
HIT TIMES 2023

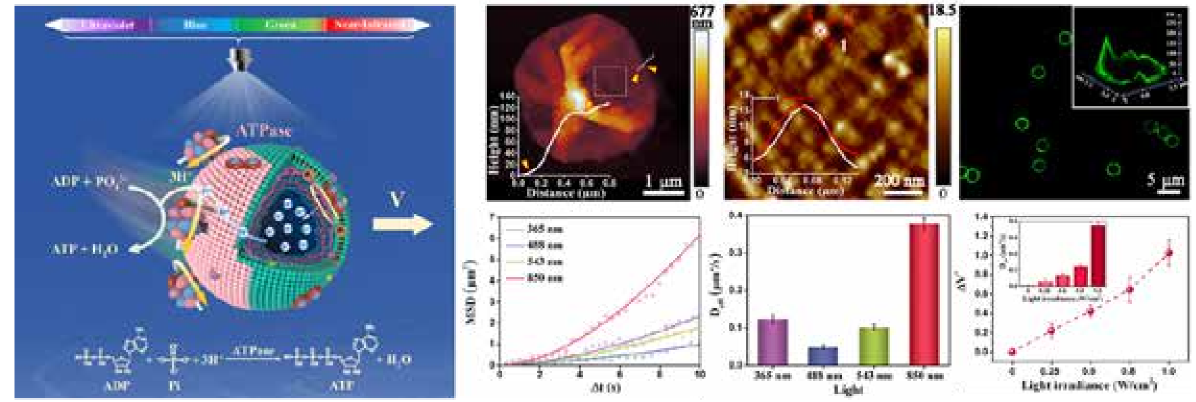
ROTARY BIOMOLECULAR MOTOR-POWERED SUPRAMOLECULAR COLLOIDAL MOTOR

In 2023, Professor He Qiang and Professor Wu Yingjie, from the School of Medicine and Health, in cooperation with associate research fellow Wu Hao from the Wenzhou Institute, University of Chinese Academy Sciences, recently published a paper titled "Rotary Biomolecular Motor-Powered Supramolecular Colloidal Motor" in the journal of *Science Advances*.

In living organisms, cells perform a variety of mechanical tasks on multiple scales, such as intracellular material transport, cell movement and muscle contraction, by coordinating the movement and force of hundreds or thousands of protein molecular motors. However, it is still a great challenge to design active biomimetic materials and machines based on nanoscale protein motors that consume energy to propel micrometer-scale assemblies in continuous motion. In response to this challenge, the research team proposed for the first time a novel supramolecular colloid motor driven by rotating biomolecular motors. The smallest molecular motor in nature, rotating biomolecular motor ATP synthase, was used as the power unit to construct a new system of biomolecular motor collaborative drive of supramolecular colloid motors by controllable chemical molecular assembly.

The research team found that the fusion process of chromatophore vesicles containing F_0F_1-ATP synthase motor on the surface of polyelectrolyte microcapsules follows a "parachute" mechanism, which can achieve the regulation of the internal and external orientation of ATP synthase motor, and obtain the asymmetric structure of supramolecular colloidal motor. Combined with the physical analysis and theoretical simulation of the experimental data, the surface of the supramolecular colloidal motor is driven by asymmetric photophosphorylation under light in the reaction solution of ADP and inorganic phosphorus, showing high energy conversion and driving efficiency. By changing the light intensity, the synergistic effect of multiple biomolecular motors can be realized and these molecular forces and motions can be amplified, to regulate the motion behavior of supramolecular colloid motors, and simulate the phenomenon of amplification work of organisms from molecular to mesoscopic to macroscopic.

The research results creatively use the energy conversion of biomolecular motors to realize dynamic regulation of the power unit of supramolecular colloid motors, which confirms the possibility of larger scale machines driven by biomolecular machines, provides a new idea for the bionic design of swimming nanorobots, and provides a new way for the active regulation of energy metabolism of cells in the future to achieve accurate diagnosis and treatment of diseases.



Biomimetic design and characterization of cellular scale supramolecular colloid motor driven by nano-scale rotating biomolecular motor

REFERENCE

Jun Liu, Yingjie Wu, Yue Li, Ling Yang, Hao Wu, Qiang He. Rotary biomolecular motor-powered supramolecular colloidal motor. Science Advances, 2023, 9, eabg3015. DOI: 10.1126/sciadv.abg3015

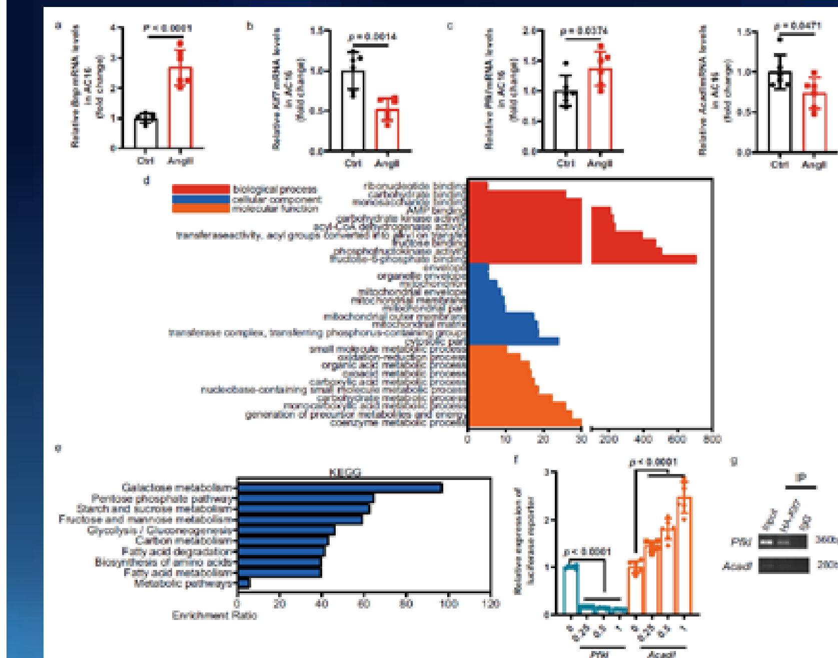
THE KLF7/PFKL/ACADL AXIS MODULATES CARDIAC METABOLIC REMODELLING DURING CARDIAC HYPERTROPHY

Recently, Professor Tian Weiming's group from the School of Life Science and Technology at Harbin Institute of Technology revealed a new mechanism by which the transcription factor Kruppel-like factor 7 (Klf7) regulates the balance of glycolysis and fatty acid oxidation in the heart and is involved in the pathogenesis of cardiac hypertrophy. This work provides new insights and potential therapeutic targets for regulating the treatment of cardiac hypertrophy and heart failure. The related research article titled "The KLF7/PFKL/ACADL Axis Modulates Cardiac Metabolic Remodelling during Cardiac Hypertrophy in Male Mice" was published in *Nature Communications*.

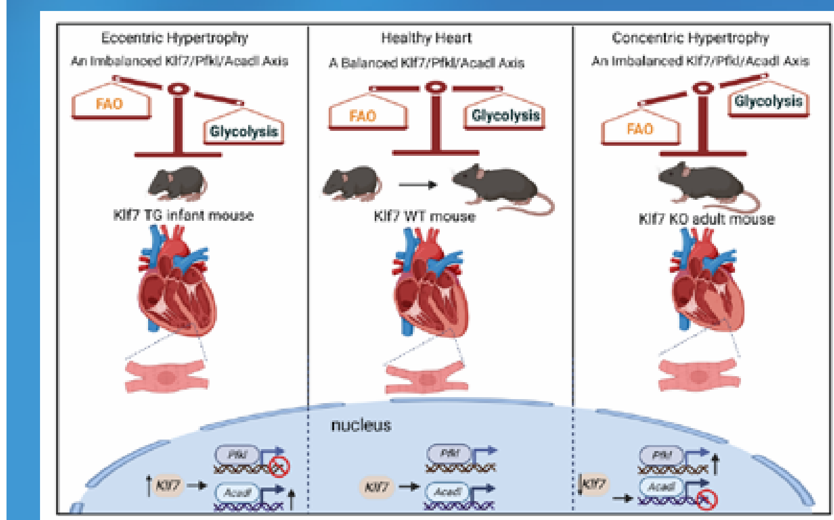
Myocardial substrate utilization preference changes throughout the life cycle and under physiological and pathological conditions. The fetal heart is highly dependent on glycolysis as the main source of ATP energy supply, and fatty acid oxidation plays a major role in the transition to adult stage. Moreover, the conversion of substrate utilization from fatty acid oxidation to glycolysis and the gradual transformation of metabolism to embryonic mode are important features of cardiac hypertrophy to heart failure. However, the close correlation between glycolysis and fatty acid oxidation and the underlying mechanism of cardiac remodelling remain unclear. The research article revealed the specific role of Klf7 in cardiac hypertrophy for the first time, and the mechanism of its two-way transcriptional regulation of fatty acid oxidation and glycolysis metabolism was clarified so as to promote the balance of myocardial glucose and fatty acid metabolism. This will be the future research direction of metabolic drugs for cardiac hypertrophy and heart failure.

In this work, Tian's team identified the key transcriptional regulatory role of Klf7 in pathological cardiac hypertrophy and metabolism, which is to mediate the pathological progression of cardiac hypertrophy by simultaneously regulating the expression of enzymes related to glycolysis and fatty acid oxidation. Moreover, cardiac specific knockout and overexpression of Klf7 induced concentric and eccentric cardiac hypertrophy, respectively. The KLF7/PFKL/ACADL axis is a key regulatory mechanism that may provide feasible insights and therapeutic targets for the treatment of metabolic balance in hypertrophic and failing hearts.

This research was financially supported by the National Key R&D Project, the National Natural Science Foundation of China, and the Heilongjiang Touyan Innovation Team Program. Professor Tian Weiming is the corresponding author and PhD Cao Wang is the first author of this paper.



PFKL and ACADL function as direct targets of KLF7 in the cardiac metabolism



KLF7/PFKL/ACADL axis regulates cardiac metabolism balance and participates in cardiac hypertrophy

REFERENCE

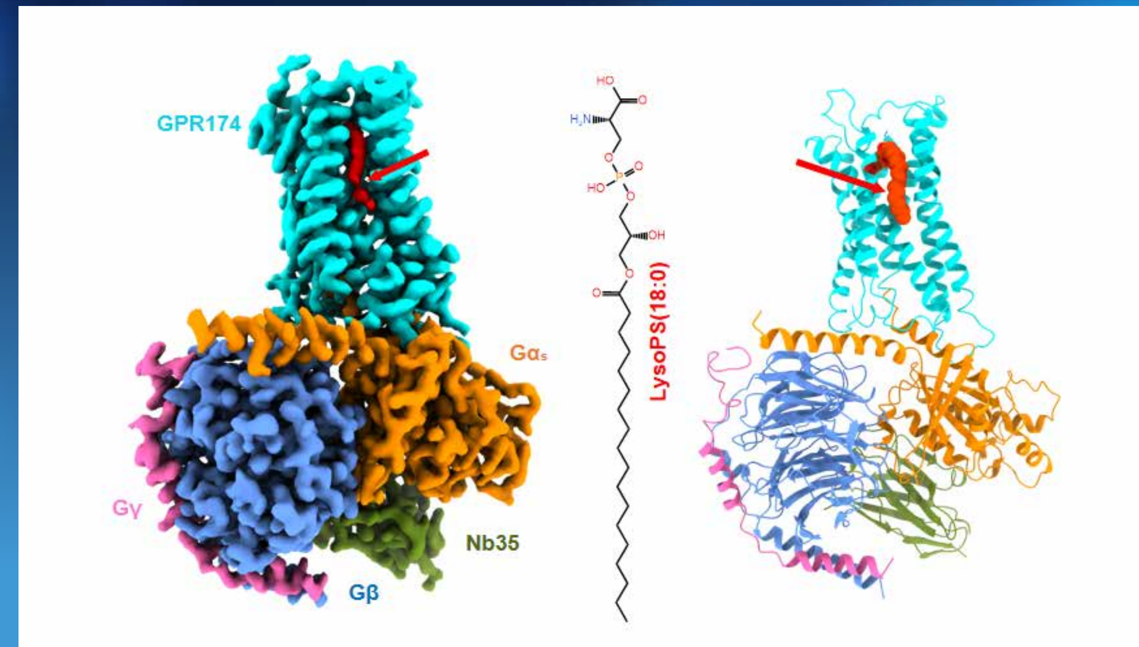
Cao Wang, Shupei Qiao, Yufang Zhao, et al. The KLF7/PFKL/ACADL axis modulates cardiac metabolic remodelling during cardiac hypertrophy in male mice. Nature Communications, 2023, 14, 959. DOI: https://doi.org/10.1038/s41467-023-36712-9

Research & Academia
HIT TIMES 2023

MECHANISM OF LYSOPHOSPHATIDYLSERINE RECEPTOR LIGAND RECOGNITION AND ACTIVATION

A research team led by Dr. He Yuanzheng at the Center for Life Sciences of Harbin Institute of Technology has elucidated the unique ligand recognition mode and G_s protein coupling information of GPR174. The findings were published in the journal *Nature Communications*. Lysophosphatidylserine (LysoPS) is a lipid mediator that binds to specific G protein-coupled receptors, including GPR174, GPR34, and P2Y10, collectively known as lysophosphatidylserine receptors, to induce various cellular responses. GPR174, primarily expressed in differentiated and mature regulatory T cells (Tregs), plays a negative regulatory role in Treg cell accumulation and functions as a key target for inflammation and autoimmune diseases.

Given the significant involvement of LysoPS in immune responses and its potential therapeutic implications for inflammation and autoimmune diseases, Dr. He's team employed cryo-electron microscopy (cryo-EM) to determine the structure of the LysoPS-bound GPR174 in complex with G_s protein, achieving



The cryo-EM structure of LysoPS-bound GPR174 in complex with G_s protein

a resolution of 2.76 Å. This structure revealed a distinctive mode of ligand recognition, wherein the negatively charged head group of LysoPS is buried within a positively charged cavity of the ligand binding pocket. Additionally, the structure unveiled a unique G_s coupling mechanism, in which the tip of helix 5 (αH5) deeply penetrates the intracellular cavity of GPR174, facilitating extensive polar interactions between the receptor and αH5. The insights gained from Dr. He's study provide a framework for understanding LysoPS signaling and offer a rational basis for the design of drugs targeting LysoPS receptors.

REFERENCE

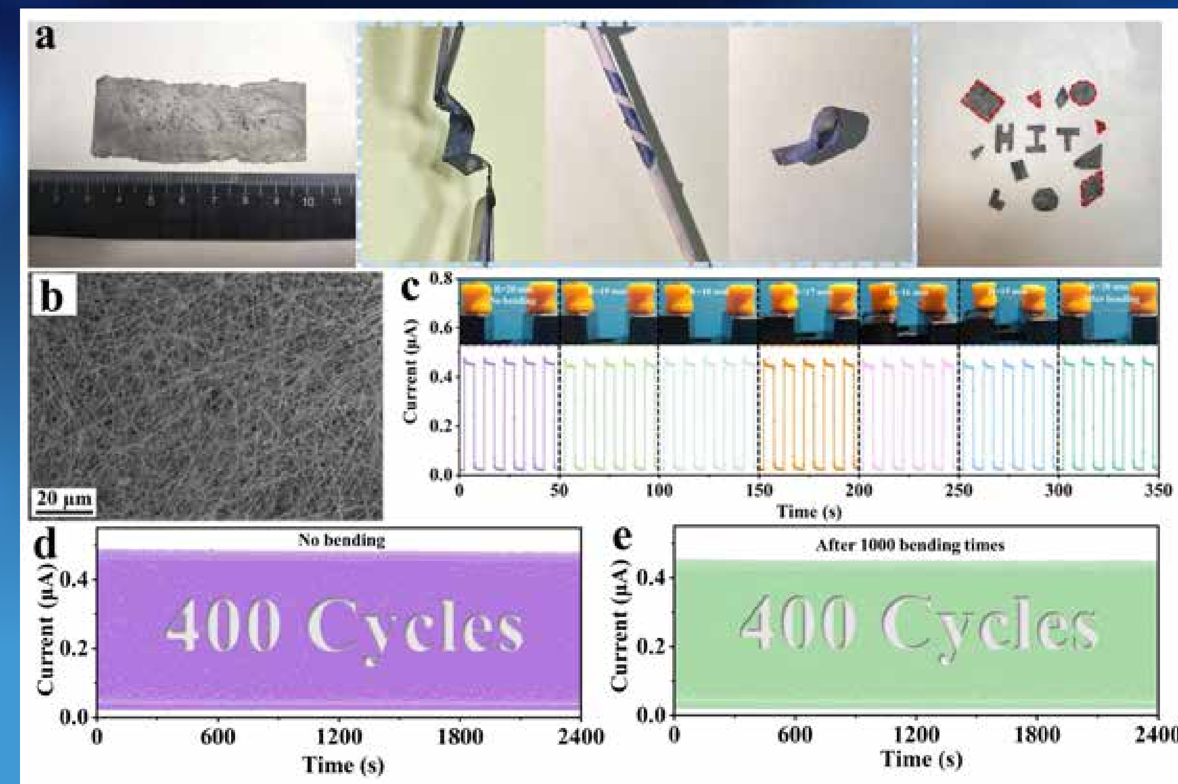
Liang J., Inoue A., Ikuta T., Xia R., Wang N., Kawakami K., Xu Z., Qian Y., Zhu X., Zhang A., Guo C., Huang Z., He Y. Structural basis of lysophosphatidylserine receptor GPR174 ligand recognition and activation. Nature Communications, 2023, Feb 23;14(1):1012. DOI: 10.1038/s41467-023-36575-0

LARGE-AREA FREESTANDING Bi_2S_3 NANOFIBROUS MEMBRANES FOR FLEXIBLE OPTOELECTRONIC DEVICES

Recently, Professor Wang Jinzhong's group from the Faculty of Materials Science and Engineering, Harbin Institute of Technology, has provided a new idea for large-area flexible optoelectronic devices. The related research article titled "Large-Area Freestanding Bi_2S_3 Nanofibrous Membranes (NFMs) for Fast Photoresponse Flexible IR Imaging Photodetector" was published in *Advanced Functional Materials*. This study proposes a method to synthesize large-area freestanding Bi_2S_3 NFMs with high flexibility and fast photoresponse, which has great potential in flexible and wearable optoelectronic devices.

Flexible photodetectors have attracted great attention due to their light weight, bendability, foldability, and good impact resistance. However, most reported flexible photodetectors have so far been achieved by depositing or coating semiconductor materials on a bendable flexible substrate, which severely restricts the commercialization of flexible optoelectronic devices, especially the wearable devices due to their good performance having a strong dependence on substrates. Therefore, exploring highly flexible semiconductor materials that do not rely on specific flexible substrates is significant for the practical applications of flexible and wearable devices.

Given that, the research team successfully prepared a large-area freestanding Bi_2S_3 NFM through a simple one-step hydrothermal method on the basis of preliminary studies. The as-prepared Bi_2S_3 NFM is self-assembled from ultralong nanowires over a length of 1,000 μm crisscrossing each other. Significantly, the as-prepared Bi_2S_3 NFM can not only be bent, twisted, and folded optionally without creating any cracks but also tailored into any shape. In addition, the Bi_2S_3 NFMs are apparently undamaged and remain highly flexible when immersed in liquid conditions (tap water, deionized water, normal saline, and ethanol) for one week, indicating that the Bi_2S_3 NFM has certain potential applications in a liquid environment. Impressively, the photodetector based on the Bi_2S_3 NFM still reaches more than 86% of its initial photocurrent even after 1,000 bending-flattening times and can maintain its excellent photodetection ability after multiple on/off cycles. Moreover, the robust photoresponse of the Bi_2S_3 NFM photodetector after two months of exposure in the air and after one week in the bending state demonstrate its excellent air-stability and flexible detection ability. The flexible Bi_2S_3 NFM infrared photodetector exhibits high responsivity, fast response, excellent stability and splendent imaging capability under both flat and bent state. This work provides a new method of large-area freestanding Bi_2S_3 NFMs fabrication which could be commercially used in various flexible optoelectronic devices due to their excellent performance and independence on substrates, shedding light on the fabrication of new freestanding materials and next-generation flexible optoelectronic devices.



(a, b) Photographs and FESEM images of the prepared Bi_2S_3 NFM (c) The current of the Bi_2S_3 NFM photodetector after different bending radii; Long-term cycling stability measurement of the Bi_2S_3 NFM photodetector before (d) bending and (e) after bending 1,000 times

Associate Professor Gao Shiyong and Professor Wang Jinzhong are the corresponding authors of this research paper; PhD student Rong Ping is the first author. This work was supported by the National Key Research and Development Program of China, the National Natural Science Foundation of China, the Natural Science Foundation of Heilongjiang Province of China, and the Heilongjiang Touyan Team.

REFERENCE

Ping Rong, Shiyong Gao, Shuai Ren, Huiqing Lu, Jun Yan, Lin Li, Mingyi Zhang, Yajie Han, Shujie Jiao, and Jinzhong Wang. Large-area freestanding Bi_2S_3 nanofibrous membranes for fast photoresponse flexible IR imaging photodetector. Advanced Functional Materials, 2023, 2300159.

SNACIP: A NEW INDUCED PROXIMITY SYSTEM FOR CONTROL OF CELLULAR PROCESSES

Recently, the research group of Professor Chen Xi at the HIT Center for Life Sciences (HCLS) reported small molecule-nanobody conjugate induced proximity (SNACIP) as a new generation of induced proximity approach. The article was published in *Nature Communications* under the title "Small Molecule-Nanobody Conjugate Induced Proximity Controls Intracellular Processes and Modulates Endogenous Unligandable Targets". This paper introduces a solution to the problem of designing drugs that inhibit tumor growth through targeting microtubule nucleation, a challenge that has not been addressed for around 30 years since the discovery of microtubule nucleation phenomena in the 1990s.

In recent years, induced proximity has been considered a core principle for regulating various biological processes. Among them, chemically induced proximity (CIP) technology is one of the most important means of employing cell permeable bifunctional small molecules to induce the proximity between two proteins for control of cellular functions. However, CIP intrinsically requires genetic modification of cells and therefore cannot directly regulate endogenous targets, making it difficult to develop therapeutic drugs. Therefore, the development of induced proximity technology has encountered bottlenecks. On the other hand, although biological molecules such as antibodies and bivalent antibodies can bind to endogenous proteins, their large molecular weight (150 kDa) has rendered them difficult to penetrate plasma membranes that modulate intracellular proteins.

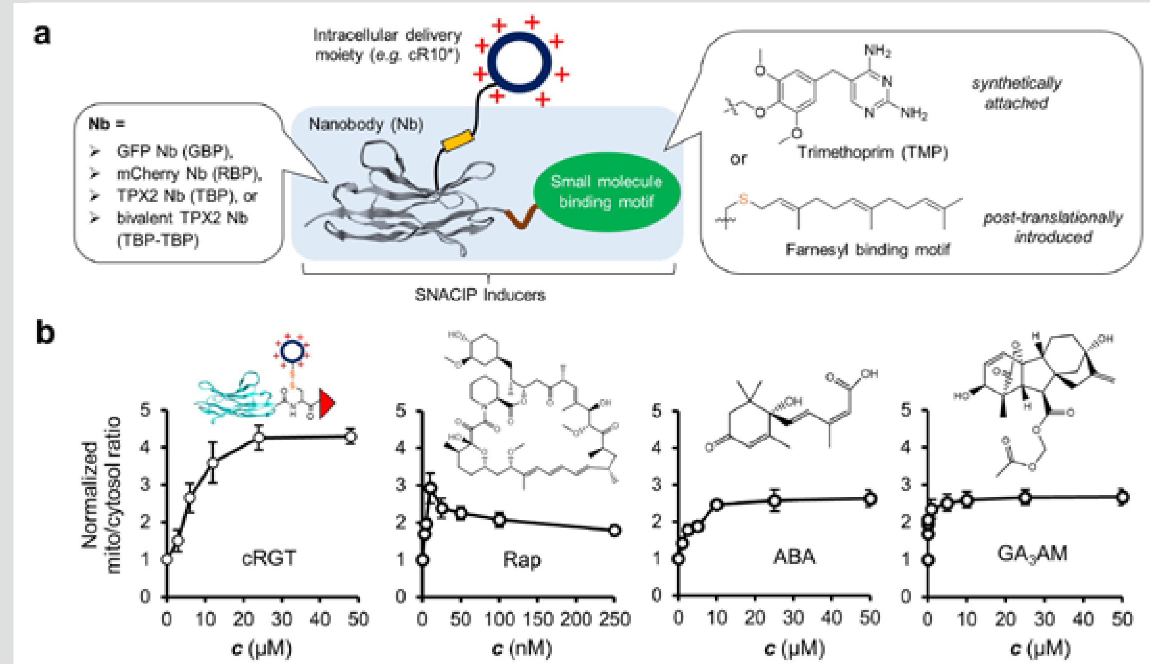


Figure 1 Design and evaluation of SNACIPs. a) The structural elements of a SNACIP molecule which features a nanobody module (left), a small molecule binding motif (right), and an appropriate cell-penetrating peptide (CPP), preferably a cyclic CPP. b) Comparison between a representative SNACIP, cRGT, and other state-of-the-art CIP molecules including rapamycin (Rap), (+)-abscisic acid (ABA) and gibberellic acid (GA_3AM) using an intracellular protein translocation assay, which shows that cRGT is advantageous in terms of translocation dynamic range, reversibility, and dose-dependent response.

Professor Chen's research group solved the dilemma faced by CIP development by combining three recent innovative breakthroughs from several scientific fields: CIP technology, chemical nanobody engineering, and cyclic cell-penetrating peptide-based non-endocytic delivery system. They designed a SNACIP proximity inducing system. Compared with small molecules, nanobodies have high specificity and affinity to their binding partners. Therefore, using nanobodies as one of the binding modules, it can greatly expand the application potential of traditional CIP and achieve rapid regulation of endogenous proteins. The research group also introduced a cyclic decaarginine cell-penetrating peptide, called cR10* to achieve non-endocytic cellular entry and finally established a new generation of proximity-induced system for modulating intracellular targets.

TPX2, a key microtubule nucleation factor in spindle assembly, is an intrinsically disordered protein (IDP) without known small molecule binding ligands. This protein factor is overexpressed in many cancer cells and is therefore considered as a promising target for cancer treatment. In addition, targeting branching microtubule nucleation rather than just binding to microtubules

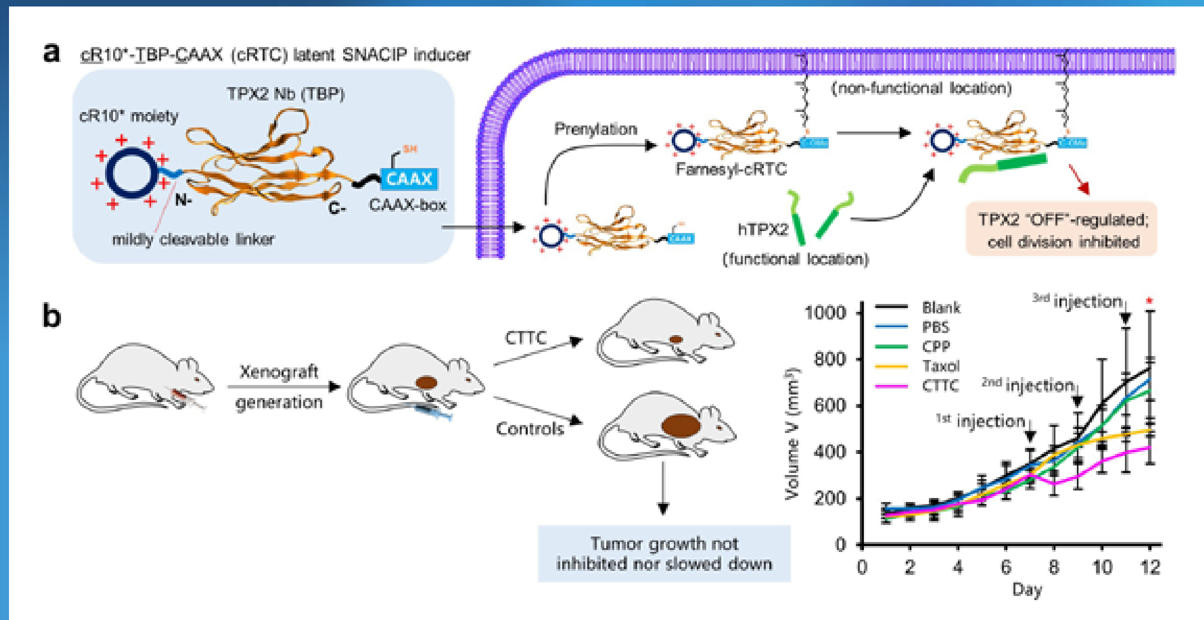


Figure 2 Design of latent SNACIPs cRTC and CTTC for inhibition of microtubule nucleation via off-regulation of hTPX2 function. a) Design and working mechanism of cRTC for off-regulation of the microtubule nucleation factor hTPX2. b) Bivalent SNACIP, CTTC, effective inhibits tumor growth *in vivo*.

themselves is also considered a better option for cancer treatment. Therefore, the research group first used phage display to screen a TPX2 nanobody and then developed SNACIP inducers targeting microtubule nucleation using SNACIP technology. The SNACIP inducers not only effectively inhibit cancer cell proliferation but also successfully suppress tumor growth *in vivo*.

In this work, doctoral student Sun Xiaofeng and Zhou Chengjian and research assistant Xia Simin from Professor Chen Xi's group are the co-first authors of the paper. Professor Chen is the corresponding author of the paper. This research was supported by the National Natural Science Foundation of China, the Natural Science Foundation of Heilongjiang Province of China, and the Harbin Institute of Technology "Double First-Class" Funding.■

REFERENCE

X. Sun, C. Zhou, S. Xia, and X. Chen. Small molecule-nanobody conjugate induced proximity controls intracellular processes and modulates endogenous unligandable targets. Nature Communications, 2023, 14, 1635.

LONG NONCODING RNA HITT COORDINATES WITH RGS2 TO INHIBIT PD-L1 TRANSLATION IN T CELL IMMUNITY

Recently, Professor Hu Ying's group from the School of Life Science and Technology, Harbin Institute of Technology, revealed the pivotal function of lncRNA HITT in boosting antitumor T cell immunity. This work highlights activation of HITT as a potential therapeutic strategy to enhance cancer immunotherapy. The related research article was published in *The Journal of Clinical Investigation*.

Programmed death ligand 1 (PD-L1) is a primary immune checkpoint protein frequently expressed in human cancers, which contributes to immune evasion through its binding to PD-1 on activated T cells. At present, immune checkpoint blockades (ICBs) represented by PD-1/PD-L1 inhibitory antibodies have been widely used in the clinical treatment of various advanced solid tumors and have attracted attention due to their long-lasting therapeutic effects. However, only 10-30% of unselected patients with solid tumors benefit from this therapy. How to improve the efficacy of anti-PD-1/PD-L1 therapy is currently an urgent clinical challenge. Expression levels of PD-L1 on tumor cells have been shown to affect the clinical efficacy of anti-PD-1/PD-L1 therapy. Thus, fully understanding the regulatory mechanism of PD-L1 expression in tumor cells is expected to provide new clues for improving the efficacy targeted inhibition of PD-1/PD-L1 signaling.

With the completion of the Human Genome Project and the development of sequencing technology, long chain non-coding RNA (lncRNA) has become an indispensable component in the comprehensive understanding of various physiological and pathological processes. Increasing evidences indicate that lncRNA can participate in the

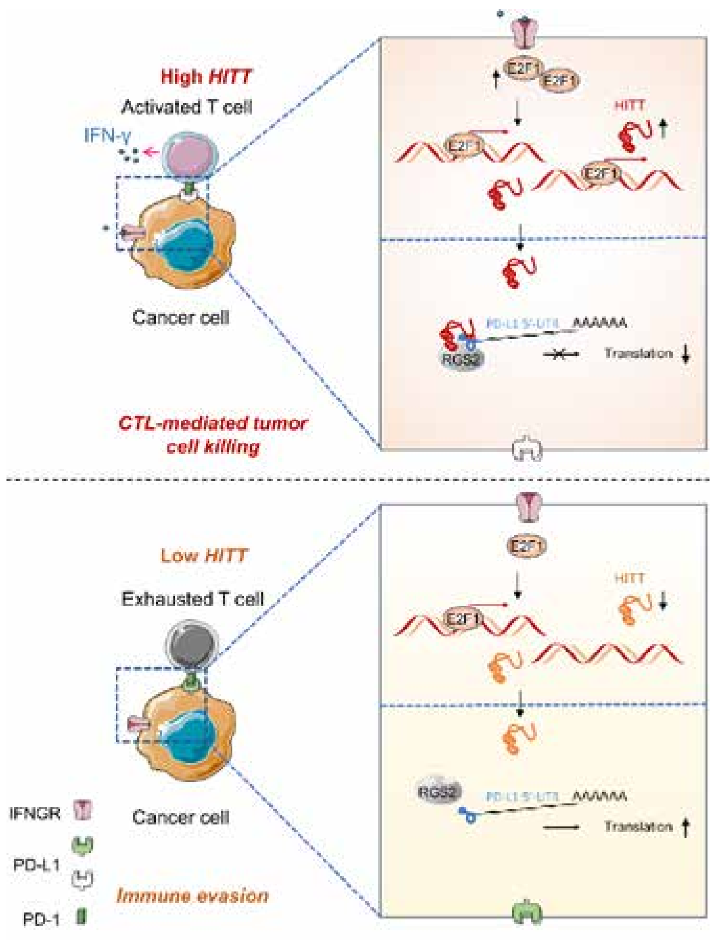


Figure 1 The mechanism of HITT coordinates with RGS2 to inhibit PD-L1 translation

regulation of differentiation and activity of immune cells and also affect the occurrence and development of tumors. However, research on the tumor cell intrinsic function of lncRNA in regulating T cell immunity is relatively lagging.

Hu Ying's group discovered an lncRNA, namely HITT (HIF-1α inhibitor at translation level), which can be transactivated by E2F1 under interferon-γ stimulation. In co-ordination with Regulator of G Protein Signalling 2 (RGS2), HITT subsequently binds with the 5′-untranslated region (UTR) of PD-L1, resulting in the reduced PD-L1 translation. Increased HITT expression enhanced T cell-mediated cytotoxicity both in vitro and in vivo in a PD-L1 dependent manner (Figure 1). The clinical correlation between HITT/PD-L1, RGS2/PD-L1 expression was also detected in breast cancer tissue. Furthermore, HITT functional fragments demonstrated a significant anti-tumor effect by blocking PD-1/PD-L1 signaling. Together, these findings highlight the important roles of HITT in targeting PD-1/PD-L1 signals, indicating the potential clinical application value of HITT molecules as ICB factors.

The paper was financially supported by the Original Exploration Project of the National Nature Science Foundation, the Project of National Excellent Young Scientists, and Interdisciplinary Research Foundation of HIT.■

REFERENCE

Qingyu Lin, Tong Liu, Xingwen Wang, Guixue Hou, Zhiyuan Xiang, Wenxin Zhang, Shanliang Zheng, Dong Zhao, Qibin Leng, Xiaoshi Zhang, Minqiao Lu, Tianqi Guan, Hao Liu, Ying Hu. Long noncoding RNA HITT coordinates with RGS2 to inhibit PD-L1 translation in T cell immunity. The Journal of Clinical Investigation, 2023, 4, e162951. DOI: 10.1172/JCI162951

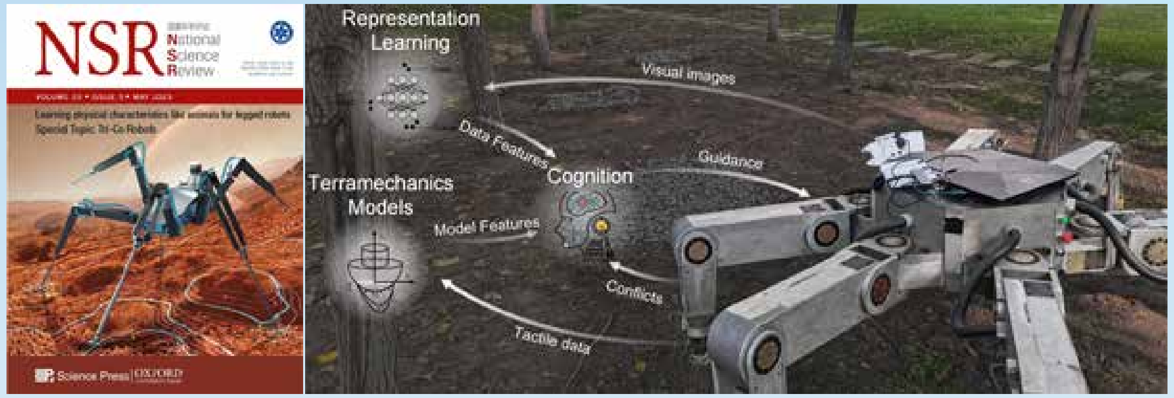
LEGGED ROBOTS LEARN DYNAMIC PHYSICAL CHARACTERISTICS OF TERRAINS LIKE ANIMALS

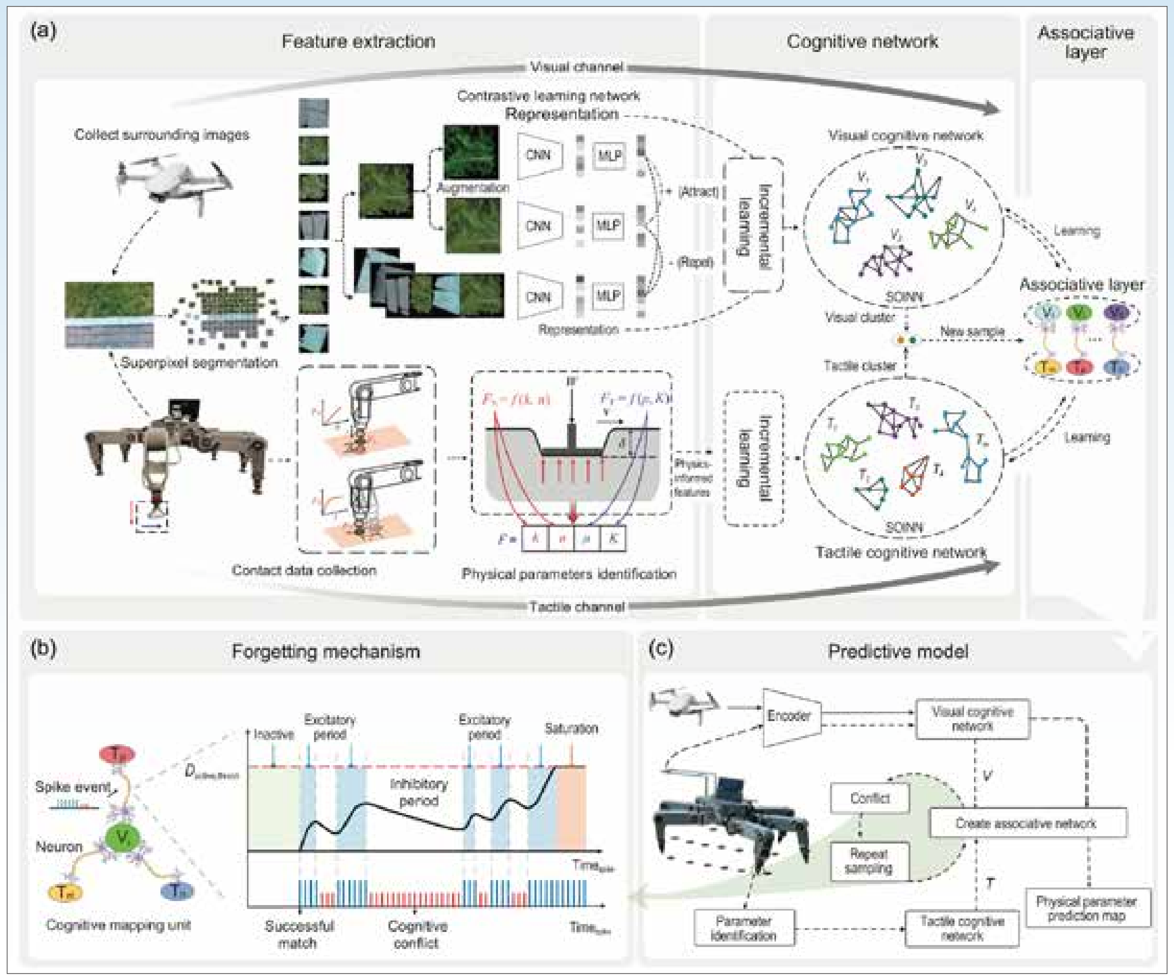
When a kitten is walking in a dangerous environment, it will gently step on the terrain with its feet to estimate the friction or bearing capacity. Based on this experience, the kitten can then predict the physical parameters of terrain with a similar appearance and avoid the soft, wet ground. However, it is not easy for robots to achieve such behavior because of the many challenges involved. For example, how to extract effective features to characterize a dynamically changing environment? How to generalize the robot's experience of interacting with the environment? How to resolve cognitive conflicts caused by dynamically changing environments?

A recent cover paper in *National Science Review*, "Learning Physical Characteristics like Animals for Legged Robots," presents their solution. The paper was published by Professor Ding Liang's team at Harbin Institute of Technology with PhD student Xu Peng as co-first authors.

The research team proposes an unsupervised learning framework for legged robots to learn physical characteristics of the terrain. Based on normal/tangential foot-terrain contact models, the unsupervised model-data-based learning framework is designed to achieve incremental online visual-tactile fusion perception with cognitive conflict-solving capabilities. This is the first online, incremental, and cognitive conflict-solving report that enables a robot to learn the physical characteristics of the environment independently and autonomously, endowing the robot with physical artificial intelligence.

Finally, the work conducts both indoor and outdoor hardware experiments, and the experimental results demonstrate that the proposed approach can effectively help robots to accurately perceive and predict the physical features of the environment, while learning and adjusting their cognitive models. Finally, the robot successfully and safely performs navigation tasks in complex environments.■





REFERENCE

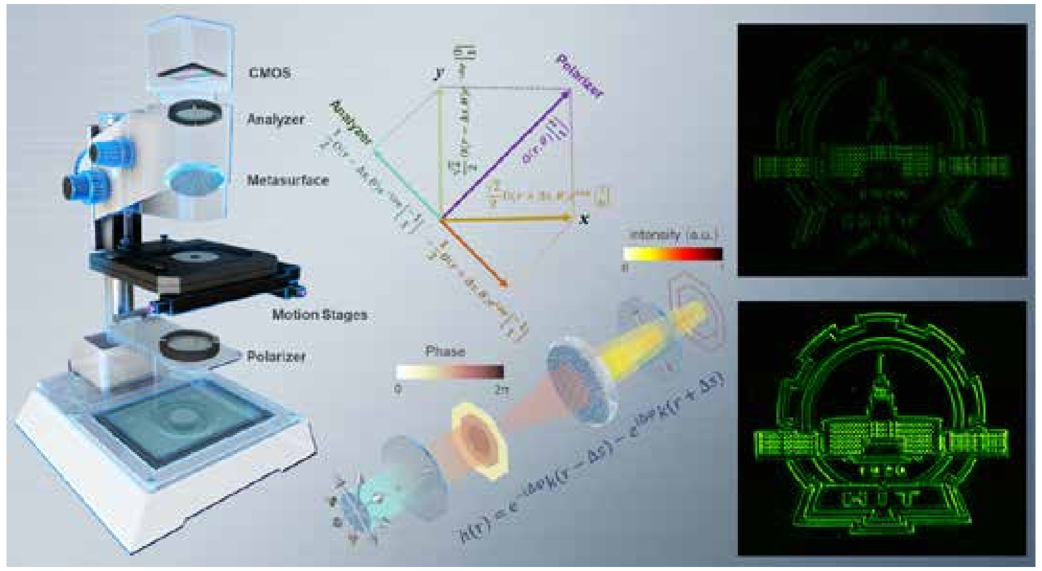
Peng Xu, Liang Ding1, Zhengyang Li, Huaiguang Yang, Zhikai Wang, Haibo Gao, Ruyi Zhou, Yang Su, Zongquan Deng and Yanlong Huang. Learning physical characteristics like animals for legged robots. National Science Review, 2023, 10: nwad045. DOI: https://doi.org/10.1093/nsr/nwad045

SINGLE-SHOT ISOTROPIC DIFFERENTIAL INTERFERENCE CONTRAST MICROSCOPY

In 2023, Professor Ding Xumin's group from the Advanced Microscopy and Instrumentation Research Center, the School of Instrumentation Science and Engineering, published a research paper titled "Single-Shot Isotropic Differential Interference Contrast Microscopy" in *Nature Communications*.

DIC microscopy can record phase variations induced by the lateral shear between two orthogonally polarized lights to recover fine details, featuring the advantages of high contrast, fine spatial resolution and pseudo-3D relief imaging and free from the halo and shade-off artifacts of phase contrast microscopy. Hence, they are widely used in measuring cellular morphology and segmentation, particle tracking and other applications. However, conventional DIC microscopes have strong orientation sensitivity as they rely on Nomarski prisms to generate the rectilinear shear between two orthogonal linear polarizations. Hence, the image contrast is created along that direction but absent in the orthogonal. So far, obtaining a single-shot isotropic DIC microscopy for fast phase imaging remains a critical challenge, due to the limited functionalities of conventional optical elements.

In order to address these issues, the researchers theoretically proposed and experimentally demonstrated an ultracompact single-shot isotropic differential interference contrast microscopy (i-DIC) to overcome orientation sensitivity of conventional DIC microscopy by exploiting the nontrivial independent phase modulation of two orthogonal polarization states to apply the desired rotationally symmetric shear along radial directions in polar instead of Cartesian coordinate. To showcase the unique capability of metasurface-assisted i-DIC, the



Single-shot isotropic differential interference contrast microscopy

direct real-time tracking of microparticles were realized in the background of strong scatterings which might be applied in studying dynamics of biomolecules in complex cellular environments for targeted drug delivery and others. Furthermore, the i-DIC is employed to capture breast cancer cells and tissues and demonstrate superior performance with much sharper images, which fuses meta-optics with cancer screening and diagnoses and other bio-applications.

This work could show the impressive performance of single-shot, isotropic, highly flexible, phase-based optical imaging capabilities using only a single metasurface. The work unveils numerous opportunities in high-contrast biological imaging, particle tracking and other technologies, which may serve as an add-on compact module to be easily integrated in the existing imaging system.

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

REFERENCE

Xinwei Wang, Hao Wang, Jinlu Wang, Xingsi Liu, Huijie Hao, You Sin Tan, Yilei Zhang, He Zhang, Xiangyan Ding, Weisong Zhao, Yuhang Wang, Zhengang Lu, Jian Liu, Joel K.W. Yang, Jiubin Tan, Haoyu Li, Cheng-Wei Qiu, Guangwei Hu, Xumin Ding. Single-shot isotropic differential interference contrast microscopy. Nature Communications, 2023, 14, 2063. DOI: 10.1038/s41467-023-37606-6

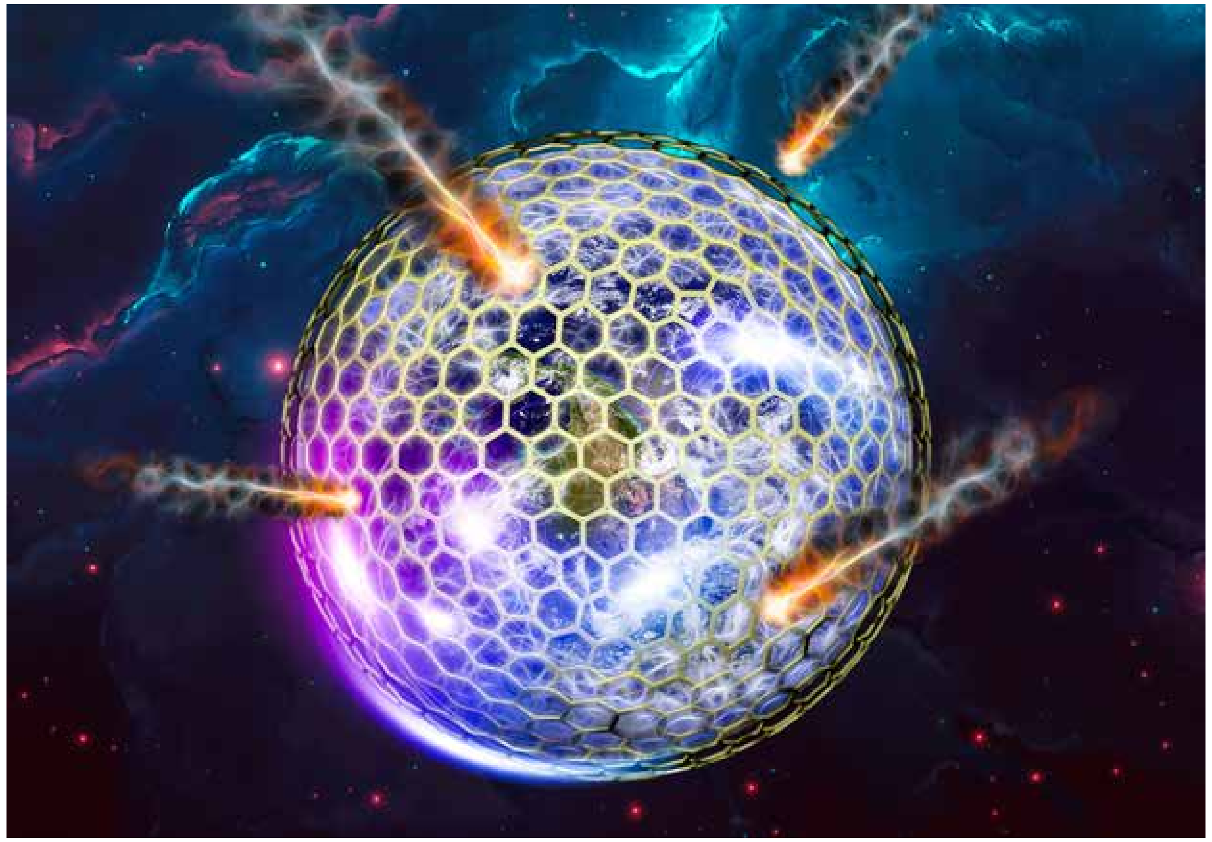
Research & Academia
HIT TIMES 2023

2D COVALENT ORGANIC FRAMEWORK WITH HIGHLY-ENERGY DISSIPATION CAPABILITY UNDER HIGH-VELOCITY IMPACT

Professor Wang Chao's group in the School of Astronautics published a research paper titled "Multiple Impact-Resistant 2D Covalent Organic Framework" in *Nano Letters*. This paper revealed that the hexagonal frame structure of covalent organic framework (COF) can effectively promote energy dissipation through large deformation and suppresses crack propagation. More importantly, the defect-insensitivity of COF retains its mechanical performance under multiple impacts.

2D COF is an emerging kind of long-range order and crystalline organic polymer assembled by linking the precursors of organic molecules with covalent bonds. So far, it has attracted much attention owing to its highly-ordered porous structures, light weight, excellent mechanical properties and multi-functional capabilities, including energy storage, environmental remediation, drug delivery, sensors and optoelectronic devices, etc. However, very few studies have been focused on its unique nanostructures and impacting mechanical properties so far, which is critical for the structural designs and practical applications of advanced 2D nano-armor materials.

The structure-property relationships of high-velocity impacts of different materials generally play critical roles in their protective applications, and 2D materials are no exceptions. In this study, they employed a large-scale molecular dynamics simulation to study the impacting mechanical properties and fracture mechanisms of monolayer 2D COF. It was revealed that the hexagonal nano-porous structures possess remarkable torsion and large deformation compatibility, which can remarkably contribute to the energy dissipation. Meanwhile, it was calculated that the superior 2D COF possesses penetration energy up to 49 MJ/kg, which is higher than other traditional impact-resistant materials, including steel, polymerthyl methacrylate, Kevlar,



etc. Additionally, it is verified that defect-insensitivity property of COF has a unique advantage over graphene, where the crack is only confined to the impact region which does not propagate to neighboring defects. This novel fracture mechanism can achieve out multiple impact protections. This is mainly benefited from that the local crack propagation can be suppressed via special structural deformation of COF. This work uncovers the extreme dynamic responses of COF under high-velocity impact and provides theoretical guidance for designing super-strong 2D polymer-based crystalline nanomaterials.

Professor Wang Chao, Professor He Xiaodong, and Associate Professors Sui Chao and Zhao Yushun from Harbin Institute of Technology (HIT) are the corresponding authors. PhD student Hao Weizhe is the first author. This work was financially supported by the National Natural Science Foundation of China and the Science Foundation of National Key Laboratory of Science and Technology on Advanced Composites in Special Environments.■

REFERENCE

Weizhe Hao, Yushun Zhao, Linlin Miao, Gong Cheng, Guoxin Zhao, Junjiao Li, Yuna Sang, Jiaxuan Li, Chenxi zhao, Xiaodong He, Chao Sui, Chao Wang. Multiple impact-resistant 2D covalent organic framework. Nano Letters, 2023, 23, 1416. DOI: https://doi.org/10.1021/acs.nanolett.2c04747

MECHANISMS OF Fe^{2+} REGENERATION IN THE ELECTRO-FENTON PROCESS: FUNDAMENTALS AND BOOSTING STRATEGIES

Recently, Professor Qiu Shan and her team from the State Key Laboratory of Urban Water Resource and Environment at the School of Environment published a review paper titled "A Critical Review on the Mechanisms of Fe^{2+} Regeneration in the Electro-Fenton Process: Fundamentals and Boosting Strategies" in *Chemical Reviews*. Meanwhile, this work has been selected as the front cover (Fig.1). The research paper boasts a distinguished team of co-corresponding authors, including Professor Qiu Shan, Professor Ignasi Sirés, and Professor Enric Brillas. Additionally, Associate Professor Deng Fengxia is the first author of the paper. Harbin Institute of Technology (HIT) is the primary affiliation for this groundbreaking research.

This review presents an exhaustive overview on the mechanisms of Fe^{3+} cathodic reduction within the context of electro-Fenton (EF) process (Fig.2). Different strategies developed to improve the reduction rate are discussed, dividing them into two categories that regard the mechanistic feature that is promoted: electron transfer control and mass transport control. Boosting Fe^{3+} conversion to Fe^{2+} via electron transfer control

Figure 1 The work has been selected as the front cover

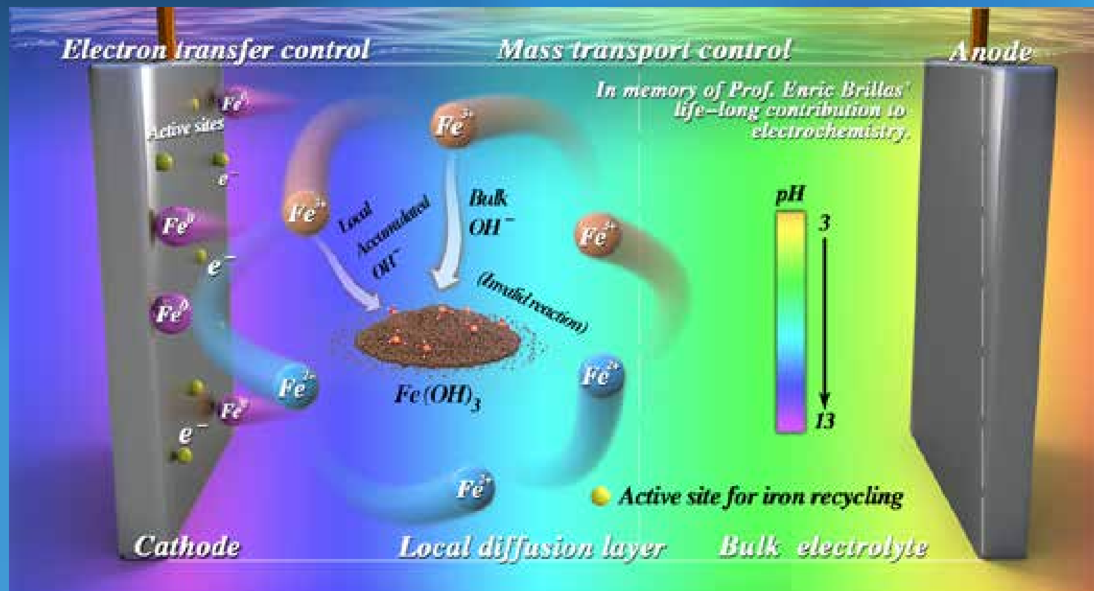


Figure 2 The content of this review paper summarizing from mass transfer, double layer and electronic effect

includes: (i) the formation of a series of active sites in both carbon- and metal-based materials, and (ii) the use of other emerging strategies such as a single atom catalysis or confinement effects.

Concerning the enhancement of Fe^{2+} regeneration by mass transport control, the main routes involve the application of magnetic fields, pulse electrolysis, interfacial Joule heating effects, and photoirradiation. Finally, challenges are singled out and future prospects are described. This review aims to clarify the Fe^{3+}/Fe^{2+} cycling process in EF process, eventually providing essential ideas for the smart design of highly effective systems for wastewater treatment and valorization at an industrial scale.

This work was supported by the National Natural Science Foundation of China and the State Key Laboratory of Urban Water Resource and Environment. The postdoctoral scholarship awarded to Deng Fengxia (the State Scholarship Fund, CSC) is acknowledged.

REFERENCE

Fengxia Deng, Hugo Olvera Vargas, Minghua Zhou, Ignasi Sirés, Shan Qiu, Enric Brillas. A critical review on the mechanisms of Fe^{2+} regeneration in the electro-Fenton process: Fundamentals and boosting strategies. Chemical Reviews, 2023, 123, 8, 4635-4662.

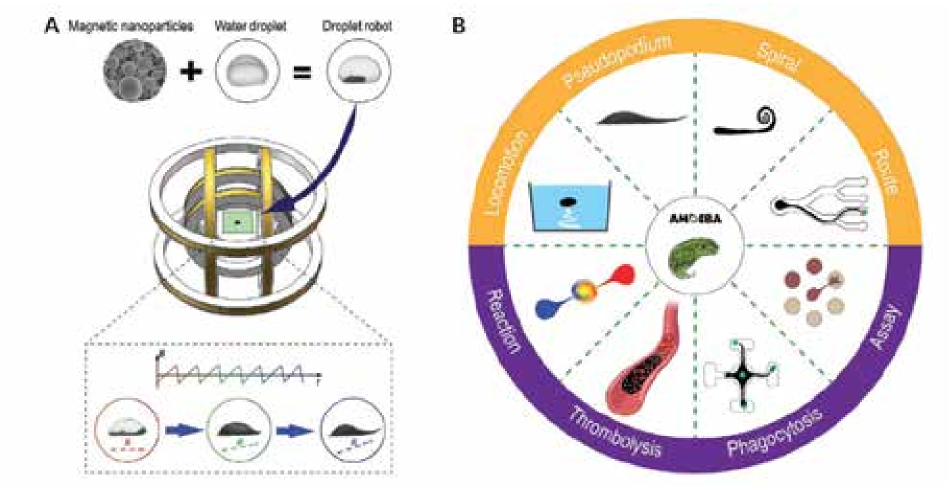
AMOEBA-INSPIRED MAGNETIC VENOM MICROROBOTS

Recently, Professor Li Tianlong and his team, from the School of Mechanical and Electrical Engineering, published a research article titled "Amoeba-Inspired Magnetic Venom Microrobots" in *Small*.

Nature provides a successful evolutionary direction for single-celled organisms to solve complex problems and complete survival tasks – pseudopodium. Amoeba, a unicellular protozoan, can produce temporary pseudopods in any direction by controlling the directional flow of protoplasm to perform important life activities such as environmental sensing, motility, predation, and excretion.

However, creating robotic systems with pseudopodia to emulate environmental adaptability and tasking capabilities of natural amoeba or amoeboid cells remains challenging.

Dr. Li Tianlong's group presents a strategy to reconfigure magnetic droplets into amoeba-like microrobots with excellent maneuverability and versatility, using programmed alternating magnetic fields. By simply adjusting the inclination of magnetic fields, amoeboid robots performed various pseudopod actions, such as active extension, contraction, bending, and phagocytosis. The pseudopodia give droplet robots with superior mobility to adapt to environmental variations, including navigating



across 3D terrains and swimming in bulk liquids, greatly expanding their application.

Moreover, this research demonstrated the reversible reconfigurations of the robot in monopodia, biopodia, and locomotion patterns and explored the mechanisms of pseudopodia protrusion and locomotion of amoeboid robot. Inspired by "Venom," the phagocytosis and parasitic behaviors of the microrobot have also been investigated. The robots that parasitized liquid droplets dissolved with various biological and chemical reagents will be endowed with versatile talents, such as reagent detection, biochemical reaction, and dissolution of calculi. Especially in the thrombolysis, the venom robot loaded with thrombolytic drugs was navigated to ablate artificial thrombi and successfully dredged the embolic vessels. This venom microrobot with diverse unprecedented functionalities may contribute to understanding the fundamental principles of unicellular biological systems and provide a promising application prospect in lab-on-a-chip, microchemical reactions, biotechnology, and biomedical applications.■

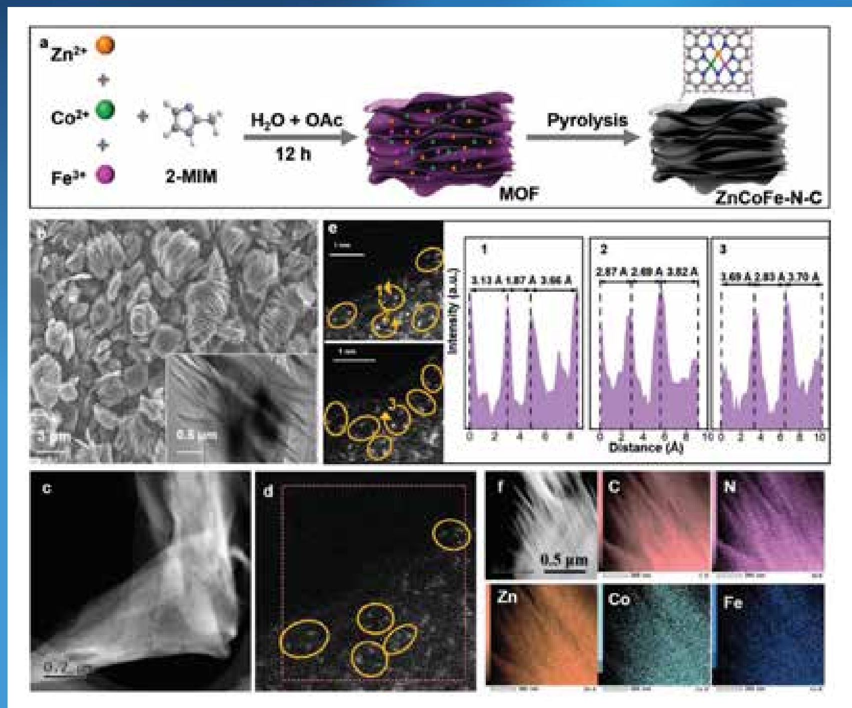
REFERENCE

Weiwei Zhang, Yuguo Deng, Jinhao Zhao, Tao Zhang, Xiang Zhang, Wenping Song, Lin Wang, and Tianlong Li. Amoeba-inspired magnetic venom microrobots. Small, 2023, 2207360. DOI: https://doi.org/10.1002/smll.202207360

REVEALING ATOMIC CONFIGURATION AND SYNERGISTIC INTERACTION OF SINGLE-ATOM-BASED Zn-Co-Fe TRIMETALLIC SITES FOR ENHANCING OXYGEN REDUCTION AND EVOLUTION REACTIONS

Recently, Professor Qiu Hua-Jun's group, from the School of Materials Science and Engineering at Harbin Institute of Technology (Shenzhen), reported their discovery in synergistic interaction generated by uniformly isolated trimetal single-atom sites, resulting in reduced energetic barriers and accelerated reaction kinetics for ORR/OER. This article was recently published in a high-impact international journal *Small*, titled "Revealing Atomic Configuration and Synergistic Interaction of Single-Atom-Based Zn-Co-Fe Trimetallic Sites for Enhancing Oxygen Reduction and Evolution Reactions."

Electrochemical reactions such as oxygen evolution reaction (OER), oxygen reduction reaction (ORR), and nitrogen reduction reaction (NRR) are crucial to solving the energy crisis and realizing the conversion of renewable energy. Anchoring single metal atom to carbon supports represents an exceptionally effective strategy to maximize the efficiency of catalysts. In this article, atomically dispersed triple Zn-Co-Fe sites anchored to nitrogen-doped carbon (ZnCoFe-N-C) prepared by one-step pyrolysis of a designed metal-organic framework precursor are reported. The atomically isolated trimetallic configuration in ZnCoFe-N-C is identified by annular dark-field scanning transmission electron microscopy and spectroscopic techniques. Benefiting from the synergistic effect of trimetallic single atoms, nitrogen, and carbon, ZnCoFe-N-C exhibits excellent catalytic performance in bifunctional oxygen reduction/evolution reactions in an alkaline medium, outperforming other SACs and DACs. The ZnCoFe-N-C-based Zn-air battery exhibits a highly specific capacity (liquid state: 931.8 Wh kgZn^{-1}),



a) Schematic illustration of the synthesis process of accordion-structured ZnCoFe-N-C; b) SEM and inserted TEM images; c) Low-magnification STEM and d) HAADF-STEM images of the trimetal ZnCoFe-N-C; Some ZnCoFe triple-atom sites are marked in (d) with yellow circles. e) The corresponding Z-contrast analysis of regions 1, 2, 3 and the atomic distance of the trimetal sites (the direction of the atomic distance measurement is indicated by the arrows); Some ZnCoFe triple atoms are marked with yellow circles. f) STEM-EDS mappings

power density (liquid state: 137.8 mW cm^{-2}; all-solid-state: 107.9 mW cm^{-2}), and good cycling stability. Furthermore, density-functional theory calculations rationalize the excellent performance by demonstrating that the ZnCoFe-N-C catalyst has upshifted d-band center that enhances the adsorption of the reaction intermediates.

The experimental observations and the theoretical studies indicate that the uniformly isolated trimetal single-atom sites generate synergistic interaction, resulting in reduced energetic barriers and accelerated reaction kinetics for ORR/OER. This work demonstrates an efficient approach to ration-ally design trimetallic active sites in M-N-C-based catalysts and opens up enormous possibilities for designing polynary SACs.

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

REFERENCE

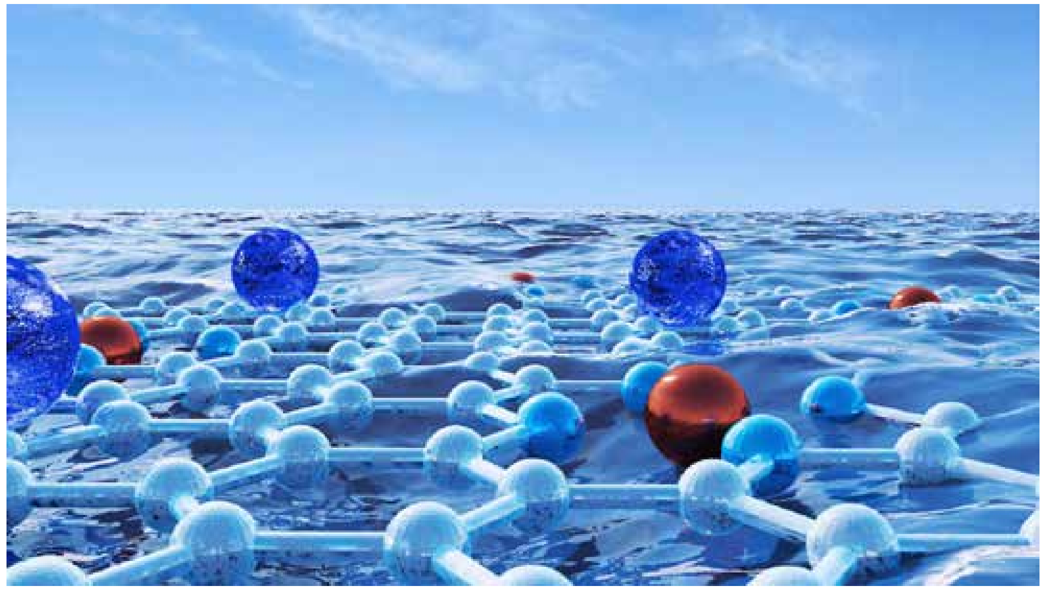
Xiaorong Lin, Qingqing Li, Yixuan Hu, Zeyu Jin, Kolan Madhav Reddy, Kaikai Li, Xi Lin, Lijie Ci, and Hua-Jun Qiu. Revealing atomic configuration and synergistic interaction of single-atom-based Zn-Co-Fe trimetallic sites for enhancing oxygen reduction and evolution reactions. Small, 2023, 2300612. DOI: 10.1002/smll.202300612

ARCHITECTING FeN_x ON HIGH GRAPHITIZATION CARBON FOR HIGH-PERFORMANCE OXYGEN REDUCTION BY REGULATING d-BAND CENTER

Recently, Professor Yin Geping and Associate Professor Kong Fanpeng from the School of Chemistry and Chemical Engineering published a paper titled “Architecting FeN_x on High Graphitization Carbon for High-Performance Oxygen Reduction by Regulating d-Band Center” in *Small*. This article reports an effective phase transition strategy to improve the stability of Fe-N-C oxygen reduction reaction catalysts, which greatly improved the prospects for commercialization of Fe-N-C catalysts.

The second active site of Fe nanoparticles was introduced by the second iron source, generating significant synergy with monoatomic Fe. Fe nanoparticles can catalyze carbon reduction to improve the graphitization degree of the catalyst. At the same time, acetate ions are introduced to generate pore structure to compensate for the decrease of porosity to maintain the high specific surface area of the catalyst, so as to ensure a more active site towards oxygen reduction reaction.

A composite catalyst (Fe@Fe N-C) containing both Fe single atoms (Fe SA) and Fe nanoparticles coated with a graphite carbon layer (Fe NP) was prepared, which significantly improved the degree of graphitization and specific surface area. DFT theoretical calculation shows that the electronic structure of Fe SA realizes the negative shift of the d-band center under the action of Fe nanoparticles, thus improving the ORR performance. In addition, the introduction of Fe NPs is beneficial



Schematic diagram of catalyst structure

for improving the free energy change of Fe single atom detachment from the active center, thereby inhibiting the dissolution of the Fe single atom from the active center and enhancing the stability of the catalyst.

In summary, the strong interaction between Fe-SA and surrounding Fe-NP, the enhanced degree of graphitization, and the synergistic effect between significantly maintained porosity endow the Fe/Fe N-C catalyst with high activity and stability. This study provides new insights for the preparation of highly stable transition metal nitrogen doped carbon catalysts, thereby promoting the transition of oxygen reduction catalysts from platinum group catalysts to non-noble metal nitrogen doped carbon.

This work was supported by the National Natural Science Foundation of China, the Open Project of the State Key Laboratory of Urban Water Resource and Environment (HIT), and the China Postdoctoral Science Foundation.

REFERENCE

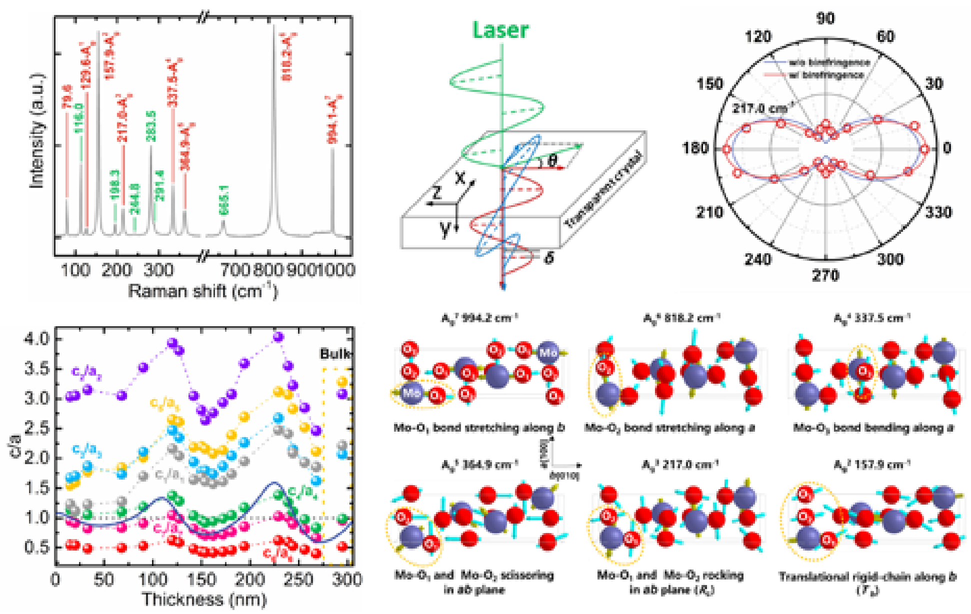
Lingfeng Li, Yandi Wen, Guokang Han, Fanpeng Kong, Lei Du, Yulin Ma, Pengjian Zuo, Chunyu Du, Geping Yin. Architecting FeN_x on high graphitization carbon for high-performance oxygen reduction by regulating d-band center. Small, 2023, 2300758. DOI: https://doi.org/10.1002/smll.202300758

DISTINGUISHING THE EFFECTS OF BIREFRINGENCE AND LINEAR DICHROISM IN RAMAN SPECTROSCOPY OF OPTICAL CRYSTAL α-MoO_3

In 2023, Professor Sun Huarui's team from the School of Science and Ministry of Industry and Information Technology Key Laboratory of Micro-Nano Optoelectronic Information System at Harbin Institute of Technology (Shenzhen) published a research paper titled "Optical Effect Modulation in Polarized Raman Spectroscopy of Transparent Layered α-MoO_3" in the high-impact international journal *Small*.

Optical anisotropy, which is quantified by birefringence (Δn) and linear dichroism (Δk), can significantly modulate the angle-resolved polarized Raman spectroscopy (ARPRS) response of anisotropic layered materials (ALMs) by external interference. For opaque ALMs such as BP, the birefringence and linear dichroism are intermixed through a complex refractive index, and both contribute to anisotropic interference. This poses a challenge in distinguishing the respective contributions of these two optical effects to fully understand the ARPRS response. Therefore, a wide-band-gap transparent ALM with large birefringence and without linear dichroism may provide an excellent platform for achieving this goal. Transparent α-MoO_3 with a band gap up to 3.8 eV is used to individually study the influence of birefringence on the ARPRS response.

In this paper, a systematic ARPRS study was conducted on α-MoO_3 nanoflakes with different thicknesses from 15 to 268 nm under a 532 nm excitation laser. The ARPRS responses of 11 well-defined Raman modes within 100-1,000 cm^{-1} were studied, and several anomalous responses of A_g modes were observed. These anomalous responses cannot be reproduced by the real



The modulation of birefringence on the ARPRS response of α-MoO_3 and the physical origin of its intrinsic response

Raman tensor widely used in non-absorbing materials; however, they can be well explained by considering the birefringence-induced Raman selection rules. Moreover, thickness-dependent polarized Raman studies show that the birefringence effect modulates the ARPRS responses to present an interference pattern. Nevertheless, these responses are similar because the modulation amplitude is rather small. These similar responses facilitate the determination of the crystal orientation, and it was discovered that the *a*-axis and *c*-axis of α-MoO_3 can be unambiguously determined by the ARPRS response of the Raman modes A_g^6 (818.2 cm^{-1}) and A_g^2 (157.9 cm^{-1}), respectively. Furthermore, through the ARPRS responses of the bulk and thin α-MoO_3 nanoflake, the intrinsic ARPRS responses of A_g modes were obtained. The physical origin of these intrinsic responses was studied by combining the atomic vibrational patterns and the bond polarizability model.

This paper was supported by the Key-Area Research and Development Program of Guangdong Province, the Natural Science Foundation of Guangdong Province, and the Science and Technology Planning Project of Shenzhen Municipality.

REFERENCE

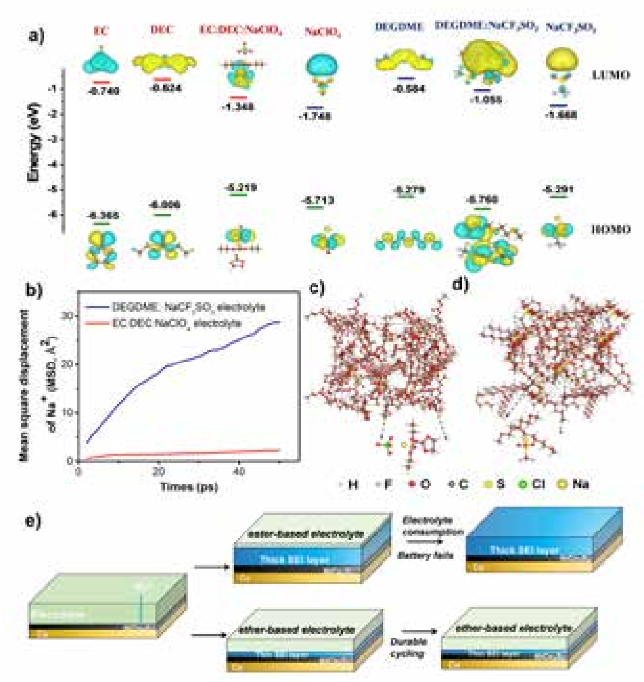
Bo Zou, Xiaonan Wang, Yu Zhou, Yan Zhou, Yanyan Wu, Tiantian Xing, Yang He, Jinfeng Yang, Yuxiang Chen, Peng Ren, and Huarui Sun. Optical effect modulation in polarized Raman spectroscopy of transparent layered α-MoO_3. Small, 2023, 2206932.

ELECTROLYTE ENGINEERING ON PERFORMANCE ENHANCEMENT OF $NiCo_2S_4$ ANODE FOR SODIUM STORAGE

Professor Liu Haiping's group from the School of Marine Science and Technology, Harbin Institute of Technology (Weihai) and Professor Guo Zaiping from the University of Adelaide developed an ether-based electrolyte (1.0 M $NaCF_3SO_3$-DEGDME) through electrolyte engineering, which forms a stable electrode/electrolyte interface on the surface of $NiCo_2S_4$ electrode, greatly improving its sodium storage performance. The research results were published in the high-impact international journal *Small*, titled "Electrolyte Engineering on Performance Enhancement of $NiCo_2S_4$ Anode for Sodium Storage". Professor Liu and postdoctoral Zhang Shilin from the University of Adelaide are the co-corresponding authors. HIT was the first and corresponding affiliation.

Rechargeable sodium-ion batteries (SIBs) are considered a viable alternative to lithium-ion batteries for large-scale grid storage applications because of the abundance and low cost of sodium-containing precursors and the comparable redox potential of Na^+/Na to Li^+/Li (-2.71 V vs -3.04 V). As a metal sulfide, $NiCo_2S_4$ is an attractive anode material for SIBs, due to its high capacity and excellent redox reversibility. However, the practical application of $NiCo_2S_4$ electrodes in SIBs is still hindered by poor cycling performance, mainly due to the mismatch between the electrolyte and the electrode material.

This work systematically studied the electrochemical behavior of $NiCo_2S_4$ electrodes in ester-based and ether-based electrolytes, developing a functional electrolyte (1.0 M $NaCF_3SO_3$-DEGDME) containing 1.0 M $NaCF_3SO_3$ in diethylene glycol dimethyl



The frontier orbitals of different solvent and solvation structures, and the schematic image of the SEI layer and the possible mechanism of electrolyte consumption on $NiCo_2S_4$ electrode surface

ether (DEGDME), which can be easily used for $NiCo_2S_4$ electrodes, with high initial coulombic efficiency (96.2%) and excellent cycling stability (still reaching 341.7 mA h g^{-1} specific capacity after 250 continuous cycles at a current density of 200 mA g^{-1}). The electrolyte's solvation structure was revealed to have an impact on the electrode/electrolyte interface chemistry through electrochemical experiments and related phase characterization and theoretical calculations. In addition, this work also studied the importance of voltage window for further optimizing the electrochemical performance of $NiCo_2S_4$ electrodes. The formation of sulfide intermediates during charging and discharging processes was predicted by DFT calculations and verified by in situ XRD and HRTEM. Meanwhile, it also provides a reference for the practical application of other high-performance sulfides in sodium-ion batteries.

The paper was financially supported by the Natural Science Foundation of Shandong Province and the China Scholarship Council.

REFERENCE

Shanshan Fan, Haiping Liu, Ying Xie, Sifu Bi, Xiaohuan Meng, Kaiqi Zhang, Liang Sun, Shilin Zhang, Zaiping Guo. Electrolyte engineering on performance enhancement of $NiCo_2S_4$ anode for sodium storage. Small, 2023, 2300188. DOI: 10.1002/smll.202300188

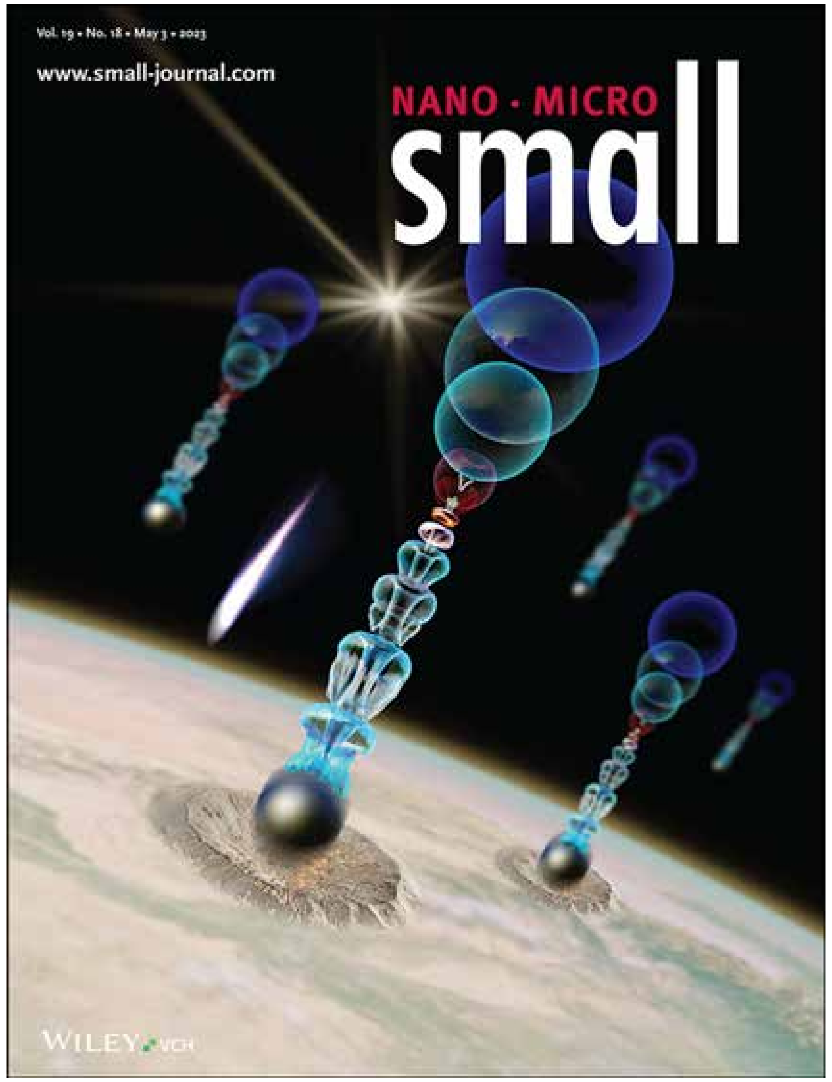
BREAKING THROUGH BARRIERS: ULTRAFAST MICROBULLET BASED ON CAVITATION BUBBLE

Recently, Associate Professors Zhou Dekai and Chang Xiaocong, from the School of Mechatronics Engineering (HIT), published a research paper titled "Breaking through Barriers: Ultrafast Microbullet Based on Cavitation Bubble" in *Small*. This paper was also selected as the front cover of this journal. Associate Professors Zhou Dekai, Chang Xiaocong, and Li Shuai (Harbin Engineering University) were the co-corresponding authors. PhD student Feng Yiwen from HIT and Jia Deli from the PetroChina Research Institute of Petroleum Exploration and Development were the co-first authors. HIT was the first and corresponding affiliation.

Artificial micromotors are energy conversion devices that effectively convert ambient energy into mechanical energy. Equipped with unique features, such as autonomous motion and efficient cargo loading, these miniaturized moving devices have broad application prospects in targeted drug delivery, minimally invasive surgery, and microporous reservoir exploitation. A major challenge for micromotors is crossing physical barriers in a complex environment. However, the ejection speed and penetration ability of existing micromotors driven by traditional propulsion methods are inadequate, which severely limits their application in the biomedical and oil industries.

In this work, the laser-induced cavitation effect was introduced to dramatically improve the instantaneous speed and penetrating ability of a micromotor. This novel type of micromotor, which was called "microbullet" in this article, was investigated from theoretical and experimental perspectives. According to the results, surprisingly, it was found that the microbullet could achieve more than 500 times the speed of the previous micromotors. For the polystyrene/magnetic nanoparticles (PS/MNP) microbullet, the instantaneous velocity could reach over 5 m/s. This kind of enormous energy of the cavitation bubble makes it possible for the microbullet to cross the oil-water interface. These findings open up new possibilities for the micromotor to break through barriers such as reservoir boundaries.

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



REFERENCE

Yiwen Feng, Deli Jia, Honger Yue, Jie Wang, Wenping Song, Longqiu Li, A-Man Zhang, Shuai Li, Xiaocong Chang and Dekai Zhou. Breaking through barriers: Ultrafast microbullet based on cavitation bubble. Small, 2023, 2207565. DOI: https://doi.org/10.1002/smll.202207565

Research & Academia
HIT TIMES 2023

A NOVEL METHOD FOR PREDICTING MULTI-CRACK SYSTEMS IN LONG FIBER-REINFORCED COMPOSITES

Long fiber-reinforced composites have a complex mesostructure composed of different components, such as fiber and matrix, and can obtain tailored mechanical properties by stacking plies with different fiber orientations. Due to the above reasons, long fiber-reinforced composites have complex failure mechanisms during progressive failure. Although physical experiments can also be used to establish various failure processes, they frequently necessitate significant amounts of people, material resources, and time. The expense of numerical simulations, on the other hand, is low because it simply involves modeling and analysis in a computer simulated environment. As a result, credible simulations are required to comprehend these complicated phenomena. The fracture phase field method can naturally simulate a range of complex fracture phenomena, from complete crack initiation and expansion to branching and convergence, and is considered to be a very effective tool for modeling progressive failure. However, effectively predicting the complex failure behaviors of long fiber composites (such as fiber failure and matrix failure) is still a challenge for the fracture phase field method.

Recently, Professors He Xiaodong and Xu Zhonghai's group from the National Key Laboratory of Science and Technology on

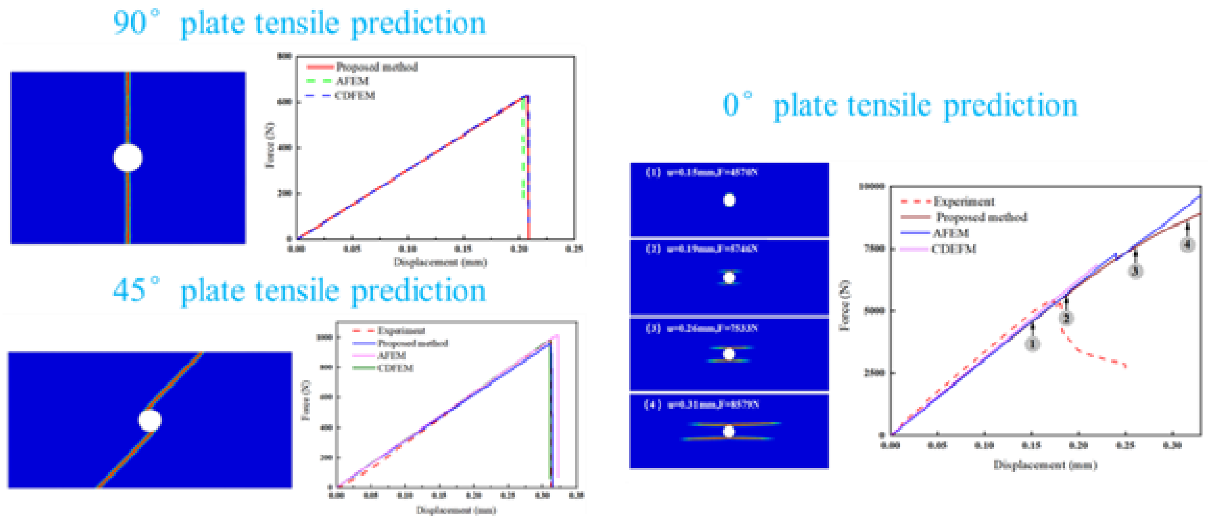


Figure 1 Open-hole tension (OHT) tension of unidirectional plate

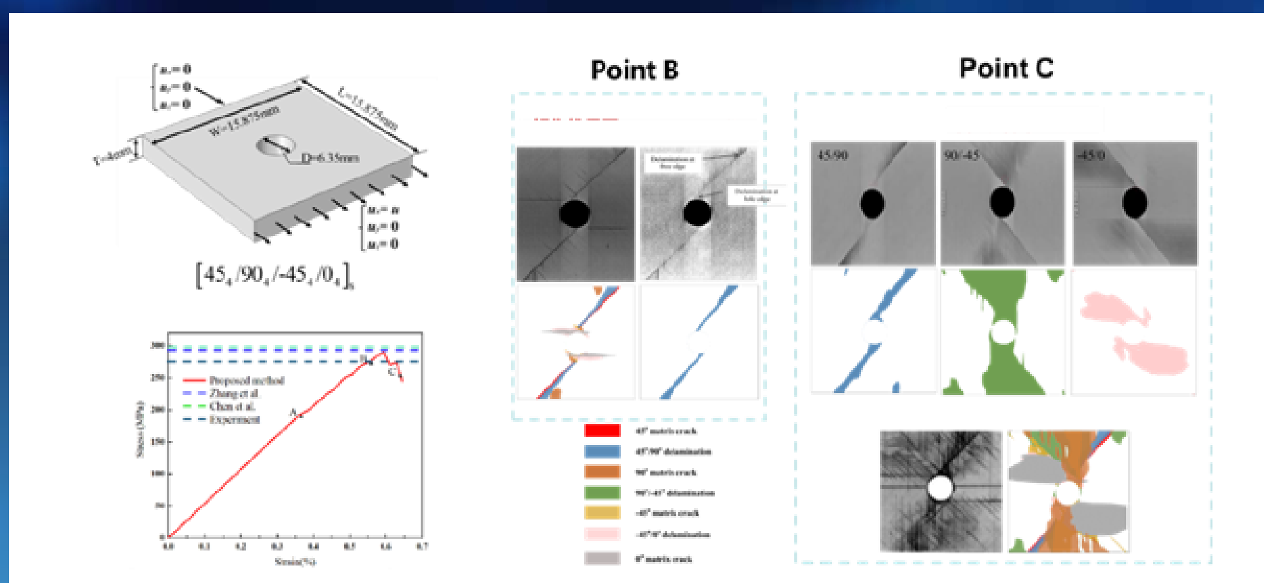


Figure 2 Open-hole tension (OHT) tension of the laminate

Advanced Composites in Special Environments at Harbin Institute of Technology published a paper titled “An Explicit Multi-Phase Field Damage Model for Long Fiber-Reinforced Composites” in *Composite Structures*.

In this work, a multi-phase field damage model based on failure criteria is proposed to predict the progressive failure process of composite laminates. The proposed method makes necessary corrections for two different failure forms of fiber and matrix to ensure the reasonable damage prediction results. The results show that the model can not only capture the tensile failure of unidirectional plates with different fiber orientations but also the tensile failure and delamination of each layer in laminates. Additionally, the model utilization of explicit dynamics does not need to take the convergence issue into account and can considerably increase the computing efficiency of multi-threaded parallel operations. Combining the ideas makes it possible to address the phase field damage model’s poor convergence and low computing efficiency issues.

Finally, it can be concluded that the multi-phase field model proposed in this study, which corrects the traditional phase field model based on the difference between fiber failure and matrix failure behavior, coupled with display dynamics, has a good prediction effect on the initiation and propagation of multi-crack systems. This work paves a new, feasible approach for phase field methods in damage prediction of long fiber composites.■

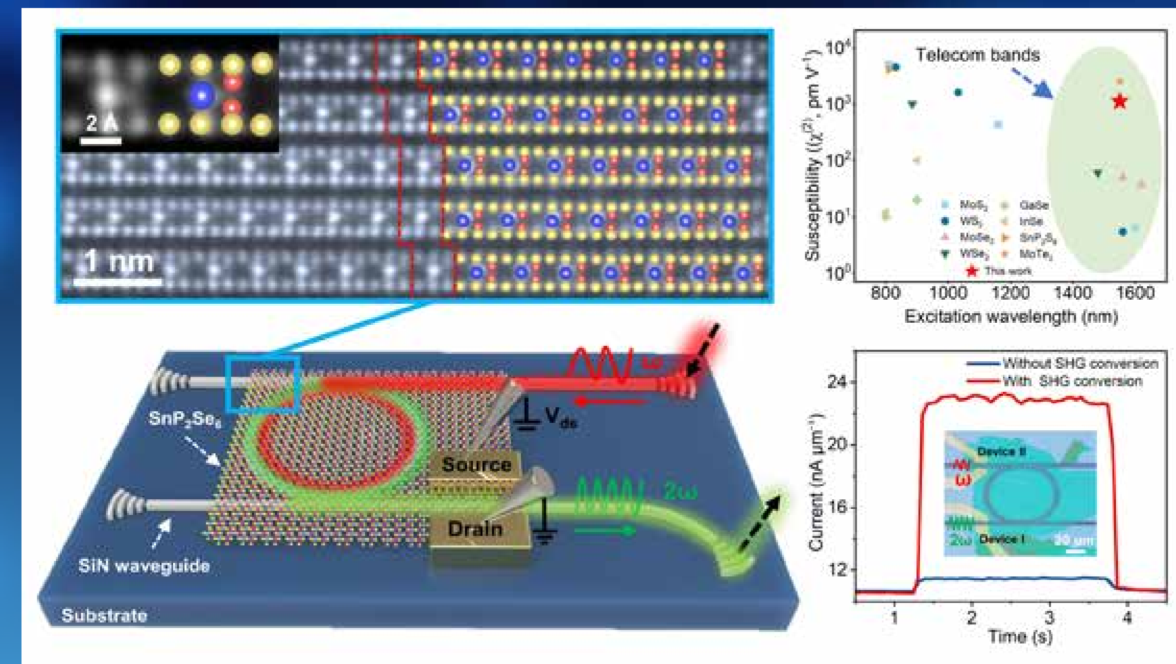
REFERENCE

Xiaocan Zou, Zhonghai Xu, Jin Gao, Shibao Wu, Ruoyu Li, Wenjie Li, Xiaodong He. An explicit multi-phase field damage model for long fiber-reinforced composites. Composite Structures, 2023, 309, 116737, 1-15.

TWO-DIMENSIONAL SEMICONDUCTOR SnP_2Se_6 ENABLES MONOLITHIC ELECTRONIC-PHOTONIC INTEGRATION

The rapid development of electronic information technology has raised more requirements for multifunctional, compact, and low-power electronic-photonic integration technology. Recently, Professor Xu Cheng-Yan and his colleagues from the School of Materials Science and Engineering at Harbin Institute of Technology, Shenzhen, successfully synthesized two-dimensional (2D) semiconducting SnP_2Se_6 using the space-confined chemical vapor transport (SCCVT) method. 2D SnP_2Se_6 exhibits excellent nonlinear optical (NLO) properties and optoelectronic properties. The team combined the 2D SnP_2Se_6 with a SiN photon chip to construct an on-chip hybrid photonic device based on SnP_2Se_6/SiN waveguides, achieving the monolithic integration of optical modulation and detection in the telecom band (1,550 nm). The article titled "Two-Dimensional Semiconducting SnP_2Se_6 with Giant Second-Harmonic-Generation for Monolithic On-Chip Electronic-Photonic Integration" was published in *Nature Communications,* a prestigious multidisciplinary journal dedicated to publishing high-quality research in the areas of the biology, health, physics, chemistry, and earth sciences.

2D semiconductors have demonstrated plenty of fascinating phenomena and ground-breaking technological applications in optoelectronics due to their atomic-level thickness, surface without dangling bonds, excellent optoelectronic properties, and NLO properties. Unlike traditional 2H phase transition metal dichalcogenides, 2D NLO semiconductors can be integrated in on-chip silicon photonics without considering the traditional lattice mismatch issue and used to achieve optical signal modulation in the telecom band (1,310-1,550 nm). By combining the NLO properties of 2D semiconductor materials with excellent optoelectronic properties, it is expected to achieve monolithic integration of electronic and photonic integrated circuits (EPICs) on a single chip. In recent years, a series of 2D materials with outstanding NLO properties have been experimentally verified in integrated photonics, providing a good foundation for the design of new optoelectronic devices. Despite these promising results, there are still some challenges that need to be overcome in order to fully realize the potential of 2D NLO semiconductor materials in practical applications, such as how to achieve efficient NLO modulation and optoelectronic detection in the telecom band. Therefore, further research is needed in the selection of 2D materials and the structural design of



photon chips to improve the performance of the devices and promote the practical application of electronic and photonic integrated circuits.

Here, Professor Xu's group reported a novel 2D layered semiconductor, SnP_2Se_6, which exhibits high second-harmonic generation (SHG) conversion efficiency at a wavelength of 1,550 nm (approximately 1.3×10^{-9} m·V^{-1}). Unlike traditional 2H phase transition metal dichalcogenides, SnP_2Se_6 can maintain center inversion symmetry, breaking in multi-layer stacking due to its disordered interlayer stacking mode and resulting in enhanced SHG signal with increasing thickness. Additionally, 2D SnP_2Se_6 photodetectors have excellent electrical and optoelectronic properties and can respond to visible light with a rate of up to 10^3 A·W^{-1} and a response time of 412 μs. By leveraging these unique properties, the team successfully constructed an on-chip prototype device based on SnP_2Se_6/SiN hybrid structures, achieving the monolithic integration of optical modulation and detection in the communication band.

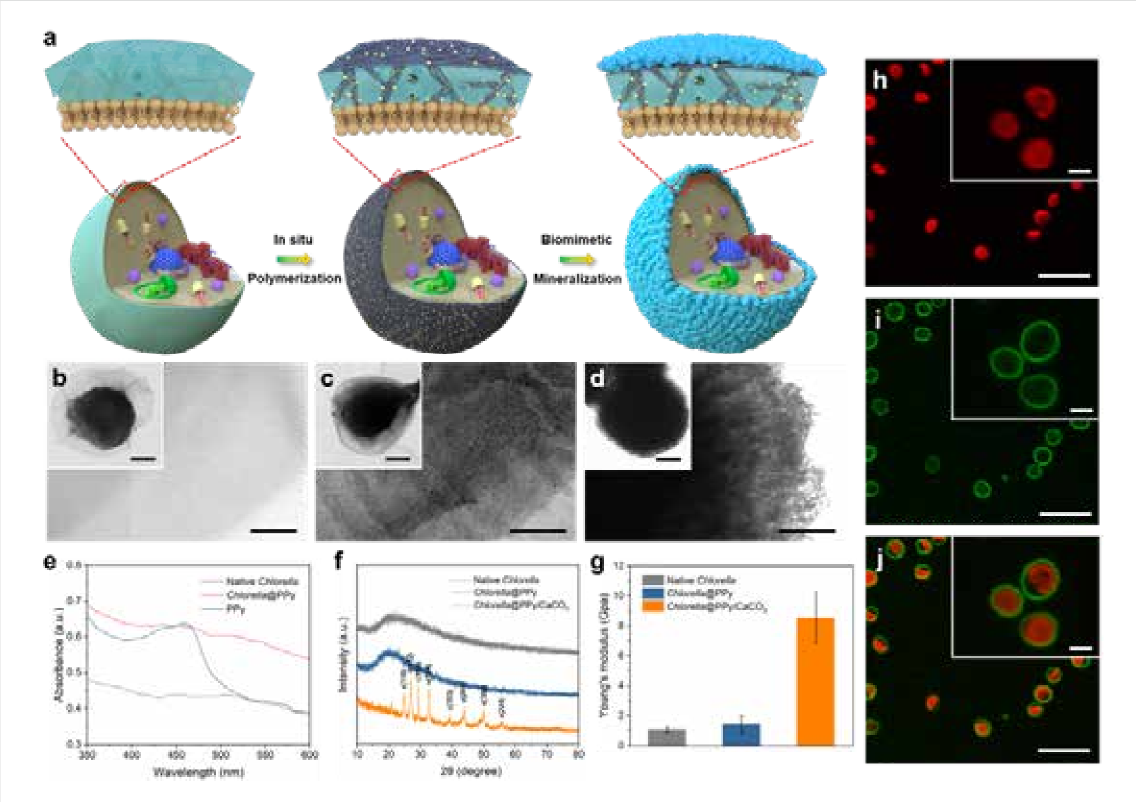
REFERENCE

C.Y. Zhu, Z.M. Zhang, J.K. Qin, Z. Wang, C. Wang, P. Miao, Y.J. Liu, P.Y. Huang, Y. Zhang, K. Xu, L. Zhen, Y. Chai and C.Y. Xu. Two-dimensional semiconducting SnP_2Se_6 with giant second-harmonic-generation for monolithic on-chip electronic-photonic integration. Nature Communications, 2023, 14, 2521.

ALGAL CELL BIONICS AS A STEP TOWARDS PHOTOSYNTHESIS-INDEPENDENT HYDROGEN PRODUCTION

The engineering and modulation of living microorganisms is a key challenge in green biomanufacturing for the development of sustainable and carbon-neutral energy technologies. Recently, Professor Huang Xin's group from Harbin Institute of Technology published a paper in *Nature Communications* to show recent important progress in this field.

In this study, Huang et al. developed a cellular bionic approach in which living algal cells are interfaced with an ultra-thin shell of a conductive polymer along with a calcium carbonate exoskeleton to produce a discrete cellular micro-niche capable of sustained photosynthetic and photosynthetic-independent hydrogen production. The surface-augmented algal cells induce oxygen depletion, conduct photo-induced extracellular electrons, and provide structural and chemical stability that collectively give rise to localized hypoxic conditions and concomitant hydrogenase activity in the air under daylight. They also show that assembly of the living cellular micro-niche opens a direct extracellular photoelectron pathway to hydrogenase, resulting in photosynthesis-independent hydrogen evolution for 200 days. In addition, dead surface-conductive algal cells continue to produce hydrogen for up to 8 days due to their structural stability and retention of functional hydrogenases. Overall, the integration of artificial biological hydrogen production pathways and natural photosynthesis in surface-augmented algal cells provides a cellular bionic approach to enhanced green hydrogen production under environmentally benign conditions and could pave the way to new opportunities in sustainable energy production.



Together, it is anticipated that integrating artificial biological hydrogen production pathways and natural photosynthesis in surface-augmented algal cells could offer a new paradigm to help solve the current bottleneck associated with short-term biological hydrogen production. The authors anticipate that a methodology based on the active interfacing of living cells and polymer/inorganic hybrid materials could provide new bioaugmentation platforms as well as contribute to the development of new cell-based living materials and microbial cell factories with potential applications in sustainable energy production and green biomanufacturing.

REFERENCE

Zhijun Xu, Jiarui Qi, Shengliang Wang, Xiaoman Liu, Mei Li, Stephen Mann and Xin Huang. Algal cell bionics as a step towards photosynthesis-independent hydrogen production. Nature Communications, 2023, 14, 1872.

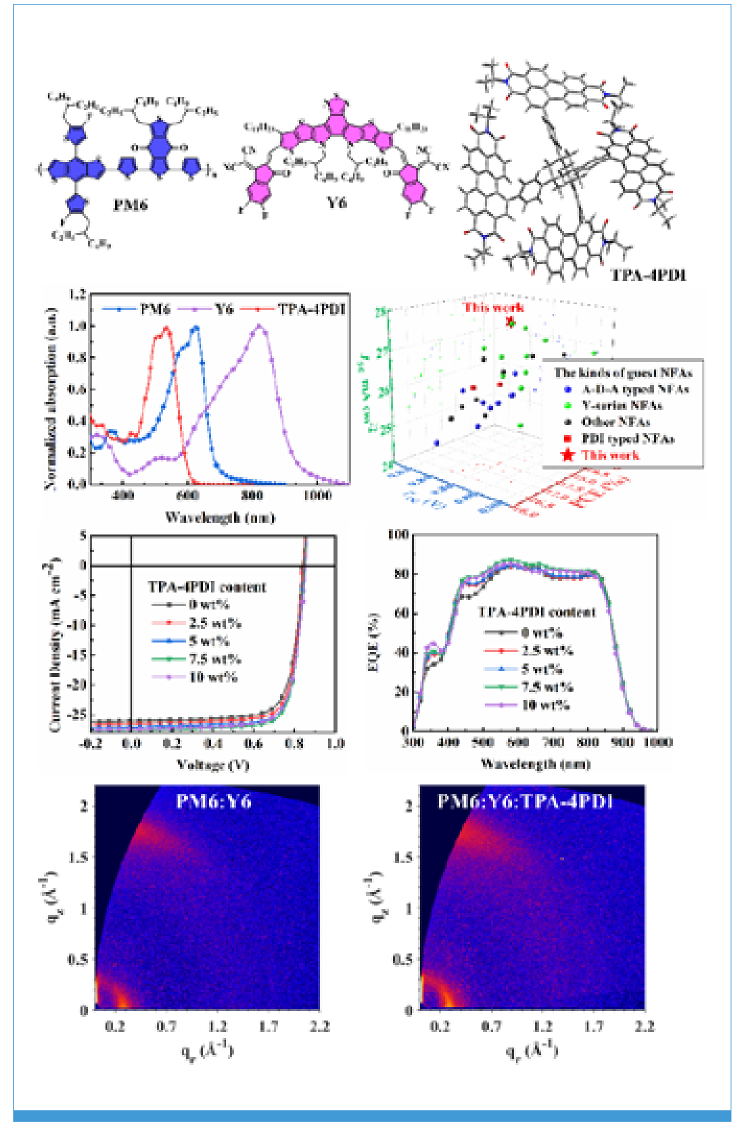
HIGH-PERFORMANCE TERNARY ORGANIC SOLAR CELLS ACHIEVED BY EMPLOYING A 3D-SHAPED PERYLENE DIIMIDE ACCEPTOR

In 2023, Professor Zhang Yong from the School of Materials Science and Engineering at Harbin Institute of Technology published a research paper titled "High-Performance Ternary Organic Solar Cells Enabled by Integrating a 3D-Shaped Guest Acceptor Derived from Perylene Diimide" in *Advanced Functional Materials*.

Organic solar cells (OSCs) have attracted significant attention in past decades due to their unique superiorities in lightweight, low-cost, flexibility, transparency, and solution processability. Currently, the state-of-art high-efficiency devices are dominated by ternary architecture, in which the active layers often consist of a wide band-gap donor polymer (like a conjugated polymer PM6), an acceptor-donor/acceptor/donor -acceptor (A-DA'D-A) typed non-fullerene acceptor (NFA, like Y6) and another guest NFA. Despite the remarkable progress in ternary OSCs with fused ring NFA as a guest acceptor, the competition with the host acceptor in light absorption makes it difficult to improve the PCE to a large extent, and the complicated synthetic process of such fused ring guest NFAs is unfeasible for large-scale fabrication. Therefore, designing novel guest electron acceptors while also overcoming the above drawbacks is greatly needed and urgent.

In this study, a novel perylene diimide (PDI) typed acceptor, TPA-4PDI, with adamantane as the central core and four PDIs as the arms was developed through a simple coupling reaction. The 3D molecular configuration of TPA-4PDI is beneficial to form a 3D charge transport property through the quasi-isotropic pathway. And the strong absorption of TPA-4PDI well supplies the photon harvesting in the range from 450 to 600 nm. With 7.5 wt.% of TPA-4PDI incorporated into the PM6:Y6 binary matrix, the optimized ternary device achieved an excellent PCE of 18.29%, which is the highest value among the PDI-based ternary OSCs and is also comparable with those fused ring NFAs based ternary devices. The utilization of TPA-4PDI can lead to more favorable morphology with suppressed charge recombination and improved exciton dissociation and charge collection. These effects contribute together to realizing simultaneously increased V_{oc}, J_{sc}, and FF in the PM6:Y6:TPA-4PDI ternary device.

This work demonstrates that the development of 3D PDI derivatives with the quasi-isotropic electron transport pathway as a guest acceptor is a prominent and effective strategy to enhance the photovoltaic performance of ternary OSCs.



REFERENCE

Liu M., Ge X., Jiang X., Guo F., Gao S., Peng Q., Zhao L., Zhang Y. High-performance ternary organic solar cells enabled by integrating a 3D-shaped guest acceptor derived from perylene diimide. Advanced Functional Materials, 2023, 33, 2300214. DOI: https://doi.org/10.1002/adfm.202300214

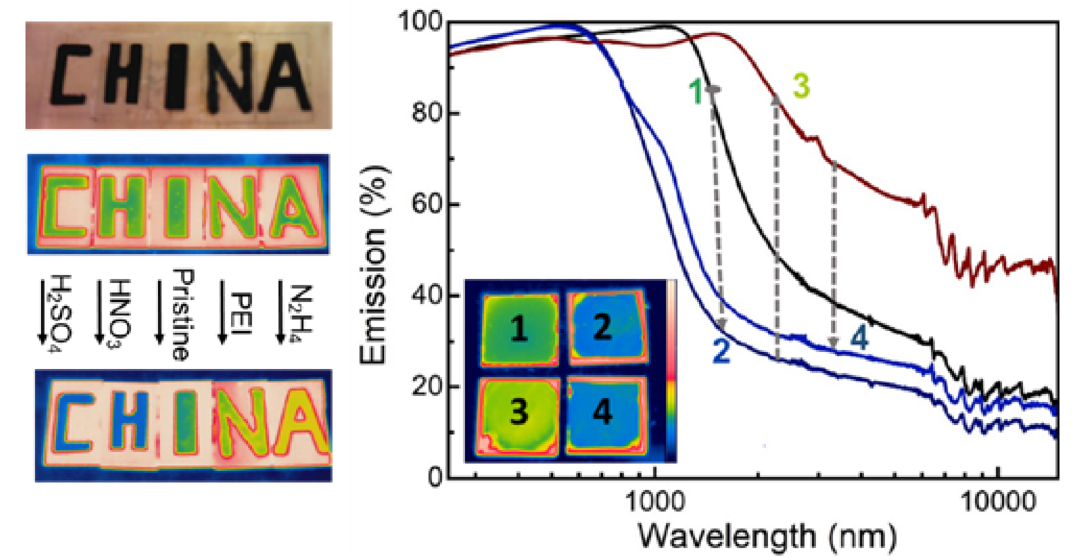
PEDOT:PSS:

SMART INFRARED REWRITABLE MATERIALS FOR INFRARED OPTICS SECURITY PRINTING

Recently, a team led by Professor Zhang Qian, from the School of Materials Science and Engineering Institute of Materials Genome & Big Data at Harbin Institute of Technology, published a research paper titled "PEDOT:PSS: Smart Infrared Rewritable Materials" in *Advanced Functional Materials*.

PEDOT:PSS is a commercially available conductive polymer with excellent electrical and optical performances that is also stable. The states of PEDOT:PSS, including neutral state, polaron and bipolaron, can be regulated by various kinds of treatment, resulting in a doping/dedoping effect. However, though the primary research focuses on improving the electrical transport the study on the optical performance of PEDOT:PSS was seldom reported. Exploring the relationship between different states of PEDOT:PSS and the optical performance, especially in infrared, and searching for an effective strategy on the regulation of the thermal radiation spectrum, will play an essential role in energy and information fields, including radiation cooling, infrared stealth, infrared information display, and storage.

In this work, we proposed a smart infrared rewritable and emissivity tunable polymer film based on PEDOT:PSS. The regulation mechanism and principle of the emission have been explored through experiments and theoretical calculations. The thermal emission can be regulated between neutral and bipolaron states of PEDOT:PSS, reaching around ~5.2 db infrared emission modulation (at 82℃), which mainly originates from the mobile polaronic transport property of PEDOT not PSS molecular under the treatment of redox agents. A completely reversible writing and erasing based on different infrared optical responses by tuning their redox states can be achieved for a maximum of five cycles, which is of great significance to infrared direct writing and password encryption in practical applications.



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

REFERENCE

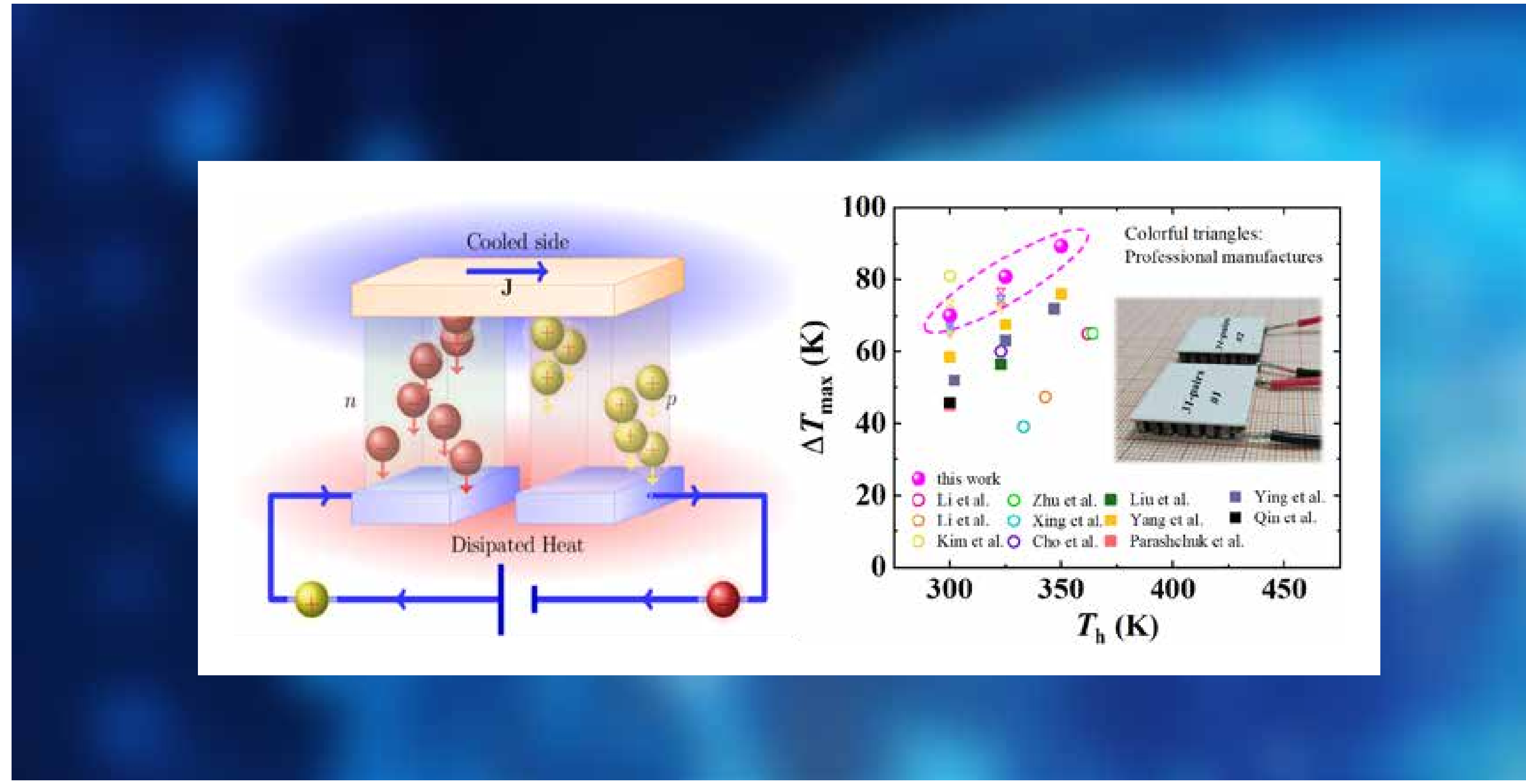
Xiaodong Wang, Zuoxu Wu, Qian Zhang, et al. PEDOT:PSS: Smart infrared rewritable materials. Advanced Functional Materials, 2023, 2300886. DOI: 10.1002/adfm.202300886

HIGH PERFORMANCE BiSbTe ALLOY FOR SUPERIOR THERMOELECTRIC COOLING

Recently, Professor Sui Jiehe's group from the National Key Laboratory for Precision Hot Processing of Metals published a research paper titled "High Performance BiSbTe Alloy for Superior Thermoelectric Cooling" in *Advanced Functional Materials*.

Thermoelectric modules directly convert heat into electricity and vice versa thus being used for waste heat recovery power generation and solid-state electronic refrigeration. Bismuth telluride-based alloys are the only type of thermoelectric materials that can currently be used for commercial semiconductor refrigeration. In this study, a great advancement has been made by adding MnO_2 in $Bi_{0.4}Sb_{1.6}Te_3$ alloy to cause an in-situ reaction, ranging from material design (high dimensionless figure of merit *ZT* and robust mechanical property) to developments in cooling modules (a 31-pair cooling module with ultrahigh cooling performance).

At first, MnO_2 decomposed to produce oxygen during the melting process, resulting in the oxidation of Sb element to generate Sb_2O_3 nano-precipitates and Te-rich phase in situ. As a result, the donor-like effect is inhibited, leading to the increase of carrier concentration and power factor. In addition, Te-rich phases volatilize during sintering, leaving dispersed nano-pores at grain boundaries. These nanostructures contributed significantly to the phonon scattering, resulting in a lower lattice thermal conductivity. Finally, a peak *ZT* value of 1.43 at 75℃ was obtained in the



$Bi_{0.4}Sb_{1.6}Te_3$+0.01MnO_2 sample, which is comparable to the state-of-art value. Based on this newly developed high-performance and robust $Bi_{0.4}Sb_{1.6}Te_3$+0.01MnO_2 sample, a 31-pair module is fabricated. The maximum cooling temperature difference (ΔT_{max}) is 70.1 K (T_h = 300 K), which is comparable with the refined results of professional manufacturers and better than most other research groups. As the T_h increases to 325 K and 350 K, ΔT_{max} values reach 80.8 K and 89.4 K, which are at the current leading level, making the p-type BiSbTe materials highly attractive for thermoelectric cooling applications.

Professor Sui Jiehe and Dr. Guo Fengkai are corresponding authors. PhD student Sun Yuxin is the first author and HIT is the first and corresponding affiliation. This work was financially supported by the National Natural Science Foundation of China.

REFERENCE

Sun Yuxin, Wu Hao, Dong Xingyan, Xie Liangjun, Liu Zihang, Liu Ruiheng, Zhang Qian, Caiwei, Guo Fengkai, Sui Jeihe. High performance BiSbTe alloy for superior thermoelectric cooling. Advanced Functional Materials, 2023, 2301423. DOI: 10.1002/adfm.202301423

BIO-INSPIRED POROUS COMPOSITE ELECTRODE FOR ENHANCED MASS TRANSFER AND ELECTROCHEMICAL WATER PURIFICATION BY MODIFYING LOCAL FLOW PATTERN

Porous electrodes offer a new opportunity for flow-through electrochemical water purification, but their irregular porous-structure makes the local flow pattern and mass transfer performance inhomogeneous, unpredictable, and uncontrollable. Recently, Dr. Yu Yuan (the first author) and Professor You Shijie (the corresponding author) from the State Key Laboratory of Urban Water Resource and Environment, developed a bio-inspired design for 3D-printed porous structure to enhance mass transfer by studying the micro-scale architectures of the wings of butterflies and owls based on analogy between heterogeneous mass transfer and sound absorption (Figure 1A). The article titled "Bio-Inspired Porous Composite Electrode for Enhanced Mass Transfer and Electrochemical Water Purification by Modifying Local Flow Pattern" has been published in *Advanced Functional Materials*.

Water pollution is a rising global crisis that leads to devastating impacts to public health and ecosystems. The World Health Organization (WHO) estimates that more than 600 million people are unable to access to clean drinking water in the world. Electrochemistry creates a sustainable platform for water decontamination driven by electrons serving as clean agents. However, challenges remain for engineered applications due to low efficiency associated with mass-transfer limitation. This is universally encountered in practically relevant conditions, especially at low pollutant concentration and high current density. Recently, flow-through porous electrodes offer a promising manner to enhance mass transfer by pore-scale convection in electro-oxidation water decontamination and redox flow battery. However, the porous electrodes prepared by bottom-up strategies (e.g. hydrothermal synthesis and high-temperature sintering) are irregularly structured, leading to, unpredictable, uncontrollable, and inhomogeneous flow patterns in the pores. The importance of flow pattern lies in its impact to the way reactants are transported onto the electrode and thus overall efficiency offered by electrochemical systems.

In this study, Dr. Yu and Professor You offered a new paradigm for designing a 3D porous composite architecture, *i.e.* CG-structure (Figure 1B), containing gyroid structure and overlying perforated plate, inspired by structural sound energy dissipation features offered by porous architectures of the butterfly and owl wings. Instead of starting with the goal of using a bio-inspired design, an optimization algorithm was used to generate a bio-inspired design with improved performance. The main function of gyroid structure is to ensure the synergic angle (*i.e.*, angle between velocity vectors and concentration gradient vectors) are as small as possible, so that water flows in uniform and minimal-average curvature pathway to make more friction with each point of the surface, whereas the perforated plate is to create a vortex region where mass transfer can be enhanced by the inertial flow effect behind it. Both theoretical modeling and experimental tests demonstrated that the CG-structure could achieve a predictable, controllable and homogeneous flow pattern that was favorable for producing micro-scale vortex and inertial flow in the porous structure (Figure 1C). They further fabricated the as-designed CG-structured Cu electrode by using the SLM process, and the electrode demonstrated an greatly improved local mass transfer (Figure 1D) for electrochemical removal of NO_3^- (95%) in water under flow-through mass-transfer-limited condition (Figure 1E).

Compared with conventional electrodes prepared by bottom-up methods, this study suggests a more advanced top-down paradigm for designing the porous structure of electrodes. The bio-inspired strategy and principle of physical field synergy developed in this study may have a broader implication that extends to other heterogeneous catalytic water and wastewater treatment processes such as electrochemical oxidation, photocatalysis and heterogeneous Fenton systems.

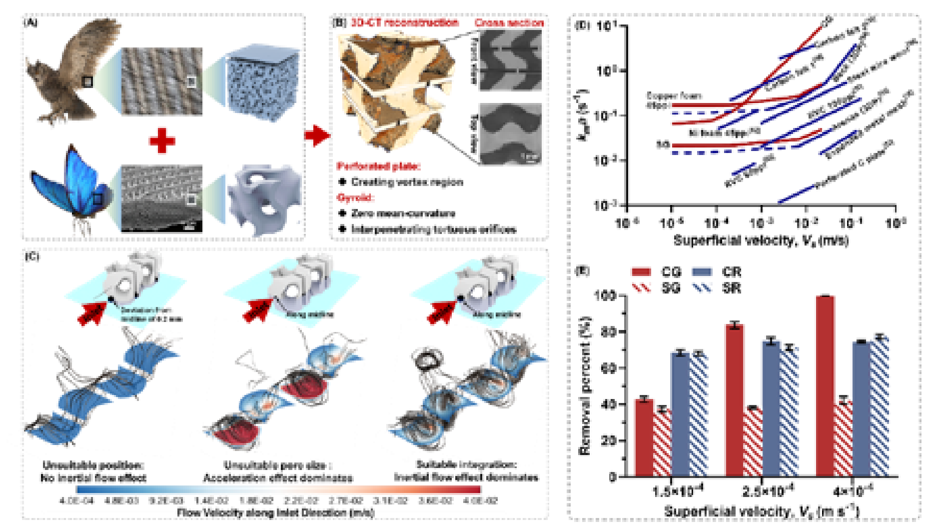


Figure 1 Design and performance of bio-inspired composite gyroid (CG) electrode: (A) Porous architectures of barn owl feather and butterfly feather for sound absorption, (B) 3D X-ray computed tomography (3D-CT) reconstruction of CG electrode, (C) The impact of integrated method between perforated plate and gyroid structure on flow pattern inside CG electrode (V_s = 4×10^{-4} m s^{-1}), (D) Overall averaged mass transfer coefficient across systems and length scales as a function of the superficial velocity, and (E) Nitrate removal performance

REFERENCE

Yu Y., Pei SZ., Zhang JN., Ren NQ., You SJ. Bio-inspired porous composite electrode for enhanced mass transfer and electrochemical water purification by modifying local flow pattern. Advanced Functional Materials, 2023, 2214725.

ENZYME-POWERED TUBULAR MICROROBOTIC JETS AS BIOINSPIRED MICROPUMPS FOR ACTIVE TRANSMEMBRANE DRUG TRANSPORT

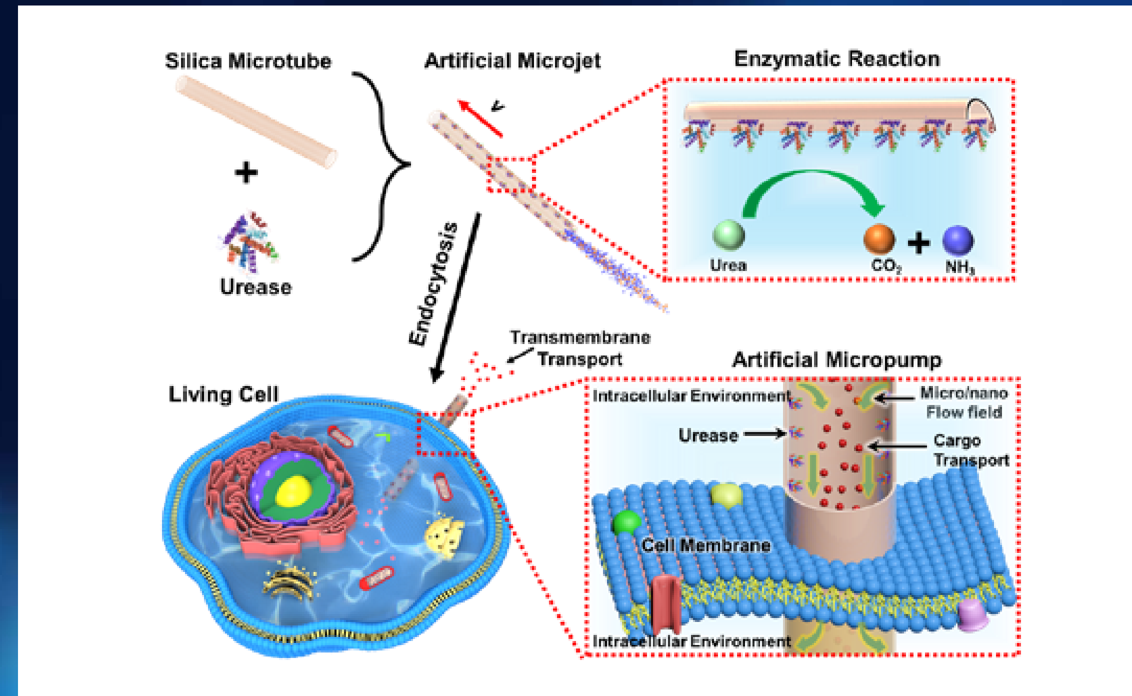
In nature, there are a variety of transport proteins on cell membranes capable of actively moving cargos across biological membranes, which plays a vital role in the living activities of cells. In recent years, researchers have attempted to develop artificial channels with mass transfer properties similar to those of biological channels, mimicking the pumping functions of the natural membrane channels. However, the reported strategies mostly rely on passive diffusion for cargo transport, and it is still challenging to design and construct artificial transmembrane channels with an active pumping mechanism.

Recently, Professor Ma Xing's group from the School of Materials Science and Engineering at Harbin Institute of Technology (Shenzhen) published a research paper titled "Enzyme-Powered Tubular Microrobotic Jets as Bioinspired Micropumps for Active Transmembrane Drug Transport" in *ACS Nano*.

In this study, Professor Ma's group proposed a strategy for the construction of a bionic micropump for active transmembrane transportation of molecular cargos across living cells by using enzyme-powered microrobotic jets. Firstly, the research group prepared a silica-based microtube (SMT) functionalized with enzyme urease, which could catalyze the decomposition of urea in surrounding fluidic environment and form a microjet to drive its own movement. Through numerical simulation and tracer particle analysis experiments, they verified that the self-propelled motion of the tubular microjet is driven by the ionic diffusionphoresis mechanism and further verified the existence of microfluidic flow.

Then, encouraged by the enzymatic reaction-induced microfluidic flow inside the microtubular structure, they explored the potential of using these microjets as artificial micropumps for transmembrane delivery. Here they designed a model experiment of a tubular active transmembrane channel to mimic a micropump, showing that it can enhance the diffusion and transport of rhodamine B (Rh B) molecules in its inner channel with the assistance of enzyme catalysis. Finally, through natural endocytosis of microjets into living HeLa cells, artificial transmembrane active microchannels were successfully established to mimic the biological pumps naturally located on cell membrane. Such "embedded" artificial microchannels successfully facilitated the entry of PI molecules into the cells and could further enhance the intracellular drug delivery efficiency when functioned as enzyme-driven micropumps. This research paper provided new ideas for the biomedical applications of micro/nanomachines, and stimulated future research on cell biology.

This work was supported by the National Natural Science Foundation of China, the Shenzhen Science and Technology Program, and the Fundamental Research Funds for the Central Universities.



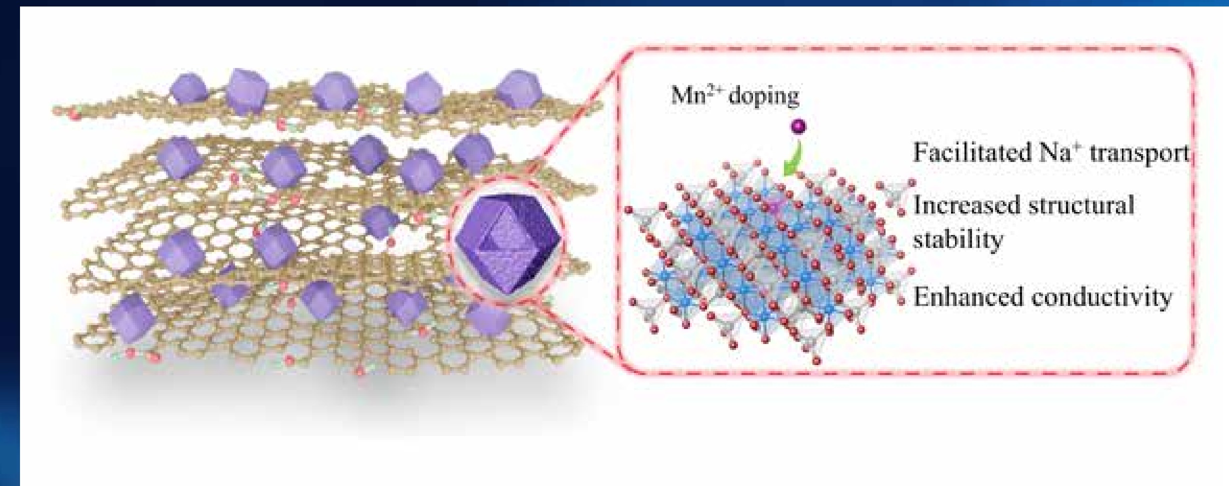
Schematic illustration of the enzyme-driven tubular microjet as a bioinspired artificial micropump for active transmembrane cargo delivery

REFERENCE

Liying Wang, Peiting Guo, Dongdong Jin, Yixin Peng, Xiang Sun, Yuduo Chen, Xiaoxia Liu, Wenjun Chen, Wei Wang, Xiaohui Yan, and Xing Ma. Enzyme-powered tubular microrobotic jets as bioinspired micropumps for active transmembrane drug transport. ACS Nano, 2023, 17, 5, 5095–5107. DOI: https://doi.org/10.1021/acsnano.3c00291

Research & Academia
HIT TIMES 2023

OPTIMIZATION OF SODIUM STORAGE PERFORMANCE BY STRUCTURE ENGINEERING IN NICKEL-COBALT-SULFIDE



Schematic image of the Mn-doped $NiCo_2S_4$ electrode constructed by structural engineering

Recently, Professor Liu Haiping's group from the School of Marine Science and Technology, Harbin Institute of Technology (Weihai), published a research article titled "Optimization of Sodium Storage Performance by Structure Engineering in Nickel-Cobalt-Sulfide" in *ChemSusChem*.

Energy storage and conversion is one of the key technologies to solve the energy crisis and global pollution problems. With abundant sodium resources, sodium ion batteries occupy a dominant position in large-scale energy storage in the future. Exploring high-performance electrode materials is of great significance for the development and commercial application of sodium ion batteries. $NiCo_2S_4$ electrode material with high specific capacity and abundant redox centers is considered as a potential anode for sodium ion batteries. However, $NiCo_2S_4$ electrode materials still have problems of large volume expansion and poor cycling stability during charge and discharge processes. Studies have shown that the rational design of electrode materials can improve the conductivity, alleviate the volume expansion, and improve the sodium storage performance.

Therefore, based on the structural engineering strategies, the work designed to anchor the hollow nano-cage structure of $NiCo_2S_4$ on the surface of graphene nanosheets (GNs) with a large specific surface area, and introduced manganese ions at the Ni site. The results show that the electrode material with a hollow nano-cage structure can increase the contact area between the electrode and electrolyte, and the introduction of GNs can alleviate the volume expansion effect of $NiCo_2S_4$ electrode materials during cycling. In addition, Mn ion doping can improve the diffusion kinetics of sodium ions and the conductivity of $NiCo_2S_4$ electrode materials. Therefore, the Mn-doped electrode exhibits excellent cycling stability (the specific capacity can still remain stable at 352.9 mA h g^{-1} after 200 cycles at a current density of 200 mA g^{-1}) and rate performance (the specific capacity can reach 315.3 mA h g^{-1} at a current density of 5000 mA g^{-1}). This achievement provides a reference for building high-performance negative electrode materials for sodium ion batteries.

The paper was financially supported by the Natural Science Foundation of Shandong Province and the China Scholarship Council.

REFERENCE

Shanshan Fan, Haiping Liu, Sifu Bi, Xiaohuan Meng, Haoyin Zhong, Qi Zhang, Ying Xie, Junmin Xue. Optimization of sodium storage performance by structure engineering in nickel-cobalt-sulfide. ChemSusChem, 2023, e202300435. DOI: 10.1002/cssc.202300435

ULTRASONIC-EXCITED ULTRAFAST SEAMLESS INTEGRATION OF HETEROSTRUCTURED LIQUID CRYSTALLINE ELASTOMERS FOR MULTI-RESPONSIVE SOFT ACTUATORS

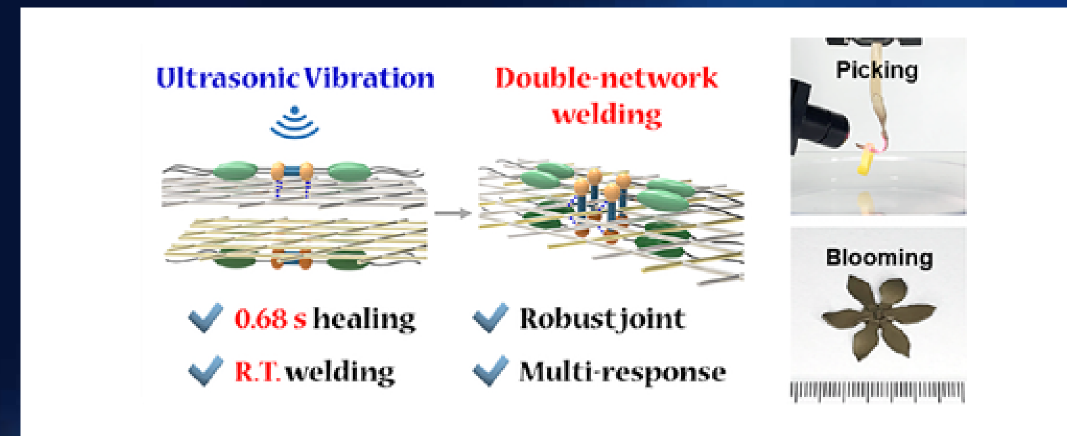
Professor Ji Hongjun's group from the State Key Laboratory of Advanced Welding and Joining, the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), reported their recent research results titled "Ultrasonic-Excited Ultrafast Seamless Integration of Heterostructured Liquid Crystalline Elastomers for Multi-Responsive Soft Actuators" in a well-known international journal *ACS Applied Materials and Interfaces*.

Soft robots (or soft actuators) are developed from intrinsically conformable materials inspired by the behaviors of living organisms, which have significant advantages over rigid robots in regard to the safe and adaptive interaction with humans and harsh environments. Stimuli-responsive liquid crystalline elastomers (LCEs) are promising candidates for soft robots, featuring unique optomechanical response, reversible large actuation, and robust mechanical properties, due to the synergistic effect of polymer entropy elasticity and anisotropic liquid crystalline (LC) alignment. However, the reported integration strategies of LCEs seriously suffer from high welding temperature, long processing time, and poor joint quality.

Herein, Professor Ji demonstrated the ultrasonic-excited high-efficiency seamless integration of well-designed reprogrammable silver nanowire-liquid crystalline elastomer composites (AgNW-LCEs) for multi-responsive entirely soft actuators, based on the dynamic silver-disulfide coordination interactions (Ag-S and S-S bonds). The introduction of AgNWs simultaneously endows exchangeable LCEs with improved mechanical properties, enhanced transmission of ultrasonic vibration, and remote infrared (IR) light control of deformations *via* photothermal effect. During the ultrasonic welding (UW) process, the high-frequency ultrasonic vibration can substantially facilitate the increase of interfacial temperature and diffusion of polymer chains, because of the high acoustic impedance at the interface between workpieces, which continuously triggers the exchangeable reactions of disulfide bonds. On the other hand, the AgNWs can also be welded together at the interface upon ultrasonic vibration, constructing a double-network welding mechanism of AgNWs and dynamic LC networks. In addition, the ultrasonic vibration will maintain the orientation of LCEs *via* mechanical shearing, which guarantees the robust actuation stability of soft actuators. Thus, the precut monolithic AgNW-LCEs can be freely integrated into arbitrarily desired multicomponent actuators by UW technology at room temperature within 0.68 s, in the absence of any auxiliary reagents (adhesives, catalysts, or initiators). Furthermore, the welded AgNW-LCEs exhibit an outstanding strain healing efficiency of ~ 100% and a stress healing efficiency of ~ 85%, benefiting from the double-network welding mechanism. Based on it, the heterostructured AgNW-LCE actuators have been designed with different LC alignments and nematic-to-isotropic transition temperatures (T_i), for the multi-degree-of-freedom soft robotic arm and time-modulated blooming "flower", respectively. The elaborately designed polymer composites and advanced UW technology provide brand-new opportunities for the high-efficiency integration of multi-responsive soft actuators, further generating enormous potential applications in the field of smart materials.

This work was financially supported by the National Natural Science Foundation of China and the Guangdong Province Key Research and Development Program.

Research & Academia
HIT TIMES 2023



Working mechanism and applications of ultrasonic-assisted integration of heterostructured actuators

REFERENCE

Xiaoxiong Zheng, Qiuchen Ma, Yuan Tao, Yan Huang, Mingyu Li, Hongjun Ji. Ultrasonic-excited ultrafast seamless integration of heterostructured liquid crystalline elastomers for multi-responsive soft actuators. ACS Applied Materials & Interfaces, 2023, 15, 10, 13609. DOI: https://doi.org/10.1021/acsami.2c21888

I_3^-/I^- REDOX REACTION-MEDIATED ORGANIC ZINC–AIR BATTERIES WITH ACCELERATED KINETICS AND LONG SHELF LIVES

Recently, Professor Huang Yan from the School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), cooperating with Professor Fan Jun from the Department of Materials Science and Engineering, City University of Hong Kong, published an article titled "I_3^-/I^- Redox Reaction-Mediated Organic Zinc–Air Batteries with Accelerated Kinetics and Long Shelf Lives" in *Angewandte Chemie International Edition*.

A very common problem in current battery research is that many superior electrochemical performances are obtained based on fresh battery samples. When these samples are rested for a long time, performances greatly degrade and even fail to work entirely. This immensely hinders the practical application of research results. This problem is particularly acute for aqueous batteries, especially air batteries that require oxygen to react (i.e., need to be open), because the electrolyte evaporates quickly.

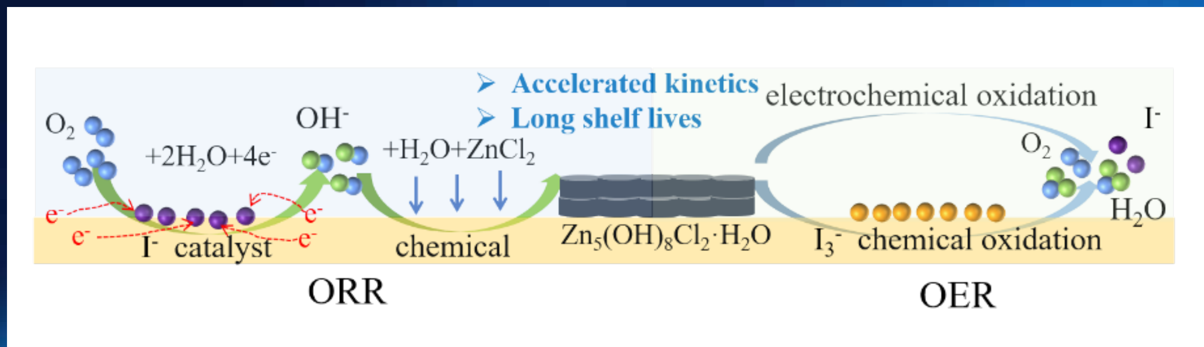
Among many air batteries, Zn-air batteries (ZABs) attract much attention owing to their high energy density (1086 Wh kg^{-1}), economic viability, etc. Despite remarkable achievements obtained in the design and modification of Zn anode and electrocatalyst cathode, the shelf lives of ZABs have not been reported. As discussed above, the rapid volatilization of aqueous electrolyte during long-term storage decreases the ionic conductivity of ZABs, which is the deep-rooted problem. Therefore, commercial ZABs need to be sealed for storage. Unless the battery is ready for use immediately, the seal cannot be removed. Once it is removed, air enters to activate the electrochemical reaction and starts working continuously. Even if the seal is affixed again, ZABs cannot be stored.

Additionally, ZABs that commonly employ high concentration alkaline as electrolytes are prone to corrode the nearby parts of the battery and cause electrolyte leakage, causing permanent irreparable damage. Moreover, the Zn anode in high concentration alkaline also suffers from dendrites, passivation, corrosion, and gas production. Recent studies have shown that the deactivation of the Zn anode during resting also plagues the entire aqueous Zn battery. As for the cathode electrocatalyst, the dissolution of atmospheric CO_2 in the alkaline electrolyte is liable to the formation of insoluble carbonate products and eventually blocks the porous air cathode, resulting in the decay of catalytic activity. These factors also exacerbate performance decline and even failure of ZABs during the long-term placement.

Recent studies have shown that utilizing mild aqueous electrolytes could alleviate Zn dendrites, corrosion, and carbonates. Nevertheless, these ZABs also usually exhibit a short cycle life and fail after prolonged standing. ZABs systems with organic solvent do not have afore-mentioned shortcomings and thus can be an alternative. The sluggish kinetics and high overpotential, determined by the low ionic conductivity, should be solved.

Redox mediators (RMs) have been served as a soluble charge catalyst to meliorate reaction kinetics and reduce overpotential of oxygen evolution reactions (OER) and oxygen reduction reactions (ORR). Recently, they have been demonstrated to relieve the charge transport limitation via chemical oxidation instead of direct electrochemical oxidation in Li-O_2 and aqueous ZABs. Among various RMs, iodine (I_2) has variable valence, stable voltage profile, low redox potential, and high redox kinetics, making it especially suitable as a RM to tune the cell chemistry and reduce the overpotential. Previous efforts on Li-O_2 batteries have confirmed that the addition of I_2-containing species to the electrolyte can regulate battery mechanism from LiO_2 to $LiOH{\cdot}H_2O/LiOOH{\cdot}H_2O$. Although the formation of LiOH could provide a higher specific capacity via a four-electron reaction, the reversibility of LiOH/O_2 chemistry is difficult and requires charge at a high potential (> 4.3 V vs Li^+/Li). Additionally, controversy has always existed regarding the reaction mechanism of I_2-containing RMs in both ORR and OER.

Besides nonaqueous Li-O_2 batteries, the benefits of I_3^-/I^- RMs have also been investigated in alkaline ZABs. Potassium iodide (KI) has been proposed to accelerate the charge transfer and reduce the overpotential.



During the charge process, I^- is first oxidized to IO_3^- (iodide oxidation reaction, IOR) in the highly alkaline environment. Compared with OER, IOR has faster kinetics and lower oxidation potential, thus reducing the charge potential of ZABs. Although related studies have been reported, the mechanism of I_2-containing RMs is still vague, especially considering the influence of different solvent. More importantly, the effect of I_2-containing RMs on ORR pathways, which is a pivotal component of ZABs, has been neglected. Herein, we report a ZAB with long shelf lives in a low-cost and low-volatility ethylene glycol (EG) electrolyte. Its reaction kinetics and overpotential have been greatly improved via the I_2 additive. We find for the first time that I_3^- enables a chemical pathway to accelerate the oxidation of $Zn_5(OH)_8Cl_2 \cdot H_2O$ at low voltage in the charge process. In the discharge process, I^- adsorbed on the electrocatalyst remarkably reduces the ORR overpotential. Therefore, our ZABs with I_3^-/I^- RMs show remarkable energy efficiency, cycling life, and shelf lives in open air. The concept of designing an organic ZAB with I_2-containing RMs tackles critical issues confronted by traditional ZABs, and the achieved exciting performance greatly promotes the industrialization of ZABs, which also lights the way for various other battery systems.

REFERENCE

Mangwei Cui, Ninggui Ma, Hao Lei, Youfa Liu, Wei Ling, Sheng Chen, Jiaqi Wang, Hongfei Li, Zhaohui Li, Jun Fan, Yan Huang. I_3^-/I^- redox reaction-mediated organic zinc–air batteries with accelerated kinetics and long shelf lives. Angewandte Chemie International Edition, 2023. DOI: https://doi.org/10.1002/anie.202303845

HIT ORGANIZED THE 3RD NATIONAL CONFERENCE ON ENVIRONMENTAL CONTROL AND LIFE SUPPORT TECHNOLOGY OF MANNED SPACECRAFT

HIT Party Secretary Xiong Sihao

On April 13th and 14th, the 3rd National Conference on Environmental Control and Life Support Technology of Manned Spacecraft was held in Harbin. HIT Party Secretary Xiong Sihao delivered a speech at the opening ceremony.

Xiong Sihao said that the conference focused on the research of environmental control and life support technology, further stimulated innovation, accelerated cooperation and innovation under the guidance of the manned spaceflight project, and provided important support for breakthroughs in key core technologies. He believes that the conference will further consolidate the wisdom and strength of all parties, and jointly contribute new strength to realizing the dream of becoming a strong aerospace country.

Signing the cooperation agreement

Crew of Shenzhou-15 in space

Dong Wenping, deputy director of the China Astronaut Research and Training Center, and HIT Vice President Liu Hong signed a strategic cooperation agreement on behalf of both parties. According to the agreement, the two sides will aim to cultivate aerospace medical talents, carry out in-depth cooperation in scientific and technological innovation, cultivate talent to jointly strengthen the national strategic scientific and technological strength, and promote the development of the aerospace industry.

At the opening ceremony, the crew of Shenzhou-15 in space sent a video for the conference. Expert and scholar representatives in the field of aerospace science, human factors engineering, mechanics, materials science, environmental science, botany, microbiology and other fields made special reports on the environmental control and life support technology, and explained the latest technology development trend. Academician Liu Hong and Professor Feng Yujie from Harbin Institute of Technology delivered a keynote speech.

HIT ORGANIZED THE 3RD NATIONAL CONFERENCE ON ENVIRONMENTAL CONTROL AND LIFE SUPPORT TECHNOLOGY OF MANNED SPACECRAFT

News & Events
HIT TIMES 2023

HIT PRESIDENT HAN JIECAI VISITED EUROPE

Visiting the Emlyon Business School

Visiting the Université Paris Cité

From May 10^{th} to 19^{th}, HIT President Han Jiecai led a delegation to visit France, Italy, and Spain. They successively visited the Emlyon Business School, the Université Paris Cité, the Polytechnic University of Milan, the Politecnico di Torino, and the Complutense University of Madrid. They signed a joint training agreement with the Polytechnic University of Milan, discussed cooperative educational projects with the Emlyon Business School and the Politecnico di Torino, and negotiated the joint training and disciplinary exchanges at the Université Paris Cité and the Complutense University of Madrid. They further promoted the deep integration of high-quality educational resources between HIT and European universities and expanded a new situation of collaboration with Europe.

During the meeting, Han stated that Harbin Institute of Technology has always attached great importance to international exchange and cooperation. To build a world-class university, it is necessary to increase the efforts of opening up to the outside world and encouraging international competition. HIT will further carry out

Visiting the Politecnico di Torino

Signing cooperation agreement with the Polytechnic University of Milan

comprehensive, multi-level, and wide-ranging international exchanges and cooperation, actively expand the introduction of high-quality global resources, expand the international perspective of top talents, and comprehensively enhance the level of international cooperation and exchange in education and its international influence. He hoped to further strengthen exchanges with other universities, fully leverage their respective strengths and characteristics, and promote dialogue between HIT and European universities in areas such as cultural exchanges, talent cultivation, and scientific research cooperation, in order to achieve more fruitful cooperation results in a wider range and deeper level.■

Visiting the Complutense University of Madrid

OLYMPIC LECTURE HELD

On February 24th, the Olympic lecture was held. HIT Vice President Shen Yi awarded Zhang Hong the Olympic lecturer certificate. As the first gold medalist of speed skating in China's Winter Olympics, Zhang Hong, member of the International Olympic Committee and researcher of the Sports Department, shared her story of Olympic champions with students at three campuses.

At the end of 2022, Zhang Hong received a reply from the International Olympic Committee in Lausanne, Switzerland, granting Harbin Institute of Technology the qualification to establish the "Olympic Research Center". Over the past 40 years, the International Olympic Committee has established 59 research centers (colleges) in 23 countries worldwide. The Olympic Research Center of Harbin Institute of Technology will fully utilize the advantages in international talent cultivation, international scientific and technological cooperation, and international teaching staff, promote international cooperation and exchange, carry out Olympic sports and cultural education, cultivate students' Olympic spirit, promote the vigorous development of ice and snow sports in the university, and continue to increase scientific research in the field of ice and snow.

As a public welfare activity of Olympic education, the "Olympic Lecture" will invite Olympic champions, world champions, Olympic experts, international organization officials and other professionals to serve as honorary lecturers. Through forums, speeches, picture exhibitions, memorial exhibitions etc., it will impart knowledge of snow and ice sports and Olympic culture to students, so as to better promote the integration of sports and education.

CHINA SPACE DAY 2023

April 24th witnessed the 8th Space Day of China. Harbin Institute of Technology held a flag-raising ceremony on the three campuses—Harbin, Weihai, and Shenzhen—as well as a painting activity, a flight performance, and a quiz competition.

CHINA SPACE
DAY 2023

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: