北京科技大学
University of Science and Technology Beijing

USTB FRONTIERS

Contact Us

Address: Office of International Affairs
University of Science and Technology Beijing, 100083
Beijing, China
Email: io@ustb.edu.cn

VOLUME 1 MAY 2023

USTB FRONTIERS

Interdisciplinary Science to Serve Industry

Adding Strength to China's Steel Credentials

Refining Steel with Carbon Dioxide

Providing Sustainable Access to Sanitation

Building Corrosion Resistant Infrastructure for a Sustainable World

A Cleaner Way to Deal with Mining Waste

A Two-dimensional Solution for Extending Moore's Law

Engineering Advanced Materials from Start to Finish

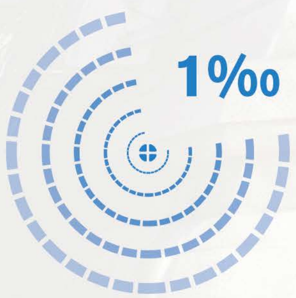
INTERDISCIPLINARY SCIENCE TO SERVE INDUSTRY

From a steel powerhouse to a technology innovator, the University of Science and Technology Beijing looks to build a world-class university.

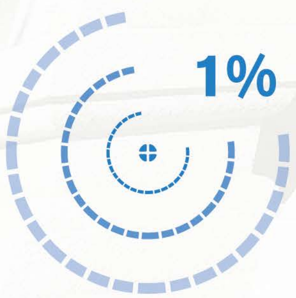
The University of Science and Technology Beijing (USTB) has a historic reputation as China's "Cradle of Iron and Steel Engineers." Its predecessor Beijing Institute of Iron and Steel Technology was founded in 1952, but can trace its roots back to the 1890s when the first mining and metallurgy disciplines in modern Chinese history were established by the Peiyang University. From the beginning of its establishment, the university has been committed to serving China's major industrial needs.

Officially named USTB in 1988, the university was one of the 100 universities listed among "Project 211," and in 2017 became one of the national "Double First-class" universities, all of which were part of China's ambition to build several key world-class universities to compete on a global stage.

USTB is now known both nationally and internationally in four key disciplines: Metallurgical Engineering, Material Science and Engineering, Mining Engineering, and the History of Science and Technology. Seven of their disciplines entered the top 1% of the Clarivate Essential Science Indicators (ESI) world ranking, including Materials Science, Engineering Science, Chemical Science, Physics, Computer Science, Environmental and Ecological Science, and Geosciences, among which the first two entered the top 1‰.



Materials Science, Engineering Science



Chemical Science, Physics, Computer Science, Enviornmental and Ecological Science, Geoscience

Metallurgical Engineering

Materials Science and Engineering

Mining Engineering

History of Science and Technology

FROM TRADITIONAL STUDIES TO INTERDISCIPLINARY RESEARCH

While strengthening traditional advantages, USTB is now transforming from an engineering-focused institution to a multidisciplinary university. "Responding to the emerging industrial needs, we are accelerating the establishment of an interdisciplinary platform and promoting interdisciplinary integration to spur innovation," says YANG Renshu, president of USTB and a professor of rock blasting theory and technology.

Take the discipline of Safety Science and Engineering as an example. In the past, USTB's safety discipline mainly focused on the safety of resource development, but now it also investigates the safety of metal smelting after mining and the long-term service safety of materials. The university has come up with an initiative called '1+2+N' big safety discipline, which is based on Safety Science and Engineering discipline, and supported by the National Centre for Materials Service Safety (NCMS) and the Technical Support Base for Prevention and Control of Major Accidents in Metal Smelting — both are new institutes at USTB.

"We have also formed an innovation platform system integrating basic research, technology development, and transformation into production," YANG says, "Many of our research results have generated huge economic and social benefits."

USTB boasts many breakthroughs in the fields of high-performance metal structural materials and new inorganic functional materials. Scientists have been working on interface regulation of one-dimensional zinc oxide, leading to the development of third-generation semiconductor materials. Research on the structure and toughening of bulk amorphous alloys has opened up a new direction for amorphous structural materials research.

9 Research Papers Have Been Published in *Nature* and *Science*

SERVING INDUSTRY WITH SCIENCE

USTB has also made major contributions to numerous national projects in multiple fields, such as high-speed trains, developing innovative axles for high-speed and heavy duty trains, helping to reduce their prime cost by up to 40%.

The university has developed corrosion-resistant steel and supporting technologies that were used in facilities for the Beijing 2022 Winter Olympics. Using big data, the research team has developed an approach for materials corrosion evaluation, which can halve the research and development period needed for corrosion-resistant steels.

USTB has been a strong player in China's Belt and Road Initiative (BRI). It provided an innovative mining waste tailings treatment technology to enhance mining safety in Zambia, and helped manufacture high-tech seamless pipelines for the oil and gas industries across China, Russia, the United States, the United Kingdom, Iran and Saudi Arabia, making significant contribution to international energy cooperation among BRI countries.

Now USTB is turning its attention to the enormous challenge China faces to cut carbon emission and reach carbon neutrality, YANG says.

The steel sector accounts for roughly 17% of China's total carbon emissions, so decarbonization processes are essential for the industry. USTB has developed China's first apparatus which can produce 300,000 tonnes of direct reduced iron from coke oven gas — a by-product of the coke-making process — annually. The university has also developed new automotive steels with reduced energy consumption, which have been used in the factories of some of China's leading car makers such as Beijing Automotive Industry Corporation and Guangzhou Automobile Group.

In the past 70 years, 300,000 students graduated from USTB, many of whom have become pillars in various fields, especially the metallurgy and materials industries. There are 41 USTB alumni who are members of the Chinese Academy of Sciences or the Chinese Academy of Engineering. Many others serve as leaders of industrial giants.

> **"THESE INITIATIVES ARE AN EMBODIMENT OF USTB'S SPIRIT OF 'SEEKING TRUTH AND PROMOTING INNOVATION'"**


Professor YANG Renshu
President of USTB

BUILDING A WORLD-CLASS UNIVERSITY

USTB aims to significantly improve its academic reputation, and become a world-leading research centre of metallurgy and materials science, as YANG unveils his vision for the future. By 2052 when USTB celebrates its 100th anniversary, YANG believes it will have evolved into a world-class university with distinctive characteristics and notable influence.

To reach these goals, it aims to make a series of original research achievements with great influence. It will continue to lead scientific progress in steel, metallurgy and other industries to serve the national economy, and will unlock more core technologies to tackle major challenges in national projects. It also plans to accelerate technological innovation in fields such as precision medicine, biomedicine and environmental protection.

The university also plans to invest a total of 2.5 billion yuan on building its first-class disciplines between 2021 and 2025. "These initiatives are an embodiment of USTB's spirit of Seeking Truth and Promoting Innovation," says YANG.

ENGINEERING ADVANCED MATERIALS FROM START TO FINISH

Professor XIE Jianxin
Academician,Chinese Academy of Engineering

The University of Science and Technology Beijing (USTB) embraces materials innovation through data and computational techniques.

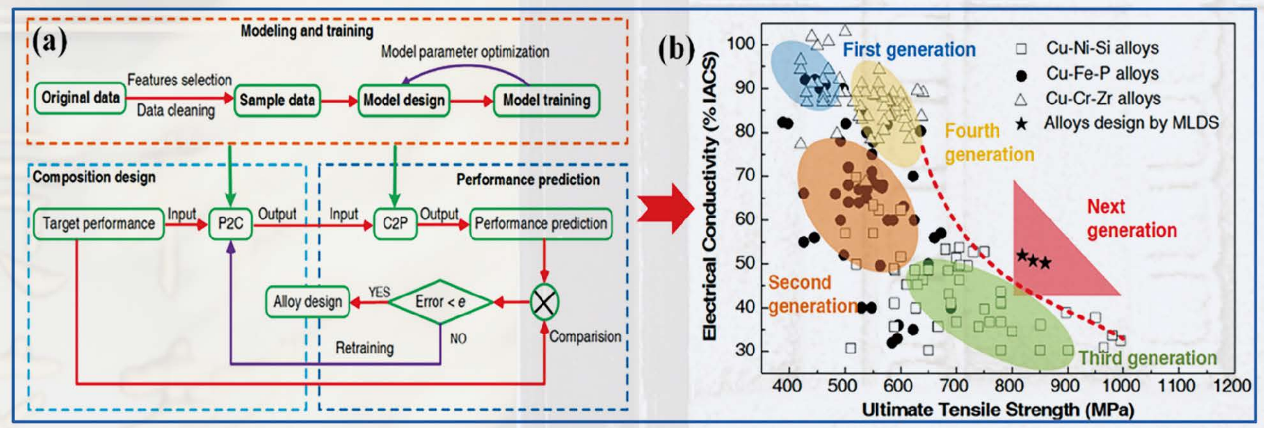
Society relies heavily on advances in materials science, with applications spanning spacecraft and infrastructure, to automobiles and LED lights. Increased demand for new and better materials calls for scientists to embrace technologies such as big data and artificial intelligence for material discovery, design, and manufacturing.

One of the trailblazers in this field is USTB. Founded in 1952, USTB was initially the Beijing Institute of Iron and Steel Technology, and has long been known as the 'Cradle of iron and steel engineers.' Witnessing China's transformation into a giant steel consumer and the world's largest steel manufacturer, USTB is moving even faster with cutting-edge technology and big data to "increase the efficacy of advanced materials and processes from start to finish," says XIE Jianxin, Director of the Beijing Advanced Innovation Center for Materials Genome Engineering at USTB, an Academician of the Chinese Academy of Engineering, and an esteemed materials scientist.

ENGINEERING MATERIALS

USTB was one of the pioneers in China in applying data and AI-powered materials genome engineering (MGE) for materials discovery and development. MGE is analogous to genome engineering in biology in a conceptual sense, an approach integrating computation, experiment and big data to support materials design and discovery. The traditional trial-and-error method for materials design "is costly, time-consuming, and often less informative," says XIE. "The advent of MGE altered the whole process of the materials industry. Harnessing the power of materials data can speed up discovery, enabling on-demand design and precise control of materials characteristics."

XIE highlighted how his research team at USTB applied machine learning techniques based on more than 300 text-mined datasets from scientific and technical literature to successfully identify key alloy factors that affect materials' hardness and electrical conductivity. This discovery helped them obtain strengthened copper alloys with enhanced mechanical and electrical properties. ***"MGE can aid in testing millions of materials compositions and phases with high-throughput experiments and finding of alternatives for rare minerals with desired properties,"*** he adds.



SUSTAINABLE AND RELIABLE

Beyond materials discovery and improvement, USTB is applying MGE to optimize the manufacturing process. For example, automotive steel is usually manufactured through two stages featuring complex procedures and high energy consumption. Slabs are first hot-rolled and then cold-rolled to a desired thickness. Cars produced in this high-emitting way may be levied at a higher tax rate, or even restricted from export to the European Union countries according to the legislative proposal of 'Fit for 55'.

A team led by MAO Xinping, a professor at USTB and an Academician of the Chinese Academy of Engineering, proposed a low-carbon short-process path to make automotive steel by deploying thin slab casting and direct rolling, which eliminates the cold rolling and annealing steps. This innovative approach can slash energy consumption by 71.5% while enhancing the steel's overall performance.

The team also developed steels for cars, such as quenching-and-partitioning steel-a type of steel with excellent strength and elongation, which is produced through a multi-step heat treatment. These steels are now being produced by the world' s top steelmaker, Baowu Group, and many thousands of tonnes of finished steel has been supplied to automakers both domestically and internationally.

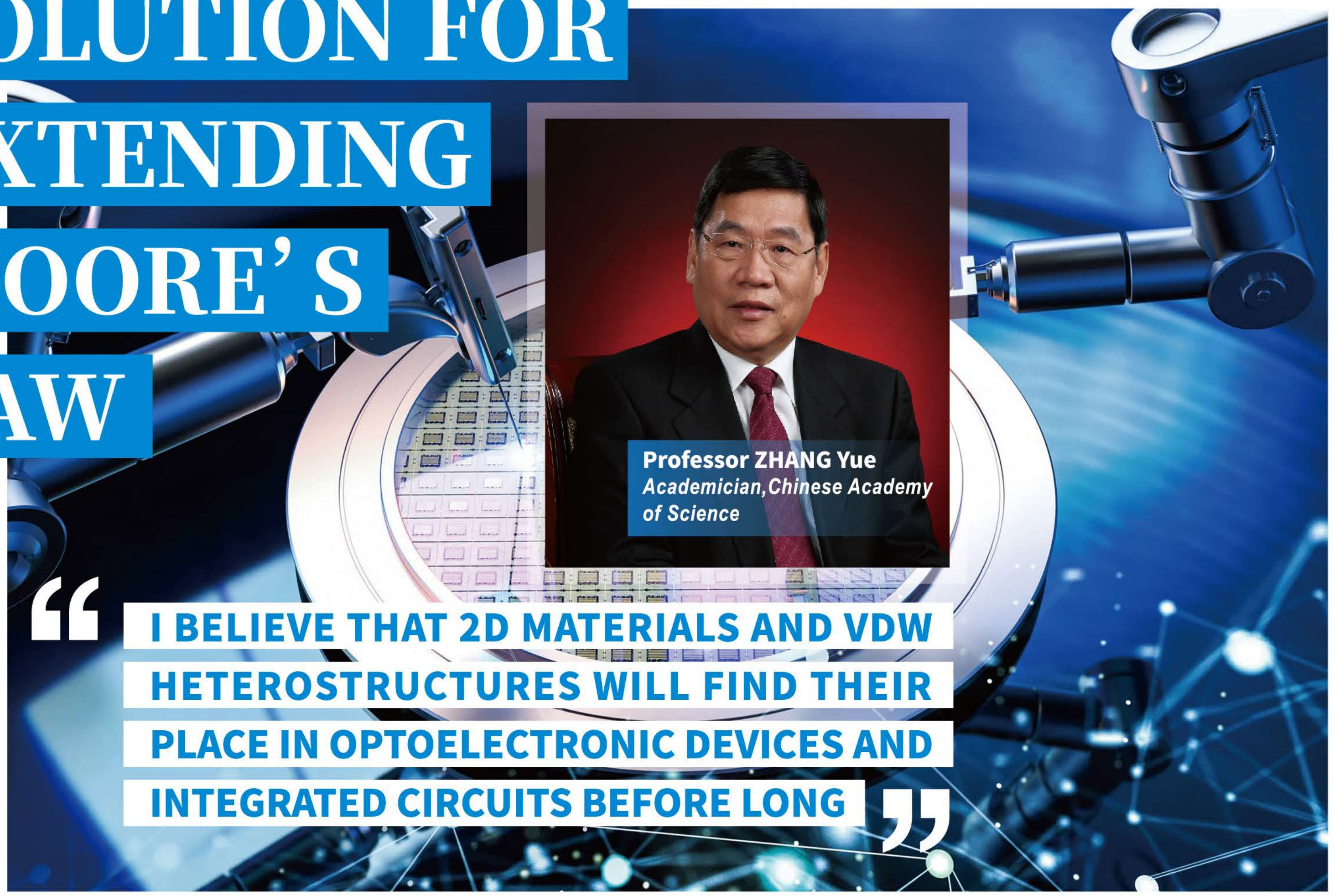
KEEPS ON ITERATING

Researchers at USTB have been banking on another advanced material – carbon fibre reinforced polymers (CFRP), a choice for lightweight construction across many areas.

CFRP has been a hot topic in materials science since the 1990s, with recent research looking at refining its properties and scaling up using MGE approaches. A team led by YUE Qingrui, a professor at USTB and an Academician of the Chinese Academy of Engineering, has made great progress in research on CFRP' s reinforcement technology and new structures. Their reinforcement technology has been applied in many industrial and civil infrastructures, and a new CFRP cable developed by the team has been successfully applied in a stadium in Sanya, a city in China's Hainan Province. Completed in September 2021, the-88,000-square-meter stadium with large-span space structure is the first of its kind in China to be constructed with CFRP cables.

So far, steel and CFRP are both commonly consumed in various circumstances through material modification. According to XIE Jianxin, advanced materials used to be relatively 'slow' to translate into practice, due partly to their relatively longer supply chain and trial-and-error R&D cycles. "That' s why we concentrate on growing MGE-based intelligent manufacturing, taking inputs from industries and iterating fast, to build sustainable and high-quality materials that will last," Says XIE.

A TWO-DIMENSIONAL SOLUTION FOR EXTENDING MOORE'S LAW



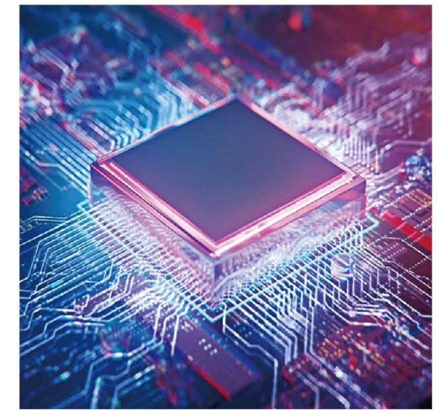
"I BELIEVE THAT 2D MATERIALS AND VDW HETEROSTRUCTURES WILL FIND THEIR PLACE IN OPTOELECTRONIC DEVICES AND INTEGRATED CIRCUITS BEFORE LONG"

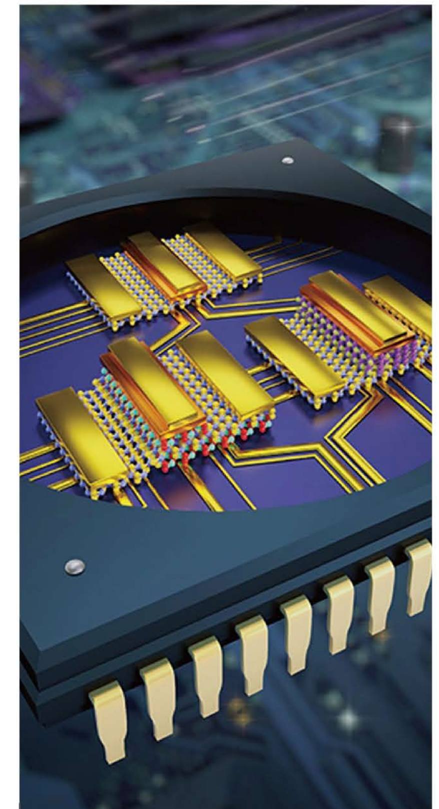
A research team in China is exploring the use of ultrathin materials to downsize chips.

For half a century, the rapid evolution of information technology has been described by a trend known as Moore' s Law: the number of transistors in integrated circuits doubles every two years or so. However, silicon based transistors are fast approaching their size limits, forcing researchers to look for alternative technologies. A team led by ZHANG Yue, a professor of Materials Science and Engineering at the University of Science and Technology Beijing (USTB) and an Academician of the Chinese Academy of Science, has been examining atomically thin material candidates as a way to fit more transistors on a chip.

Despite exponential development for decades, conventional silicon semiconductors, materials are used to make transistors, are reaching the edge of their capacity. Chips keep shrinking, and the performance of conventional semiconductors declines significantly at the sub-5 nanometre scale. Another issue is the chemical bond, integral for mixing different materials, including semiconductors, oxide materials and metals, to make a transistor. Only limited types of materials can be chemically bonded to form a heterostructure, a combination of multiple dissimilar materials. This approach can cause defects that reduce the efficiency of electron transport, which is exacerbated by the shrinking size of transistors.

"Imagine 100 kids are hand in hand, trying to form a 10 by 10 array. While some of them are much slimmer than others, it won' t be easy to bring them in alignment. You can ask the slimmer kids to keep a wider distance from others, but it will be much harder when they are getting really close," says ZHANG Zheng, a materials scientist at USTB and a member of ZHANG Yue' s team. "That' s what happens with atoms when mixing different materials in conventional ways."





THINNER AND FLATTER

For ZHANG Yue and his colleagues, one of the promising solutions is two dimensional (2D) materials. These ultrathin materials, which can be only 0.6 nanometres thick for one-layer 2D compounds, have shown similar carrier mobility to bulk silicon, with atomically flat and dangling-bond free surface that allow carriers to flow relatively smoothly through them. This kind of material allows the fabrication of integrated circuits closer to one nanometre.

Instead of chemical bonding, ZHANG Yue and his colleagues are exploring the approach of stacking atom layers using van der Waals (vdW) force to form heterostructures.

"Using Van der Waals force is like making these 2D compounds combined back to back. You don' t have to worry about whether their chemical bond connected together or not," says ZHANG Zheng. This has provided great flexibility to integrate distinct atomic layers beyond the traditional limits of lattice-matching requirements.

This approach has proven fruitful. - By stacking the 2D metal — a metallic phase molybdenum ditelluride — and the semiconducting monolayer, molybdenum disulfide, using vdW force, the team reported a near-ideal Schottky diode, a semiconductor diode formed by the junction of a semiconductor with a metal.

However, it is much more challenging to prepare high-order vdW superlattices with a larger number of alternating materials by mechanical restacking or sequential synthesis, because of material damage associated with each sequential restacking or synthesis step. To address this, the team worked with both local and international researchers, and developed a new strategy of "rolling up" van der Waals heterostructures. As ZHANG Zheng explains, "as the atoms don't have to 'hold hands,' two types of vdW integrated 2D materials can be rolled up to form a tubulous structure."

As one of the early players in this area, ZHANG Yue's team has established a long-term schedule for exploring these materials. They look to combine 2D materials with silicon chips and eventually translate the innovations to industry.

"I believe that 2D materials and vdW heterostructures will find their place in optoelectronic devices and integrated circuits before long," ZHANG Yue says.

ADDING STRENGTH TO CHINA'S STEEL CREDENTIALS

A research team at USTB has increased the strength and ductility of steel at a modest cost.

Steel alloys with ultrahigh strength (UHSSs) above 1,500 megapascals (MPa) are in great demand for infrastructure subject to extreme conditions, such as aircraft landing gears, and rocket engine cases. There are challenges presented by the need for combining increased strength and good ductility to prolong the steel' s service lifetime, saving energy and reducing emissions.

A research team led by LYU Zhaoping, Vice President of USTB and a professor at the State Key a professor at the State Key Laboratory for Advanced Metals and Materials at the University of Science and Technology Beijing (USTB), have designed a steel with strength up to 2,200 MPa, and ductility of over 8%, to be produced at a reduced cost.

The high strength in conventional maraging steels, a class of UHSSs, is due to the presence of semi-coherent precipitates, particles whose elastic energy comes from a crystallographic misfit through the addition of high-cost metallic elements such as cobalt and titanium. At the same time, the lattice mismatch between these precipitates and the surrounding steel matrix, can lead to strain, which can cause earlier cracking under load.

"The strength-ductility trade-off has been a long-lasting dilemma. When moving to structural applications, the cost is another important factor to be balanced," says LYU.

LYU and his colleagues have been dedicated to improving the comprehensive performance of steels. They envisaged a steel with outstanding strength and maximum ductility for forming into any shape, with improved toughness and margin of safety in service.

After observing an experimental steel exhibiting a

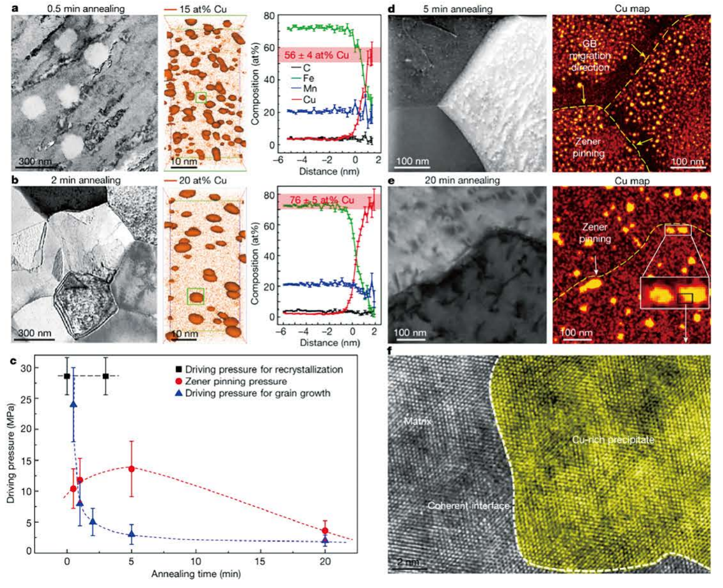
Professor LYU Zhaoping
Vice President of USTB

surprising performance, LYU and his team explored the strengthening mechanism. After years of research, the team has developed a pathway to this ultra-strong steel using high-density nanoprecipitation with minimal lattice misfit. They found that the evenly dispersed, fully coherent precipitates — their lattice structure was almost the same as that of the steel matrix — strengthen the alloys without sacrificing ductility.

"The steel alloy is hardened by a very dense distribution of nano-sized aluminium-iron-nickel precipitates. We also enhance the ordering effect that creates back stresses, the forces opposing deformation," says LYU. The team also replaced cobalt and titanium with aluminium, which is lighter and more economical.

The toughness, another importance index of the performance, is also significantly improved in the team' s experiments, but the mechanism for this not yet defined, according to LYU. This class of ultra-strong steel is in a pilot production run.

> "THIS INNOVATIVE DESIGN CONCEPT HAS PROVEN APPLICABLE FOR OTHER METALLIC ALLOYS"



LYU points out. The same mechanism of coherent nanoprecipitation is leveraged in his other research topics, such as high-entropy alloys and TWIP steels.

"Despite hundreds of years of research in this subject, there are opportunities for innovation along with emerging technologies. For example, the new testing and inspection facilities such as three-dimensional atom probe tomography, can bring light to the microscopic world of structural materials, while computer science such as machine learning can make it to a macro level with powerful data processing to improve the alloy design processes. New application scenarios and requirements can also be the source of innovation," LYU says.

NATIONAL CENTER FOR MATERIALS SERVICE SAFETY


Professor ZHANG Weidong
Vice President of USTB

USTB also puts a premium on the importance of material service safety assessment, seeking to improve the service safety of structural materials, and establish related standards and specifications for material service. " We have developed large physical testing facilities and multi-scale simulation systems under the support of Materials Service Safety Assessment Facilities (MSAF), a major national science and technology infrastructure project supported by the National Development and Reform Commission. Relying on these facilities, we have established the National Center for Materials Service Safety (NCMS)," says ZHANG Weidong, NCMS' Chief Director and Vice President of USTB.

"We aim to unveil the damage mechanism of key materials and components, and improve their reliability under their real service conditions, providing technical support to various industrial sectors such as nuclear power, petroleum, marine engineering and transport engineering," ZHANG notes.

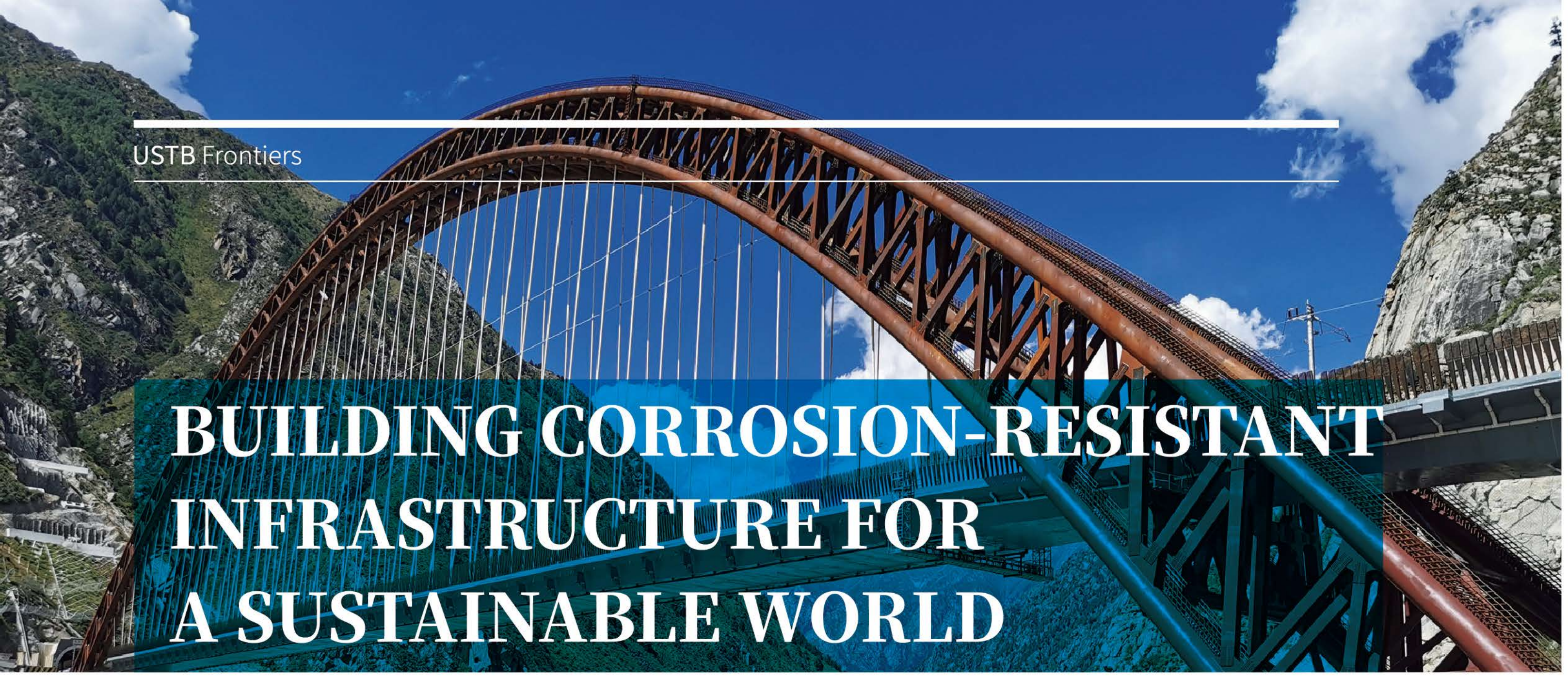
According to ZHANG, NCMS has carried out a series of major assessments in recent years. One of the highlights was providing materials service safety assessment for the Beijing 2022 Winter Olympic Games. NCMS conducted reliability evaluation, selected key components for the hydrogen fuel supply system for the main torch under low temperature environment, and performed fatigue tests on the steel cable net structure of the National Speed Skating Oval to assess the life span of this landmark stadium.

STATE KEY LABORATORY FOR ADVANCED METALS AND MATERIALS

Established in 1990, the laboratory is committed to discovering advanced materials and upgrading traditional materials. To push the limits of metallic materials research and meet national development needs, five principal research directions have been formed: Frontier metallic materials, Novel functional materials, Advanced steels, Advanced materials processing, and Materials genome engineering. Over the last decade, it has made insightful contributions in design principles, preparation and application of advanced materials. The lab will actively refine its research priorities to transform materials processing and raise its global profile.

BEIJING ADVANCED INNOVATION CENTER FOR MATERIALS GENOME ENGINEERING

Launched with the support from Beijing Municipal Government in October 2017, the center strives to inspire the growth of emerging industries and high-end manufacturing with innovative solutions of materials genome engineering. It intends to develop high-quality materials that can be applied at a lower cost and higher efficiency by incorporating big data technologies and databases, high-throughput processing and characterization, computation approaches, and performance assessment. The center gathers top-notch talents and carries out frontier research, with the ultimate goal of transforming into a global leader in materials genome engineering.



BUILDING CORROSION-RESISTANT INFRASTRUCTURE FOR A SUSTAINABLE WORLD

Professor LI Xiaogang
National Materials Corrosion and Protection Data Center

Big data and international collaboration helps engineers model and forecast corrosion.

Corrosion causes severe damage to infrastructure and vital equipment, leading to more than US$4 trillion in capital losses globally each year. While corrosion control is essential, increasingly unpredictable climate patterns make modelling for anti-corrosion design extremely challenging. Now, LI Xiaogang, a professor at the Institute for Advanced Materials and Technology, University of Science and Technology Beijing (USTB), is using big data to build major infrastructure that will stand up to harsh environments.

For more than two decades, LI's team has been at the forefront of materials corrosion and protection research in China and beyond, including promoting data sharing to identify corrosion risks, predicting failures, and develop durable and smarter corrosion-resistant materials.

Corrosion control is particularly important in developing countries, where economic growth is often set back by ageing infrastructure, increasing the risks of asset loss and accidents. Corrosion processes in varying microclimates are complex and difficult to model. At the same time, the lack of knowledge and transparent data shared between industries and the scientific community presents a major hurdle to developing preventive strategies for corrosion failures.

Through strengthened international cooperation on infrastructure investment projects under the Belt and Road Initiative, LI's team took the lead in establishing the world's largest corrosion data sharing platform and a corrosion observation network in China and the Belt and Road countries, and collating what he calls "corrosion big data" — including inspection data from more than 60 national and international field corrosion test stations in typical atmospheric, soil and water environments, covering more than 800 types of materials with a total of 30 million pieces of life-cycle corrosion data, as well as 5 billion pieces of corrosion monitoring data.

The information concerns specific metal composition, and electrochemical and environmental factors — which would enable researchers to perform precise and context-appropriate corrosion modelling to inform engineering designs, improve forecasts of corrosion failures, and enhance the service performance of materials for infrastructure and major equipment.

This kind of data analytics, assisted by machine-learning techniques, has proven key to enabling accelerated and cost-effective design of many new corrosion-resistant steel products for Shougang, Anshan Steel and Nanjing Iron and Steel. Working with these leading manufacturers, LI has designed high-performance low-alloy steels for use in facilities for the Beijing 2022 Winter Olympics. The steels, with fine-tuned alloy compositions and microstructures, have high purity, fine crystallization, high strength, excellent weldability and exceptional corrosion resistance. They were widely used in the main stadium and many other supporting facilities.

Beyond China, LI's team uses corrosion big data approaches to rapidly evaluate and screen corrosion-resistant materials for complex and harsh environments in key international projects. Their technologies have led to the successful construction of the High-speed railway in Indonesia, and Sinamalé Bridge, also known as the 'China-Maldives Friendship Bridge'.

In the last few years, LI was recognized by the prestigious W.R. Whitney Award and Fellow honours by Chinese, US and European corrosion societies for his contribution to corrosion research, data sharing and international cooperation, raising the bar for corrosion prevention and control for infrastructure investment across China and beyond. One of his plans is to further establish an open data powered research platform on corrosion and protection that would help foster collaboration in addressing the many challenges in Belt and Road countries.

NATIONAL MATERIALS CORROSION AND PROTECTION DATA CENTER

Along-standing champion for data-driven corrosion research and knowledge sharing, LI Xiaogang's effort led to the birth of National Materials Corrosion and Protection Data Center, where he serves as director.

Established by the Ministry of Science and Technology in 2019 as one of the first 20 national scientific data centres in China, it focuses on the R&D of advanced corrosion-resistant materials and corrosion management tools, technology transfer and knowledge sharing. It is now one of the world's leading research platforms for the production, accumulation, analytics and sharing of corrosion data and also collaboration in corrosion research and education. It has provided data services to 320 enterprises, institutions and universities worldwide.

A CLEANER WAY TO DEAL WITH MINING WASTE

Chinese researchers transform tailings into paste to put back into voids

Mining produces valuable minerals for human use, but the waste it produces is a longstanding problem. WU Aixiang, a professor of mining engineering at the University of Science and Technology Beijing, has extensively researched the issue and found a process known as paste backfill, which transforms the tailings, left after the target minerals are removed from the ore, into paste and then fill them back into the underground voids created by mining. This technology has helped about 200 mines around the world to reduce their waste by up to 70%.

Currently, tens of billions of tonnes of waste tailings from mines are held back by dams around the world — and they are still piling up. The clean energy infrastructure that cities and countries are racing to build for a sustainable society demands huge amount of raw materials, the majority of which need to be mined. While discussion about climate change focuses on the need for solar panels, wind turbines, and electric vehicles, dealing with existing waste tailings is another important part of protecting the environment and obtaining clean energy.

WU and his team have been working on the problem of waste tailings management for nearly 20 years. They have designed a complete system which includes preparing the paste by mixing the tailings with a binding material, filling the underground voids created by ore removal, and monitoring the paste in long term. This approach removes the need for tailing dams at the land surface. The tailings are backfilled to the underground, which avoids hazards like ground subsidence or dam failure, while reducing the significant cost for building and managing tailing dams on the ground.

WU's research shows that paste backfill can save more energy and resources compared

with traditional methods, as it eliminates several other processes. Cement is often used as a binder in traditional tailing treatment measures, while WU and his team have found more economical but equally effective materials from other industries, such as slag from smelters or fly ash, slashing emissions by avoiding carbon-intensive cement.

As mining usually take places in remote areas with limited infrastructure and unique mineral composites, paste backfill comes with many challenges. The paste should not leak water, but must also be fluid enough to be pumped in pipe lines. Since no two mines produce the same tailings, the physical and chemical properties vary greatly. It is necessary to design mine specific solutions for each project. "We are prepared for any conditions," says WU, "We need to be able to handle whatever we are given."

> **"WE NEED TO BE ABLE TO HANDLE WHATEVER WE ARE GIVEN."**

WU's team has designed a controllable preparation method to combine waste tailings and other materials into paste, a systematic approach to produce paste continuously, and a pipe transportation system to move the paste to target underground voids. Using artificial intelligence, WU's team is now working on a new smart method to adjust the whole tailing process to local sites, and make it easier for the monitoring and management of paste backfill.

The widespread adoption of paste backfill has improved mining efficiency, and at the same time helped reduce waste, bringing a brighter future for clean energy infrastructure.

REFINING STEEL WITH CARBON DIOXIDE

Professor ZHU Rong
School of Metallurgical and Ecological Engineering

Utilizing carbon dioxide in steelmaking helps offset carbon emissions while producing better quality steel.

Steel is a top greenhouse gas emitter, its manufacture producing almost twice its own weight in carbon dioxide emissions, according to the World Steel Association. Decarbonizing the steel industry is now an urgent priority for nations including China, which intends to become carbon-neutral by 2060, while continuing to build necessary steel-intensive infrastructure.

But environmental impact was not on ZHU Rong' s mind when he embarked on his research pursuit to utilize carbon dioxide in steelmaking at the University of Science and Technology Beijing (USTB). It was 2002, and ZHU was agonizing over a question that a student raised in his ferrous metallurgy class.

"He asked how we could reduce the amount of black dust generated from steel mills," ZHU recalls. "His parents were farmers, and they grew vegetables near a steel mill. The dust made the produce unappetizing and difficult to sell."

Having spent almost a decade observing and working with steel factories, ZHU understood how dust is generated. In a furnace, molten iron is purified by allowing its impurities to react with oxygen. When oxygen gas makes contact with the molten iron, an extremely hot fire spot is generated. When the temperature of the spot exceeds 2,700 ℃, the steel evaporates and reacts with the oxygen, generating fine iron oxide dust particles.

The challenge of reducing dust in this process, however, stumped ZHU. "I felt terrible for not having a solution to this issue," he said. ZHU spent the next year and a half turning the problem over in his mind, eventually wondering whether lowering the temperature of the fire spot might help.

ZHU and his team started mixing different compounds in the oxygen gas in a labora tory-scale furnace at USTB, which also hosts China' s State Key Laboratory of Advanced Metallurgy, to find out which type of chemical reactions might result in a cooling effect. One compound they tried, calcium carbonate, lowered the amount of dust generated considerably. "We thought, perhaps it was because calcium carbonate generated carbon dioxide," ZHU recalled. The chemical reactions between carbon dioxide and steel impurities consume heat, thus helping to lower the mixture's temperature. So, the team tried mixing carbon dioxide gas in with oxygen. Not only did it help to reduce the amount of dust by 9.95%, the team would also learn years later, that refining steel with carbon dioxide comes with additional benefits.

Today, ZHU' s technology of utilizing carbon dioxide in steelmaking has received significant attention. "It helps offset carbon emissions produced by the steel industry by 10%," says ZHU. The resulting steel is also of a higher quality, says ZHU, because carbon dioxide turns into carbon monoxide after it reacts with impurities in the melt, and stays as a gas that aids mixing.

ZHU and his team have since brought the technology out of the laboratory. Over the past two decades, the researchers established the theoretical principles and optimized the reaction conditions for using carbon dioxide to refine steel. Along the way, ZHU' s team also established new industrial methods, such as a technique for precisely monitoring the high temperatures of the steel melt.

There are currently 10 steel companies in China refining steel with carbon dioxide using this method, says ZHU, including top steelmaker, Shougang, which invested in a state-of- the-art carbon capture facility to reuse its own carbon emissions. ZHU and his team hope to welcome and introduce international steelmakers to this beneficial technology.

STATE KEY LABORATORY OF ADVANCED METALLURGY

The State Key Laboratory of Advanced Metallurgy (SKLAM) was founded in October 2011, approved by the Ministry of Science and Technology of China. With two Academicians of the Chinese Academy of Science, a faculty of around 60 professors and senior engineers, and more than 400 post-doctoral, doctoral and graduate students, it focuses on the research of high-temperature reactive mechanisms and kinetics, low carbon metallurgy, resource utilization, and clean steel production. SKLAM aims to realize high-efficiency energy conversion, resource utilization, and high-end steel production for the iron and steel industry.

PROVIDING SUSTAINABLE ACCESS TO SANITATION

A research team is providing sustainable sanitation solutions, while generating clean energy.

In 2020, as many as 1.7 billion people worldwide still lacked basic sanitation services, with 494 million without toileting facilities. The spread of water-related illness, such as diarrhoea, continue to claim the lives of around 600,000 children every year.

One of the experts leading the world' s race to achieve universal access to sustainable sanitation services, reflected in Sustainable Development Goal 6, is LI Zifu, a professor of Environmental Engineering, who heads the National Environment and Energy International Science and Technology Cooperation Base, and the Beijing Key Laboratory of Resource-oriented Treatment of Industrial Pollutants at the University of Science and Technology Beijing (USTB).

LI began researching wastewater treatment and sanitation in the late 1990s during his postgraduate studies in Germany. In 2004, he returned to China to take up a professor position at USTB' s School of Civil and Environmental Engineering (currently School of Energy and Environmental Engineering), while spearheading the country's many international bilateral and multilateral initiatives in developing sustainable sanitary systems. He is considered a world-leading expert in sanitation technologies and urban water management, having participated in the development of Non-sewered Sanitation Systems and Faecal Sludge Treatment Units from the International Standardization Organization.

HARNESSING THE 'GREEN' POTENTIAL FROM WASTEWATER

In 2013, LI' s team successfully launched the Reinvent the Toilet Challenge China (RTTC-China), funded and supported by the Bill & Melinda Gates Foundation, which encouraged Chinese investigators to design, research and develop innovative, decentralized sanitation solutions. The programme resulted in many innovations for sanitary, sustainable and affordable toilets in rural areas of China.

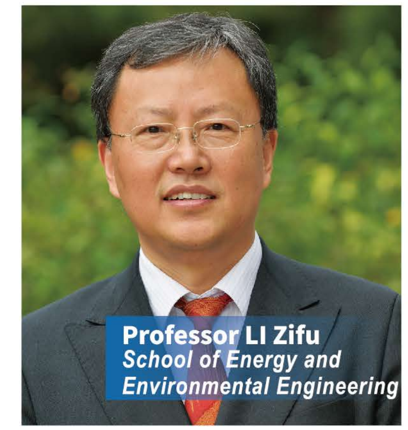
LI' s team at USTB also strives to extend its impact beyond China by working closely with international research institutions and development agencies to improve access to water and sanitation in poor communities across Africa and South Asia.

A recent success is a newly installed faecal sludge treatment system in Ouagadougou, Burkina Faso. With a daily treatment capacity of 400 tonnes, the facility is the largest of its kind in West Africa. When LI' s team first assessed the city' s status in the city, they noticed that untreated human waste was routinely discharged or dumped in the open.

Based on the success of RTTC-China programme, his team adopted the technology for toilet design, waste storage, transportation, treatment, and reuse to best meet the city' s need for faecal sludge treatment, and successfully demonstrated to be feasible on a commercial scale.

What started off as a sanitation solution also sought to address the issues of energy access and emission reduction by producing biogas from the faecal sludge, an affordable and clean energy source. The results align with China' s vision for strengthened cooperation with Africa on climate action and low-carbon transition.

ADDRESSING THE MULTIFACETED CHALLENGES THROUGH COOPERATION



Professor LI Zifu
School of Energy and Environmental Engineering

For many developing countries, the path towards a low-carbon, resilient economy is difficult. As LI notes, infrastructure projects face economic and technical constraints, including identifying local solutions, securing investments to operational maintenance, and inadequate local expertise.

LI believes that multilateral or cross-sectoral collaboration is the key to overcoming these barriers and accelerating sustainable development in tandem. His team spans more than 20 countries and regions, with more than 30 research institutions and non-profit organizations serving as strategic partners on project development, research exchange, technology transfer and capacity building.

Despite COVID-19 disruptions to international cooperation, LI remains hopeful that China' s growing climate leadership and the momentum brought by the Belt and Road Initiative will promote wider adoption of sustainable sanitation solutions in meeting some of the world's most pressing challenges.