East China University of Science and Technology

ENGINEERING A BETTER WORLD

65th ANNIVERSARY OF EAST CHINA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Produced by natureresearch for ECUST

EAST CHINA UNIVERSITY OF SCIENCE AND TECHNOLOGY

ENGINEERING A BETTER WORLD

Located in Shanghai, China's most modern city, East China University of Science and Technology (ECUST) is the country's first higher-education institution specializing in chemical engineering. As a witness to, and in fact a central protagonist of China's rapid industrialization and modernization, it has made many key contributions to the chemical industry, and is regarded as one of the birthplaces of China's chemical engineering work.

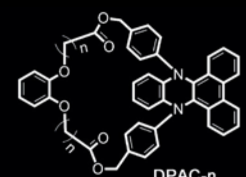
In the 65 years since it was established, ECUST has stayed true to its mission to nurture talent and better society. Its educational philosophy is people-oriented and focuses on the process of learning, while highlighting the significance of heritage and innovation. With high-quality research as its bedrock, ECUST provides a high-quality education and has cultivated almost 300,000 graduates, who have carried on the university's principles of 'diligence, factuality, aspiration and virtue'.

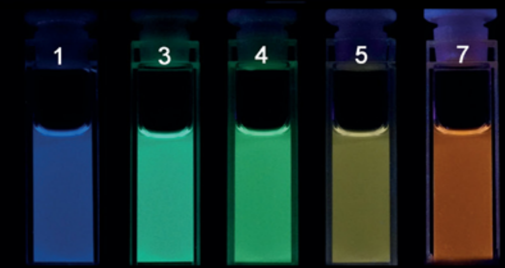
Today, ECUST is a multidisciplinary, research-oriented university renowned globally for its distinctive features, with a number of academic programmes ranked highly globally. Housing nine national-level research bases, including the State Key Laboratory of Chemical Engineering and the State Key Laboratory of Bioreactor Engineering, 25 provincial and two international joint research bases, ECUST is listed among the world's top 500 universities in a number of rankings and also occupies a leading position among its domestic peers. The university has made some remarkable achievements in chemical manufacturing, clean energy, biomedicine, material engineering equipment and process control and optimization. One of its key achievements has been a large-scale packaged technology for chemical engineering (i.e. its coal-water slurry gasification technology with opposed multi-burner, which has earned a reputation world-wide for its success in industry).

Standing at a historic turning point, the university continues to break ground, emphasizing quality and efficiency, rather than quantity and size. Its strategy is to drive innovation, focus on talent, and enhance international collaboration. Through fostering and attracting talents, targeting cutting-edge science, and responding to economic and social needs, ECUST is now making unfaltering strides to construct more first-class academic programmes and to become a world-class university, while retaining its distinct Chinese character. ■

CHEMISTRY

A shining example of luminescence research





The VIE mechanism can be used to explain anomalous luminescence phenomena.

ECUST scientists have revealed a novel luminescence mechanism of conjugated molecules, lighting the way to a new area of research.

Led by He Tian, a professor of chemistry at ECUST and an academician of the Chinese Academy of Sciences, a research group observed in 2015 that in solution, a single phenazine derivative showed two distinct fluorescence peaks, one in the blue-light range, and one in the red. By modulating intramolecular vibrations, colour-tunable luminescence, even white light emission could be readily achieved.

Tian also proposed the concept of a new luminescence mechanism called vibration-induced emission (VIE). Collaborating with Pi-Tai Chou, a professor from the National Taiwan University, Tian's group further validated the VIE mechanism and used it to explain anomalous luminescence phenomena. In-depth experimental and theoretical studies produced a clear picture of the VIE photophysics, which is a three-step kinetic process: an initial charge transfer state, intermediate state, and final planarization state.

"VIE means Very Important Emission", Tian joked. The mechanism opens a new avenue for luminescence research and gives rise to a series of novel advanced functional materials. One possible application is in molecular sensing, which requires probe materials with high accuracy and rapid response. Based on selective binding of the core-shell VIE dots, Tian and colleagues have developed highly sensitive ratiometric fluorescent probes for influenza virus.

Tian's group's work is widely renowned and has received significant government support. "We are eager to expand our research and enrich the application of VIE," said Tian. ■

CHEMICAL ENGINEERING

Awesome foursome engineers perfect chemistry

The chemical engineering talent of four significant universities joined forces in 1991 to form the State Key Laboratory of Chemical Engineering (SKLOCHE). Representing Tsinghua University, Zhejiang University, Tianjin University and ECUST, the latter's site focuses on chemical reaction engineering, including studies on reaction kinetics, fluid mechanics and chemical reactor modelling and optimization. It has devised a systematic method for chemical reactor development and successfully industrialized a number of large-scale reactors for China's petrochemical industry.

In response to energy and environmental challenges, research at the ECUST site centres on heterogeneous catalysis, micro-kinetic analysis, and innovative solutions to improve the efficiency of chemical processes and equipment. The laboratory has developed technologies to reduce energy consumption for ethylene, purified terephthalic acid (PTA), and polyester production, lower emissions in refining and petrochemical plants.

Studying the mechanism and kinetics of materials' structural evolution, researchers have achieved effective control over the multiphase and interface structure of polymer and carbon materials, and have developed advanced materials for lightweight vehicles, energy storage and chamber air cleaning. ■

Watch this space for single-minded molecular studies

Single-molecule analysis allows insight into the attributes and dynamics of individual molecules and their behaviours. Using nanopore techniques, ECUST researchers have improved the tools used for single-molecule detection. Professor Yitao Long at ECUST and colleagues proposed the concept of electrochemical confined space effect. Their research suggests that a nanopore, as a single-molecule sensing interface, with comparable confined space of the analyte, offers the strongest capacity for single-molecule characterization. Using solid-state and biological nanopores, the team also developed wireless nanopore electrodes with a greatly enhanced electric field at their tip. This nanopore electrode is easy to fabricate and allows great reproducibility for nanoelectrochemical studies. It has great potential for use in high-throughput testing in single-molecular analysis. Also, by revealing the capacity of confined electrochemical space to converge energy around the confined nanopore or nanoparticles, Long improved the study of heterogeneous structure-function relationships between single molecules in biosystems.

ENERGY AND ENVIRONMENTAL SCIENCES

Burning ambition leads to world firsts

China is the world's largest consumer of coal, so improving efficiency while minimizing emissions is a national priority. Novel coal gasification technologies developed by ECUST researchers are contributing to this goal.

Coal gasification is an essential technology for clean and efficient coal conversion and has been furthered by more than 30 years of research and development at ECUST Institute of Clean Coal Technology (ICCT). In 2005, the ICCT's coal-water slurry gasification technology with opposed multi-burner was the first of its kind independently developed in China. The burner's design has significantly improved the carbon conversion rate and reduced energy consumption. Applicable to various coal types, the technique is now used by 51 companies worldwide, in 141 gasifiers (including some under construction). The ECUST team is now working on improving the processing capacity of single gasifiers and in 2014, achieved the world's largest, with a processing capacity of 3,000 tons of coal per day.

In collaboration with Sinopec Group, the ECUST team has also developed the SE pulverized coal pressurized gasification technology, widening the range of usable coals.

The technology was applied in a plant of Sinopec's Yangzi Petrochemical Company in 2014 and has now been used in 16 gasifiers of four companies in China. As the only research institution that has mastered both coal-water slurry gasification and pulverized coal gasification technologies, ECUST is renowned as one of the world's top three technology providers. ■

Rock solid opportunities

China's many salt lakes provide huge sources of inorganic minerals. ECUST's National Engineering Research Center for Integrated Utilization of Salt Lake Resources is dedicated to making the best use of these resources, focusing on potassium, magnesium, lithium, boron and other scattered element resources.

The centre, led by Professor Jianguo Yu, has made breakthroughs in the synthesis and combination of flotation reagents, multiphase separation at high altitude, design of large-scale crystallizer, magnesium electrolysis, and the extraction of lithium from salt-lake brine with a high magnesium/lithium ratio. Its technologies for preparing potassium chloride and pure magnesium hydroxide are used in large-scale engineering projects. Thailand has imported its technology for making potassium chloride from potassium rock salt, using it for equipment capable of processing 0.14 million tons per year.

WASTEWATER TREATMENT AND ENVIRONMENTAL RISK ASSESSMENT

Solutions for water pollution reduce health risks from vital industrial processes

Wastewater treatment technologies developed at the ECUST-based National Engineering Laboratory for High-concentration Refractory Organic Wastewater Treatment have provided solutions to water pollution caused by processes such as chemical engineering, petrochemicals, pharmaceutical production and pulp and paper-making.

Wastewaters from these operations are typically of large volume with a high concentration of refractory organics. If left untreated they pose serious environmental and health threats. To meet national environmental standards, regular physical or biological treatment techniques may be insufficient to remove pollutants.

Targeting wastewater from these heavily polluting industries, the ECUST team has improved physical separation and chemical oxidation-biochemical coupling technologies and developed an integrated approach, combining biological pre-treatment, chemical oxidation, hydrocyclone, and biological post-treatment technologies. The methods have been used successfully for dozens of engineering projects in processing high-concentration refractory organic wastewater at a relatively low cost.

ECUST's technologies have helped to lower the cost of wastewater treatment for chemical engineering projects.

Working on source control, the team has developed a system of fast and efficient simultaneous pollutant removal and recovery used by hundreds of companies.

Researchers at the laboratory have designed an intelligent sensor interface based on the physical and chemical properties of pollutants, which achieves fast and accurate water quality analysis and risk evaluation. They have also developed methods for separation of various mixed salts and preparation of mineral salts to achieve reutilization of wastewater containing salt. ■

ECUST RESEARCH HIGHLIGHTS

BIOENGINEERING

Bespoke bioreactors a catalyst for success

The State Key Laboratory of Bioreactor Engineering (SKLBE) at ECUST performs cutting-edge research at molecular and cellular levels. Meeting strategic needs in agriculture and medicine, it has made key achievements in four areas.

Rational regulation and scale-up of industrial fermentation processes: By developing online biosensors for real-time monitoring of cell physiological and metabolic characteristics, SKLBE has proposed the multi-level bioprocess optimization methodology and rational bioprocess scale-up strategy, which are successfully applied in industry for more than 30 products. In addition, SKLBE researchers have designed and manufactured many tailor-made bioreactors to support industrial innovation in biosciences.

Biocatalysis and molecular engineering: Focusing on structure-activity and reaction-transfer, SKLBE has genetically engineered new enzymes. It has also improved existing enzymes for efficient biocatalysis, upgrading bio-manufacturing technologies for high-value chemical products.

Metabolic monitoring and precise control of living cells: SKLBE has applied photosensitive molecules and improved light-based tools for more precise monitoring and control of biological functions.

Aquatic microbial vaccines: Using molecular, cellular and genetic approaches, SKLBE has resolved the virulence regulatory and interacting networks for aquatic pathogenic microbes and established strategies to design protective vaccines, greatly improving disease control in aquaculture.

Findings at SKLBE are widely applied in industry, and by promoting the development of biomedicine, chemical engineering, food supply and safety, and plant protection, it brings key economic and social benefits. SKLBE are recognized by several national awards for technological innovation and for science and technological progress. ■

PHARMACEUTICAL AND PESTICIDE STUDIES

Keeping it green in pesticides

In the past, developing new green pesticides has been expensive and demanded a long commercialization process. A team at ECUST, led by CAE academician Xuhong Qian, has developed a system covering the entire process of pesticide innovation, from target identification and lead compound discovery to the innovation and the commercialization of products.

They have established novel quantitative structure-activity relationship (QSAR) modelling for candidate screening and built active molecule and macromolecule models. They conducted target selection studies with a focus on ecological safety. Using a class of nicotine-like chemical compounds that are known as neonicotinoids, they have developed a series of novel pesticide products, which are applied in industry. The invention of cis-Configuration Nitromethylene Neonicotinoids compounds, such as cycloxaprid, earned a 20 million RMB royalty payment from a Chinese company. "Cycloxaprid has lower toxicity than imidacloprid, another neonicotinoid," said Qian. "It helps with reducing damage to bees."

The group also designed plant activators and a relevant fluorescent sensor method for pest control, which has led to infection resistance in plants with no environmental or health detriments. ■

Encoded for impact

ECUST Professor Yi Yang has applied synthetic biology and optogenetic approaches to invent genetically encoded fluorescent sensors for key metabolites. These sensors enable real-time monitoring of cell metabolism in single live cells and *in vivo*, providing opportunities for studying metabolism regulations in physiological and disease states, and shedding light on drug discovery.

Another ECUST professor, Jian Li, has led a team to develop strategies that repurpose old drugs. They found that naftifine, an antifungal drug typically used for treating athlete's foot, can fight a superbug by inhibiting a key enzyme. Their research identified a new target to overcome drug resistance, and led to a novel technology for antibacterial treatment, which is now licensed to a Chinese pharmaceutical company.

BIOMATERIALS

Moulding the future of bioactive materials

A team at ECUST has developed a series of novel *in situ* guided bone regeneration biomaterials that mimic the body's self-healing process.

Under Professor Changsheng Liu, the ECUST team successfully designed calcium phosphate cement (CPC), which is easily moulded, biologically compatible, and efficiently degradable. They systematically studied the *in vitro* and *in vivo* conversion processes of CPC, and how physicochemical properties of materials affect their biological performance. By manipulating these conversion processes, the researchers have converted once lifeless materials into living tissues.

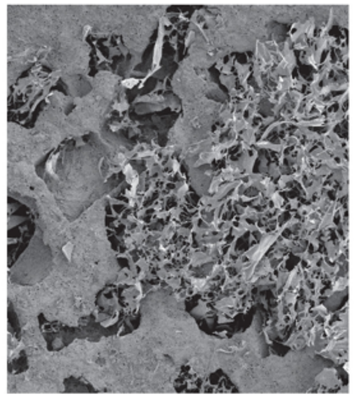
Based on these fundamental studies, the first Chinese-made CPC product was developed and widely used in orthopedics and stomatology in more than 500 hospitals nationwide, winning high acclaim for its excellent clinical performance. Given the great social and economic benefits it has brought, the research has earned the team national awards for science and technology progress and in natural sciences.

Recently, the group has been working on materiobiology, which looks into regulative cues of biomaterials to stimulate scalable behaviours in cells and organs. A combination of strategies are engaged for *in situ* regeneration.

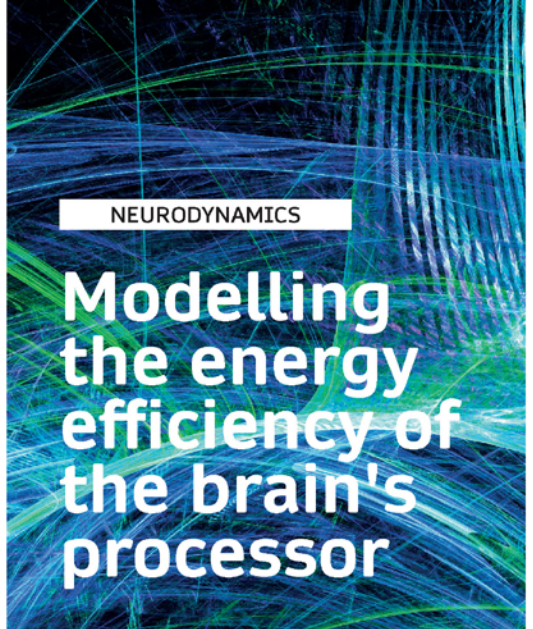
To enhance osteogenetic capacity further, the team used genetic engineering technology to prepare rhBMP-2, a notable cytokine that enhances bone formation and bone tissue reconstruction. This was further introduced into CPCs to produce a novel material, CPC/rhBMP-2. Approved for clinical use in 2013, CPC/rhBMP-2 is now used in more than 30 hospitals and has achieved excellent therapeutic efficacy.

The team's endeavours will undoubtedly continue to benefit the medical and healthcare industry at home and abroad. ■

The calcium phosphate cement (CPC) material designed by Liu's team is biologically compatible and injectable.



By introducing rhBMP-2 into CPC, ECUST researchers developed a novel material for bone regeneration.



NEURODYNAMICS

Modelling the energy efficiency of the brain's processor

ECUST researchers are leaders in neurodynamics, an emerging interdisciplinary field. By integrating molecular and cellular studies with investigation of neural networks, cognitive functions and behaviours, they have explored the brain's information processing and created computational models.

Led by Professor Rubin Wang, the team proposed a novel theory that links neural signal transmission in the cerebral cortex with its associated energy consumption. Wang used signal energy ratios to measure the energy efficiency of information coding in a network, which improves our understanding of the coding mechanism in the cerebral cortex. The team has also applied its neurodynamics research to the development of bipedal robots and treatments for neurodegenerative diseases, and have made progress in electroencephalography (EEG) analyses, olfactory network models, bioinformatics, and visual information processing. ■

Neutrino breakthrough

ECUST's theoretical physicist, Wei Liao, is a key player behind China's attempts to track ghostlike particles – neutrinos. He has been working on the Daya Bay Reactor Neutrino Experiment and the Jiangmen Underground Neutrino Observatory (JUNO). The former, aiming to precisely measure the mixing angle θ13, discovered the third mixing pattern of neutrino oscillation in 2012, shedding light on how electron neutrinos transform. In 2016, as a member of the project, Liao shared the Breakthrough Prize in Fundamental Physics with other collaborators.

ECUST's physics advantages are also demonstrated in its optics and photonics research. Led by Shangqing Gong, research on the quantum control of optical properties has explored new ways of using light to control atoms or molecules, which has implications for biomedicine.

ECUST RESEARCH HIGHLIGHTS

INFORMATION TECHNOLOGY

Smart manufacturing in the petrochemical industry

Influential research by an ECUST team has given rise to a series of patented technologies, which improve process control and optimization for sustainable development in the petrochemical industry.

Led by Professor Feng Qian, a CAE academician, the ECUST team has developed intelligent control and optimization solutions for ethylene plants, which are widely applied in the domestic ethylene industry and commands the highest market share in China. Their technologies for fast and accurate evaluation based on near-infrared spectroscopy, and for blending of refined oil are internationally advanced. The real-time blending optimization system offers long-term efficiency. The team has also made breakthroughs in optimal operation for purified terephthalic acid (PTA) plants, having substantially reduced energy consumption in the chemical fibre industry.

These technologies have been applied in dozens of large-scale industrial plants for oil refining and for ethylene cracking, PTA and polyethylene production, bringing economic and social benefit. They have also won numerous science and technology awards. This year, the project on smart optimal manufacturing in the petrochemical industry, led by Qian, has been selected into the Plan 111, a national programme to boost innovation by gathering top talents from around the world. This will further expand ECUST's collaboration with leading global academic institutions and enterprises, as well as integrate information and artificial intelligence technologies. ■

APC&RTO technologies of ECUST are applied at Sinopec & Petrochina (Pictured at Sinopec Zhenhai Refining & Chemical)

MECHANICAL ENGINEERING

Easing the pressure on the vessel industry

Technologies developed by ECUST researchers are applied in a monitoring and diagnostic system for high temperature and high pressure main steam pipeline.

Extreme conditions, such as high temperatures, high pressure, very low temperatures or complex erosion, shorten the life of the pressure-equipment that handles gases or liquids. ECUST researchers have developed technologies to improve their design, manufacture and safety, and to boost reliability.

Pressure equipment, such as vessels, piping and tanks, are vital in the petrochemical, chemical engineering, and the gas and power industries, and are often used in extreme conditions today. They tend to have extra-large diameters and capacity, requiring new designs to accommodate changes in failure modes and mechanisms.

After years of research, a team headed by Shan-Tung Tu, a professor at ECUST, has identified the failure modes and mechanisms of pressure-vessel steels under cryogenic-temperatures (-269 °C), high-temperatures (1000 °C), high-pressure (350 MPa) and complex loading conditions and corrosive environments. The design criteria they developed offer solutions to prevent brittle fractures at cryogenic temperatures and creep-fatigue failures at high temperatures, and enhance stability for vessels with extra-large diameters. They have also improved the design based on fitness for service evaluation and material selection in complex working environments.

The team has established an on-line monitoring and diagnostic analysis system for pressure systems based on the concept of total life-cycle risk management and advanced sensing technology. They have also developed technologies for damage identification and improved welding and repair techniques.

These technologies have greatly improved the capability of China's pressure-vessel industry. The software tools, databases and national technical standards developed by the team are also widely applied in the pressure-equipment industries, enhancing safety supervision and lifting China's pressure-vessel industry into a new era of design, and of manufacturing and maintenance. ■

传承 创新 服务 发展

华东理工大学 | 65周年校庆

EAST CHINA UNIVERSITY OF SCIENCE AND TECHNOLOGY