PART 3: Research in the natural sciences

The Natural Sciences Division

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The Natural Sciences Division comprises six colleges or institutes: the Institute for Advanced Studies (IAS), the School of Physics and Technology (SPT), the College of Chemistry and Molecular Sciences (CCMS), the College of Life Sciences (CLS), the School of Mathematics and Statistics (SMS), and the School of Resource and Environmental Sciences (SRES). A brief summary of this critical sector of Wuhan University follows.

I. The Institute for Advanced Studies

IAS was established in 2014 to enhance the natural sciences at Wuhan University. It has recruited high-energy and particle physicists, biologists, chemists, materials, and informatics scientists in five research centers with the aim of promoting interdisciplinary studies targeting critical scientific issues likely to have a profound near-term impact (Figure 1).

1. The Omics Center (TOC). Biology is a multifaceted discipline with methodologies that draw on chemistry, physics, computation, mathematics, and even engineering. IAS founded the TOC to create resources for studying genomics, transcriptomics, translatomics, proteomics, and metabolomics of both animals and plants, primarily in nonmodel organisms. The TOC is actively recruiting chemists to discover novel natural and synthetic small molecules for translational studies in biomedicine and agriculture.

2. The Nano-Catalysis Center (NCC). The NCC, directed by Aiwen Lei, aims to solve fundamental problems in chemistry, physics, materials, and energy research (Figure 2). The NCC team actively encourages interdisciplinary collaborations to facilitate innovation. Lei conceived a program whereby graduate students and postdoctoral fellows train for the required technical skills by rotating through different subgroups within the NCC as well as international laboratories. The team has worked diligently on photocatalysis, electrocatalysis, and activation of small molecules, such as CH_4, H_2O, CO_2, and N_2. Notably, they have achieved hydrogen evolution by an external, oxidant-free, oxidative cross-coupling reaction.

FIGURE 1. The new IAS building, which is near the main gate of Wuhan University and can house more than 60 laboratories.

FIGURE 2. Aiwen Lei, Nano-Catalysis Center (NCC) director, discusses oxidative cross-coupling reactions with his students.

3. The Quantum Materials Center (QMC). The QMC concentrates on condensed matter physics and material science. The goal of the center is to investigate physical mechanisms of exotic properties in quantum systems for the design and development of novel quantum materials with superior electric, optical, acoustical, and thermal properties that can be applied in energy and electronic devices. Specific areas of focus include light–matter interactions, correlated electronic systems, nanomaterials and nanodevices, topological phases and related phenomena, quantum behaviors of low-dimensional systems, thin films, and heterostructures. The QMC also serves as a facilitative platform to provide chemists, biologists, and material scientists with various experimental and theoretical approaches for investigating subjects such as soft matter, organic material, and biomaterials.

4. The Center for Precision Synthesis (CPS). The CPS is building a competitive research team comprising outstanding scholars and young talents from China and overseas. The team is poised to achieve groundbreaking innovations at the frontiers of synthetic chemistry. The research program focuses on the

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development of conceptually new catalytic methods that allow for more efficient and cost-effective "green" synthesis of pharmaceuticals, agrochemicals, energy, and functional materials.

5. The Wuhan Photon Source (WHPS). The WHPS is set to open its doors in the early 2020s. It will be led by its current and founding dean, **Yuxian Zhu,** and will be one of the key interdisciplinary platforms at IAS and Wuhan University. Zhu, a fellow of the Chinese Academy of Sciences (CAS), is internationally renowned for his contributions to basic cotton research, especially in genomics and genetics (Figure 3). The WHPS aims to be the first world-class, medium-energy synchrotron radiation source in China that uses fourth-generation technologies for achieving high brightness, high resolution, high coherence, and low emittance (Figure 4). The WHPS is particularly keen to promote scientific and technological innovation, education reform, and industrial upgrades in the central and western regions of China.

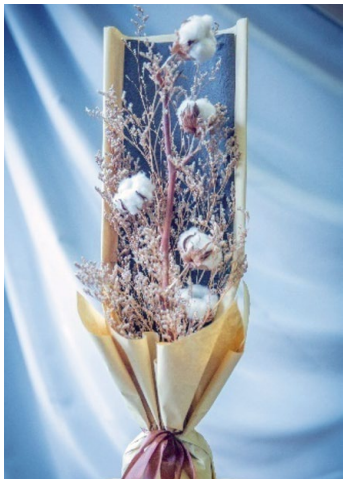

FIGURE 3. A cotton "flower" bouquet that Yuxian Zhu, founding director of the Wuhan Photon Source (WHPS), keeps in his office. An ex-student sent it to him for his 60th birthday party a few years ago. Though cotton is not a flower, its Chinese translation, *mianhua*, sounds like the Chinese words *baihehua* (for lily) and *meiguihua* (for rose).

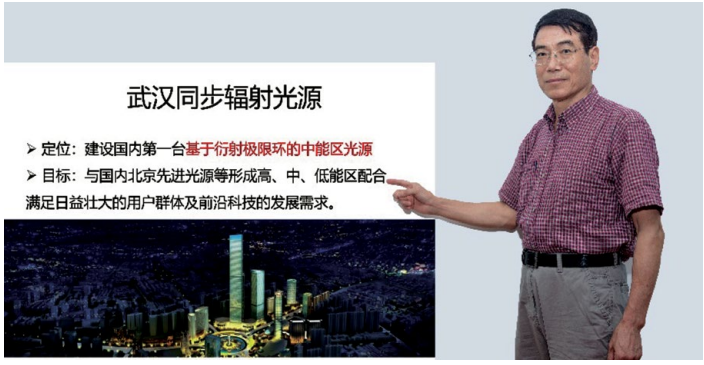

FIGURE 4. Yuxian Zhu reporting on the progress of the Wuhan Photon Source (WHPS).

FIGURE 5. Dean Hongxing Xu (left) and Deputy Dean Jiangbo Wang (right), discussing the future development of the School of Physics and Technology (SPT).

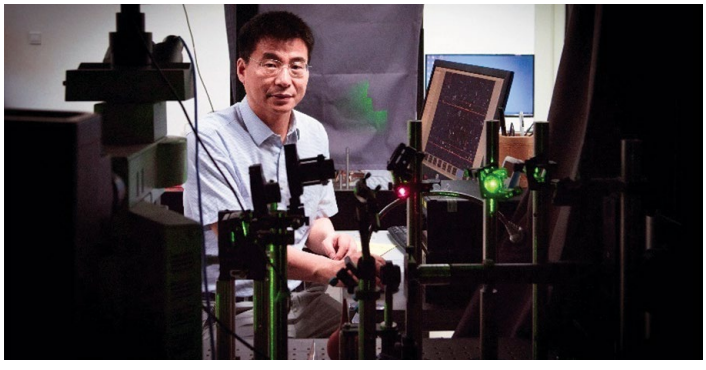

FIGURE 6. Hongxing Xu doing experiments on a Raman microscope, exploiting the electromagnetic enhancement in plasmonic nanogaps.

II. The School of Physics and Technology

Physics at Wuhan University traces back to 1893, when the discipline of *gezhi*, or natural sciences, was founded at the Ziqiang Institute. Currently, physics at Wuhan University is ranked in the top 1% among similar institutional departments in the world by the Essential Science Indicators (ESI) international ranking system. The School of Physics and Technology (SPT) consists of the Department of Physics, the Department of Materials Physics, the Department of Microelectronics, and a national experimental teaching demonstration center. The SPT focuses on six major areas: theoretical physics, condensed matter physics, optics, radio physics, particle physics, and nuclear physics. Minor working groups also conduct research in acoustics, atomic and molecular physics, computational physics, semiconductor physics, and nanoscience and nanotechnology. The SPT houses the Hubei Province Key Laboratory of Nuclear Solid Physics and the Ministry of Education (MOE) Key Laboratory of Artificial Microstructures. Among the current 150 faculty members, one is a member of the CAS, four are MOE Changjiang Scholars, four are National Natural Science Foundation Distinguished Young Scholars, and 11 are young 1,000 Talents Scholars supported by the national 1,000 Youth Talents Program. The SPT publishes about 200 papers per year in international journals, a number that substantially increases each year.

The SPT has established cooperative relationships with research institutes in more than 40 countries and holds several international conferences and workshops annually. Moreover, over 50 faculty members and students are invited to present at international conferences each year.

Hongxing Xu, the dean of the SPT, has published more than 190 papers (Figure 5). He has over 13,000 cumulative citations and an h-index of 56 in the Web of Science. Xu was associate editor of the journals *Nanoscale* and *Optics Express*. He has given more 70 invited presentations at international conferences and organized more than 20 international conferences and workshops. Xu was elected to CAS in 2017.

He has made his most notable contributions in the following two areas of nanoscience:

1. Single-molecule surface-enhanced Raman spectroscopy (SERS) and the plasmonic nanogap effect: Xu has demonstrated both experimentally and theoretically that in a metal nanoparticle dimer, the surface plasmons of each of two nanoparticles can couple across the

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FIGURE 7. The College of Chemistry and Molecular Sciences building.

nanogap between them, confining the electromagnetic field into a tiny volume and resulting in an enormous enhancement of electromagnetism (Figure 6). One representative publication from this work has been cited more than 1,700 times (*1*) and another, which was honored by the journal *Physical Review E* as a milestone paper, was cited more than 1,200 times (*2*).

2. Surface-plasmon propagation in metal nanowires and networks: Xu has pioneered this critical area of plasmonics, performing the most systematic studies to date. He discovered the highly tuneable beating of surface plasmon modes, which is the basis for manipulating light propagation in nanowaveguides and nanocircuits. He also discovered the chiral propagation of surface plasmons in metal nanowires and the strong spin–orbit interaction of light in plasmonic nanostructures and nanocircuits. These studies have enabled the miniaturization and high-density integration of optical devices at the nanoscale, and form the basis for nanophotonic circuit development.

III. An Overview of the College of Chemistry and Molecular Sciences

The College of Chemistry and Molecular Sciences (CCMS) is one of the first chemistry institutions in China, dating back to a chemistry school founded by Governor Zhidong Zhang in 1893. When National Wuhan University was formed in 1928, the chemistry school became the Department of Chemistry in the Science and Engineering College, with Professor Xinggong Wang as its first departmental chair. Then in August 2000, Wuhan University, the Wuhan University of Hydraulic and Electrical Engineering, the Wuhan Technical University of Surveying and Mapping, and Hubei Medical University amalgamated to form what is now Wuhan University. The college was reorganized and renamed CCMS in January 2001 (Figure 7).

The department has trained and advanced numerous chemistry professionals and eminent entrepreneurs. At least 15 academicians at CAS and the Chinese Academy of Engineering have either graduated from or taught at CCMS. The college is home to a state key discipline in analytical chemistry, and provincial key disciplines in physical chemistry, organic chemistry, and polymer chemistry.

Since 2013, chemistry at Wuhan University has been ranked in the top 0.1% by ESI, and in 2017 was selected by the MOE as a key discipline in the national "Plan for the Construction of World-Class Universities and First-Class Disciplines."

FIGURE 8. Chuansin Cha, renowned electrochemist and CCMS academician.

Chuansin Cha is a fellow of CAS and an outstanding figure among the earlier generation of electrochemists in China (Figure 8). His research interests include the adsorption of surfactants on electrode surfaces, electrochemical catalysis, semiconductor electrochemistry, bioelectrochemistry, fuel cells, and chemical power sources. Cha's monograph *Introduction to the Kinetics of Electrode Processes* is one of the most influential academic works and postgraduate teaching materials in the field of electrochemistry in China.

Renxi Zhuo is a fellow of CAS. He has concentrated his research on biomedical and biodegradable polymers that can be used in biomedical applications for the controlled release of drugs and gene delivery (Figure 9). Zhuo has published more than 600 journal articles and received many honors recognizing his research achievements, including the National Natural Science Award, the National Science Congress Award, and the MOE's Natural Science Award.

Lina Zhang is a fellow of CAS and associate editor for *ACS Sustainable Chemistry & Engineering* (Figure 10). *Chemistry World* has named her "China's green chemistry vanguard." She has devoted her career to studying the green conversion of natural polymers, pioneering new technologies for dissolving intransigent macromolecules, such as cellulose, chitin, and polyaniline, in urea-based alkaline aqueous solutions with cooling, and has proposed new dissolution mechanisms for low temperatures. In 2011, she was the first Chinese scientist to receive the Anselme Payen Award from the American Chemical Society. Zhang has published 16 books and

FIGURE 9. Renxi Zhuo, CCMS academician, is a preeminent expert in biomedical and biodegradable polymers.

FIGURE 10. Lina Zhang, China's foremost authority on green chemistry, the design of chemical products and processes that reduce or eliminate pollution.

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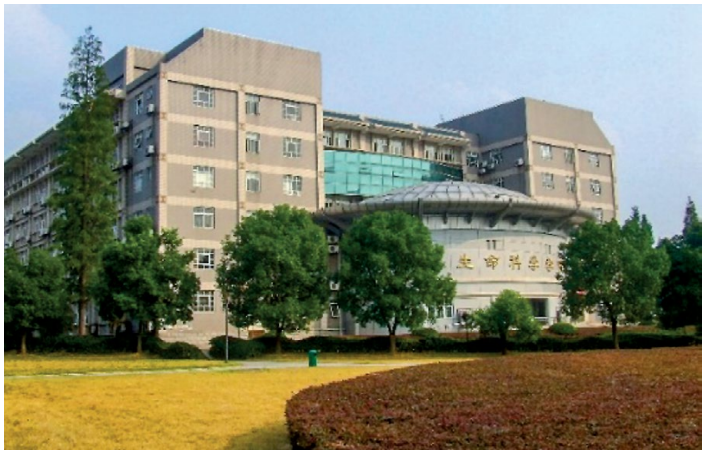

FIGURE 11. The College of Life Sciences (CLS) building, which is located at the center of the natural science complex of Wuhan University, and hosts more than 80 laboratories working on almost all aspects of biology.

FIGURE 12. The famous Liangzi Lake shoreline. CLS has a National Field Station there that is at the forefront of restoring the health of lake ecosystems.

nearly 600 papers in international journals; her work has been cited over 18,000 times.

IV. The College of Life Sciences

The College of Life Sciences (CLS) at Wuhan University is one of China's earliest higher education institutions dedicated to biological science. Its history dates back to 1893, when it was called the School of "*Gezhi*" ("the study of natural phenomena") (Figure 11). The current CLS consists of 109 faculty with diverse research interests, studying organisms ranging from viruses, bacteria, and yeast to plants, animals, and humans, and addressing questions spanning from molecules to cells, and from organisms to ecosystems. Among the CLS's faculty members, three are members of the Chinese National Academy of Sciences, nine are MOE Yangtze River Scholars, and 10 are Chinese National Science Foundation Distinguished Young Scholars. Several faculty members serve on editorial boards and national grant advisory boards.

The CLS currently houses the State Key Laboratories for Virology and Hybrid Rice. Its National Field Station for the Freshwater Ecosystem at Liangzi Lake is at the forefront of restoring aquatic vegetation in degraded lakes in China, and has made remarkable progress in improving the health of lake ecosystems (Figure 12). The CLS comprises seven academic departments in biochemistry, cell biology, ecology, genetics, microbiology, plant science, and virology. It also manages the China Center for Type Culture Collection, and operates a well-equipped instrument core facility, an animal facility, and a greenhouse.

FIGURE 13. Huijiang Zhao, dean of the School of Mathematics and Statistics, in a discussion with young scholars Shuyang Dai, Shangkun Weng, Zhijian Yang, Wanke Yin, and Jin Zhou.

Over the past five years, CLS research groups have published around 900 research articles in Science Citation Index journals, with more than 60 in leading scientific journals, such as *Science*, *Cell*, *Immunity*, *Cell Host & Microbe*, *Molecular Cell*, *Developmental Cell*, and *Proceedings of the National Academy of Sciences of the United States of America*.

The CLS undergraduate program enrolls approximately 150 students per year and teaches a curriculum emphasizing both fundamental knowledge and experimental technologies. The CLS undergraduate teaching facility serves as a National Biology Experimental Teaching and Demonstration Center. The CLS graduate program currently enrolls around 900 M.S. and Ph.D. students. The CLS website (www.bio.whu.edu.cn) provides more in-depth information about the college, including highlights of each faculty member and their laboratory.

V. The School of Mathematics and Statistics

Wuhan University's School of Mathematics and Statistics (SMS) originated from the "*Suanxue*" (mathematics) school of Ziqiang College, which was established in 1893. The faculty's research interests represent almost all core areas of modern mathematics, with a particular focus on partial differential equations, complex analysis and complex geometry, probability theory, and stochastic analysis as well as applied and computational mathematics (Figure 13).

The partial differential equations research group at the SMS is investigating several questions at the vanguard of this field: the theory of microlocal analysis in partial differential equations, spectral analysis of degenerate elliptic operators, the well-posedness theory

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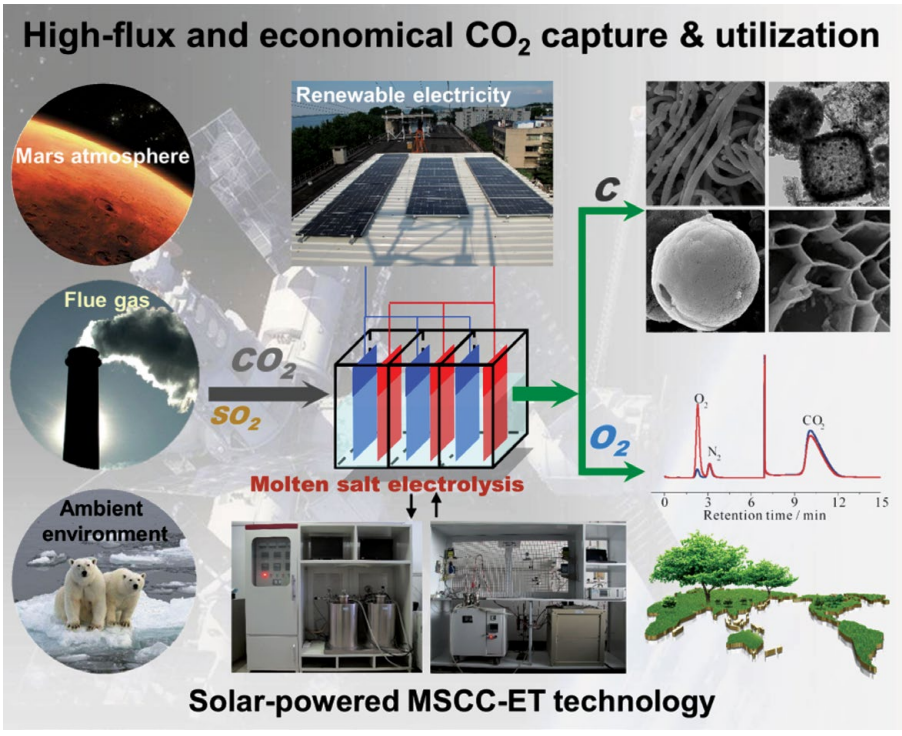

FIGURE 14. A research team led by Dihua Wang in the School of Resource and Environmental Sciences is developing a novel approach to effectively convert CO_2 into value-added carbonaceous materials and oxygen gas (O_2) through the so-called "molten salt CO_2 capture and electrochemical transformation" (MSCC-ET) process. The process, driven by renewable electricity, can capture and utilize CO_2 in a high-flux, economically and environmentally friendly way, making it a promising technology for large-scale carbon sequestration and utilization.

of the Prandtl equation in Sobolev and Gevrey spaces, the boundary layer and incompressible Navier–Stokes–Fourier limit of the Boltzmann equation in bounded domains, global well-posedness of complex kinetic equations in the perturbative framework, the De Giorgi conjecture, and the classification of finite Morse index solutions to the Allen–Cahn equation.

The complex variables and complex geometry group is primarily interested in the geometric aspects of several complex variables. They have made breakthroughs in proper holomorphic mappings between bounded symmetric domains, equivalence and complex Plateau problems on codimension-two real submanifolds embedded in complex spaces, deformation problems in complex manifolds, and the Ohsawa–Takegoshi extension theorem for pseudoconvex domains as well as embedding theorems on Cauchy–Riemann (CR) manifolds.

The probability theory and stochastic analysis team focuses on singular stochastic differential equations, stochastic analysis of nonlocal operators, large deviations in Markov processes, and statistics.

The applied and computational mathematics group mainly studies multiscale modeling, simulation and analysis in materials science, ill-posed mathematical problems and their analysis and computation, problems in computational fluid mechanics and their applications, numerical solutions of partial differential equations, finite element methods, intelligent computation, and biological computation. The group has made significant progress in modeling, the algorithms and analysis of materials problems, regularization theory, calculations of ill-posed problems, and computational biology.

VI. The School of Resource and Environmental Sciences

The School of Resource and Environmental Sciences (SRES) is an intellectually vibrant, research-intensive school that focuses on geography and environmental science and engineering. The school comprises the Department of Geoinformation Science and Cartography (DGSC), the Department of Environmental Science and Engineering (DESE), and the Department of Geography and Land Resource Management (DGLRM). SRES offers seven bachelor's, seven Master's, and eight doctoral degree programs, and presently enrolls approximately 1,200 undergraduate students and 700 graduate students, including Ph.D. students. The school enjoys tremendous faculty strength with 119 full-time members. According to the *QS World University Rankings* for 2018, Wuhan's geography and environmental science disciplines ranked 150th and 251st in the world, respectively.

The geography department houses several vital research and teaching platforms: the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing; the MOE Key Laboratory of Geographic Information Systems; and the MOE International United Laboratory of Geo-Information Science (GIS). DGSC and DGLRM research is strong in GIS principles and applications, cartography and geovisualization, spatial analysis and data mining, land use and land-cover change, economic geography and regional planning, and complex geographical computation and aquatic ecosystems. Recently, the department began advancing cutting-edge research areas such as coupled human–nature system analysis, health geography, and smart cities. It is recognized worldwide for its competitive teaching and research in geospatial technology.

DESE is a central training center for talents in environmental science and engineering in China. Its signature research areas include the behavior and effects of chemical pollutants, ecotoxicology and environmental biology, environmental pollution control and restoration, environmental materials and resource efficiency, construction of a sky–earth combined platform for environmental observation and big-data processing, regional environment and risk management, mine safety, and environmental engineering. DESE has been nationally and internationally recognized for its work in the environmental field (Figure 14).

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