香港城市大學
City University of Hong Kong

CityU RESEARCH

Foreword from President

As one of the most rapidly rising universities in the world, City University of Hong Kong (CityU) is firmly maintaining its reputation as an innovative hub for addressing global issues and empowering positive change through world-class research and professional education. Our upward trend in a range of ranking exercises for higher education reflects how our achievements have been recognised globally.

To further establish our identity as a world-class university, we have newly launched a vision for the future development of CityU. Our *Strategic Plan 2020–2025: World-class Research and Education* serves as a roadmap for raising CityU's levels of excellence in both research and education and in bringing benefits to the world. In particular, it identifies five interdisciplinary strategic themes – One Health, Digital Society, Smart City, Matter, and Brain – and a set of action plans.

In a highly interconnected and complex world, a single discipline is often inadequate for seeking solutions to pressing global problems. That's why at CityU, in order to contribute to creating a better world, we foster interdisciplinary research and promote diversity in a variety of methodological approaches.

For example, around 70% of emerging infectious diseases among humans are closely related to animals. This is important to note because the current Covid-19 pandemic has emphasised strongly the importance of the One Health concept. Recognising the gap in knowledge, CityU founded the first world-class veterinary school in Asia, now named the Jockey Club College of Veterinary Medicine and Life Sciences, through which we promote scientific research into food safety and zoonotic diseases.

In addition, the establishment of the Hong Kong Institute for Data Science highlights our vision and effort in bringing together faculty members and researchers from across disciplines to develop innovative solutions in a data-driven world. The recent launch of the state-of-the-art High-Performance Computing facility will also boost our researchers' ability to make scientific breakthroughs across the disciplines.

Here we are proud to present *CityU RESEARCH*, which features insights into the groundbreaking discoveries and world-class research undertaken by our outstanding faculty members and researchers under the five strategic themes mentioned above.

By pursuing more impactful research, we will continuously contribute to making the world a better place.

Professor Way Kuo
President and University Distinguished Professor
City University of Hong Kong
February 2021

Introduction from Vice-President (Research and Technology)

While Covid-19 has greatly disrupted our daily lives, it has vividly demonstrated how interdisciplinary research is urgently required if we are to solve the major problems facing the world today. In *CityU RESEARCH*, we are pleased to share with you recent discoveries and innovations by both faculty members and students. Their work highlights our capacity to engage in research that makes a genuine difference to people's lives. Under the five strategic research themes, i.e. One Health, Digital Society, Smart City, Matter, and Brain, as identified in our most recent Strategic Plan, this collection spotlights our groundbreaking work.

One Health features research related to solving health-related issues, from preventing future pandemics, facilitating healthcare provision and drug development with new technologies, to protecting the marine ecological environment.

In Digital Society, we read about technological advancement for data and image analysis, fintech solutions and understanding political polarisation as well as how creative media can be merged with science, design, fintech, poetry and ethics to help us reflect on human values.

Smart City meets with teams who work on developing information technology in 6G communications and data-driven management for railway systems. We also learn about a range of sustainable innovations in energy.

Matter details breakthroughs in designing high-performance alloys, additive manufacturing and sensing technology as well as deformation behaviour in complex materials via neutron scattering.

Brain highlights the time and effort neuroscientists and biomedical engineers are investing in developing effective diagnostic tools and treatments for tackling neurodegenerative diseases.

CityU is very proud that its faculty members are committed to advancing the frontiers of knowledge by undertaking cutting-edge research. A dedicated section in this publication features scholars who are recognised for their top-level research.

In 2021, I will be working with my colleagues to support all our faculty members in their quest to pursue research excellence. I hope you enjoy discovering more about research endeavours at CityU, and I look forward to exploring collaboration opportunities with universities and research institutes around the world so that we can contribute to improving societies we live in.

Professor Michael Yang Mengsu
Vice-President
(Research and Technology)

Contents

ONE HEALTH

Developing and integrating interdisciplinary, problem-based research collaboration and communication in all aspects of health-related issues, particularly those involving the complex interactions and inter-dependencies of animal and human populations and the environment.

Professor Dirk Pfeiffer and Professor Sophie St-Hilaire

One Health Approach to Prevent Another Pandemic

While the world is still trying to cope with the Covid-19 pandemic, **Professor Dirk Pfeiffer**, Chow Tak Fung Chair Professor of One Health at the Jockey Club College of Veterinary Medicine and Life Sciences (JCC) and Director of the Centre for Applied One Health Research and Policy Advice (OHRP), warned that the next pandemic could be even worse. The whole world must learn the lessons from the current pandemic, and one of them is that we need to adopt the "One Health" approach to better manage and ideally prevent such pandemics, and to deal more effectively with other global human, animal and environmental health issues, he said.

"One Health is not just about medics working together with vets and virologists. It needs to be based on a truly interdisciplinary approach to research and policy development, which means generating integrated knowledge by bringing together different scientific disciplines, including the social sciences," emphasised Professor Pfeiffer, who is a veterinary epidemiologist and has provided scientific expertise to international organisations and governments, including the World Organisation for Animal Health and the Food and Agriculture Organization of the United Nations. "There are many ways to control a pandemic, but a key driver is human behaviour," he said.

Wet market issues: social science perspective

He mentioned wet markets as an example. Wet markets with different livestock and poultry species being freshly slaughtered and sold are regarded as a hotbed for new infectious diseases associated with animal-human transmission, he said. These include severe acute respiratory syndrome (SARS), avian flu (H5N1 and H7N9) and the current Covid-19. "But why do people still prefer to buy raw meat from wet markets? Is it based on a traditional cultural perception or fresh meat tasting better? How can you manage changes in people's behaviour? To understand this better we need to adopt social science approaches," he explained.

With the establishment of the JCC and the OHRP, Professor Pfeiffer believes CityU can contribute by improving our understanding of what the drivers of infectious disease emergence are and recommending interventions using the "One Health" approach to reduce the risk of future pandemics.

AMR: another global threat

Antimicrobial resistance (AMR) is another pressing issue that he thinks needs to be addressed using the "One Health" approach. The World Health Organization declared AMR one of the top 10 global public health threats facing humanity. The misuse and overuse of antimicrobials, as well as poor infection and disease prevention and control in healthcare facilities and livestock production, are some of the main drivers in the development of AMR.

"For both humans and animals, antimicrobials should be used only for treating clearly identified bacterial diseases, but not for prevention," explained Professor Pfeiffer. "Otherwise, as drug-resistant pathogens continue to spread, we will have more and more infections that are untreatable using currently available antibiotics. And it is unlikely that new antibiotics will become available in the short to medium term."

With support from the Sustainable Agricultural Development Fund, Professor Pfeiffer is leading two research projects to improve pig and poultry health and production in Hong Kong. One of the key missions of these projects is to help local pig and poultry farmers reduce the use of antimicrobial drugs. The team works with farmers to develop an understanding of each farm's drug usage and the antimicrobial resistance level, so that the team's veterinarians can prescribe effective medications for pigs and poultry, when such treatment is required.

Providing clinical services for pig, poultry and fish farms

The pig and poultry veterinary teams provide professional clinical services for farms and take samples of serology from pigs and poultry during their regular visits. By producing reports on the productivity of each farm and the level of different infectious diseases, farmers can make strategic decisions about health and production management. The veterinary teams provide tailor-made advice to farmers in these areas, which can include more effective control of temperature and ventilation, and strengthen farm biosecurity to prevent diseases and other pests from entering the farms.

"Our teams are dedicated to improving farmers' biosecurity awareness and strengthening their animal husbandry and general farm management knowledge so that we can reduce their reliance on antimicrobials," he said. "While we realise that it will take time to change mind-sets and behaviours, our collaboration with farmers during the past one and a half years has shown us that it will be possible to develop sustainable pig and poultry farming in Hong Kong without having to compromise the health of humans, animals or the ecosystem."

In addition, **Professor Sophie St-Hilaire**, Professor of Aquatic Animal Health at the JCC and a member of the OHRP, is leading a project to provide veterinary diagnostic and disease-prevention services for marine fish and pond fish culture operators in Hong Kong, with support from the Sustainable Fisheries Development Fund (SFDF). The fish team has established a pharmacy for fish farmers to purchase medications for fish under the supervision of the team's veterinarians. They evaluated the purity of antibiotics commonly used in fish farms in Asia and found emamectin benzoate, an insecticide, can be an effective alternative treatment for reducing the level of sea lice in fish farms in Hong Kong.

With another round of funding from SFDF, they are continuing to improve the sustainability of the Hong Kong aquaculture industry by increasing the fish health veterinary capacity regionally, preventing infectious disease spread, and addressing key limitations the industry facing through applied research and outreach.

Major Awards

Professor Dirk Pfeiffer

- The President's Award 2019, CityU
- Roger Morris Award for Outstanding Contribution to Veterinary Epidemiology and Economics 2018

Key Projects

Professor Dirk Pfeiffer

- Sustainable Agricultural Development Fund:
  - Improving Pig Health and Production in Hong Kong
  - Improving Poultry Health and Production in Hong Kong
- Research Matching Grant Scheme: Applied Food Safety and Quality Research

Professor Sophie St-Hilaire

- Sustainable Fisheries Development Fund:
  - Improving Fish Health and Production in Hong Kong
  - Improving Fish Health and Production in Hong Kong in 2020

Selected Publications

- Vergne, T., Guinat, C. & **Pfeiffer, D.U.** 2020, "Undetected circulation of African swine fever in wild boar, Asia", *Emerging Infectious Diseases*, vol. 26, no. 10.
- Willgert, K., Meyer, A., Tung, D.X., Thu, N.V., Long, P.T., Newman, S., Thuy, N.T.T., Padungtod, P., Fournié, G., **Pfeiffer, D.U.** & Vergne, T. 2020, "Transmission of highly pathogenic avian influenza in the nomadic free-grazing duck production system in Viet Nam", *Scientific Reports*, vol. 10, no. 1.
- Dixon, L.K., Stahl, K., Jori, F., Vial, L. & **Pfeiffer, D.U.** 2020, "African swine fever epidemiology and control", *Annual Review of Animal Biosciences*, vol. 8, pp. 221-246.
- Wada, M., Lam, C.T., Rosanowski, S., Patanasatienkul, T., Price, D. & **St-Hilaire, S.** 2020, "Development of simulation models for transmission of salmonid rickettsial septicaemia between salt water fish farms in Chile", *Transboundary and Emerging Diseases*.
- Leung, K.C., Huang, Q., **St-Hilaire, S.**, Liu, H., Zheng, X., Cheung, K.B. & Zwetsloot, I.M. 2020, "Fraudulent antibiotic products on the market for aquaculture use", *Preventive Veterinary Medicine*, vol. 181.
- Vergne, T., Meyer, A., Long, P.T., Elkholly, D.A., Inui, K., Padungtod, P., Newman, S.H., Fournié, G. & **Pfeiffer, D.U.** 2019, "Optimising the detectability of H5N1 and H5N6 highly pathogenic avian influenza viruses in Vietnamese live-bird markets", *Scientific Reports*, vol. 9, no. 1.
- Høg, E., Fournié, G., Hoque, M.A., Mahmud, R., **Pfeiffer, D.U.** & Barnett, T. 2019, "Competing biosecurity and risk rationalities in the Chittagong poultry commodity chain, Bangladesh", *BioSocieties*, vol. 14, no. 3, pp. 368-392.
- Kim, Y., Biswas, P.K., Giasuddin, M., Hasan, M., Mahmud, R., Chang, Y.-., Essen, S., Samad, M.A., Lewis, N.S., Brown, I.H., Moyen, N., Hoque, M.A., Debnath, N.C., **Pfeiffer, D.U.** & Fournié, G. 2018, "Prevalence of avian influenza A(H5) and A(H9) viruses in live bird markets, Bangladesh", *Emerging Infectious Diseases*, vol. 24, no. 12, pp. 2309-2316.

Building a Quality, Efficiency-driven Healthcare Delivery System

The CityU research team provides infection-control education and distributes anti-epidemic items, such as masks and hand sanitizers, to older people with poor social support, who were identified during the team's comprehensive geriatric assessment in collaboration with NGOs.

Given the rapidly ageing population and an overstretched public healthcare system in Hong Kong, a CityU-led interdisciplinary team comprised of experts from various institutions has offered a new perspective on healthcare system monitoring and management in a big data environment.

The Theme-based Research Scheme (TRS) project, led by **Professor Frank Chen Youhua**, Dean of the College of Business and Chair Professor of Management Sciences at CityU, was undertaken by a strong collaborative team made up of researchers from CityU's Department of Management Sciences, School of Data Science and College of Engineering, as well as the Jockey Club School of Public Health and Primary Care (JCSPHPC) of the Chinese University of Hong Kong (CUHK).

To develop a quality, efficiency-driven healthcare delivery system in Hong Kong, they focused on two areas: improving public hospital resources management to maximise limited resources and cope with increasing demand; and providing better integrated community elderly care to enhance their self-management skills and minimise the need for hospitalisation.

Healthcare data analytics and AI

With the use of data analytics and artificial intelligence (AI) technologies, the team processed vast amounts of data collected from healthcare delivery and management systems. They achieved tremendous results, including over 115 articles published in reputable, refereed journals and the following research output:

i) identified target elderly patient segments for the most effective and affordable post-discharge care portfolios in the community;

ii) developed machine-learning models to predict the onset of critical chronic diseases, including heart failure, mitral regurgitation, acute myocardial infarction and dementia, and to conduct suicide and depression risk assessments;

iii) developed advanced machine-learning models to predict future high-cost patients, such as those with chronic obstructive pulmonary disease or infectious diseases;

iv) applied algorithms for predicting the re-hospitalisation of discharged patients to reduce emergency department admissions, compare public-private partnership (PPP) subsidy schemes to reduce waiting time for public healthcare services, and analyse and allocate hospital resources;

v) designed a personalised telehealth monitoring system for community-dwelling older people, utilising sensor technology to monitor their health, including general wellness, blood pressure, gait and balance, for comprehensive evaluation of health conditions and fall risk prediction; and

vi) proposed a general framework for health system monitoring and management, covering continuous surveillance, analysis, and interpretation of related data.

The AI and data analytics tools developed in the project can have an additional social impact. For instance, by applying their newly developed algorithms to the Hong Kong-wide Electronic Health Records, made accessible by the Hospital Authority Data Collaboration Lab, the team was able to characterise district-specific profiles of high-risk residents and their secondary and tertiary prevention needs. With further development, these tools can be used for service planning for upcoming District Health Centres in Hong Kong. Also, the CityU team, led by **Professor David Li Yanzhi**, has been commissioned by the Hospital Authority to prepare the planning and provision of patient transport services to cope with service demand in the next 10 years.

"The completion of the TRS project is just the start of a new phase of healthcare management research in Hong Kong," said Professor Chen. "With these AI-driven service innovations for community care, we can help expand the capacity of our primary care resources and better utilise them to provide coordinated care for older people and deploy community nurses in the neighbourhood."

Homecare to promote ageing with dignity

A team comprising faculty members from the College of Business and the JCSPHPC is currently working towards transforming the existing ecology of institutional elderly care and centre-based health management to the actualisation of ageing-in-place with sufficient support from quality homecare, to fulfil the desire of older people to live at home rather than in a nursing home.

Through piloting a world-renowned innovative community nursing model - *Buurtzorg* - in Hong Kong, the team led by CityU is exploring a PPP home-based care scheme prototype in collaboration with local non-governmental organisations (NGOs) and an acute hospital, with the introduction of self-steering nursing teams and care coordinators, who will be equipped with case management skills and health-coaching qualifications.

The localised model will be tech-enabled, with an IT platform for care coordination and integration, and portable and mobile app-based solutions to facilitate home-based care, such as telemedicine and an electronic pillbox.

"Our ultimate goal is to develop a comprehensive solution that can provide sustainable and affordable holistic home-based care to help individual older people live with dignity, despite the gradual deterioration of their body functions," said Professor Chen. He added that with modifications, their AI and data analytics tools could be applied outside Hong Kong.

Key Projects

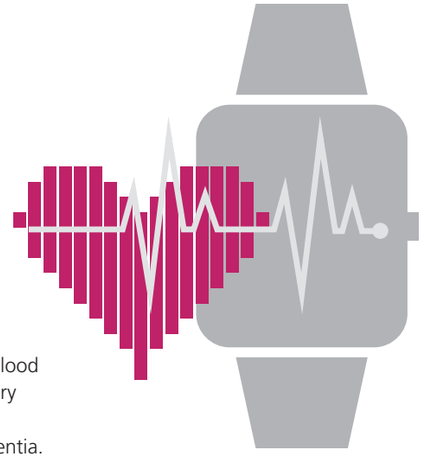
- Theme-based Research Scheme: Delivering 21st Century Healthcare in Hong Kong – Building a Quality-and-Efficiency Driven System
- BOCHK Centenary Charity Programme: HomAge: Home-based Aging for Transformative Community Care
- Public Policy Research Funding Scheme: Development of a Longitudinal Database on Adult Development and Aging

Co-Principal Investigators and collaborators from CityU and CUHK: (front row, from second left) Professor Yan Houmin, Professor Fung Hong (advisor, CUHK), Professor Frank Chen Youhua and Professor Tsui Kwok-leung from CityU; (second row, second right) Professor Yeoh Eng-kiong and (third row, second right) Professor Eliza Wong Lai-yi from CUHK.

Selected Publications

- Lin, S., **Zhang, Q.**, **Chen, F.**, Luo, L., Chen, L. & Zhang, W. 2019, "Smooth Bayesian network model for the prediction of future high-cost patients with COPD", *International Journal of Medical Informatics*, vol. 126, pp. 147-155.
- Zhou, J., Wang, X., Lee, S., Wu, W.K.K., Cheung, B.M.Y., **Zhang, Q.** & Tse, G., 2020, "Proton pump inhibitor or famotidine use and severe COVID-19 disease: A propensity score-matched territory-wide study", *Gut*, *(in press)*.
- Wang, H., Zhao, Y., Yu, L., Liu, J., Zwetsloot, I.M., Cabrera, J. & **Tsui, K.L.** 2020, "A personalized health monitoring system for community-dwelling elderly people in Hong Kong: Design, implementation, and evaluation study", *Journal of Medical Internet Research*, vol. 22, no. 9.
- **Tsui, K.L.**, **Zhao, Y.** & Wang, D. 2019, "Big data opportunities: System health monitoring and management", *IEEE Access*, vol. 7, pp. 68853-68867.
- **Xu, Z.**, **Zhang, Q.**, Li, W., Li, M. & Yip, P.S.F. 2019, "Individualized prediction of depressive disorder in the elderly: A multitask deep learning approach", *International Journal of Medical Informatics*, vol. 132.
- **Zhu, H.**, **Chen, Y.**, **Leung, E.** & **Liu, X.** 2018, "Outpatient appointment scheduling with unpunctual patients", *International Journal of Production Research*, vol. 56, no. 5, pp. 1982-2002.

Health Technology Ecosystem to Tackle Cardiovascular Diseases



Cardiovascular disease (CVD) is the world's leading killer. To address this health challenge, **Professor Zhang Yuanting**, Chair Professor of Biomedical Engineering at CityU, is leading a health engineering team to develop ground-breaking health technologies, from wearable sensing devices to artificial-intelligence (AI)-based early diagnostic and monitoring systems. His long-term goal is to establish an innovative health technology system for effective disease prevention and therapy in Hong Kong and beyond.

According to the World Health Organization, cardiovascular diseases, including strokes, are the number one cause of death globally, claiming an estimated 17.9 million lives every year.

There are a variety of heart and blood vessel disorders, including coronary heart disease, rheumatic heart disease, stroke and vascular dementia. They have remained the major causes of morbidity and mortality globally in the past 15 years, and it is estimated that the increasing trend of CVDs will continue.

"Despite major advances in the treatment of CVDs, a large number of patients appear to be healthy but suddenly die without any prior symptoms. A major cause of this sudden death is the rupture of vulnerable plaque in an artery, blocking the blood flow and leading to heart attack or stroke," explained Professor Zhang. "However, there are insufficient screening and diagnostic methods to identify such at-risk patients before the tragedy happens, so it is difficult to provide prevention or medical treatment in a timely manner."

Application scenarios of wearable devices, unobtrusive sensors and tele-health systems during pandemics. (X. -R. Ding et al., "Wearable Sensing and Telehealth Technology with Potential Applications in the Coronavirus Pandemic," in *IEEE Reviews in Biomedical Engineering*, doi: 10.1109/RBME.2020.2992838.)

Wearable sensing devices for disease monitoring

Professor Zhang's research focuses cover cardiovascular health engineering, as well as unobtrusive sensing and wearable devices. Together with collaborators from top universities and research institutes, his team is working on different studies to address the major gaps in early diagnosis and condition management of CVDs.

In particular, they are working on the development of wearable, soft sensing devices, made of flexible and stretchable materials, together with a system that can monitor cardiovascular condition and associated risks based on physiological models.

They are developing affordable biomedical devices that are highly sensitive to CVD-related biomarkers, so that more people can have access to this useful technology for CVD prevention. "These wearable devices can help us identify the CVD risks as early as possible," he said.

To enhance the screening of at-risk patients, they are also investigating new imaging technologies for more precise evaluation of vulnerable plaque.

Given the complex medical data collected from these monitoring devices and screening tools, a system is needed to put them together for analysis and evaluation. Therefore, the team is designing an AI-based platform for integrating all the CVD markers for early prediction and diagnosis of acute CVDs. They are also developing a closed-loop drug-delivery device based on wearable technologies for vascular intervention and therapy to provide timely treatment for acute CVD patients. In the long run, Professor Zhang hopes to build an integrated system of health technology for effective disease prevention and therapy in Hong Kong and the Greater China region.

International joint study on mobile health tech

Earlier, Professor Zhang participated in a 60-person expert task force organised and led by a team from the Harvard Medical School, which published a joint study on how mobile health technologies can help mitigate the effects of the Covid-19 pandemic. The task force identified technologies that could be deployed in response to the Covid-19 pandemic and would likely be suitable for future pandemics. They found that wearable-based mobile health technologies are viable options for monitoring Covid-19 patients who are instructed to self-quarantine at home or who have mild symptoms and undergo monitoring in community treatment facilities. They can be used to predict symptom escalation for intervention as early as possible.

"To mitigate and control diseases effectively, whether it is Covid-19 or CVDs, there is an urgent need to develop an innovative health management system that can integrate different health technologies, such as wearable health monitoring devices, biosensors, medical imaging and AI. This will enable early prediction and detection, as well as early diagnosis and intervention, for disease prevention and management," said Professor Zhang.

Professor Zhang Yuanting

Major Awards

- IAMBE Fellow
- IEEE Fellow
- AIMBE Fellow

Selected Publications

- Ding, X., Clifton, D., Ji, N., Lovell, N.H., Bonato, P., Chen, W., Yu, X., Xue, Z., Xiang, T., Long, X., Xu, K., Jiang, X., Wang, Q., Yin, B., Feng, G. & **Zhang, Y.** 2020, "Wearable sensing and telehealth technology with potential applications in the coronavirus pandemic", *IEEE Reviews in Biomedical Engineering, (in press)*.
- Zhang, G., Mei, Z., Zhang, Y., Ma, X., Lo, B., Chen, D. & **Zhang, Y.** 2020, "A noninvasive blood glucose monitoring system based on smartphone PPG signal processing and machine learning", *IEEE Transactions on Industrial Informatics*, vol. 16, no. 11, pp. 7209-7218.
- Bonato, P., Chen, Y., Chen, F. & **Zhang, Y.** 2020, "Guest editorial: Flexible sensing and medical imaging for cerebro-cardiovascular health", *IEEE Journal of Biomedical and Health Informatics*, vol. 24, no. 11, pp. 3189-3190.
- Yang, G., Pang, Z., Rahmani, A.M., Dong, M., **Zhang, Y.**, Deen, M.J. & Lovell, N. 2020, "Guest editorial: Enabling technologies in health engineering and informatics for the new revolution of healthcare 4.0", *IEEE Journal of Biomedical and Health Informatics*, vol. 24, no. 9, pp. 2442-2443.
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Microfluidic Technology for Accelerated Screening of Anti-Cancer Drugs

New medicines can save and improve lives, but drug discovery is an extremely long and expensive process. One of the top scientists at CityU is developing an integrated system based on his internationally recognised, award-winning biochip technology, with the aim of providing a novel drug-screening tool with greatly reduced drug development time and cost.

Professor Michael Yang Mengsu

Professor Michael Yang Mengsu, Yeung Kin Man Chair Professor of Biomedical Sciences and Vice-President (Research and Technology), has focused on the study of the biological processes involved in cancer, and the development of biochip technology and nanotechnology for molecular diagnostics and therapeutic applications, with the aim of improving people's lives by converting high-quality research into clinical applications. The Research Impact Fund project conducted under his leadership is working on a microfluidics-based technology platform for efficient screening of potential drug candidates.

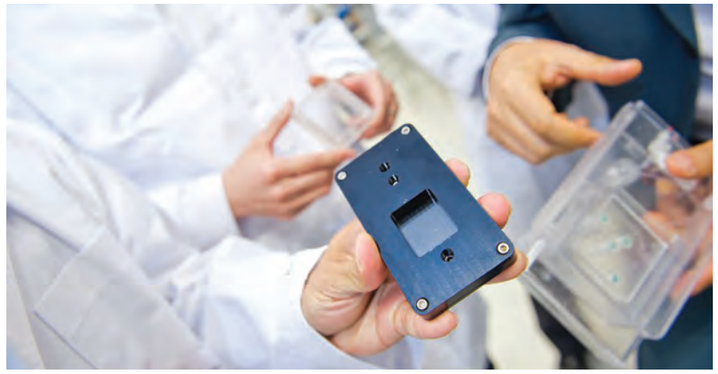
Efficient screening of drug candidates

"Drug screening is the first step in the long process of drug development," explained Professor Yang. "It identifies lead compounds and eliminates false candidates from thousands to millions of compounds, which is critical in the subsequent steps."

Two commonly used technologies are high-throughput screening (HTS) and high-content screening (HCS). HTS enables the screening of millions of chemicals for their biological or pharmacological activity to identify active compounds, which serves as a starting point for drug design and development. HCS allows the evaluation of biochemical and morphological parameters in intact cell-based biological systems, which is complementary technology to HTS.

Despite their wide applications, both technologies have drawbacks: HTS is expensive, requiring heavy use of reagents, and HCS suffers from low throughput, slow speed, and a lack of microenvironments to accurately reflect the effects of a compound on cellular behaviour. For efficient and cost-effective screening of potential drug candidates, there is great demand for new high-throughput, high-content platforms, which reduce reagent consumption and mimic the in-vivo environment to which cells are exposed.

Combining the strengths of HTS and HCS, the research team led by Professor Yang has been developing an integrated microfluidics platform that can mimic the physiological and pathological microenvironments for cell-based assays. That will facilitate the simulation of in-vivo conditions of cell growth, communication and migration for high-throughput, high-content screening of drugs that target and affect cell-cell interactions.



Microfluidics array technology with nano-amplification for drug screening and molecular diagnosis, developed by a research team led by Professor Yang.

The platform will integrate multiple parallel channels and docking structures for high-throughput formation of cell and particle arrays by fluid dynamic control. The specially designed microfluidic chip enables tumour cell and spheroid arrays to be formed for screening anti-cancer drugs with different concentration gradients and combinations. It can test the effectiveness of currently available treatments, and identify the most efficient drugs and optimal dosage.

Sensitive detection of cancer cells

Previously, Professor Yang and his team developed a microfluidic chip which can be used for highly sensitive multiplex detection of gene mutations and pathogens on barcoded microbead arrays integrated with nanoparticle-based signal amplification. Detecting gene mutations helps identify drug targets for precise medicine, and identifying pathogens contributes to early diagnosis and treatment of infectious diseases.

This patented technology won Professor Yang and his team the Gold Medal at the 47th International Exhibition of Inventions Geneva in Switzerland. It has been licensed to Cellomics International Limited, a CityU spin-off company, which was co-founded in 2018 by PhD students who graduated from Professor Yang's laboratory. The technology has been developed into products for disease detection and diagnosis in hospitals and clinical laboratories. For example, it is used for accurate identification of tumour cells circulating in the blood, enabling early screening for cancer cells through blood tests.

Professor Yang has already turned several research projects into clinical applications, including the previously developed DNA chip technology for the early detection of cervical cancer. "By translating new discoveries and findings generated in our laboratories into innovative technologies and products for clinical applications, we hope to contribute to improving the health and wellbeing of the people," said Professor Yang.

Major Awards

- Gold Medal, 47th International Exhibition of Inventions Geneva, 2019
- Wuxi AppTech Life Science and Chemistry Award, 2016
- Natural Science Award, Ministry of Education, 2015

Key Projects

- Research Impact Fund: Development of an Integrated Microfluidics System for Multi-level High Content Screening of Anti-tumor Drugs
- Innovation and Technology Fund – Public Sector Trial Scheme: Rapid Detection of SARS-CoV-2 Virus Using Isothermal Nucleic Acid Lateral Flow Assay (IsoNALFA)
- General Research Fund: Development of an Integrated Microfluidic-Based System for Single Cell Mutation Analysis and Drug Sensitivity Test of Circulating Tumor Cells/Cell Clusters

Selected Publications & Patent

- Liu, D., Hong, Y., Li, Y., Hu, C., Yip, T.-C., Yu, W.-K., Zhu, Y., Fong, C.-C., Wang, W., Au, S.-K., Wang, S. & **Yang, M.** 2020, "Targeted destruction of cancer stem cells using multifunctional magnetic nanoparticles that enable combined hyperthermia and chemotherapy", *Theranostics*, vol. 10, no. 3, pp. 1181-1196.
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Sustainable Aquaculture Techniques to Revitalise the Marine Fish Culture Industry

To protect the marine ecological environment and facilitate the sustainable development of the marine economy in Hong Kong, a CityU-led marine research team has developed a new aquaculture technique by establishing a floating, indoor weatherproof fish farm with a seawater recirculating system to replace conventional fish rafts. The promising results, including increased productivity and improved food safety, will contribute to supporting the livelihood of fish farmers and revitalising the local marine culture industry.

Hong Kong's traditional marine aquaculture industry, which provides about 5% of local demand for live marine fish, relies on good seawater quality in designated fish culture zones and their surroundings. One main challenge faced in recent years is the frequency and occurrence of harmful algal blooms, commonly referred to as "red tides", which cause oxygen depletion in seawater and the death of farmed fish. Toxic algal blooms spreading across Hong Kong waters in 1998 and 2015 resulted in massive fish kills and economic losses. The seasonal occurrence of parasites, followed by microbial infections, also put stress on cultured fish. Juveniles (i.e. fish fry) are particularly vulnerable.

Addressing the threat of red tides

These incidents have discouraged local fish farmers from investing in cultivating fish fry. Many fish rafts were abandoned or their operators were forced to switch their usage to recreational activities.

Supported by Sustainable Fisheries Development Fund from the Agriculture, Fisheries and Conservation Department, the team from the State Key Laboratory of Marine Pollution (SKLMP) at CityU worked on developing better culture techniques for raising the juveniles of fish like the giant grouper *(Epinephelus lanceolatus)* with the use of a seawater recirculating system, housed inside a floating fish farm. There are three main decks inside this floating fish farm: the lowest deck houses a complex water-filtration system, and the other two are "fish fry chambers", which consist of tanks for raising fish fry. The new techniques have demonstrated encouraging results by reducing the chance of microbial and parasitic infections, as well as the use of antibiotics.

Professor Kenneth Leung Mei-yee (left) and Professor Paul Lam Kwan-sing in front of the newly established indoor floating fish farm (the green structure) in the fish culture zone of Lamma Island.

A batch of giant grouper fry, which the research team has reared in the fish fry chamber for three months since August 2020, has a survival rate of nearly 100%. No apparent microbial or parasitic infections have been recorded. This represents a remarkable improvement compared to what is commonly seen in open-sea-cage fish rafts without a seawater filtration system, with 30% or above mortality of newly imported fish fry.

In addition, the issue of antimicrobial resistance can be mitigated. Fish cultured under these conditions are safer for human consumption, as less or even no medical treatment such as antibiotics is needed.

Improvement in fish and marine health

The productivity of fish rafts has also increased with the use of new fish feed. Instead of using trash fish, the team uses only dry pellet feed, which significantly reduces pollution caused by traditional fish feed and improves both feed efficiency and fish health.

"This project is a very good example of the One Health concept, how we can achieve optimal health for humans, animals and the ecosystem with technologies and innovations," said **Professor Paul Lam Kwan-sing**, Jeanie Hu Professor of Science, Chair Professor in the Department of Chemistry and SKLMP member, who led the study. The team plans to demonstrate these techniques to local fish farmers and supply healthy fish fry to them. The "fish fry chamber" concept can be adopted in any fish culture zone in Hong Kong and other places in Asia.

Established in 2009, the SKLMP is a consortium of seven universities, with CityU the leading institute. "Capitalising on a multi-disciplinary team and its collective expertise, we strive to protect the marine environment of Hong Kong and southern China by identifying major threats, such as harmful algal blooms and contaminants of emerging environmental concern, and developing tools, technologies and policies to address these problems," said **Professor Kenneth Leung Mei-yee**, Director of the SKLMP. "We look forward to more collaboration with different institutions and laboratories, as well as the industry, to tackle the complex environmental challenges together."

To support marine water quality management in the Greater China region and beyond, SKLMP also endeavours to scientifically derive water quality criteria (WQC) for chemical contaminants that represent safe environmental concentrations at or below which the marine ecosystem is safeguarded. For instance, Professors Lam and Leung recently established a set of interim WQC for 21 chemicals of emerging concern to help protect marine ecosystems in the Greater Bay Area of China. Professor Leung has also helped the international Nickel Producers Environmental Research Association (NiPERA) generate toxicity data with tropical marine organisms and derive the WQC of nickel for the Southeast Asia and Melanesia regions.

Fish tanks are supplied with filtered and sterilised seawater inside the fish fry chamber.

Key Projects

- Sustainable Fisheries Development Fund: Establishment and Demonstration of Recirculation Aquaculture System for Fry Culture on Rafts
- Theme-based Research Scheme: Assess Antibiotic Resistome Flows from Pollution Hot-spots to Environments and Explore the Control Strategies
- Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai): Coastal Changes and Material Transports in the South China Sea
- CityU's Start-up Fund: Global Estuaries Monitoring (GEM): Occurrence and Environmental Risks of Pharmaceuticals in the Major Estuaries Around the World

Selected Publications

- Lee, J.H.W., Guo, J.H., Chan, T.S.N., Choi, D.K.W., Wang, W.P. & **Leung, K.M.Y.** 2020, "Real time forecasting and automatic species classification of harmful algal blooms (HAB) for fisheries management", *Hydrolink*, vol. 4, pp. 109-113.
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DIGITAL SOCIETY

Developing digital innovations for daily life and a thorough understanding of the relationship between digital advancement and society.

Professor Maurice Benayoun (first row, second from left), Dr Tobias Klein (first row, first from left) and the Neuro-Design Lab team members.

Finding the "Real Value" of Human Values

With the advancement of information and communication technologies, digitalisation has permeated our daily lives. We can easily quantify many different things, but how about abstractions like *love*, *peace*, *respect*, and other human values? **Professor Maurice Benayoun**, in the School of Creative Media (SCM) and a renowned artist, theorist and curator in media art, has been working on the "MindSpaces HK - Responsive Neuro-design for Urbanism, Architecture and Interior Design" project with interactive exhibitions to consider social, innovation and technology challenges in a different way.

MindSpaces is a big project funded by the European Union (EU) to improve the design process in indoor and outdoor environments through participatory design, involving multisensory measurements of individuals' responses. Started in Europe, it has formed a consortium of 12 partners worldwide, including Professor Benayoun and CityU. As one of the two projects funded by the Research Grants Council (RGC) under the EU-HK Research and Innovation Cooperation Co-funding Mechanism, the *MindSpaces HK* project is an extension of this, using the same technologies, like artificial intelligence (AI), machine learning and Brain-to-Computer Interface (BCI), to create individual and collective "neuro design", from shaping abstractions to shaping objects and architecture.

Neuro design and the *Brain Factory*

"Neuro design is the idea to use brain to control the evolution of shapes and forms," said Professor Benayoun. With external contributions from the

Visitors are invited to produce various shapes based on different abstractions at the exhibitions.

MindSpaces consortium partners and neuroscience support from **Dr Rosa Chan Ho-man**, **Professor Sir Colin Blakemore** and **Professor Bruce Ransom** from CityU as advisors, he worked with **Dr Tobias Klein**, Associate Professor in the SCM and the team at the Neuro-Design Lab, part of the CityU Centre for Applied Computing and Interactive Media (ACIM) lab and developed a technology called a "Brain to Shape" machine, based on Brain-Computer Interaction. It can get electroencephalography (EEG) information from the users' brains, which helps them figure out how the users react to the shapes they see.

To calibrate the system accurately, the team started with the most difficult things to design - abstractions, like *space*, *power* and *love*. They created the *Brain Factory* project and exhibitions, in which they invited exhibition visitors to produce various shapes based on different abstractions. The EEG headsets monitored the visitors' brain waves, and the produced electrical signals contributed to the assessment and the evolution of the 3D shapes on a screen.

The shapes, which look like liquid in motion or dancing flames, were then converted using 3D printing into actual objects for distributing to the visitors, or sculptures for displaying in exhibitions. Professor Benayoun described this materialisation process as "reification", meaning converting thoughts into objects.

In collaboration with a CityU alumnus **Dr Nicolas Mendoza**, they went one step further, creating the *Value of Values* project to help people understand human values better "by giving shapes to values". Instead of receiving a 3D-printed shape, this time the visitors got a "Value of Values" (VoV) token in their digital wallet and owned the shapes registered on a blockchain. The shapes are converted into "VoV" tokens, so that people can barter or sell the "values". "On this blockchain trading platform, we can see what the transaction and ranking of values is for different human values across various individual cultural backgrounds and countries," said Professor Benayoun.

Trading human values on blockchain

Based on the transactions, a series of *ethical statements* were automatically generated, creating "Transactional Poetry". "If you give love for peace, or if you give money for sex, it says different things. This is what we called an 'ethical statement'," he said. "A collection of VoV tokens also reflects the collectors' priorities in their life."

Professor Benayoun and his team are working on the next step of the project by adapting the technologies to architectural design. They will generate shapes in a different way, using a huge database of architectural history, AI and machine learning, and see how people react.

Also, as part of the *MindSpaces* project, he is working with famous American-Turkish artist **Refik Anadol** on "DïaloG" to reflect on the difficulty of building mutual understanding beyond social and cultural differences. This is an urban art installation project in which each of them is developing a "living entity". "These two artworks will be like aliens, strangers or immigrants landed in a city that they don't know. They will need to learn how to understand each other. And they will be affected by the reactions of the people around them," Professor Benayoun explained. At Ars Electronica Festival 2020, a major global media art festival, they presented the "baby aliens" for the first time before they were fully grown. They will meet face to face later.

"So this global project is very complex," said Professor Benayoun. "We develop technological tools to make 3D design, to design objects, to design architecture, and to give shape to human thoughts. We make artworks with a high level of engagement in society, going beyond aesthetics, into the fields of ethics, finance, neuroscience and social awareness. This may allow us to have a better understanding of the real value of human values."

"Reification", converting thoughts into objects through 3D printing.

" By developing technological tools to let people give shape to thoughts, we make artworks with a high level of engagement in society. This may allow us to have a better understanding of the real value of human values. "

– Professor Maurice Benayoun

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Value of Values at Digital Art Festival 2019 in Taipei.

Major Awards

- Novum Design Award, Golden Interior Design Award
- ACIM SCM-CityU Research Fellowship

Key Projects

- EU-HK Research and Innovation Cooperation Co-funding Mechanism by RGC 2018/19: MindSpaces HK – Responsive Neuro-design for Urbanism, Architecture and Interior Design (Other CityU project members include: Professor Lu Jian, Dr Rosa Chan Ho-man and Dr Tobias Klein)
- HORIZON 2020 S+T+Arts Lighthouse EU Collaborative Research Programme 2019-2021

Highlights of Participation in International Exhibitions

- *Ars Electronica Festival 2020*, Hong Kong, September 2020:
  - "Refik Anadol & Maurice Benayoun's Dialogue about DïaloG" (opening talk)
  - "DïaloG: Alien Life in the Telescope" (live performance & streaming)
  - "Speculative Speculations on Art and Values. How Linking the Brain to the Blockchain Reveals the Value of Human Values" (lecture)
- *International Symposium of Electronic Arts (ISEA) 2020*, "After the Tunnel, the Shifting Ontology and Ethology of the Emerging Art-subject" (paper & lecture), Montreal, October 2020
- *Ars Electronica Festival 2019*, "Value of Values by the Brain Factory", Linz, Austria, 6 September 2019
- *ISEA 2019 Special Exhibition*, Lux Aeterna, "Value of Values", Gwangju, June - July 2019
- *Digital Art Festival 2019*, MoCA Taipei, October 2019
- *Microwave Festival*, (Exhibition & Conference), Hong Kong, 2018
- *"Why the Future Still Needs Us"* Exhibition, Brisbane, 2017, and Art Center Nabi, Seoul, 2017

Video: *Value of Values*, Transactional Art on the Blockchain

Intelligent Multidimensional Data Analysis for Imaging and Medical Advancement

As the mechanisms of biomolecular interactions, which are the key to finding the causes of diseases and developing new drugs, have yet to be fully understood, developing the concepts and tools of multidimensional data analysis and image recognition can help advance medical science and other fields to the next level. Having made a significant contribution to image and biomolecular pattern recognition techniques, **Professor Yan Hong**, a CityU expert in imaging science, has proposed new theories and the computation of complex tensors to expand its application in imaging, biology, medicine and beyond.

Professor Yan's current research focuses on tensor computing to detect and analyse meaningful patterns in datasets. A tensor is a multidimensional array of data. In mathematics, a number can be considered as a tensor of order zero, a vector as a first-order tensor, and a matrix as a second-order tensor. These data representations and structures are now well-understood. "However, the existing mathematical theories and computation methods are far from mature for analysing higher-order tensors of order three or more. We need new concepts and theories for tensors, which cannot be simply extended from matrix theories," explained Professor Yan, Wong Chun Hong Professor of Data Engineering and Chair Professor of Computer Engineering in the Department of Electrical Engineering.

New theories for analysing higher-order tensors

Although biomolecules and image analysis are studied in two different disciplines, biomolecular interactions appear to follow the same principle of the perception of images by computer technology. "Computers recognise an object in an image with consistent positions of points, lines, areas and their relations. Similarly, two molecules interact with each other because they fit consistently with complementary surfaces and charges," he elaborated. "Therefore, understanding tensors is crucial. They provide a rigorous mathematical model to represent consistent features and their higher-order relations."

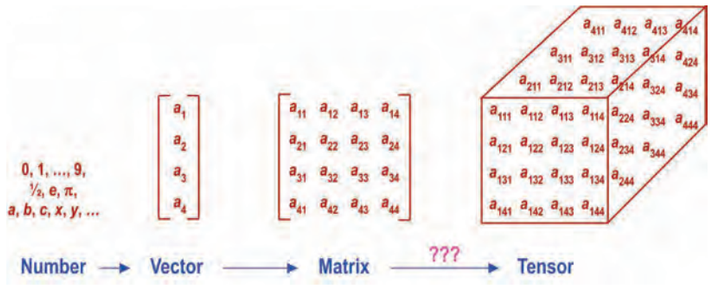
Working in close collaboration with mathematicians, biologists, medical doctors and computer engineers, Professor Yan and his team have developed co-clustering methods, based on tensor models. While conventional machine learning and pattern recognition methods classify objects according to their features, their new approach can classify both objects and features.

"For example, a group of genes may be co-regulated under a group of conditions. These genes and conditions form co-clusters. If there are many genes and conditions, the computational time will increase exponentially," he said. "But our group has solved this problem using tensor methods. Our new method enables the simultaneous detection of several types of co-clusters, which can even overlap in the data."

Based on tensor and hypergraph models, the research team has developed efficient computer algorithms for matching datasets. They have solved an optimisation problem to deal with all the compatibilities among matched data entries through high-order relations.

Application in lung cancer cell mutation analysis

Furthermore, Professor Yan has applied tensor computing to cell division data analysis and biomolecular surface characterisation. Lung cancer is the leading cause of cancer deaths worldwide. Non-small-cell lung cancer (NSCLC) constitutes about 85% of all lung cancer cases. Mutation of the epidermal growth factor receptor (EGFR), a type of protein, is a common cause of NSCLC, whose incidence can reach 60% in East Asian populations.

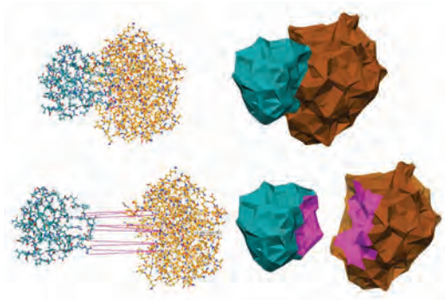


A tensor is a multidimensional array of data.

Working with medical doctors at Queen Mary Hospital in Hong Kong, Professor Yan's team analysed all known EGFR mutants and created a database of their 3D structures. The innovative methods proposed will help researchers understand the mechanisms of drug resistance and help doctors plan optimal personalised treatment for cancer patients.

In addition to contributing to medical advancement, Professor Yan has used tensor models to tackle other problems in science and engineering. One discovery involves detecting objects in images and tracking motion in videos, which does not require prior training and represents a major improvement over commonly used classifier-based systems.

Professor Yan and his team will continue to work on tensor and hypergraph theories with the aim of developing robust computer algorithms and parallel processor-based hardware and software, and applying them to many more real-world systems for image, video and biomedical data analysis.



Two molecules interact with each other because they fit consistently with complementary surfaces and charges. The original protein data (upper left diagram) are obtained from the Protein Data Bank (rcsb.org) and the other three diagrams are done by Professor Yan's team after analysing the shape and charge complementarities and how two proteins are matched to form an interaction complex.

" Throughout history, many major technological breakthroughs have relied on fundamental theories. For example, information theory was the key to the development of modern digital communications systems. To solve the multidimensional big data analysis problem, I believe we need to understand tensors, and develop new theories and computational methods. "

- Professor Yan Hong

Major Awards

- Elected Member of European Academy of Sciences and Arts, 2019
- Norbert Wiener Award for contributions to image and biomolecular pattern recognition techniques, IEEE Systems, Man and Cybernetics Society, 2016

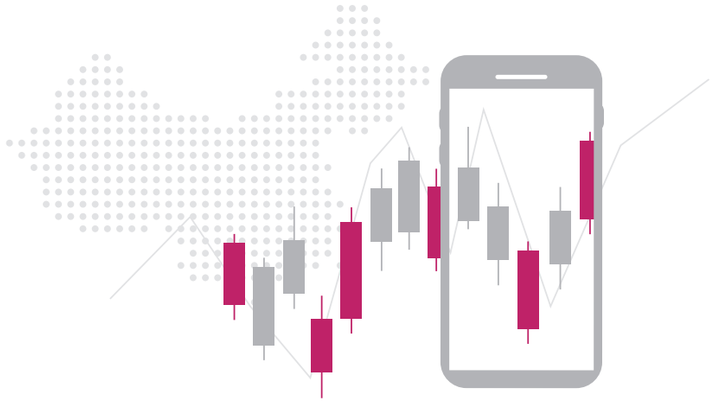
Key Projects

- Collaborative Research Fund: Efficient Algorithms and Hardware Accelerators for Tensor Decomposition and Their Applications to Multidimensional Data Analysis
- Health and Medical Research Fund: Computational Platform for Modeling, Analysis and Prediction of Anti-EGFR Drug Resistance for Lung Cancer
- General Research Fund:
  - Analysis of Interface Patterns Between Biomolecules Based on Alpha Shape Models
  - Detection of Hyperplanar Co-cluster Patterns in Multidimensional Singular Vector Spaces

Selected Publications & Patents

- Cao, J., Guan, G., Ho, V. W. S., Wong, M. K., Chan, L. Y., Tang, C., Zhao, Z. Y. & **Yan, H.** 2020, "Establishment of morphological atlas of Caenorhabditis elegans embryo using deep-learning-based 4D segmentation", *Nature Communications*, vol. 11, no. 1.
- Che, M., Wei, Y. & **Yan, H.** 2020, "The computation of low multilinear rank approximations of tensors via power scheme and random projection", *SIAM Journal on Matrix Analysis and Applications*, vol. 41, no. 2, pp. 605-636.
- Khan, S., Nawaz, M., Guoxia, X. & **Yan, H.** 2020, "Image correspondence with CUR decomposition-based graph completion and matching", *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 30, no. 9, pp. 3054-3067.
- Cui, C., Li, Q., Qi, L. & **Yan, H.** 2018, "A quadratic penalty method for hypergraph matching", *Journal of Global Optimization*, vol. 70, no. 1, pp. 237-259.
- **Yan, H.** 2017 "Co-clustering of multidimensional big data, a useful tool for genomic, financial and other data analysis", *IEEE Systems, Man and Cybernetics Magazine*, 3(2):23-30.
- Zhou, W. Q. & **Yan, H.**, "Methods for modeling and analysis of interface between point patterns", US Patent US10,475,528, granted 2019.
- **Yan, H.**, Chan, L.H.L., Chim, H., Ching, H.Y., & Choi, C., "Monitoring user activity using wearable motion sensing device", US Patent US10,347,108, granted 2019.
- Chen, L., Zhao, Z., & **Yan, H.**, "Method for tracking an object in an image sequence", US Patent US10,255,692, granted 2019.

Data-driven Solutions for Fintech in Greater China and Beyond



Digital innovations are reshaping our daily lives in many areas. Digital finance, for example, is transforming how people transact and borrow, and how financial services are provided. Combining the advantages of first-class scientific research capability and extensive fintech industry experience, a joint laboratory in financial technology and engineering at CityU has been undertaking cutting-edge research to create industry-leading solutions, especially in financial risk identification and management. The joint endeavour will help define the way forward for the future of fintech development in the Greater China region and beyond.

Established in early 2019, the joint laboratory was formed between CityU and JD Digits, which was the financial technology arm of JD.com, a global e-commerce platform, and has now become one of the leading digital technology companies in the region, offering technology solutions to corporates and other clients to enhance their digital development.

Data modelling for loan pricing

With the aim of creating cutting-edge data-driven business solutions for the development of the financial industry, the joint laboratory specialises its research in areas such as asset pricing, financial risk monitoring and user behaviour. It focuses particularly on uncovering new data modelling and analysis techniques to develop practical applications of financial engineering, technologies and big data in risk-based loan pricing.

"In the School of Data Science, we have a strong team of world-class faculty with expertise in both theory and application. This provides a strong foundation for us to excel in research and offer solutions that benefit both industry and society," said **Dr Wu Qi**, Associate Professor in the School of Data Science and also Director of the CityU-JD Digits Joint Laboratory of Financial Technology and Engineering.

Dr Wu received interdisciplinary training in mathematics, business and engineering, and specialises in quantitative finance and business analytics within the broad area of operations research and management science. His previous research centred on modelling financial derivatives and their risk implications for market participants.

Understanding consumer credit risk

One of his recent research collaborations with researchers from JD Digits features the use of cutting-edge, industrial-level deep-learning architecture developed by the team to estimate and forecast consumer credit risk. When an e-commerce platform provides unsecured lending to finance customers' purchases, it needs to manage the subsequent credit exposure. The research team proposes that the inclusion of shopping behavioural data in addition to conventional payment records, and using a deep-learning approach to break down a consumer credit risk into three determinants: i) subjective risk, indicating the consumer's willingness to repay; ii) objective risk, indicating the ability to repay; and iii) behavioural risk, indicating behaviour characteristics.

The findings demonstrate the effective forecasting performance of this new approach compared to conventional machine learning and other deep-learning models. This enables real-time assessment of future default risk, particularly when payments are financed without providing collateral.

Novel approach to managing retail credit risk

Another joint research project conducted by Dr Wu in collaboration with JD Digits represents the first retail credit risk study. It focuses on the expected difference in borrower's repayments when there is a change in the lender's credit decisions.

To address the problem of classical estimators that overlook the confounding effects between the lender's credit decisions and the borrowers' credit risk, as well as significant biases in risk assessment, the research team put forward a novel approach to construct the estimators that have proven to substantially reduce the estimation error. This will help technology conglomerates manage retail credit risks in the online marketplace, which are fundamentally different from the credit-card default risks faced by commercial banks.

(From left) Dr Wu Qi, Professor Alex Jen Kwan-yue, Professor Way Kuo and Professor Lu Jian from CityU, and representatives from JD Digits in the strategic collaborative agreement signing ceremony.

"In addition to providing innovative solutions for the development of global financial markets, we offer a common platform for technology firms, academics and students to explore new models in the research and application of financial technologies," said Dr Wu. "We aspire to help groom management professionals in Hong Kong, mainland China and the region by promoting exchange and training, organising academic forums and sharing resources."

Key Projects

- General Research Fund:
  - Generative Models of Multivariate Dependence for Asset Returns
  - Studies on Margin Procyclicality - the Impact of Volatility Persistence and Nonlinear Payoffs
- CityU New Research Initiatives: Interpretable Machine Learning Methods for Financial Risk Management
- JD Finance Strategic Collaboration: Fundamental Research of Financial Technology and its Strategic Application in Financial Industry

Selected Publications

- Huang, Y., Leung, C.H., Yan, X., **Wu, Q.**, Peng, N., Wang, D. & Huang, Z. 2020, "The causal learning of retail delinquency", *Thirty-Fifth AAAI Conference on Artificial Intelligence (AAAI 2021)*.
- Zhang, Y., **Wu, Q.**, Peng, N., Dai, M., Zhang, J. & Wang, H. 2020, "Memory-gated recurrent networks", *Thirty-Fifth AAAI Conference on Artificial Intelligence (AAAI 2021)*.
- Wang, D., **Wu, Q.** & Zhang, W. 2019, "Neural learning of online consumer credit risk", *Management Science*.
- **Wu, Q.** & Yan, X. 2019, "Capturing deep tail risk via sequential learning of quantile dynamics", *Journal of Economic Dynamics and Control*.
- Yan, X., **Wu, Q.** & Zhang, W. 2019, "Cross-sectional learning of extremal dependence among financial assets", *Advances in Neural Information Processing Systems (NeurIPS 19)*.
- Yan, X., Zhang, W., Ma, L., Liu, W. & **Wu, Q.** 2018, "Parsimonious quantile regression of financial asset tail dynamics via sequential learning", *Advances in Neural Information Processing Systems (NeurIPS 18)*.

Understanding Political Polarisation in the New Media Age

Dr Chris Shen Fei

The distribution of public opinion signals social preferences. People make many decisions in their daily lives based on their perception of the opinion climate. Similarly, policy makers formulate policy proposals based on their understanding of public opinion. With digital and social media becoming an integral part of people's daily lives for information and communication, the proliferation of digital technologies is changing not only how public opinion can be represented, but also how it can be studied. By adopting a big data-based approach, **Dr Chris Shen Fei**, a CityU scholar in the Department of Media and Communication specialising in the social and political impact of new media technologies, has proposed ways of understanding public opinion through online textual mining.

Big data analysis of public opinion

"We are living in a time in which timely and comprehensive understanding of public opinion is greatly needed," said Dr Shen. He pointed out that traditional polling has many limitations, such as high cost and respondents' sensitivity to question wording. "But big data provides us with a new direction for public opinion analysis by taking full advantage of people's openly shared expressions on the internet," he said.

Launched by Dr Shen and his team, the Hong Kong Online Public Opinion Data Mining Project (http://www.webopinion.hk/) aims to understand online public opinion using automatic textual analysis. After identifying 12 important online platforms as data sources, including discussion forums, news portal sites, and alternative news media sites, the team performed data crawling, data cleaning, tokenisation, lexicon development and data analysis to transform unstructured data into a visualised pattern of public opinion over time in Hong Kong.

"We hope the datasets and analysis derived from the platform can benefit decision-making by policy makers, the public and the academic community in the long run," said Dr Shen.

The project found that in the past several years, online political discussions have become more and more sensational, which have led to polarised opinions and a divided society in Hong Kong. This poses a great challenge to political discussion, which is Dr Shen's other research interest.

"Hong Kong's problem does not lie in the ideological differences among citizens; rather, the major issue is that people of different political stripes view each other as enemies. Sensational discussions and hate speech are commonly seen on social media platforms. While it is undesirable and even impossible to eliminate political differences, reducing political affective polarisation is one of the greatest tasks faced by society," said Dr Shen. "Political affective polarisation means the tendency of people to dislike or distrust others simply because of a different political stance."

Pilot experiments on deliberation

Much evidence suggests that when communication and discussions are not properly facilitated and conducted, they can easily lead to the proliferation of extreme ideas and negative emotions. To explore the ways of reducing political polarisation in Hong Kong through communication, Dr Shen conducted two experiments to compare the effects of deliberation and casual discussion.

In Study 1, people holding opposing views on Article 23 of the Hong Kong Basic Law were invited to participate in a 90-minute discussion session. They were randomly assigned into one of two groups: deliberation or casual discussion. The deliberation group received an information booklet on the issue and had to strictly follow the rules, whereas the casual discussion group had no such stimulus. In Study 2, which tested whether watching other people's discussion and deliberation would have a similar effect, video recordings from Study 1 were presented to another two groups of participants. One group watched the deliberation video and the other group watched the causal discussion video. Pre-test and post-test surveys were conducted in both experiments.

The studies revealed the following:

i) Both deliberation and casual discussion had mixed effects on reducing political polarisation. While issue attitude and issue polarisation remained largely unchanged, people's attitude towards those with opposing views became more favourable and affective polarisation was effectively reduced.

ii) After discussion, people's knowledge level remained largely unchanged, but their sense of national identity became stronger.

iii) These effects were more prominent in the deliberation group than in the casual discussion group.

iv) People who watched others participating in deliberation and causal discussion showed similar effects, but to a much smaller extent.

Based on these findings, Dr Shen recommends the policymakers provide opportunities and set up platforms for political dialogue among the public. These activities could be organised at the community level by non-governmental organisations. A more realistic approach would be to identify a few communities as field experiment sites and conduct a longitudinal study to follow the long-term impact of a community-based social dialogue programme. "In the long run, Hong Kong society needs institutions and organisations to promote discussions among citizens, with the government acting as an incubator, providing the necessary resources," said Dr Shen.

Major Awards

- Facebook Research Award (Foundational Integrity Research) 2020
- External Fellow, Center for Information and Communication Studies, Fudan University, 2016 - present
- External Fellow, Center for Internet and Governance Research, Sun Yat-sen University, 2015 - present
- Faculty Associate, The Berkman Klein Center for Internet and Society, Harvard Law School, Harvard University, 2015-2016
- Google Faculty Research Award 2014

Key Projects

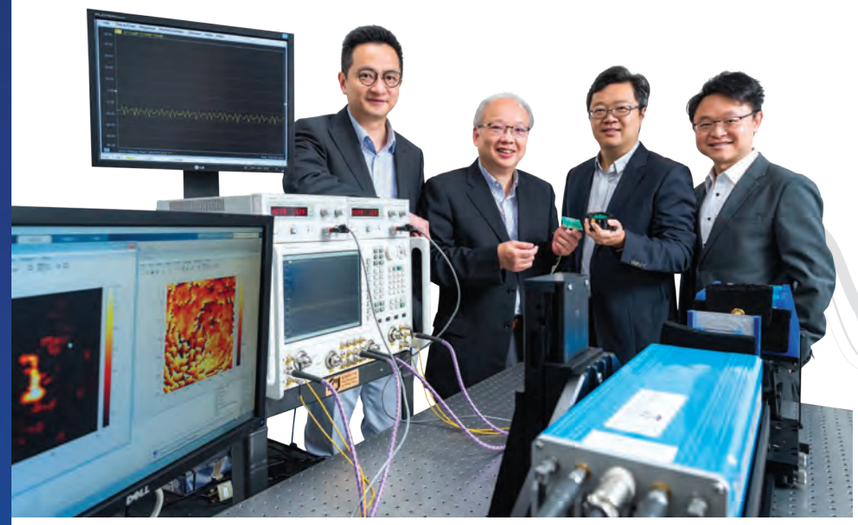
- Facebook Research Award (Foundational Integrity Research): Can Third Party Fact-checkers on Facebook Reduce Affective Polarization?
- Public Policy Research Funding Scheme (Special Round): How to Reduce Political Polarization in Hong Kong: A Pilot Experiment of Deliberation
- General Research Fund:
  - Tracking Public Opinion Through Real-time Textual Mining: A Public Service Platform with Big Data-based Approach
  - Trust in Media Revisited: A Rational-emotional Model
- Google Faculty Research Award: An Empirical Study of Asian Values and Freedom of Expression

Selected Publications

- Min, C. & **Shen, F.** 2021, "Grievances, resources, or values? Predicting online citizen-initiated government contacts in China", *Telematics and Informatics,* vol. 56.
- **Shen, F.** & Tsui, L. 2018, "Revisiting the Asian values thesis: An empirical study of Asian values, internet use, and support for freedom of expression in 11 societies", *Asian Survey*, vol. 58, no. 3, pp. 535-556.
- **Shen, F.** 2017, "Internet use, freedom supply, and demand for internet freedom: A cross-national study of 20 countries", *International Journal of Communication*, vol. 11, pp. 2093-2114.
- **Shen, F.** & Liang, H. 2015, "Cultural difference, social values, or political systems? Predicting willingness to engage in online political discussion in 75 societies", *International Journal of Public Opinion Research*, vol. 27, no. 1, pp. 111-124.

SMART CITY

Creating innovative solutions to address regional and global concerns, such as sustainable energy, climate change, environmental degradation, urban planning, government regulation and the law, through collaborative efforts among diverse disciplines and programmes.



(From left) Dr Steve Wong Hang, Professor Chan Chi-hou, Professor Johnny Ho Chung-yin, and Professor Kenneth Lo Kam-wing join hands to advance the development of terahertz (THz) technology.

Building a Compact System for Terahertz Technology and 6G Communications

With the arrival of fifth-generation (5G) wireless technology, which is set to provide massive, ultra-high speed connectivity in the next five to 10 years, the development of sixth-generation (6G) technology is already on its way. A team of multi-disciplinary experts, led by **Professor Chan Chi-hou**, Chair Professor in the Department of Electrical Engineering (EE) and Director of the State Key Laboratory of Terahertz and Millimeter Waves (SKLTMW) at CityU, has been working on advancing the development of terahertz (THz) technology for 6G communications, imaging and spectroscopy.

THz waves exist in the electro-magnetic spectrum between the conventional microwave and infrared regions. This is a broad frequency band with a wide range of applications. For example, THz technologies have been used to detect melamine in milk powder, antibiotics in food matrices, pesticides in vegetables, and foreign objects in drugs.

Developing highly-efficient THz sources

"However, the widespread application of THz technologies is hindered by bulky and expensive THz sources," said Professor Chan, who is leading a team of electronic engineers, materials scientists, biologists and chemists to work on the Theme-based Research Scheme project, whose aim is to develop high-power THz sources using integrated circuits and optoelectronic approaches, and exploring different applications of THz technology.

Professor Chan explained that THz radiation sources are usually generated in two ways: i) using integrated circuits (ICs) to generate up-conversion from the lower microwave frequency to THz radiation, and then transmit it via antennas; or ii) using the optoelectronic approach, which involves using materials science to generate down-conversion from the higher optical frequency. But both approaches face the same problem: the output power of the THz source is relatively low.

To enhance the radiation efficiency for both approaches, **Dr Steve Wong Hang**, Associate Professor in the EE Department, is developing high-performance antennas in the terahertz spectrum, while **Professor Johnny Ho Chung-yin**, in the Department of Materials Science and Engineering, is working with his team to synthesise high-quality nanowires to generate THz sources through

down-conversion. "These nanowires have properties that are not found in the bulk size and exhibit good performance in enhancing the efficiency of converting visible light to THz," said Professor Ho. He is also synthesising high-quality monolayer graphene to explore its potential in generating THz radiation.

Active antennas for 6G communications

"With compact, low-cost THz sources available, we can apply them in different ways," said Professor Chan. "For instance, the antennas we developed can be used to generate THz and for 6G wireless communications."

Earlier, the International Telecommunication Union announced the frequency range for future 6G wireless communications, which exactly matches Dr Wong's research focus – developing antennas for a frequency range of 0.2 to 0.5 THz. After years of fundamental research by Dr Wong and the SKLTMW team, they are now developing a new technology of programmable antennas using functional materials, which can enable beam-forming techniques.

"With functional materials, we can manipulate the properties of the generated waves, and control the beam formation and beam direction of THz waves. This means the direction of the beams emitted can be changed according to need. To put it simply, an active antenna system on a mobile device enables beam-searching and beam-forming technology, eliminating poor connection problems," explained Dr Wong. "This can greatly enhance communications quality and will be of great demand in the age of high-speed, high-volume 6G wireless communications."

Spectroscopy and imaging for cancer drug development

The team is also exploring THz applications in spectroscopy and imaging for addressing health-related issues. "Many studies have shown that the absorption of THz radiation by cancer and normal tissues is different. So we are interested in finding out how we can apply THz in cancer studies," said **Professor Kenneth Lo Kam-wing**, in the Department of Chemistry, who is also one of the members of the multi-disciplinary team.

In particular, he is investigating whether THz imaging can reveal the cancerous parts of tissues more precisely and the changes of the tumour cells for drug testing; and whether THz can be used as a spectroscopic tool for tracing compounds inside tissues for cancer drug development, as a supplemental approach to fluorescent biological probes to stain tissues.

"We hope our project will improve the performance of the THz system and generate more new research ideas by integrating the input from experts from different disciplines, thus achieving wider benefits for society," said Professor Chan.

Antenna measurement system developed by the team.

Integrating an antenna measurement system on their own

Performance characterisations of antennas for different application scenarios are essential for exploiting the benefits of the THz frequency band. However, the SKLTMW team has found that there are no antenna measurement facilities for higher millimetre and THz wave bands that meet their needs available in the market. "Therefore, we are trying to build a high-resolution antenna measurement system for millimetre and THz research on our own with bought components to support research and development activities in both academia and industry," said Dr Wong, who is the Project Coordinator of an equipment grant project supported by the Collaborative Research Fund (CRF).

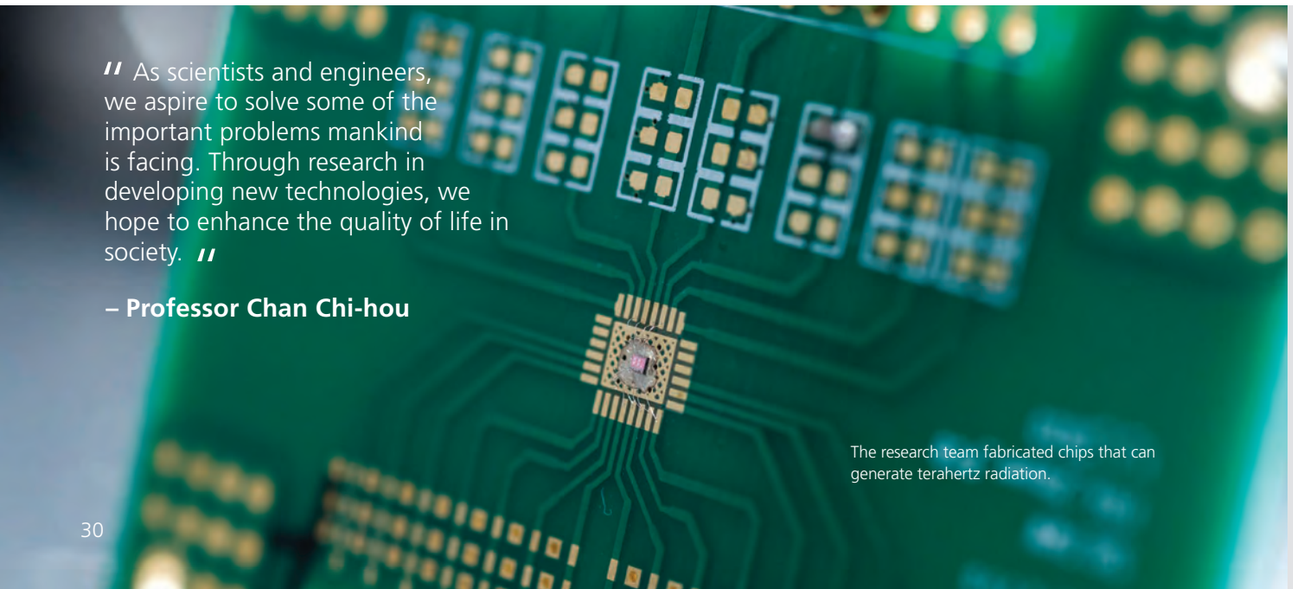
In collaboration with a team from the University of Hong Kong, they will build a world-class antenna measurement facility that can conduct near-field and far-field radiation measurements through the help of robotic arms. "We hope the new facility will drive high-frequency electronic development to a new level of excellence and promote more collaboration with other institutes in southern China, with CityU playing a leading role, contributing to Hong Kong's role as an international hub for innovation," said Dr Wong.

Major Awards

- **Professor Chan Chi-hou**
  - IEEE Antennas and Propagation Society Harrington-Mittra Computational Electromagnetics Award, 2019
  - Distinguished Alumni Award, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 2019
- **Professor Kenneth Lo Kam-wing**
  - Croucher Senior Research Fellowship 2015
- **Professor Johnny Ho Chung-yin**
  - RGC Research Fellow 2020
  - The President's Award 2020, CityU

Key Projects

- Theme-based Research Scheme: A Compact System for Terahertz Imaging and Spectroscopy
- Collaborative Research Fund: High-Resolution Antenna Measurement System with Robotic Arms for Millimeter-wave Frequencies



" As scientists and engineers, we aspire to solve some of the important problems mankind is facing. Through research in developing new technologies, we hope to enhance the quality of life in society. "

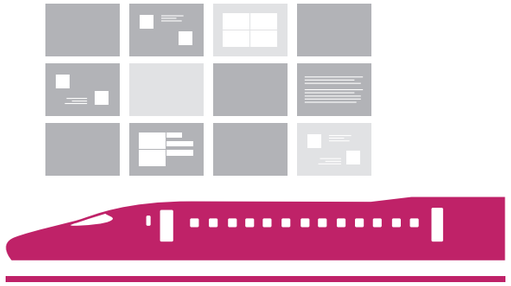
– Professor Chan Chi-hou

The research team fabricated chips that can generate terahertz radiation.

Selected Publications & Patents

- Huang, S.-X., Zeng, Y.-S., Wu, G.-B., Chan, K.-F., Chen, B.-J., Xia, M.-Y., Qu, S.-W. & **Chan, C.H.** 2020, "Terahertz Mueller matrix polarimetry and polar decomposition", *IEEE Transactions on Terahertz Science and Technology*, vol. 10, no. 1, pp. 74-84.
- **Lo, K.K.-W.** 2020, "Molecular design of bioorthogonal probes and imaging reagents derived from photofunctional transition metal complexes", *Accounts of Chemical Research*, vol. 53, no. 1, pp. 32-44.
- Guo, Q. Y. & **Wong, H.** 2020, "155 GHz dual-polarized Fabry-Perot cavity antenna using LTCC based feeding source and phase-shifting surface", *IEEE Transactions on Antennas and Propagation*, *(in press)*.
- Meng, Y., Li, F., Lan, C., Bu, X., Kang, X., Wei, R., Yip, S., Li, D., Wang, F., Takahashi, T., Hosomi, T., Nagashima, K., Yanagida, T. & **Ho, J.C.** 2020, "Artificial visual systems enabled by quasi-two-dimensional electron gases in oxide superlattice nanowires", *Science Advances*, vol. 6, eabc6389.
- Li, D., Lan, C., Manikandan, A., Yip, S.P., Zhou, Z., Liang, X., Shu, L., Chueh, Y.-L., Han, N. & **Ho, J.C.** 2019, "Ultra-fast photodetectors based on high-mobility indium gallium antimonide nanowires", *Nature Communications*, vol. 10, no. 1.
- Yip, A.M.-H. & **Lo, K.K.-W.** 2018, "Luminescent rhenium(I), ruthenium(II), and iridium(III) polypyridine complexes containing a poly(ethylene glycol) pendant or bioorthogonal reaction group as biological probes and photocytotoxic agents", *Coordination Chemistry Reviews*, vol. 361, pp. 138-163.
- Zhou, H., Shum, K.M. & **Chan, C.H.**, "A wide locking range injection locked frequency tripler based on a dual-band voltage controlled oscillator", US Patent 16/931,790, filed 2020.
- Kong, S.C., Shum, K.M. & **Chan, C.H.**, "On-chip antenna and on-chip antenna array", US Patent 63/031,727, filed 2020.
- **Wong, H.** & Yi, X., "Waveguide fed open slot antenna", US Patent 16/029,289, filed 2018.

Data-driven Management for Safe and Reliable Railway Systems



As high-speed rail and metro systems are rapidly developing in speed and complexity in many cities and regions, identifying effective ways to ensure their safe, reliable and efficient operation has become more pertinent. A multi-disciplinary research project, led by CityU, has developed a platform of tools to improve safety and reliability in railway system health monitoring, crowd safety and disruption management.

"As with other large-scale technologies, there have been major accidents around the world related to high-speed rail and metro systems. These systems require continual improvement in condition monitoring, safety and reliability engineering, operation and maintenance, and decision systems to prevent accidents," said **Professor Tsui Kwok-leung**, Chair Professor of Industrial Engineering and Adjunct Professor in the School of Data Science at CityU. He was the former project coordinator of the five-year Theme-based Research Scheme (TRS) project, with team members from CityU and other local and overseas institutions. The aim of the project was to innovate and advance rail system technologies to ensure safety, avoid and managing disruptions, and ensure operational efficiency.

"We are striving to fill at least two unique niches in high-speed rail and metro systems research," said **Professor Xie Min**, Chair Professor in the School of Data Science and Department of Systems Engineering and Engineering Management (SEEM) at CityU, who is the current coordinator of the TRS project. "One is to develop new knowledge in self-cognisant fault detection and prognostics and health management of railway systems by synergising prominent sensor-based data management technologies and sophisticated modelling expertise. Another is to allow dynamic train deployment in response to abrupt events, accidents or disruptions using real-time transportation network data."

Sensor-based monitoring of suspension systems

One of their key studies is the design of a novel domain-knowledge-guided data-driven framework to monitor and predict the health status of high-speed rail suspension systems by measuring real-time train vibration signals from sensors installed in multiple locations. "Suspension systems play a major role in high speed railways. The failure of springs and dampers may lead to accelerated wear of wheels and rails. Suspension damage may even increase derailment risk," said **Dr Li Lishuai**, Assistant Professor in SEEM, who led the study.

Existing methods rely mainly on sophisticated dynamic models or simulations that require precise suspension and inertial parameter values. They are difficult to use in different rail systems, and the results can be distorted if the parameter values are inaccurate.

To overcome these limitations, the team proposed a model that can be trained quickly and adapted easily to different rail systems. It includes a feature extraction method, based on a simple dynamics model, to select the relevant information in the multi-location vibration data. Also, it introduces a novel way to generate training datasets via a simple dynamic model and impact analysis.

Having evaluated and tested the proposed method with 10 months of tracking data in a railway system operating in mainland China, as well as simulation data from different laboratories, the team found that it performed well. While more field tests are needed to prove its effectiveness and reliability, Dr Li believes the proposed method will be implemented in parallel with existing tools in the near future.

Analysing alighting and boarding behaviour

Applying an agent-based computer simulation model, **Professor Lo Siu-ming**, in the Department of Architecture and Civil Engineering, and his team conducted a study on passengers' alighting and boarding movements in metro stations and the effects of passengers' non-compliant behaviour. Different alighting and boarding rules in different passenger volume conditions were recommended to increase alighting and boarding efficiency.

Riding on the achievements of the TRS project, Professor Tsui said that several research projects with industry and university collaborators from Hong Kong, Taiwan and mainland China are ongoing, including establishing an escalator health condition analytics model, monitoring the wear of high-speed train wheels based on wheel profile data and multi-location vibration data, passenger flow forecasting for disruption management, traffic scheduling, and maintenance planning.

The research team expects the leading-edge technologies developed to not only contribute to safety and revenue management for inter- and intra-city rail systems, but also serve as a prototype that can be transferred to other complex network systems, such as shipping, air traffic, electricity transmission, health care systems, supply chain management, internet connectivity and finance.

Professor Tsui Kwok-leung (front row, centre), Professor Xie Min (back row, second from right), Professor Lo Siu-ming (back row, first from left) and other CityU team members.

Key Projects

- Theme-based Research Scheme: Safety, Reliability, and Disruption Management of High Speed Rail and Metro Systems
- Research Impact Fund: Enhancing Safety, Punctuality and Ride Comfort of Railway Transportation: From Local Metro System to Global High-speed Rail Network
- National Natural Science Foundation of China (NSFC): Evaluation Models of Railway Emergency Plan Considering the Prioritization and Synergy of Action Alternatives

Selected Publications

- Chen, Z.-S., Liu, X.-L., Rodríguez, R.M., Wang, X.-J., **Chin, K.-S.**, **Tsui, K.L.** & Martínez, L. 2020, "Identifying and prioritizing factors affecting in-cabin passenger comfort on high-speed rail in China: A fuzzy-based linguistic approach", *Applied Soft Computing Journal*, vol. 95.
- Hong, N., **Li, L.**, Yao, W., Zhao, Y., Yi, C., Lin, J. & **Tsui, K.L.** 2020, "High-speed rail suspension system health monitoring using multi-location vibration data", *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 7, pp. 2943-2955.
- Li, Z., Lo, S.M., Ma, J. & **Luo, X.W.** 2020, "A study on passengers' alighting and boarding process at metro platform by computer simulation", *Transportation Research Part A: Policy and Practice*, vol. 132, pp. 840-854.
- Liu, B., Wu, S., **Xie, M.** & **Kuo, W.** 2017, "A condition-based maintenance policy for degrading systems with age- and state-dependent operating cost", *European Journal of Operational Research*, vol. 263, no. 3, pp. 879-887.
- Liu, B., Yeh, R.-H., **Xie, M.** & **Kuo, W.** 2017, "Maintenance scheduling for multicomponent systems with hidden failures", *IEEE Transactions on Reliability*, vol. 66, no. 4, pp. 1280-1292.
- Xu, F., Huang, Z., Yang, F., Wang, D. & **Tsui, K.L.** 2020, "Constructing a health indicator for roller bearings by using a stacked auto-encoder with an exponential function to eliminate concussion", *Applied Soft Computing Journal*, vol. 89.

Professor Michael Leung Kwok-hi

Turning Waste Heat from Air-conditioners into Electricity

As the world gets hotter, the use of air-conditioners is bound to increase. But powering air-conditioning (AC) units requires energy, and the cooling process ejects heat into the surroundings, which has an adverse impact on the environment. To achieve energy-efficient cool air supply, **Professor Michael Leung Kwok-hi**, Shun Hing Education and Charity Fund Professor of Energy and Environment, is developing a novel technology which efficiently converts the waste heat from AC systems into useful electricity.

"AC is often the largest energy consumer in urban cities, and demand will continue to grow because of the global urbanisation trend," said Professor Leung, who is also the Director of the Ability R&D Energy Research Centre at CityU. "AC systems produce an enormous amount of waste energy in the form of heat and wind, resulting in the ineffective utilisation of energy resources."

Recycling the waste heat into power is nothing new. But Professor Leung explained that the commonly used Organic Rankine Cycle (ORC) technology can work only with heat at temperatures of 200°C or above, so it cannot be applied to the heat from AC systems, which is usually 50°C to 80°C. Also, fouling contamination commonly found in AC systems results in poor indoor air quality and indirectly increases energy consumption, he added.

Recycling energy from low-temperature waste heat

Therefore, Professor Leung is developing a new generation of AC systems to recover the thermal energy from low-temperature waste heat and convert it into electricity, which can then be used by the AC unit itself, or for lighting or other electrical appliances.

The new system features the integration of thermoscience and nanotechnology, namely thermal nano technologies (TNT), to achieve high energy efficiency and clean air supply. Modelling and experimental results have shown that this TNT solution can raise the coefficient of performance (COP) of an AC system and reduce energy use up to 20%.

Professor Leung introduced that the TNT solution, which involves a number of key technologies, described as follows:

i) **Ultra-low-temperature integrated organic Rankine cycle**
The thermodynamics of the ORC is highly feasible for the recovery of low-temperature waste heat to generate kinetic energy. A novel refrigeration cycle, based on the integration of ORC into the conventional AC cycle, maximises the overall energy efficiency of the system.

ii) **Direct thermal-charging cell**
A thermo-electrochemical capacitor, made of graphene oxide based electrodes, can store thermal energy in the form of electricity. The mechanism features low-temperature heat-to-electricity conversion.

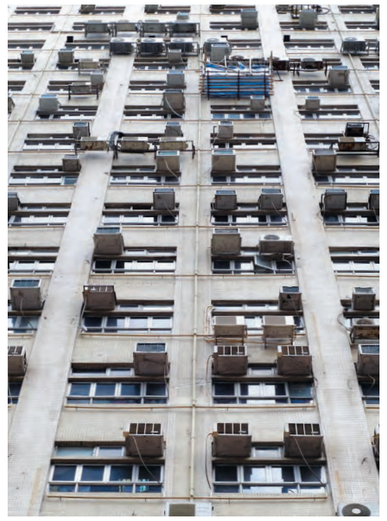
iii) **Waste-heat-recovery adsorption cooling system**
Innovative metal-organic framework (MOF) adsorbent materials have been developed for a modified adsorption cooling system. The application involves recovering the heat rejected by the AC system for an additional cooling effect.

iv) **Nanostructured biphilic heat exchanger**
A nanostructured biphilic surface is composed of superhydrophobic substrate and hydrophilic sites. As water vapour cools and condenses onto the biphilic surface, jumping droplets occur, resulting in enhanced heat transfer. This technology is applied to improve low-temperature heat recovery.

v) **Forward-backward-swept vertical-axis wind turbine**
For air-cooled condensers, cooling towers and exhaust air fans, the air leaving the unit at high speed is a form of waste energy. Vertical-axis wind turbines built with specially designed forward-backward-swept blades effectively capture this wind and use it to generate electricity.

The five technologies can be applied separately or they can be integrated for a synergistic effect. Professor Leung and his team are working to push the practical efficiency towards the theoretical maximum value.

"In addition to the increase in energy efficiency, the benefits include reduced greenhouse gas emissions and the reduction of unwanted waste heat rejection," said Professor Leung. "The revolutionary technological breakthrough anticipated in this project has the potential to not only contribute to enhanced sustainability, but also generate many new business opportunities worldwide."



The advanced TNT solutions can convert the low-temperature waste heat from AC units into electricity and reduce the energy use of an AC system.

Major Awards

- Shun Hing Education and Charity Fund Professorship in Energy and Environment
- Highly Cited Researcher (Engineering), Clarivate, 2018

Key Projects

- General Research Fund: Rational Design of MoS_2 Electrocatalyst for pH-universal Hydrogen Evolution: Mechanisms, Kinetics and Optimization
- Innovation and Technology Fund:
  - Integrated System of Advanced Thermal Nano Technologies (TNT) for Energy-Efficient Air-Conditioning and Clean Indoor Air: Part 1 - Energy Efficiency
  - High-efficacy, Environmental- And Eco-friendly Nano-photocatalytic Marine Antifouling Paint

Selected Publications & Patents

- Liu, J., Zhang, H., Qiu, M., Peng, Z., **Leung, M.K.H.**, Lin, W.-F. & Xuan, J. 2020, "A review of non-precious metal single atom confined nanomaterials in different structural dimensions (1D-3D) as highly active oxygen redox reaction electrocatalysts", *Journal of Materials Chemistry A*, vol. 8, no. 5, pp. 2222-2245.
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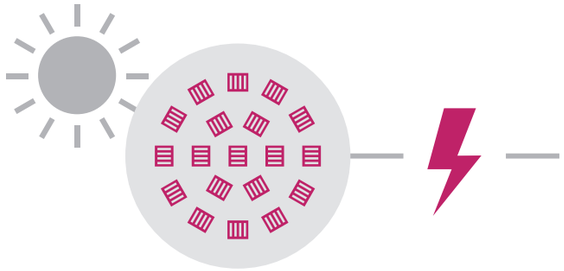
- He, Y., Yuan, R. & **Leung, M.K.H.** 2019, "Highly efficient AgBr/$BiVO_4$ photoanode for photocatalytic fuel cell", *Materials Letters*, vol. 236, pp. 394-397.
- **Leung, M.K.H.**, Daoud, W. & Xu, Y., "Method for making aerogel", US patent 16/007,003, filed 2018.
- **Leung, M.K.H.**, Wang, B., Xuan, J., Zhang, H., Xu, H., Zhang, L. & Wang, H., "Microfluidics self-breathing photocatalytic membraneless fuel cell", China patent ZL201310085223.8, granted 2015.

More Stable and Environmentally Friendly Solar Cells



Solar energy is the fastest-growing electricity source. But the commonly used silicon-based solar cells are close to their theoretical maximum efficiency and cost-reduction limit. At CityU, **Professor Alex Jen Kwan-yue**, Lee Shau Kee Chair Professor of Materials Science, has been working on developing more stable and environmental friendly perovskite and organic solar cells, which are believed to offer more promising and diverse applications to replace silicon as the future of photovoltaic technology.

Hybrid perovskites are a class of new materials that display many exciting properties, such as remarkable efficiency in absorbing light and converting it into electric currents in photovoltaic solar cells. They have become a buzzword in the field of solar cells.

Printable solar cells

As a leading expert and highly cited scholar in the field of perovskite and solar cell research, Professor Jen pointed out that research on perovskite solar cells started just about a decade ago, but their power conversion efficiency has greatly improved from 3.8% to 25.5%, rivalling that of their silicon-based counterparts, which were developed more than 50 years ago.

Perovskites are efficient and can be made via low cost solution processing. They can be made inexpensively from solutions. "Like the ink used in newspaper printing, the solution can be 'printed' on plastic films as flexible solar cells, or it can be coated on a window, looking like tinted glass but generating power," said Professor Jen. "The application potential is huge."

But the problems of instability and potential environmental impact of perovskite solar cells have yet to be overcome. One of the main concerns is the potential environmental contamination from the lead-containing component of perovskites. "As solar cells age, the lead component can potentially leak from the cells and leach into the soil through rainwater, for example," he explained.

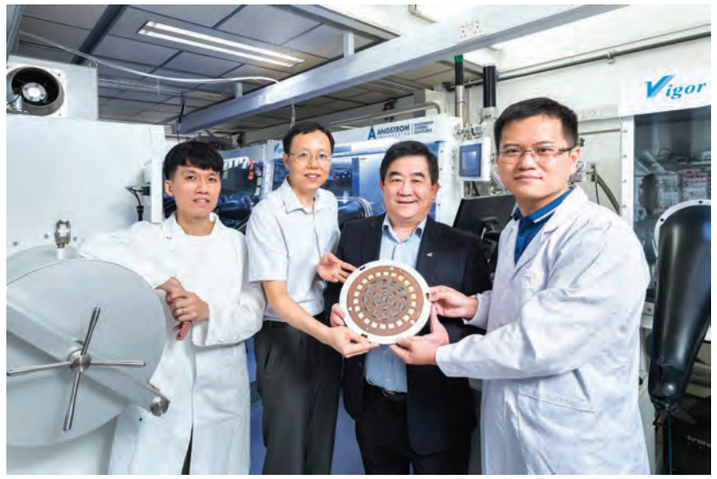
Together with **Professor Xu Zhengtao** and **Dr Zhu Zonglong**, from the Department of Chemistry, Professor Jen led the team to overcome these challenges by applying two-dimensional (2D) metal-organic frameworks (MOFs) to perovskite solar cells.

Protective layer mitigates lead leakage

The MOF layer is a multi-functional honeycomb-like structure. It has semiconducting properties and can "capture" heavy metal ions to form water-insoluble complexes, mitigating lead leakage. It can also act as a protective layer against moisture and oxygen, while maintaining high efficiency. Both the power conversion efficiency (over 22%) and the open-circuit voltage recorded were among the highest values reported for planar inverted perovskite solar cells.

Moreover, the MOF layer provides superior long-term operational stability. The device retains 92% of its initial efficiency after operating for 1,000 hours under continuous light irradiation at 85°C, meeting the commercialisation standard set by the International Electrotechnical Commission (IEC).

"Our findings offer an integrated solution to address both the stability and environmental issues, the two main hurdles before large-scale applications of perovskite solar cells," said Professor Jen. The team is working to further enhance the power conversion efficiency and explore ways to lower the production cost.



Key members of the research team: (from left) Dr Wu Shengfan, postdoc fellow, Professor Xu Zhengtao, Professor Alex Jen Kwan-yue, and Dr Zhu Zonglong.

Highest efficiency organic solar cell

Professor Jen and Dr Zhu have also designed various organic, inorganic and hybrid materials for applications in different types of solar cells and photonic devices. In September 2020, their organic solar cell, developed in collaboration with the University of Washington, was recognised by the National Renewable Energy Laboratory (NREL) in the US, a benchmark testing lab in the renewable energy research field, in its "Best Research-Cell Efficiency Chart". Its power conversion efficiency of 17.5%, certified by NREL, was the highest among organic solar cells at that time.

Though the power conversion efficiency of organic solar cells is not as high as that of perovskite solar cells, Professor Jen pointed out that the production process for organic solar cells is even more environmentally friendly and consumes less energy than that for perovskite solar cells. The semi-transparent organic solar cells can also be applied to building-integrated photovoltaics, the glass roof panels of greenhouses and other buildings, enabling power self-sufficiency. And the foldable flexibility of organic solar cells definitely has huge potential for applications in new-generation wearable electronic devices.

"Solar energy is no longer limited to bulky and hard panels on rooftops," said Professor Jen. "These new materials can be installed everywhere, from coatings on buildings and windows to mobile devices and even clothing, composing an integrated system of sustainable energy."

The perovskite solar cells developed by CityU team.

Major Awards

- Highly Cited Researcher (Materials Science), Clarivate, 2014-2020
- Top 10 Researchers in Perovskite Solar Cell Research, Times Higher Education, 2018
- World's Most Influential Scientific Minds (Materials Science), Thomson Reuters, 2015 & 2016
- Fellow, European Academy of Sciences and Washington State Academy of Sciences
- Fellow, American Association for the Advancement of Science

Key Projects

- Collaborative Research Fund: Developing Non-fullerene Organic Solar Cells with Small Photovoltage Loss
- Innovation and Technology Fund:
  - Rational Design of Efficient and Stable Transporting Materials for High Efficiency Metal Halide Perovskite Solar Cells and Large-Scale Fabrication
  - Development of Highly Efficient Perovskite/Polymer Hybrid Solar Cells

Selected Publications & Patent

- **Wu, S.**, Li, Z., Li, M.-Q., Diao, Y., Lin, F., Liu, T., Zhang, J., Tieu, P., Gao, W., Qi, F., Pan, X., **Xu, Z., Zhu, Z.** & **Jen, A.K.-Y.** 2020, "2D metal–organic framework for stable perovskite solar cells with minimized lead leakage", *Nature Nanotechnology*, vol. 15, no. 11, pp. 934-940.
- Wang, J., Zhang, J., Zhou, Y., Liu, H., Xue, Q., Li, X., Chueh, C.-C., Yip, H.-L., **Zhu, Z.** & **Jen, A.K.-Y.** 2020, "Highly efficient all-inorganic perovskite solar cells with suppressed non-radiative recombination by a Lewis base", *Nature Communications*, vol. 11, no. 1.
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- Yan, C., Barlow, S., Wang, Z., Yan, H., **Jen, A.K.-Y.**, Marder, S.R. & Zhan, X. 2018, "Non-fullerene acceptors for organic solar cells", *Nature Reviews Materials*, vol. 3.
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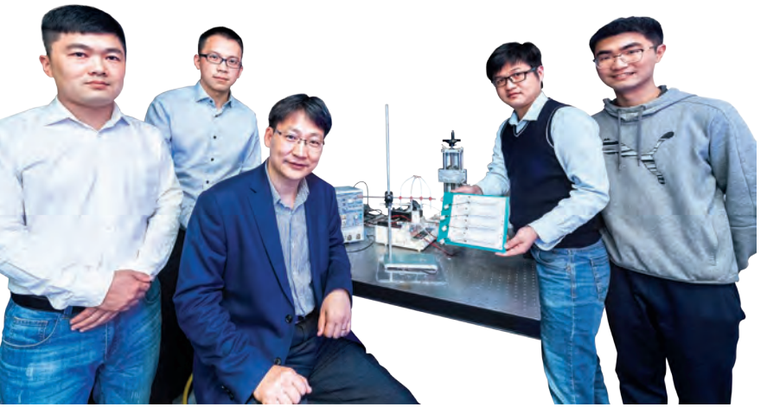
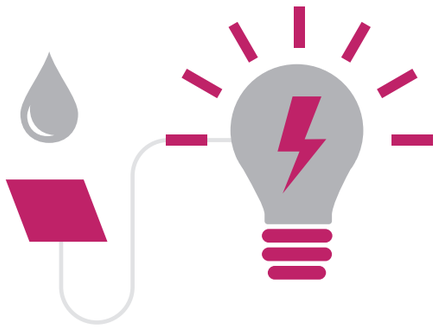
- **Xu, Z., Jen, A.K.-Y. & Zhu, Z.**, "A compound for use in an optoelectronic device including a heterojunction", US patent 16/669,697, filed 2019.





Professor Wang Zuankai (centre) and his CityU team: (from left) Zheng Huanxi, Xu Wanghuai, Dr Zhang Chao and Song Yuxin.

Harvesting Water Droplets for Sustainable Energy

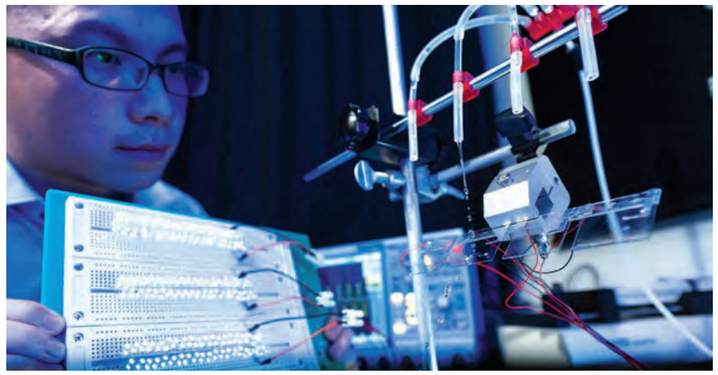
Energy needs have skyrocketed in the past two centuries or more. The main energy sources, fossil fuels, are not only polluting, but also finite. Developing sustainable energy sources has long been a key global challenge. **Professor Wang Zuankai**, Associate Dean (Internationalisation and Industry Engagement) in the College of Engineering and Professor in the Department of Mechanical Engineering, has achieved research breakthroughs in efficiently converting the kinetic energy in water droplets into electrical energy, advancing research in water-based energy harvesting.

"Harvesting water energy can help solve the global problem of renewable energy shortage," said Professor Wang. "Although droplets are small and ordinary, their power and impact can be large and far-reaching if we can efficiently harvest the kinetic energy from falling droplets." His distinguished research on water energy harvesting earned him the 2020 Xplorer Prize presented by the Tencent Foundation.

Droplet-based electricity generator with transistor-like structure

The conventional droplet-based electricity generator (DEG) is based on the triboelectric effect – a type of contact electrification in which two materials, a droplet and a surface, contact and separate. However, the electrical energy generated through it is limited to the amount of charges generated on the surface. Hence, the energy conversion efficiency is relatively low.

To enhance the energy conversion efficiency of the DEG, Professor Wang proposed a design similar to a field effect transistor, which includes two electrodes, one of which is deposited with polytetrafluoroethylene (PTFE), an electret material with a quasi-permanent electric charge. When the water droplets continuously hit the PTFE surface, the surface charges generated accumulate and gradually reach saturation. This helps to overcome the bottleneck of low charge density encountered in conventional generators.



With the new droplet-based electricity generator, a drop of water can generate a voltage of over 140V, lighting up 100 small LED bulbs.

A drop of water could light up 100 LED bulbs

More importantly, the two electrodes play a role similar to that of a field effect transistor. When a water droplet hits and spreads on the surface, it "bridges" the aluminium electrode and the PTFE/indium tin oxide (ITO) electrode, forming a closed-loop circuit. All the stored charges on the PTFE are then fully released and generate an electric current. This phenomenon contributes to the remarkably high instantaneous power density and energy conversion efficiency.

In collaboration with **Professor Zeng Xiao Cheng**, from the University of Nebraska-Lincoln, and **Professor Wang Zhong Lin**, Founding Director and Chief Scientist at the Beijing Institute of Nanoenergy and Nanosystems of the Chinese Academy of Sciences, the DEG developed by Professor Wang showed instantaneous power density of up to 50.1 W/m^2 in experiments, thousands of times higher than that of similar devices without the FET-like design. In their experiments, a drop of 100 microlitres of water released from a height of 15 cm generated a voltage of over 140V, which could light up 100 small LED light bulbs. Their DEG findings were published in *Nature* in 2020.

A specialist in nature-inspired engineering

In his research, Professor Wang loves to get inspiration from nature, which has all the characteristics that scientists and engineers dream of including in their technologies: it is adaptive, dynamic, multi-functional, energy efficient and interconnected.

One breakthrough piece of research conducted by Professor Wang and his team relating to nature-inspired engineering involves shaping drops of liquid in such a way that they can shed from a surface faster, thus creating super dry surfaces. Potential applications include preventing ice from forming on metal surfaces, like aircraft wings and engines.

In another inspiration from nature, Professor Wang worked together with **Dr Shen Yajing** from the Department of Biomedical Engineering to develop a tiny, soft robot with caterpillar-like legs, which is capable of carrying heavy loads and adaptable to adverse environments, and can be used for the accurate delivery of drugs into the human body.

"Through billion years of evolution, nature has developed extraordinary principles, which are characterised by green energy and resilience, such as how lotus leaves repel water and how certain beetles in the desert gain access to water. We can always look to principles in nature for inspiration in developing technologies," said Professor Wang. "It will never disappoint us."

Major Awards

- Xplorer Prize, Tencent Foundation, 2020
- Fellow of International Society of Bionic Engineering, 2019
- World Cultural Council Special Recognition, 2018
- Chang Jiang Chair Professor, Ministry of Education, China, 2017
- Outstanding Research Award 2017, CityU
- The President's Award 2016 & 2017, CityU

Key Projects

- Collaborative Research Fund: Bio-inspired Surface Engineering for Phase Change Heat Transfer: From Fundamental Understanding to Practical Applications
- General Research Fund: Developing Transistor-like Water Energy Generator with High Peak Power Density and High Durability
- Innovation and Technology Fund: Developing Liquid Diode Based Medical Tube

Selected Publications & Patents

- Xu, W., Zheng, H., Liu, Y., Zhou, X., Zhang, C., Song, Y., Deng, X., Leung, M., Yang, Z., Xu, R.X., Wang, Z.L., Zeng, X.C. & **Wang, Z.** 2020, "A droplet-based electricity generator with high instantaneous power density", *Nature*, vol. 578, no. 7795, pp. 392-396.
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- **Wang, Z.**, Jiang, M. & Wang, Y., "Highly effective heat dissipation architecture even on the ultrahigh temperature of more than 1000 celsius", US patent 63/072,995, filed 2020.
- **Wang, Z.**, Zhou, X. & Li, J., "Unidirectional liquid transport systems and methods of manufacture thereof", US patent US10,590,967, granted 2020.
- **Wang, Z.** & Liu, Y., "Superhydrophobic surface arrangement, article comprising same, and method of manufacture thereof", US patent 16/233,325, filed 2018.

MATTER

An interdisciplinary study of matter and materials in their various forms, covering areas from synthesis to processing and fabrication, from properties evaluation to modification, and from design to applications.

Breakthrough in High-strength but Ductile Ordered Intermetallic Alloys

The strength-ductility trade-off has always been a dilemma in materials science. The higher the strength of a material, the less the ductility and toughness, meaning that strong materials tend to be less deformable or stretchable without fracture. **Professor Liu Chain-tsuan**, University Distinguished Professor in the College of Engineering and Senior Fellow of the Hong Kong Institute for Advanced Study (HKIAS) at CityU, together with his team member **Dr Yang Tao**, Assistant Professor in the Department of Materials Science and Engineering, has developed a novel alloy design strategy to overcome this challenge, paving the way for fabricating materials for operating in extreme temperatures and aerospace systems.

"Most conventional alloys comprise one or two major elements, such as nickel and iron," Professor Liu explained. "However, by adding aluminium and titanium to form massive precipitates in an iron-cobalt-nickel (FeCoNi)-based alloy, we found a significant increase in both strength and ductility."

In the prestigious scientific journal *Science*, they reported that their high-entropy alloy had a superior strength of 1.5 gigapascals, which is five times stronger than FeCoNi based-alloys, and had ductility as high as 50% in tension at ambient temperature.

They also found that adding multicomponent intermetallic nanoparticles can greatly enhance plastic deformation stability, avoiding the common problem of early necking fracture.

Professor Liu believed this innovative strategy would allow the development of alloys that can perform well in temperatures ranging from -200°C to 1000°C, thus providing a good base for developing new cryogenic devices, as well as aircraft and high temperature systems, such as aeronautical engineering applications.

In their other research also reported in *Science* recently, they revealed a new way to resolve the strength-ductility trade-off effectively by forming disordered nanoscale layers at grain boundaries in ordered intermetallic alloys.

By adding 1.5 to 2.5 atomic percent of boron to an intermetallic alloy, they found that distinctive nanoscale layers were formed between the orderly packed grains in the alloy. "This serves as a buffer zone between

The new high-entropy alloy is extremely strong but ductile.

adjacent grains, which enables plastic-deformation extensively at the grain boundaries, resulting in the large tensile ductility at an ultra-high yield strength level," said Dr Yang, who is the first author of the research.

With nanolayers formed at the grain boundaries, the alloy showed an ultra-high yield strength of 1.6 gigapascals, with tensile ductility of 25% at ambient temperature. It also maintained the alloy's strength with excellent thermal stability at high temperature.

"The discovery of this disordered nanolayer in the alloy will have an impact on the development of high-strength materials in the future, such as structural materials for applications in high-temperature settings, like aerospace, aeronautics, nuclear power and chemical engineering," said Professor Liu.

Professor Liu, Dr Yang and the team will continue to work on ultra-high strength steels, multicomponent high-entropy alloys, lightweight materials, and nanostructured materials for various applications.

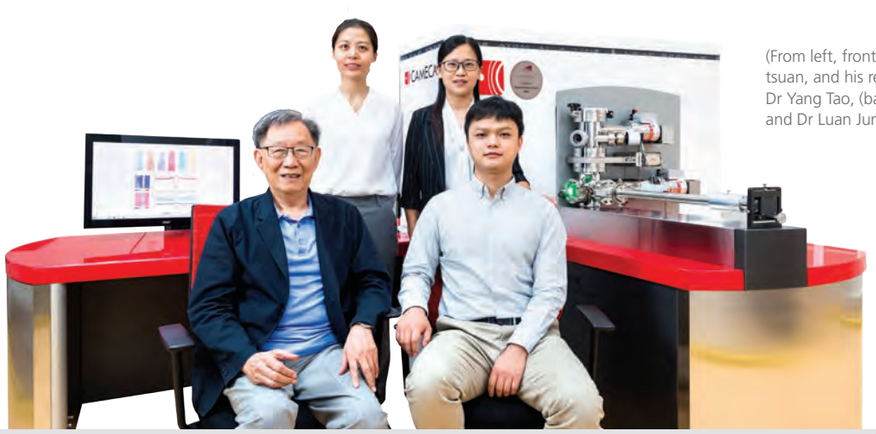
Major Award

Professor Liu Chain-tsuan

- The President's Award 2020, CityU

Key Projects

- General Research Fund:
  - Alloy Design of Novel L12-Type High-Entropy Intermetallic Alloys (HEIAs) for Advanced Structural Applications
  - Plastic Deformation Stability and Hardening Behavior of Complex High-entropy Alloys (HEAs) with Innovative Multi-component Nanoparticles



(From left, front row) Professor Liu Chain-tsuan, and his research team members Dr Yang Tao, (back row, from left) Dr Zhao Yilu and Dr Luan Junhua.

Selected Publications & Patents

- Cao, B.X., Kong, H.J., Fan, L., Luan, J.H., Jiao, Z.B., Kai, J.J., **Yang, T.**, & **Liu, C.T.** 2021. "Heterogenous columnar-grained high-entropy alloys produce exceptional resistance to intermediate-temperature intergranular embrittlement", *Scripta Materialia*, vol.194, pp. 113622.
- **Yang, T.**, Zhao, Y.L., Li, W.P., Yu, C.Y., Luan, J.H., Lin, D.Y., Fan, L., Jiao, Z.B., Liu, W.H., Liu, X.J., Kai, J.J., Huang, J.C. & **Liu, C.T.** 2020, "Ultrahigh-strength and ductile superlattice alloys with nanoscale disordered interfaces", *Science*, vol. 369, no. 6502, pp. 427-432.
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- **Liu, C.T.** & Zhang. T., "Method and system for manufacturing a structure", US patent 17/012,507, filed 2020.
- Jiao, Z.B. & **Liu, C.T.**, "ナノ金属間化合物強化超高強度フェライト鋼およびその作製方法", Japan patent 6591290, granted 2019.
- Jiao, Z.B. & **Liu, C.T.**, "銅リッチナノクラスター強化超高強度フェライト鋼およびその製造方法", Japan patent 6584961, granted 2019.
- Jiao, Z.B. & **Liu, C.T.**, "ナノ金属間化合物強化超高強度フェライト鋼およびその作製方法", Japan patent 2019-11536, filed 2019.

Professor Lu Jian (left), Dr Liu Guo and the research team have developed the world's first-ever 4D printing for ceramics.

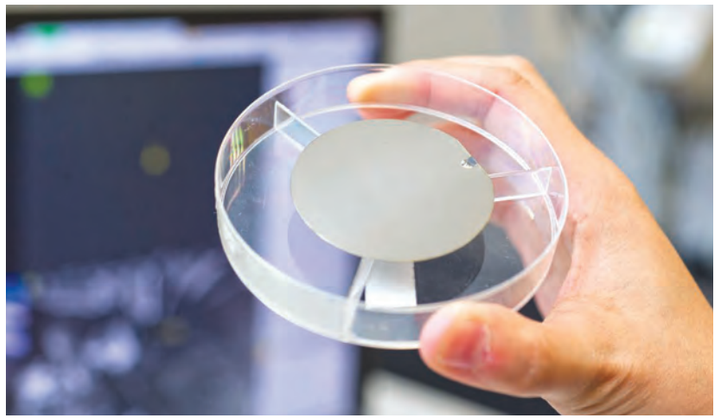
Scientific Advances in 2D/3D/4D Additive Manufacturing

Fabricating materials with complex shapes and desirable properties for various applications has long been a focus of materials scientists and engineers. A leading expert at CityU, who developed the world's first supra-nano-dual-phase alloy and four-dimensional (4D) ceramic printing, is working on integrating these two cutting-edge technologies to fabricate lightweight, high-strength metallic materials for biomedical and aerospace applications.

3D printing technology, also known as additive manufacturing, has been widely used to fabricate components with complex shapes at low cost in the manufacturing, construction, biomedical and aerospace industries. However, some applications still face limitations. For example, the 3D-printed metallic materials commonly used as moving parts in medical implants have insufficient fatigue and wear resistance, which may eventually lead to the need for a second surgery to replace the implants.

Integrating two cutting-edge technologies

Professor Lu Jian, Chair Professor of Mechanical Engineering at CityU, and Director of the Hong Kong Branch of National Precious Metals Material Engineering Research Center and the Centre for Advanced Structural Materials, is an expert in the mechanical properties of metallic and ceramic materials. He is leading a team to develop a pioneering 2D/3D/4D additive manufacturing system to fabricate metallic-based materials with desired mechanical properties for different applications.



Supra-nano-dual-phase magnesium alloy

"It is worthwhile integrating our two technologies – dual-phase nanostructuring and 4D printing – to explore any extraordinary mechanical properties or metamaterial properties that may emerge," said Professor Lu, who is also the Director of the Joint Laboratory of Nanomaterials and Nanomechanics, established by the Institute of Metal Research (IMR) of the Chinese Academy of Sciences and CityU.

Earlier, he led the team that successfully developed the first-ever supra-nano-dual-phase magnesium alloy. By using dual-phase nanostructuring technology, the team overcame the limitation of existing structural materials: high strength and high ductility cannot coexist. The new cutting-edge material developed by the team is 10 times stronger than conventional crystalline magnesium alloy and has super-deformation capacity two times higher than that of magnesium-based metallic glass. The findings were reported in the prestigious scientific journal *Nature*.

They also invented the world-first 4D printing of ceramics. The 3D-printed ceramic precursors can re-shape by themselves over time with the elastic energy stored in the stretched precursors. And the fabricated ceramics are mechanically robust with high specific strength.

Fabricating ideal implant materials

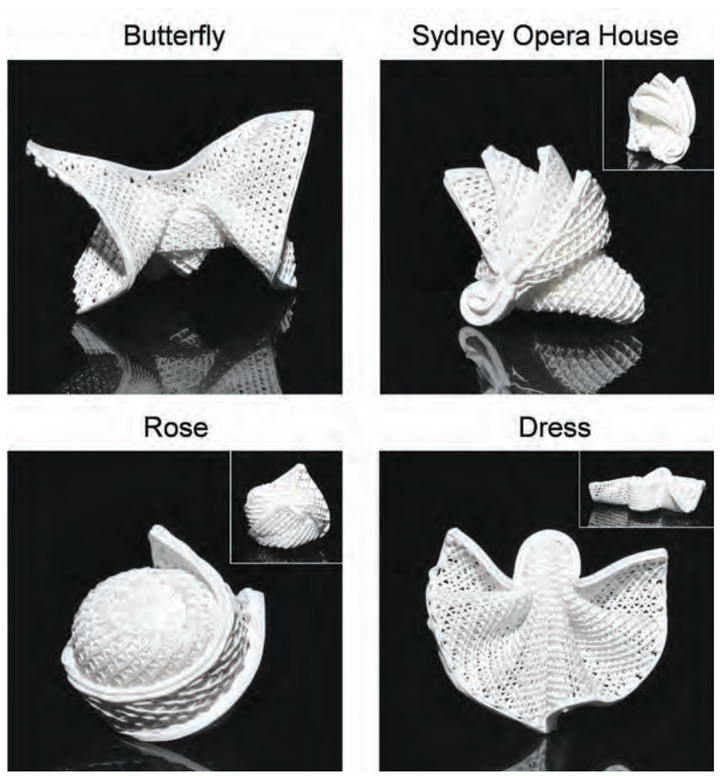
In this project, they will first develop a 2D/3D/4D manufacturing system to fabricate metallic-based materials with complex shapes, particularly those used in biomedical and lightweight structure applications. Since titanium-based alloys are considered the ideal implant material for clinical use, the team will first focus on fabricating supra-nano 3D-printed titanium-based alloy and examine its mechanical properties.

"By applying our knowledge and know-how gained in inventing the 4D printing technique, fabricating supra-nano materials, and producing surface nanostructured materials, we will further treat the 3D-printed titanium-based alloy and other metallic materials to enhance their mechanical properties. We hope to develop lightweight metallic materials with high strength and wear resistance for the medical implant and aerospace industries," said Professor Lu.

In particular, they will study the effect of post-treatment, such as Surface Mechanical Attrition Treatment (SMAT) to enhance fatigue resistance, and Physical Vapour Deposition to enhance wear resistance, on the mechanical properties of the printed materials. SMAT is a surface nano-crystallisation technology, which was first introduced by Professor Lu and **Professor Lu Ke**, Director of IMR. It involves the use of hundreds of small hard balls, which are vibrated using high-power ultrasound, so that they hit the surface of a material at high speed to enhance damage-tolerance in metallic alloys.

Biosensors for health

They aim to build up a database of 3D-printed metallic materials, with details about their mechanical properties, microstructure, treatment process and potential applications. "The database will be of great assistance to materials researchers and engineers for their research in developing more new materials and for exploring new applications," said Professor Lu. "We hope it can help facilitate the application of metallic materials in different fields, thus benefiting all of society."



The 3D-printed ceramic precursors are soft and stretchable, enabling ceramics with complex shapes, such as origami folding mimicking the Sydney Opera House.

Besides 3D printing technology, Professor Lu and his team have worked on functional metallic materials, particularly their newly developed biosensing technology based on ultrasensitive surface enhanced Raman spectroscopy (SERS). This technology can be applied in various areas, such as antibiotics detection, and food and cosmetics product safety. They are working on the feasibility of applying it in the fast detection of Covid-19, cancer and cardiovascular diseases, as well as the non-invasive detection of diabetes.

The SERS biosensing technology can be used to test contaminants in food and cosmetics.

Major Awards

- Silver Medal, 47th International Exhibition of Inventions Geneva, 2019
- The 12th Guanghua Engineering Science and Technology Award, 2018
- French Knight of the National Order of Légion d'Honneur (Chevalier de la Légion d'Honneur), 2017

Key Projects

- General Research Fund:
  - Study the Plastic Deformation Mechanism and Thermal Stability of Ultra-strong/Ductile Nano-dual-phase Alloys
  - Study the Wear and Corrosion Resistances of Ultra-Strong/Plastic Mg-Based Supra-Nano-Dual-Phase Materials
  - Development of High Strength and High Ductility Micro-alloyed Gold by Inducing Gradient Nanostructures
- Collaborative Research Fund: Joint R&D of Magnesium-based Orthopaedic Implants
- Theme-based Research Scheme: Functional Bone Regeneration in Challenging Bone Disorders and Defects
- Joint Laboratory Funding Scheme: System for 2/3/4D Additive Manufacturing of Supra-nano Metallic Materials for Biomedical and Lightweight Structure Applications
- Areas of Excellence Scheme: Aging, Skeletal Degeneration and Regeneration

Selected Publications & Patents

- Ou, W., Zhou, B., Shen, J., Lo, T.W., Lei, D., Li, S., Zhong, J., Li, Y.Y. & **Lu, J.** 2020, "Thermal and nonthermal effects in plasmon-mediated electrochemistry at nanostructured Ag electrodes", *Angewandte Chemie - International Edition*, vol. 59, no. 17, pp. 6790-6793.
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- Liu, G., Zhao, Y., Wu, G. & **Lu, J.** 2018, "Origami and 4D printing of elastomer-derived ceramic structures", *Science Advances*, vol. 4, no. 8.
- Wu, G., Chan, K.-C., Zhu, L., Sun, L. & **Lu, J.** 2017, "Dual-phase nanostructuring as a route to high-strength magnesium alloys", *Nature*, vol. 545, no. 7652, pp. 80-83.
- Li, Y., **Lu, J.** & Zhan, Y., "Method for treating a surface of a metallic structure", US patent US10,626,518, granted 2020.
- **Lu, J.** & Liu, G., "System and method for four-dimensional printing of ceramic origami structures", US patent US10,377,076, granted 2019.
- **Lu, J.** & Wu, G., "Metal material and a method for use in fabricating thereof", US patent US10,428,418, granted 2019.

Understanding Complex Materials through Neutron Scattering

Breakthroughs in materials development, which are essential for advances in technology, are based on scientists' understanding of material structure and dynamics. Neutron scattering is one of the most powerful techniques for exploring the nature of materials. At CityU, an expert in neutron-scattering measurements has applied this state-of-the-art experimental technique to find out the deformation and transformation behaviours in complex materials, in particular at ultra-low temperatures, opening up a new area of materials research.

"Neutron scattering is like a giant microscope," explained **Professor Wang Xunli**, Chair Professor and Head of the Department of Physics, and also a Fellow of the Neutron Scattering Society of America. "It can reveal the structure and dynamics of a material, such as how the atoms are packed and how they move, thus enhancing our understanding of a material's properties. It can be applied to physics, chemistry, biology, biomedical science, materials science and engineering."

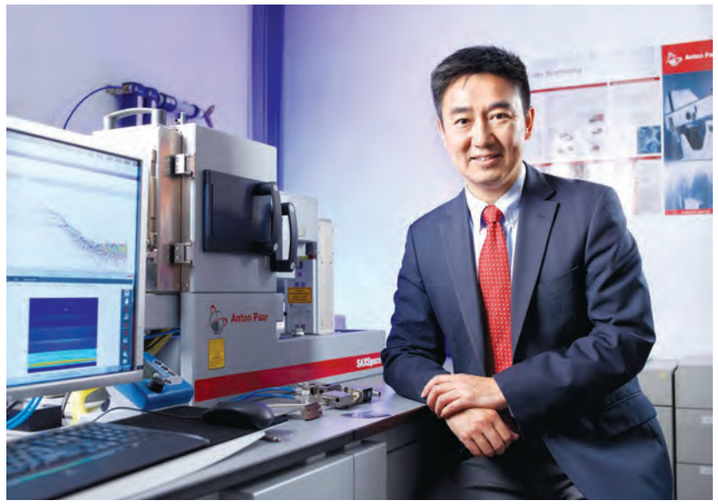
A giant microscope for materials

Neutrons are uncharged particles, so they can easily pass through material. The ways in which they bounce off a material and scatter provide scientists with important information about the material's structure and properties.

For example, experimental studies on the physical properties of amorphous materials have been very difficult owing to their disordered atomic arrangement. But using the neutron-scattering technique, Professor Wang led an international research team to overcome this challenge, and measured the atomic dynamics in zirconium-copper-aluminium metallic glass. They demonstrated the existence of high-frequency transverse phonons in metallic glass for the first time. Their findings have provided new insight into understanding the atomic structure-dynamics relationship in disordered materials.

Unveiling HEA deformation at ultra-low temperature

With the neutron-scattering instrumentation, Professor Wang and his team also discovered that high-entropy alloys (HEAs), a new class of structural materials consisting of multiple principal elements, exhibit exceptional mechanical properties at ultra-low temperatures owing to the coexistence of multiple deformation mechanisms. They revealed the sequence of deformation mechanisms in HEAs at ultra-low temperatures for the first time, opening up new terrain that very few have examined.



Professor Wang Xunli

Professor Wang was awarded the Croucher Senior Research Fellowship 2021 and will use the grant to conduct an *in situ* neutron diffraction study to pursue his research on phase transformation and deformation behaviours in HEAs at ultra-low temperatures.

Advantage of close proximity to a neutron source facility

Riding on Hong Kong's proximity to the China Spallation Neutron Source (CSNS), Professor Wang has dedicated his efforts to establishing Hong Kong as a hub for neutron-scattering science in the region.

"The CSNS is one of the largest national scientific facilities in China and is situated in Dongguan, which is about a two-hour drive from Hong Kong. It offers tremendous opportunities for researchers in Hong Kong and the region," he explained. "Since there are only four neutron sources in the world, there is huge demand to use the facility for experiments and research."

Therefore, he and his collaborators have supported the construction of a multiphysics instrument (a total scattering diffractometer) at the CSNS, with the support of the Collaborative Research Fund (CRF), in exchange for dedicated access to a suite of instruments there. "This will greatly enhance education and research activity in Hong Kong and encourage the rapid growth of a strong user community," he said.

The multiphysics instrument supported by Professor Wang's CRF project being installed in the CSNS.

Promoting neutron-scattering research

Professor Wang and **Professor Chen Hesheng**, of the Institute of High Energy Physics of the Chinese Academy of Sciences (CAS), co-founded the Joint Laboratory on Neutron Scattering at CityU, with sponsorship from the CAS and the Croucher Foundation, to carry out a variety of cutting-edge research projects. Supported by Joint Laboratory Funding from the University Grants Committee, Professor Wang and his collaborators are developing an isotope labelling platform for functional materials, which will enable precise structure identification at the CSNS. The project aims to enhance the research infrastructure of Hong Kong laboratories, utilising the neutron source at CSNS to study structural and energy materials.

Previously, with the support of the Croucher Foundation, Professor Wang started the biennial Croucher Summer Course on Neutron Scattering. "I enjoy the interaction with young researchers from different backgrounds," he said. "By boosting collaboration between the Hong Kong scientific community and the CSNS and nurturing more scientists to work in neutron scattering, we hope Hong Kong can benefit from the enhancement of this science and technology research."

Major Awards

- Croucher Senior Research Fellowship 2021
- Elected Fellow, Neutron Scattering Society of America, 2020
- Lee Hsun Lectureship, Chinese Academy of Sciences, 2018
- Elected Fellow, American Association for the Advancement of Science, 2017

Key Projects

- Croucher Senior Research Fellowship: *In Situ* Neutron Diffraction Study of Competing Deformation Mechanisms in High Entropy Alloys
- Collaborative Research Fund: Hong Kong's Participation at the China Spallation Neutron Source
- Joint Laboratory Funding Scheme: Isotope Substitution to Enable Precise Structure Determination at China Spallation Neutron Source

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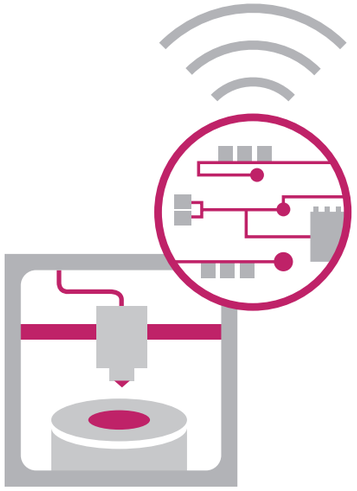
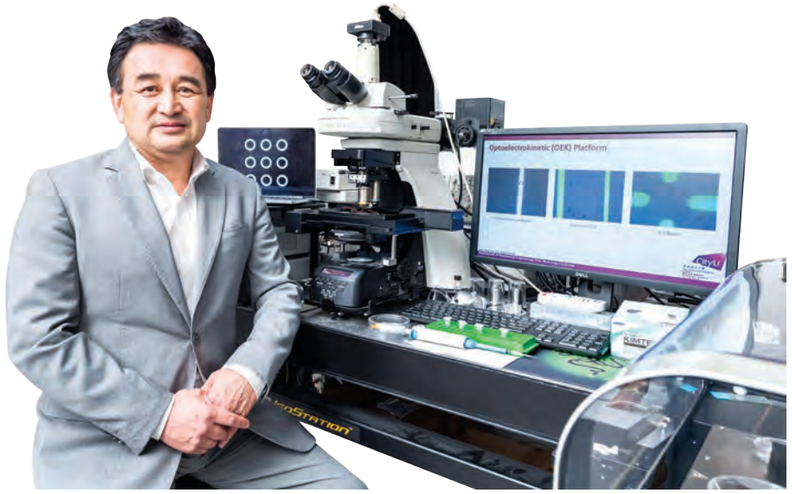
Advancing Sensing and Robotic Actuation Technology





Professor Li Wen Jung uses MEMS technology to fabricate microfluidics chips that can identify stomach cancer cells.

To take sensing and robotic actuation technologies to new heights and application domains, a collaborative research team at CityU is working on developing next-generation three-dimensional (3D) sensing systems and 4D robotics actuators for applications in digital healthcare, medical robotics and extended reality.

Professor Li Wen Jung, Chair Professor of Biomedical Engineering and Director of the Joint Laboratory for Robotic Research (JLRR), which was established by the Shenyang Institute of Automation, Chinese Academy of Sciences (SIACAS) and CityU, specialises in developing micro-electromechanical systems (MEMS) and various micro-, nano- and bio-sensing and robotics technologies.

MEMS is a process technology used to create tiny integrated devices that combine mechanical and electrical components. Ranging in size from a few micrometres to millimetres, these devices or systems can sense, control and actuate on a micro scale with high sensitivity and extreme accuracy, and generate effects on the macro scale. Based on integrated circuit technology, the batch fabrication capacity of MEMS devices enables low per-device production costs.

Fabricating sensors for health applications

Currently MEMS is widely used in applications such as actuators in inkjet printer nozzles, crash air-bag accelerometers in automobiles, projection display chips, optical switches, and blood pressure sensors. "In particular, micro-, nano- and bio-sensors are very important for digital and tele-medicines," said Professor Li. "Doctors can use many different physiological sensors to conveniently monitor their patients. And all these sensors are based on MEMS fabrication technology in one way or another."

His team has employed this widely used technology to fabricate a number of sensors for healthcare applications. One of their ongoing projects involves using flexible smart-skin sensors to decipher the correlation of a patient's arterial pulse with kidney disease progression. They also deployed MEMS to fabricate microfluidics chips that separate and identify cancer cells and stem cells, contributing to the early diagnosis of diseases and biomedical science research.

One of their current research focuses involves leveraging the latest additive 3D nano-printing technology to develop next-generation 3D sensing and 4D robotic actuation systems.

"Additive 3D nano-printing technology can integrate complex geometric features, compact electronic circuits and many new functional materials into flexible or rigid polymers, enabling the design of novel single or multi-material micro/nano sensors and actuators to have features at multiple length-scales," explained Professor Li.

Leveraging multi-material 3D nano-printing

Using an advanced 3D nano-printing system that can produce multi-layered nano-material-based structures and 3D circuitry in the JLRR at CityU, Professor Li and his team are developing flexible skin-sensors for integrating with assistive robots for the elderly, and for producing tactile sensors to enhance extended reality-based education in Hong Kong.

They will also modify the printing platform so that advanced sensing and conducting nanomaterials, such as graphene oxide, carbon nanotubes and other nanomaterials, can be embedded into 3D fabricated mechanical structures. This is expected to speed up the process of sensing device prototyping dramatically at lower cost.

Moreover, with multi-material 3D nano-printing, researchers can directly fabricate the functional body of robots, employing various soft material components with different degrees of stiffness, thus avoiding complex moulding techniques and assembly. By introducing new classes of customised materials and functionalities into 3D printing, they can fabricate new breeds of robotic actuators – 4D actuators – that are stimuli-responsive, self-morphing, and embedded with programmable architectures. The team plans to demonstrate the fabrication of several advanced actuation devices, including cell-electric-stimulation array for bio-syncretic robots, bio-syncretic cell-based actuators, and 4D micro-robots with fluorescent characteristics for biomedical applications.

"As a technologist, my research goal is very clear: develop technologies to advance human wellbeing, including extending human life, making everyday life more enjoyable, and discovering new phenomena," said Professor Li.

Major Awards

- IEEE Fellow
- ASME Fellow
- Elected President of the IEEE Nanotechnology Council (2016/2017)
- 100 Talents Awardee (Distinguished Overseas Scholar), Chinese Academy of Sciences

Key Projects

- General Research Fund:
  - Microfluidic Pervaporation Device for Fabrication of Nanoparticle-based Metalens for Dry Environment Super-Resolution Imaging
  - Development of Flexible MEMS Pressure Sensors Using Hierarchical Surface Structures for Texture Roughness Identification
  - Atomization of Viscous Fluids for Digital Scent Technology Using an Integrated Micro-droplet Generation Platform
- Innovation and Technology Fund:
  - A MEMS-based Light Detection and Ranging (LIDAR) System with Super-resolution Microlens for Enhanced Structured-light 3D Imaging and Mapping
  - An Implantable Micro-Sensing System for Tracking Animal Motion Behaviors
- Joint Laboratory Funding Scheme: Development of 3D Integrated Robotics and Sensing Structures Using Multi-layered Nano-ink Circuit Deposition
- Shenzhen Science, Technology and Innovation Commission: 大視場納米尺度超分辨測量與成像系統

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BRAIN

An interdisciplinary joint effort to provide a better understanding of the structure and functions of the human brain and the understanding of mind, including potential of human-machine interfaces.

From Memory Formation to Treatment of Brain Disorders

How memories are formed has long been a fundamental question for neuroscientists. Studies by **Professor He Jufang**, Wong Chun Hong Chair Professor of Translational Neuroscience in the Department of Neuroscience and Department of Biomedical Sciences, have shed light on the crucial role of a key neuromodulator, called cholecystokinin (CCK), in memory forming in the neocortex. As a result of the discovery of CCK's functions, Professor He is developing a treatment strategy to alleviate epilepsy, tinnitus, Alzheimer's disease, and other brain disorders.

Memory is stored in a network of neurons through the persistent changes in the strength of connections between neurons, described as synaptic plasticity. These connections, called synapses, allow neurons to communicate with each other. The strength of communication, called synaptic strength, can be modified, depending on how often these connections are activated. The more active the connections are, the stronger they become. The lasting increase in synaptic strength is called long-term potentiation (LTP). And long-term synaptic plasticity forms the model for memory storage.

Discovery of crucial neuromodulator in memory formation

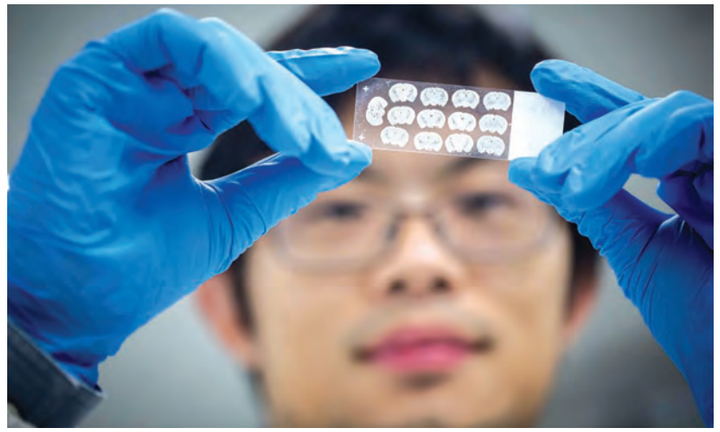
During the communication between two neurons across a synapse, an electric signal is converted into a chemical signal, in the form of neurotransmitter release. Upon binding to the receptor, the transmitter switches back into an electric form travelling through the neuron.

By investigating the chemical composition of dozens of neurotransmitters and neuromodulators in the medial temporal lobe, Professor He and his team discovered that CCK is crucial in switching on memory writing in the neocortex. In particular, they found out how memory is encoded and how visual and auditory inputs are associated.

Subsequently, they found that the N-methyl-D-aspartate (NMDA) receptor, which was once widely recognised as the most important receptor in mediating the formation of memory, actually controls the release of CCK. And it is CCK that induces long-term synaptic plasticity, enabling memory formation.

While their discovery is about memory formation, its implications and application potential extend further. "Epilepsy and many neurodegenerative diseases, such as Alzheimer's, are strongly associated with synaptic plasticity in the brain," said Professor He. "Our findings revealing the relationship among CCK, LTP and synaptic plasticity provide a theoretical basis for developing treatments for different brain diseases."

For instance, they are studying the relationship between high-frequency stimulation-induced LTP in the hippocampus and CCK, and between spatial memory and CCK. In particular, they will examine whether CCK agonists (chemicals act like CCK and therefore stimulate the same receptors) can rescue spatial learning in memory-deficient mice, with the long-term goal of future drug development to help patients with Alzheimer's or neurological disorders retain memory.



Cortical slides of the mice from experiments for studying the formation of memory.

Treatment strategy for tinnitus

The team is also investigating the possibility of treating tinnitus with the administration of CCK4, a type of CCK agonist, paired with sound therapy.

Tinnitus patients hear phantom sounds, like clicking, buzzing or ringing. Tinnitus alone can severely disrupt quality of life. The majority of tinnitus cases occur after patients suffer from peripheral hearing loss because of exposure to either long-term loud noise or a blast. In a fraction of cases, the brain is incapable of compensating for the loss of major ascending cochlear input to the major centres of the central auditory pathway, namely the auditory thalamus and auditory cortex. Neurons that lose cochlear input in these brain regions become hypersensitive and show synchronised activity, called thalamocortical oscillations. This constant activity in the loop can be perceived as a constant phantom sound, tinnitus.

"We plan to apply CCK agonists to patients to activate plasticity in the brain, and then apply sound therapy to rewire synaptic connections in the thalamocortical complex," said Professor He. "The novelty of our approach involves triggering synaptic plasticity in the brain through the administration of CCK4. Preliminary results show a promising outcome."

Application in alleviating epilepsy

Moreover, inhibiting CCK activation may help alleviate involuntary seizures in epilepsy patients.

Epilepsy is one of the most prevalent neurological disorders characterised by spontaneous recurrent seizures. "Anti-epileptic drugs have been used as long-term treatment solutions. But 35% of patients have been found to become resistant to the medication. Temporal lobe epilepsy is one of the most severe and frequent pharmaco-resistant types of epilepsies," explained Professor He.

After having established the link between epilepsy and the strengthening of the neural network with CCK from the medial temporal lobe, the team will explore a treatment strategy by blocking the synaptic strength with CCK receptor antagonists.

Professor He Jufang (back) and his research group members.

Major Award

- The President's Award 2018, CityU

Key Projects

- General Research Fund:
  - A Novel CCK Receptor Regulates the Long-term Potentiation of Inhibition in the Auditory Cortex
  - Cholecystokinin Administration Rescues Thalamocortical Neuroplasticity in Old Rodents
  - GABAergic Cholecystokinin Enhances the Local Inhibitory Effect in the Auditory Cortex
- Health and Medical Research Fund:
  - Neuroplasticity Induced by the Administration of Cholecystokinin Tetrapeptide and Noise Exposure as a Novel Strategy for the Treatment of Tinnitus
  - The Development of Upconversion-based Wireless Optogenetics as an All-optical Therapeutic Strategy to Study and Treat Parkinson's Disease
- Innovation and Technology Fund:
  - Assay Platforms for CCK-B Receptor Agonists as Potential Treatment for Amnestic Mild Cognitive Impairment

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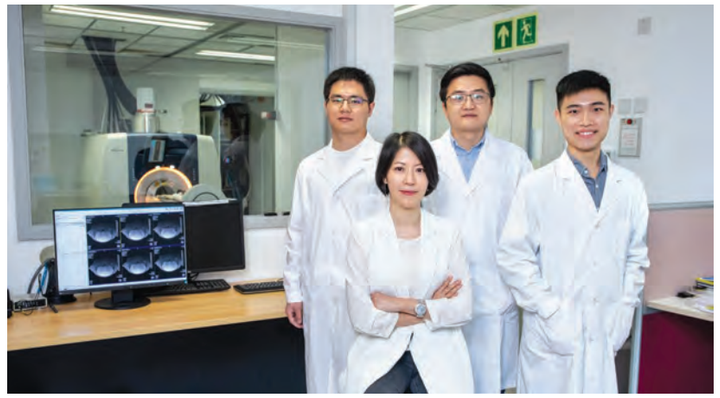
New MRI Approach for Earlier Detection of Alzheimer's Disease



Dr Kannie Chan Wai-yan (first row) and her research team.

Collaborative research by CityU and Johns Hopkins University has developed a new, non-invasive way to identify Alzheimer's disease even before any symptoms appear.

Dr Kannie Chan Wai-yan, Associate Professor in the Department of Biomedical Engineering (BME) at CityU, and her team collaborated with scientists from the US, Sweden and Hong Kong in pioneering this pre-clinical study. They developed a molecular imaging approach, based on Magnetic Resonance Imaging (MRI), to dynamically measure glucose level changes in the brain's lymphatic system, which can provide early cues about the disease. Their findings were published in the scientific journal *Science Advances* in May, 2020.

"The tricky part of fighting Alzheimer's disease is that early symptoms, such as the emergence of protein plaques in the human brain, which hamper the cognitive function, are similar to normal ageing," said Dr Chan. "Even more challenging, patients diagnosed with symptoms are most likely in the middle or late stage of the disease. Overlooked pathologies in the brain could have happened 15 or 20 years before the symptoms appear."

Dr Chan's team's new imaging approach can assess glucose uptake and clearance in the lymphatic system of the brains of mice in a non-invasive way. "By using glucose as a natural 'tracer', our imaging method can sensitively detect the distinctive changes in the lymphatic system function at the molecular level at the early stage of Alzheimer's disease, helping us to differentiate it from normal ageing," she said.

The new imaging approach is compatible with the MRI machines commonly used in clinics and hospitals, which means low set-up cost and technically easy transfer to clinical applications. Dr Chan anticipates that clinical trials can be conducted within three years.

Major Awards

- Young Investigator Award, Overseas Chinese Society for Magnetic Resonance in Medicine, 2020
- ISMRM Magna cum Laude Merit Award 2020
- Teaching Excellence Award 2020, CityU

Key Project

- General Research Fund: Development of Theranostic Hydrogels for MRI-guided Brain Tumor Treatment

Selected Publications

- Huang, J., Chen, L., Xu, X., van Zijl, P.C.M., Xu, J. & **Chan, K.W.Y.** 2020, "Multi-slice nuclear overhauser enhancement imaging with suppressed magnetization transfer for hydrogel-based therapy in the brain at 3 T MRI", *Magnetic Resonance in Medicine, (in press)*.
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Discovering the Neural Mechanisms Between Chronic Pain and Cognitive Deficits

Having developed dynamic schema-like memory consolidation, it only took the rat one training session to find the correct food location from the sand well.

While the clinical connection between chronic pain and increases in levels of anxiety, depression, cognitive dysfunction has long been established, the underlying mechanisms of brain neural networks remain less understood. **Professor Li Ying**, Chair Professor in the Department of Neuroscience and Department of Biomedical Sciences, has achieved breakthroughs by unveiling the secrets of brain molecules and tissue – astrocytes and myelin – in the central nervous system. By identifying the roles of astrocyte lactate signalling and myelin plasticity in circuitry synchrony, he has shed light on how fundamental cognitive functions, including learning, memory and decision-making, could be rescued and enhanced, especially for patients suffering from chronic pain.

Astrocytes, which are star-shaped glial cells in the anterior cingulate cortex (ACC), are crucial in influencing neuronal functions. Professor Li and his team found that during synaptic activity (when an electrical or chemical signal is passed from one neuron to another or to a target effector cell), astrocytes release a substance called L-lactate, which is utilised by neurons to promote information flow and synchrony in the brain neural circuitry, thereby improving decision-making performance.

L-lactate: a signalling molecule to improve decision-making

Recently L-lactate has been recognised as an important fuel for many cells. But Professor Li's study found another essential role: as a signalling molecule in neuronal activity plasticity and neuronal network synchrony in the brain.

Using the previously established "chronic visceral pain rat model", the research team found that L-lactate infusion into the ACC increased the proportion of good decisions by normal rats by up to 48% and significantly relieved decision-making dysfunction in rats with chronic visceral pain. The animal experiments support the idea of an "astrocyte-to-neuron L-lactate shuttle", which means that the exogenous administration of L-lactate or optogenetic activation of astrocytes can stimulate astrocytes in abnormal neural circuitry and may help alleviate cognitive deficits caused by chronic pain.

Apart from investigating the pathological mechanisms of pain-related brain disorders for years, Professor Li was also the first to decipher the critical role of myelin in advanced cognitive memory and how its growth and regeneration can be fostered to enhance the synchrony of neural networks and improve cognitive functions.

The critical role of myelin in cognitive functions

Myelin, or myelin sheath, a multi-layered fatty tissue wrapped around neuronal axons, insulates and protects neurons, and increases the rate at which information is passed along the axons. Its formation is controlled by oligodendrocytes, which are large glial cells in the central nervous system.

The team discovered that schema-like learning, which is learning through repetition, can foster the growth of brain myelin. Memory schemas have been introduced to cognitive psychology to understand how new information is integrated with pre-existing knowledge. So the team applied schema-like learning to design the study of behaviour in rats.

In weeks of training, the rats learned multiple types of flavour-place paired association, so that they could remember which kind of food was hidden in which sand well. After training, when the rats smelled a certain kind of food, they could quickly go to the correct sand well and dig it out, showing that they had developed dynamic schema-like memory consolidation and retrieval. When the rats were introduced with two new flavour-place pairs, it only took them one training session to find the correct food location, indicating that the integration of new information into established knowledge progressed very rapidly.

By analysing the changes in the rats' brains with immunohistochemistry and a transmission electron microscope, the researchers found that the myelin of the ACC of the trained rats had grown substantially in the process of learning and developing memory schema.

In addition, the team reversely demonstrated the importance of myelin in enhancing learning and memory capacity by interrupting its growth.

By injecting drugs for demyelination in rats, they concluded that the interference of myelin formation can severely disrupt the creation of memory schemas and new memories. The transmission of information within neural circuits and the synchrony of neural networks are negatively affected as well. They also found that myelination is a key factor in facilitating long-range oscillations and synchronisation of spike time arrival between neurons in different brain areas.

"With the use of cutting-edge optogenetic, chemogenetic and pharmacological technologies, we can precisely control brain oligodendrocytes to promote myelin formation," said Professor Li. "We will explore whether these methods can improve severe cognitive impairment caused by central myelin diseases such as severe depression, chronic recurrent pain, irritable bowel syndrome, and Alzheimer's disease."

He and his team will continue to investigate neural network synchronisation to identify the causality of chronic pain and associated cognitive deficits, which will lay the groundwork for developing effective treatment and prevention strategies.

"Neuroscience is a complex discipline, which covers a broad base of life sciences, and is related to other disciplines, such as physics and information technology. So we should expand our knowledge in all these fields. There is also a crucial connection between philosophy and cognitive science. The driving forces of hypotheses and advanced biotechnologies should be used in concert to explore the beauty of the philosophy of mind and cognition."

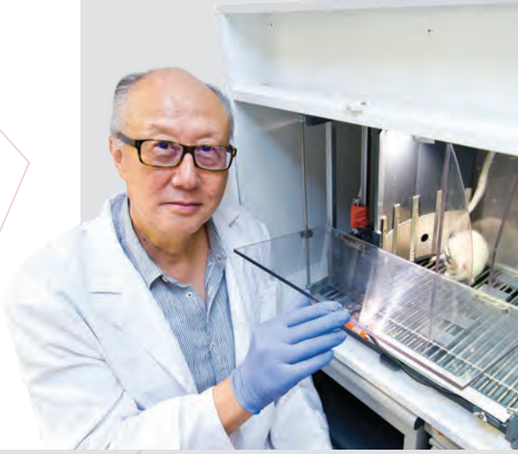
- Professor Li Ying

Major Awards

- Fellow, American Gastroenterological Association
- Guest Principal Investigator: Institute of Brain Cognition and Brain Disease, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences

Key Projects

- General Research Fund:
  - Chronic Pain Induces Hypomyelination: A Causal Mechanism for Brain Circuitry Desynchronization and Impaired Decision Making
  - Impairment of Schemas and Memory Consolidation and Disruption of Schemas-linked Interactions Between Hippocampal and Anterior Cingulate Cortex in Chronic Visceral pain
- NSFC/RGC Joint Research Scheme: L-lactate Release by Optogenetic Activation of Astrocytes Rescues Decision-making Deficit in Visceral Hypersensitive Rats
- Health and Medical Research Fund: Impaired Communications in Anterior Cingulate Cortex Neural Network in the Rats with Trigeminal Neuropathic Pain is Associated with Decision-making Deficits



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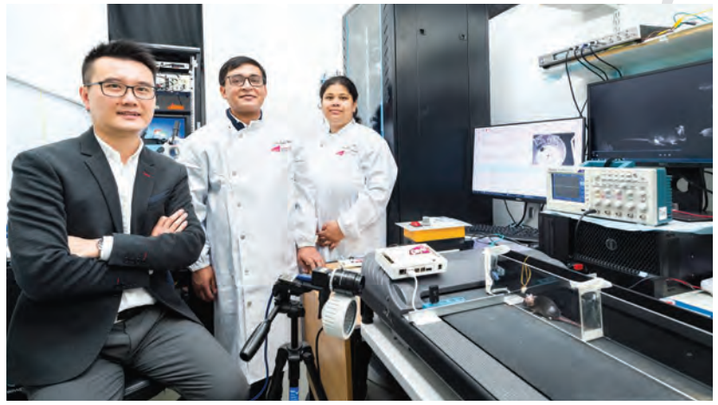
Novel Neural Prosthetic Devices for Neurodegenerative Diseases

Patients suffering from spinocerebellar ataxia (SCA) and Parkinson's disease (PD), two incurable neurodegenerative diseases, often experience problems with movement and motor coordination. **Dr Eddie Ma Chi-him**, Associate Head and Associate Professor in the Department of Neuroscience and Director of the Laboratory Animal Research Unit (LARU) at CityU, is currently developing novel neural prosthetic devices that could improve patients' motor symptoms and improve their quality of life.

Neurodegenerative diseases occur when neurons in the brain or peripheral nervous system lose function over time and ultimately die. Dr Ma, who specialises in studying the intrinsic molecular machinery for central and peripheral nervous system regeneration after injury, has adopted a multi-disciplinary approach spanning electrophysiology, molecular biology, anatomy, animal behaviour and genetics, and is working on advancing deep brain stimulation (DBS) treatment strategies to better assist patients with SCA or PD.

SCA refers to a group of genetic, progressive neurodegenerative disorders, characterised by the loss of body balance, motor coordination, speech and oculomotor difficulties, which affect five per 100,000 people worldwide. Scientists have long recognised the importance of cerebellum, which is the balance and fine movement coordination centre of the brain, as a target site for DBS in the treatment of SCA.



Dr Eddie Ma Chi-him (left) and his research team.

Closed-loop DBS to avoid side effects

"However, conventional open-loop DBS involves continuous and excessive brain stimulation, which has undesirable side effects. It also reduces the battery lifetime of deep brain stimulators, which increases the frequency of replacement surgery. It is estimated that over 50% of continuously delivered stimulation via open-loop DBS in PD patients is unnecessary and can be avoided by using a feedback biomarker, as in closed-loop DBS," explained Dr Ma.

To avoid excessive stimulation, he and his team designed a "closed-loop" deep cerebellar nuclei (DCN) stimulator prototype, which is triggered only when a symptomatic electromyography in the muscle is detected.

The research team is now testing the therapeutic potential of this stimulator prototype in genetically engineered mice with ataxia phenotype. They will first perform electromyography to record muscle activity and video kinematics at different stages of locomotion, and simultaneously record neural activities of DCN in the cerebellum to define symptomatic electromyography activity as a feedback biomarker for closed-loop DBS.

In collaboration with **Dr Tin Chun** in the Department of Biomedical Engineering, Dr Ma and his team will develop a real-time field-programmable gate array (FPGA) algorithm, targeting interposed nucleus of the DCN to close the loop in ataxia mice. The FPGA system is designed to perform complex computations in real time, completing one-second real-world activities within milliseconds. After carrying out further electrophysiology and motor behavioural assessments, the team expects the motor deficit in SCA mice to improve after DBS and the new device to become more durable, resulting in fewer side effects.

New stimulation target site for treating Parkinson's disease

Another research focus of Dr Ma is PD, the second most common chronic neurodegenerative disorder, which affects more than 6.1 million of the world's population and about 1.7% of people aged 60 years or over in China.

Conventional DBS implantation is performed in the ventral intermediate nucleus (VIM) of the thalamus, subthalamic nucleus or globus pallidus interna to modulate either a direct or indirect pathway of the thalamo-cortical-striatal loop. The imbalance between direct and indirect pathways results in abnormal activation of output nuclei and over-inhibition of the thalamus and motor cortex, leading to undesirable side effects, such as cognition impairment, depression and anxiety.

Considering that i) striatum nuclei are the motor integrating centre in the brain modulating both direct and indirect pathways; and ii) the abnormal local field potential (LFP)-beta power and neuronal firing pattern detected in the striatum nuclei of PD patients is associated with motor dysfunction, Dr Ma is exploring striatum nuclei as a novel target site for DBS. His research team has demonstrated that DBS at the striatum nuclei is more effective than DBS at the subthalamic nucleus and globus pallidus interna in improving motor symptoms in two mouse models of PD.

The research team will optimise the DBS parameters so that it is triggered only when a symptom-related biomarker is detected. In collaboration with a US-based company, the optimised therapeutic DBS parameters will be used to develop an implantable microchip prototype of a closed-loop deep brain stimulator using striatum nuclei as a novel DBS target site.

"We believe that the success of the current study will not only minimise side effects in conventional DBS with a new DBS target site, but also take DBS development to the next level by closing the loop. Our closed-loop prototype could minimise unnecessary stimulation in SCA and PD patients to reduce side effects for early intervention," said Dr Ma.

Major Awards

- World Cultural Council Special Recognition, 2018
- The President's Award 2016, CityU
- Croucher Foundation Fellowship 2005-2007

Key Projects

- Innovation and Technology Fund:
  - Therapeutic Potential of a Novel Deep Brain Stimulation Target Site and Neural Prosthetic Device for Treating Parkinson's Disease
  - Therapeutic Potential of Neural Motor Prostheses Device for the Treatment of Spinocerebellar Ataxia

The closed-loop deep brain stimulator prototype developed by Dr Ma's research team.

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- **Ma, C.H.E.** & Au, N.P. B., "Low-dose radiation therapy for traumatic brain injury and stroke", US patent 63/089,607, filed 2020.
- **Ma, C.H.E.** & Au, N.P. B., "Targeting mitochondrial dynamics by mitochondrial fusion promoter M1 as a treatment strategy for nervous system injury," US patent 63/081,371, filed 2020.
- **Ma, C.H.E.**, & Au, N.P. B., "Therapeutic potential of glycopyrrolate and mexiletine for nervous system injury", US patent 63/078,395, filed 2020.
- **Ma, C.H.E.**, Kumar, G., & TIN, C., "Neurostimulation system and method for modulating abnormal motor movement", US patent 16/454,121, filed 2019.

RESEARCHERS FEATURE

Impactful, cutting-edge research would not be possible without the commitment and efforts of dedicated scholars and researchers. Here are the highlights of some of the outstanding researchers recognised for their top-level research.

Untangling Mathematical Theories for Kinetic Systems

Professor Yang Tong

The kinetic theory, which is primarily the study of rarefied gas motion and related fluid dynamics, is widely applied in daily life in fields such as aircraft engineering, automobile design, the evaluation of resistance against strong winds for large buildings and structures, and plasma and fusion problems. But there are still many important unsolved mathematical questions, which are intriguing for many mathematicians, including **Professor Yang Tong**, Chair Professor of Mathematics.

There are two basic ways to study the motion of gases and fluids: using the macro scale, which considers large scale action of gas and fluid as a whole, and the micro scale, which investigates the motions and interactions of individual molecules.

At the macroscopic scale, where the gas and fluid are regarded as a continuum, their motion is described by the macroscopic quantities, such as mass density, temperature and pressure. At this scale, the Euler and Navier-Stokes equations are the most famous equations among the governing systems proposed in fluid dynamics.

At the microscopic scale, gas and fluid are viewed as a many-body system of individual particles. The motion of the system is governed by coupled Newton equations within the framework of classical mechanics. Since the movement of each atom takes place in three-dimensional space, an enormous number of Newton equations are involved in the calculations. "Therefore, it isn't practical to use the Newton equations to solve such a large coupled system, and specifying all the initial data is just impossible," explained Professor Yang.

Instead, statistics and probability are to be used. The fluid dynamical quantities used at the macroscopic scale are related to the statistical average of the quantities in the microscopic state. "And this is where the kinetic theory comes in, since it gives a mesoscopic description of movement of gas and fluid, linking the microscopic and macroscopic models," said Professor Yang. "The Boltzmann equation is the most fundamental equation in the kinetic theory; most of the known kinetic models were derived from it," he added.

The complexity of these models and the diversity of their structures provide a huge and extremely rich area of research for mathematical analysis.

As an awardee of the Senior Research Fellow Scheme of Research Grants Council (RGC), Professor Yang is using the grant to advance his study of the solution behaviour and fluid dynamic limits of some typical kinetic models, including the Vlasov-Maxwell-Boltzmann system and the Vlasov-Nordström-Fokker-Planck system. He hopes that the analytic techniques developed in this project will be applicable to the study of other systems of kinetic equations to enrich the existing mathematical theories in this important area.

Major Awards

- Fellow of American Mathematical Society 2021
- RGC Senior Research Fellow 2020
- Fellow of the European Academy of Sciences 2018
- Croucher Senior Research Fellowship 2011

Key Projects

- RGC Senior Research Fellow Scheme: Some Mathematical Theories for Kinetic Systems
- General Research Fund:
  - MHD Boundary Layer Theories and Beyond
  - Some Mathematical Theories for High Reynolds Number Limit
  - Instability and Critical Regularity Indice for Degenerate PDEs of Prandtl-type Systems

Selected Publications

- Li, W.-X., Masmoudi, N. & **Yang, T.** "Well-posedness in Gevrey function space for 3D Prandtl equations without structural assumption", *Communications on Pure and Applied Mathematics. (accepted)*
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- Liu, T.-P. & **Yang, T.** 1999, "Well-posedness theory for hyperbolic conservation laws", *Communications on Pure and Applied Mathematics*, vol. 52, no. 12, pp. 1553-1586.
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Developing Semiconducting Nanowires for Next-generation Electronics

Professor Johnny Ho Chung-yin

Thanks to advances in nanotechnology, materials can now be fabricated into nanoscale configurations with different dimensionalities and widely tuneable properties for technological applications. **Professor Johnny Ho Chung-yin**, from the Department of Materials Science and Engineering, has been working on the synthesis of various one-dimensional, nanoscale semiconductors for high-performance electronics and optoelectronics.

"Since the lifespan of silicon as the raw material for semiconducting chips is reaching its plateau, scientists are exploring alternative substances for next-generation electronics," said Professor Ho, who has been working in the synthesis, characterisation, integration and device applications of nanoscale materials for various technological utilisation for over 10 years. Nanowire, a kind of one-dimensional semiconductor with intriguing electrical properties, can potentially replace silicon and is one of his research focuses.

In recent years, Professor Ho and his team have made various breakthroughs in fabricating various types of semiconducting nanowires, ranging from group III–V semiconductors and halide perovskite to metal oxide nanowires. For example, they successfully synthesised highly dense and highly crystalline indium gallium antimonide (InGaSb) (a group III–V semiconductor compounds) nanowires that display superior electrical and optoelectronic properties. They demonstrated that the nanowires can be fabricated into large-scale nanowire parallel arrays-based devices, showing potential for industrialisation.

More importantly, ultra-thin films composed of highly dense semiconducting nanowires are an integral component in the expanding fields of flexible and wearable electronics for mobile phones, health monitoring devices, and other smart gadgets. "The unique physical properties of semiconducting metal-oxide nanowires, such as their excellent composition and dielectric tunability, make them an ideal active device channel material for flexible electronics," explained Professor Ho.

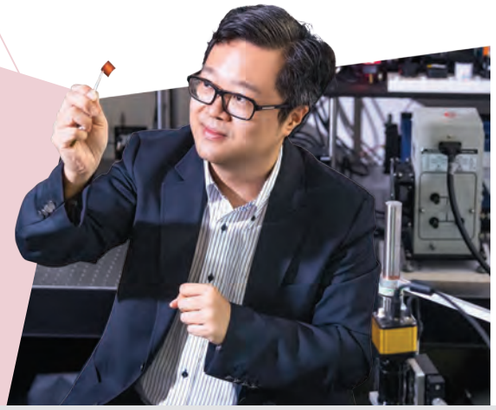
With the support of the RGC Research Fellowship, he and his team are working on the development of mechanically flexible negative-capacitance nanowire transistor arrays and integrated circuits, using metal-oxide nanowire materials. They also aim to establish design guidelines, as well as versatile and cost-effective platforms, to develop high-performance, ultra-low-power consumption devices on a large scale for next-generation flexible electronic technologies.

Major Awards

- RGC Research Fellow 2020
- The President's Award 2020, CityU
- World Cultural Council Special Recognition, 2018
- Elected Founding Member, The Hong Kong Young Academy of Sciences, The Hong Kong Academy of Sciences, 2018
- Outstanding Supervisor Award 2017-2019, CityU

Key Projects

- RGC Research Fellow Scheme: Developing Negative-Capacitance Nanowire Transistor Arrays and Integrated Circuits for Next-Generation Flexible Electronics
- General Research Fund:
  - Single-Crystal Lead-Free Perovskite Nanowire Parallel Arrays for High-Performance Thin-Film Transistors and Integrated Circuits
  - High-Performance Flexible Broadband Photodetectors Based on All-Inorganic Perovskite Nanowires
  - Wearable Toxic Gas Sensors Based on Hybrid Integration of Multifunctional Nanomaterials



Selected Publications

- Meng, Y., Li, F., Lan, C., Bu, X., Kang, X., Wei, R., Yip, S.P., Li, D., Wang, F., Takahashi, T., Hosomi, T., Nagashima, K., Yanagida, T. & **Ho, J.C.** 2020, "Artificial visual systems enabled by quasi-two-dimensional electron gases in oxide superlattice nanowires", *Science Advances*, vol. 6, no. eabc6389.
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- Meng, Y., Lan, C., Li, F., Yip, S., Wei, R., Kang, X., Bu, X., Dong, R., Zhang, H. & **Ho, J.C.** 2019, "Direct vapor-liquid-solid synthesis of all-inorganic perovskite nanowires for high-performance electronics and optoelectronics", *ACS Nano*, vol. 13, no. 5, pp. 6060-6070.

Pioneering Elastic Strain Engineering and Nanomechanics

Dr Lu Yang

Materials at nanoscale often have some intriguing properties that surprise scientists. Investigating the mechanical phenomena of nanomaterials is one of the key research interests of **Dr Lu Yang**, Associate Professor in the Department of Mechanical Engineering.

Covalent crystal is a class of crystalline solids in which the atoms are bonded by covalent bonds in a continuous network throughout the material. The materials include diamond, silicon and compounds like silicon carbide (SiC). Because of the strong, directional covalent bonding, they are usually hard and brittle (thus fracturing before deforming) at the macroscopic scale.

Scientists have found that like many other nanomaterials, covalent crystals at microscopic scale have some very different properties from their macroscopic counterparts. For example, Dr Lu and his team discovered that diamond and silicon at nanoscale show significantly enhanced elasticity. Their findings were published in the prestigious scientific journal *Science*.

This discovery has turned the concept of "elastic strain engineering (ESE)" of covalent crystals into reality. ESE refers to achieving unusual and desired functional properties, such as changing electron mobility in semiconductors, by applying ultra-large mechanical stress or strain to the crystal lattices. This has emerged as a powerful approach for optimising functional device performance for applications in microelectronics, optoelectronics and others. Despite numerous theoretical and computational efforts, the number of experimental investigations and characterisations of strained covalent crystal solids remains limited.

With the RGC Research Fellowship, Dr Lu and his team are conducting nanomechanical investigations on a few types of covalent crystal solids. Their aim is to explore their deformation behaviour at nanoscale and how to modulate the change of bandgap or other properties through strain-tuning, in order to enhance the conductivity and optoelectronic properties of nanosized covalent crystals for further applications.

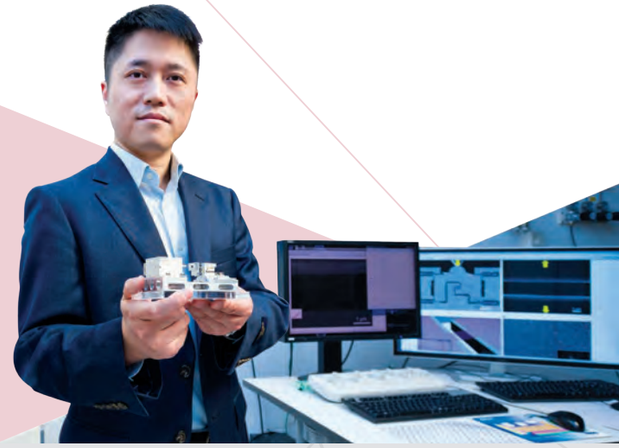
"We hope the project will provide unprecedented detail and quantitative insights into how 'deep elastic strain engineering' an effectively tune the functional properties of nanoscale solids for future novel device applications," said Dr Lu.

Major Awards

- RGC Research Fellow 2020
- Excellent Young Scientists Fund (Hong Kong and Macau), National Natural Science Foundation of China (NSFC), 2019
- Outstanding Research Award for Junior Faculty 2019, CityU

Key Projects

- RGC Research Fellow Scheme: Nanomechanics of Covalent Crystals and Their Elastic Strain Engineering
- General Research Fund:
  - Mechanics of 1-D Diamond Nanostructures
  - Elastic Strain Engineering of Low-dimensional Nanostructures: Tuning Functional Properties by Mechanical Stretching
- NSFC Excellent Young Scientists Fund: Nanomechanics



Selected Publications

- Dang, C., Chou, J.-P., Dai, B., Chou, C.-T., Yang, Y., Fan, R., Lin, W., Meng, F., Hu, A., Zhu, J., Han, J., Minor, A. M., Li, J. & **Lu, Y.** 2021, "Achieving large uniform tensile elasticity in microfabricated diamond", *Science,* vol. 371, no. 6524, pp.76-78.
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Synthesis of Luminescent Materials

Dr Wang Feng

As lighting and display devices have become an essential part of our daily lives, scientists have continued in search of more efficient and sustainable light sources. **Dr Wang Feng**, from the Department of Materials Science and Engineering, has been focusing on the synthesis and applications of luminescent materials comprising lanthanide (a family of 15 rare earth elements) and transition metal ions for optoelectronic devices.

While the adoption of light-emitting diodes (LEDs) in lighting has quickly replaced traditional tungsten and incandescent lamps in the past decade, the development of direct current-driven electroluminescence (DCEL) technology, which supports the operation of these LED devices, has reached a bottleneck. The manufacturing cost is high, device stability can be seriously affected by water and oxygen, and it is difficult to fabricate flexible devices.

Compared to DCEL, alternating current electroluminescence (ACEL) is an effective alternative. It is cost-effective and stable, and uses less energy. But the lack of available ACEL materials has greatly hindered its development.

With the RGC Research Fellowship, Dr Wang focuses on developing a new class of calcium zinc oxysulfide (CaZnOS)-based ACEL materials, replacing the conventional zinc sulfide (ZnS). CaZnOS permits rare earth doping, thereby enabling luminescence with optical tuning across the full spectrum of light, from ultraviolet to near-infrared, and opening up new opportunities for designing advanced optoelectronic devices.

With almost 20 years of experience in research on lanthanide-based luminescent materials, Dr Wang has led his group to explore the near-infrared to visible or ultraviolet up-conversion luminescence in lanthanide-doped core-shell fluoride nanocrystals in recent years. In particular, he has established a versatile protocol for the rational synthesis of core-shell nanocrystals with tuneable core particle size and shell thickness. The strategy of core/shell nanostructural engineering that he has developed permits unprecedented optical tuning with high emission efficiency using unusually high dopant concentrations.

He has also initiated several applications of up-conversion nanocrystals, such as up-conversion lasing and optogenetics.

Major Awards

- RGC Research Fellow 2020
- Asian Rising Star Lectureship, The Federation of Asian Chemical Societies, 2019
- The President's Award and Outstanding Supervisor Award 2019, CityU
- Highly Cited Researcher (Cross-Field), Clarivate, 2018

Key Projects

- RGC Research Fellow Scheme: Controlled Synthesis of Lanthanide-Doped Semiconductor Heterostructures for Flexible Display Through High-Field Electroluminescence
- General Research Fund:
  - Developing Stretchable Multicolor Mechanoluminescent Composites with High Flexibility and Durability
  - Constructing Deep Ultraviolet Microlasers through Photon Upconversion in Heavily-Doped Nanocrystals
  - Developing Lanthanide-doped Microcrystals for Photonic Applications

Selected Publications

- Zhao, J., Chen, B. & **Wang, F.** 2020, "Shedding light on the role of misfit strain in controlling core–shell nanocrystals", *Advanced Materials*, vol. 32, no. 46.
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Study of Rare Cells for New Cancer Immunotherapy

Dr Chow Kwan Ting

Cancer immunotherapy has brought hope to many cancer patients, but so far it works only for certain types of cancers. With the ultimate goal of improving current immunotherapy and designing new immunotherapy for currently incurable cancers, **Dr Chow Kwan Ting**, in the Department of Biomedical Sciences, has been exploring the basics of how the immune system, in particular a rare immune cell type, naturally fights cancer.

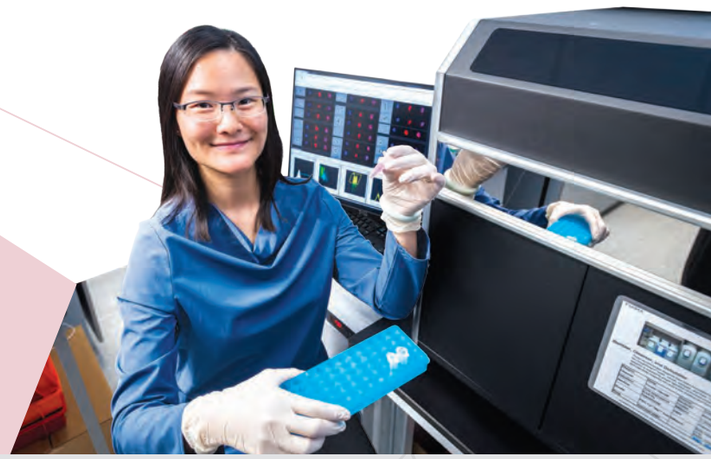
"I have always been amazed by our immune system. From viruses to parasitic worms and everything in between, it protects us from numerous and diverse types of harm every minute," said Dr Chow, who received the Croucher Innovation Award 2019. "Now we know that the immune system doesn't just fight foreign invaders; it also combats cancer that arises from within our body. And unlike conventional treatments of radiotherapy and chemotherapy, immunotherapy doesn't kill healthy cells, thus eliminating many side-effects."

After witnessing several family members die of cancer, and how devastating childhood cancers can be when she worked in a paediatric oncology lab, Dr Chow is dedicated to understanding how the immune system fights cancer. Her goal is to devise new immunotherapy to help cancer patients, especially those with currently incurable cancers.

She set up a laboratory at CityU to dig deep into the body's immune response to cancer, in particular how plasmacytoid dendritic cells (pDCs), a specific immune cell type that makes up less than 1% of the cells in our blood, can help combat cancer.

pDCs are known to be crucial virus fighters. But recent studies show that they are found in tumours, and activating them increased survival in animal models with certain type of cancers, suggesting that they may have a role in fighting cancer. By investigating the gene network of pDCs, Dr Chow's team found that they function differently to combat different dangers, apart from viruses. The team is investigating cues to instruct these cells to effectively fight cancer.

Her team recently found that liver cancer cells can suppress pDC functions, suggesting that cancer cells have ways to escape the immune response. They will investigate the exact mechanism of how cancer cells outsmart the immune system, as this will provide clues to designing new immunotherapy that can "reactivate" pDCs in tumours.



Major Award

- Croucher Innovation Award 2019

Key Project

- Croucher Innovation Award: Harnessing Plasmacytoid Dendritic Cells for Cancer Immunotherapy

Selected Publications

- Wang, M., Lim, K.H. & **Chow, K.T.** 2019, "Native polyacrylamide gel electrophoresis immunoblot analysis of endogenous IRF5 dimerization", *Journal of Visualized Experiments*, vol. 2019, no. 152.
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Unveiling the Secrets of RNA Structures

Dr Kwok Chun-kit

Since the molecular structure of DNA (deoxyribonucleic acid) was first revealed in 1950s, it has given rise to modern molecular biology, which focuses on how genes control the biochemical processes within cells. The general understanding is that DNA makes RNA (ribonucleic acid), RNA makes proteins, and proteins make us. But over 95% of the RNA in a cell is not protein-making (non-coding). So what does this 95% do? **Dr Kwok Chun-kit**, Assistant Professor in the Department of Chemistry, is investigating the role of non-coding RNA structures, their interactions in the genome, and their relevance to gene regulation, RNA metabolism and diseases.

Long non-coding RNA (lncRNA), a type of non-coding RNA, is one of his research interests. Related research won him the Croucher Innovation Award 2019. He pointed out that more than 15,000 long non-coding RNAs have been identified in the human body, but only about 200 of them have known functions.

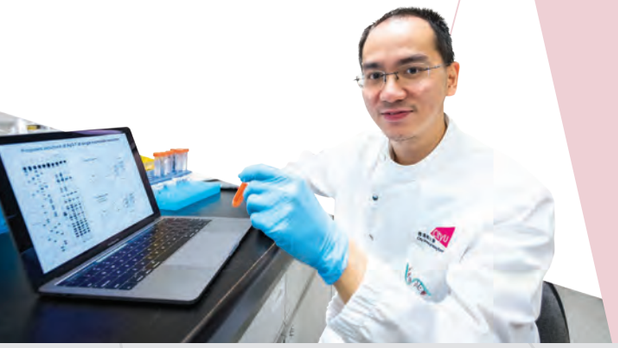
Dr Kwok's team is working on understanding the structure of lncRNAs and their interaction with other biomolecules, such as proteins. Recently he and his collaborators found that lncRNAs interact with diverse protein partners, such as RNA helicases (a large group of enzymes that function in RNA metabolism), to regulate myogenic differentiation.

Dr Kwok is also interested in a special structure of RNA, called RNA G-quadruplexes. One of his recent studies revealed the existence of RNA G-quadruplex in plants, indicating that RNA G-quadruplex structures act as important regulators of plant development and growth.

"Our long-term goal is to uncover the central RNA players in cell differentiation, stress physiologies and diseases, in order to reveal novel RNA-mediated gene regulation and develop targeted strategies for potential biotechnological applications to improve the quality of human life," said Dr Kwok.

Another one of his research focuses involves developing (bio)chemical technologies to decipher the hidden layers of information in RNA. He recently invented a transcriptome-wide method called "Structure-seq", "rG4-seq", "SHALiPE-seq", and a transcript-specific method "DMS/SHAPE-LMPCR" to detect RNA structures that are of low abundance, enabling studies of living cells that were previously unfeasible because of limitations in sensitivity and/or RNA availability.

He is also developing targeted tools for detection, imaging, and intervention of important RNA structures and interactions, which offer potential for biosensing, diagnostic and therapeutic applications.



Major Awards

- Croucher Innovation Award 2019
- The President's Award 2019, CityU

Key Projects

- Croucher Innovation Award: Deciphering Long Non-Coding RNA Structures, Interactions, and Their Functions in Skeletal Myogenic Differentiation
- General Research Fund:
  - Mapping and Targeting of RNA G-quadruplex Structures in the Human Non-coding Transcriptome
  - Interrogating the Effect of 3'UTR RNA G-quadruplex Structure in MicroRNA Target Site Accessibility and Translational Regulation

Selected Publications

- Umar, M.I. & **Kwok, C.K.** 2020, "Specific suppression of D-RNA G-quadruplex-protein interaction with an L-RNA aptamer", *Nucleic Acids Research*, vol. 48, no. 18, pp. 10125-10141.
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High-performance Photonic Chips for Optical Telecommunications

Dr Wang Cheng

Today's global data centres consume about 1% of the electricity used in the world, or nearly 70% of the electricity used in the entire UK. As demand for information services and computer-intensive applications continues to grow rapidly, this number is expected to increase. Since a major portion of data centre power consumption comes from the numerous optical fibre networks linking servers, **Dr Wang Cheng**, Assistant Professor in the Department of Electrical Engineering, who is also an awardee of the Croucher Innovation Award 2020, is tackling this problem by creating compact, high-performance integrated photonic chips.

"By replacing the existing bulky and expensive discrete optical components with chip-scale, integrated photonic devices, we can provide faster, more energy-efficient and cost-effective solutions for optical communications, quantum photonics, and millimetre-wave and terahertz photonics," said Dr Wang.

As one of the lead authors of a study in collaboration with Harvard University and renowned information technologies laboratory Nokia Bell Labs, he successfully fabricated a tiny on-chip lithium niobate modulator that is 100 times smaller and 20 times more efficient, with 10 times lower optical losses, than current lithium niobate modulators.

Electro-optic modulators are critical components in modern communications. They convert high-speed electronic signals in computational devices, such as computers, to optical signals before transmitting them through optical fibres. But the existing commonly used lithium niobate modulators require high drive voltage of 3V to 5V, which is significantly higher than 1V, the voltage provided by typical CMOS (complementary metal-oxide-semiconductor) circuitry, so an electrical amplifier is needed. But this makes the whole device bulky, expensive and highly energy-consuming.

With the advanced nano-fabrication approach developed by the team, they can now integrate lithium niobate on a small chip. It is also highly efficient, producing a higher data transmission speed, with the data bandwidth tripling from 35 GHz to 100 GHz, but with less energy consumption and ultra-low optical losses.

As a member of the State Key Laboratory of Terahertz and Millimeter Waves at CityU, Dr Wang is looking into the application of this technology for the 5G communications and beyond. He is also working on the scale-up of lithium niobate photonics for future optoelectronics.

As a researcher, he is fascinated by the enormous possibilities that one may encounter on his journey of discovery and innovation. "Often what we achieve is not what we planned. But with interdisciplinary interaction and putting our findings into real-world practice, it may result in some brand-new concepts and phenomena, which is inspiring," he said.

Major Awards

- Croucher Innovation Award 2020
- The President's Award 2020, CityU
- Excellent Young Scientists Fund (Hong Kong and Macau), National Natural Science Foundation of China (NSFC), 2019
- RGC Early Career Scheme, 2019

Key Projects

- Croucher Innovation Award: Scaling Up Lithium Niobate Photonics for Future Optoelectronics
- NSFC/RGC Joint Research Scheme: Frequency-encoded Lithium Niobate Quantum Photonic Integrated Circuit
- General Research Fund: Efficient Terahertz Generation in Nanophotonic Lithium Niobate Waveguides
- Early Career Scheme: Integrated Lithium Niobate Photonics for Millimeter-wave Applications
- NSFC Excellent Young Scientists Fund: Integrated Photonics Devices

Selected Publications

- Zhang, M., Buscaino, B., **Wang, C.**, Shams-Ansari, A., Reimer, C., Zhu, R., Kahn, J.M. & Lončar, M. 2019, "Broadband electro-optic frequency comb generation in a lithium niobate microring resonator", *Nature*, vol. 568, no. 7752, pp. 373-377.
- Zhang, M., **Wang, C.**, Hu, Y., Shams-Ansari, A., Ren, T., Fan, S. & Lončar, M. 2019, "Electronically programmable photonic molecule", *Nature Photonics*, vol. 13, no. 1, pp. 36-40.
- **Wang, C.**, Zhang, M., Yu, M., Zhu, R., Hu, H. & Lončar, M. 2019, "Monolithic lithium niobate photonic circuits for Kerr frequency comb generation and modulation", *Nature Communications*, vol. 10, no. 1.
- **Wang, C.**, Zhang, M., Chen, X., Bertrand, M., Shams-Ansari, A., Chandrasekhar, S., Winzer, P. & Lončar, M. 2018, "Integrated lithium niobate electro-optic modulators operating at CMOS-compatible voltages", *Nature*, vol. 562, no. 7725, pp. 101-104.
- **Wang, C.**, Li, Z., Kim, M.-H., Xiong, X., Ren, X.-F., Guo, G.-., Yu, N. & Lončar, M. 2017, "Metasurface-assisted phase-matching-free second harmonic generation in lithium niobate waveguides", *Nature Communications*, vol. 8, no. 1.

Facts & Figures

University Rankings

#4 Quacquarelli Symonds (QS)
"Top 50 under 50" in 2021

#48 QS World University Rankings 2021

College of Business

#36 Top 100 Business School [No. 3 in Asia]
University of Texas at Dallas (UTD)
Top 100 Business School Research Rankings in 2015-2019

College of Engineering

#16 Engineering [No. 2 in HK]

#20 Electrical & Electronic Engineering [No. 1 in HK]

#30 Materials Science [No. 2 in HK]

U.S. News & World Report - the Best Global Universities Rankings 2021

#14 Automation & Control [No. 1 in HK]

#14 Telecommunication Engineering [No. 1 in HK]

#23 Biomedical Engineering [No. 1 in HK]

Academic Ranking of World Universities (ARWU) Subject Rankings 2020

College of Liberal Arts and Social Sciences

#22 Public Administration [No. 1 in Asia]
ARWU Subject Rankings 2020

#35 Social Policy & Administration [No. 7 in Asia]

#38 Communication & Media Studies [No. 5 in Asia]

#39 Linguistics [No. 2 in HK] [No. 6 in Asia]

QS World University Rankings by Subject 2020

College of Science

#56 Mathematics [No. 2 in HK]

U.S. News & World Report - the Best Global Universities Rankings 2021

School of Energy and Environment

#30 Energy & Fuels [No. 1 in HK]

U.S. News & World Report - the Best Global Universities Rankings 2021

School of Law

#31 Law

Times Higher Education (THE) World University Rankings 2021 by Subject

Academics

70% Percentage of International Faculty

35 Number of Countries/Regions that Our International Faculty are From

Research

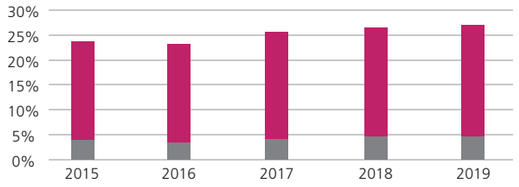
13 Faculty Members Recognised as Highly Cited Researchers 2020 by Clarivate

#1 in HK Top 100 Worldwide Universities Granted U.S. Utility Patents (2016-2019, for 4 consecutive years)

#2 in HK Citations per Faculty in QS World University Ranking 2021

CityU Outputs in Top Citation Percentiles

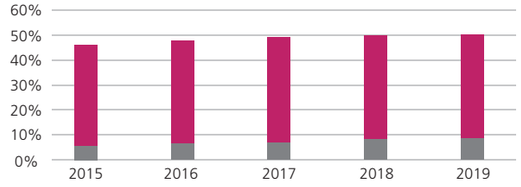
Share of publications at CityU among the most cited publications worldwide



Source: *SciVal® January 2021*

Publications in Top Journal Percentiles

Share of publications at CityU that are in the top journals by CiteScore Percentile

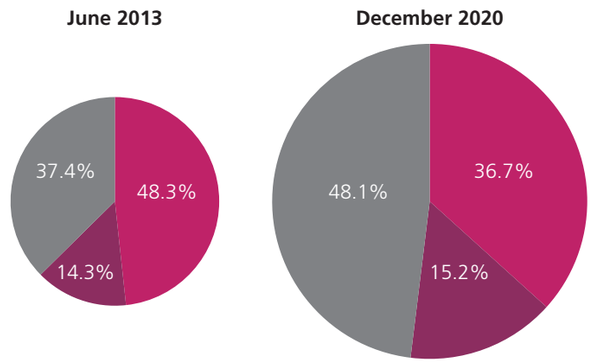


Source: *SciVal® January 2021*

Research Funding

- Research Grants Council
- Innovation and Technology Fund
- Other External Grants*

* Other external grants include:
Croucher Foundation, contract research, donations, other projects funded by government etc.



Total Funding Amount: Over HK$ 600M

Over HK$ 1,400M

Research Centres and Facilities

CityU has established 42 research institutes, research centres and laboratories to foster interdisciplinary research and pursue problem-driven research that benefits society. This includes two State Key Laboratories and one Chinese National Engineering Research Center.

The University has also jointly established four research laboratories with the Chinese Academy of Sciences.

Details can be found on www.cityu.edu.hk/research

University Research Institutes

Hong Kong Institute for Advanced Study

This institute has an interdisciplinary team of world-renowned scholars, including Nobel laureates and academicians, to pursue curiosity-driven ideas and studies.

Hong Kong Institute for Data Science

This is a leading data science platform for researchers and practitioners to harness the power of big data.

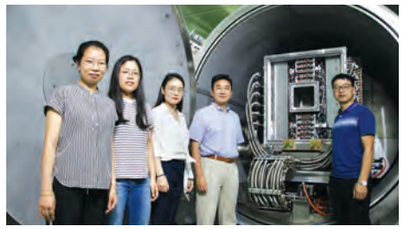
Research Facility Highlights

Inter-University 3D Atom Probe Tomography Unit

This unit allows 3D atom probe tomography, a state-of-the-art micro-analysis technique for 3D imaging and quantitative chemical analysis at the atomic scale for advanced materials research.

Laboratory Animal Research Unit

This unit caters for the need for animal research with animal husbandry services; it was awarded ISO 9001:2015 accreditation for its quality management system.



Neutron Scattering Unit

This unit provides consultation, training and assistance to novice researchers who want to apply neutron scattering to probe structure and dynamics problems in their own research.

High-Performance Computing (HPC) facility: CityU Burgundy

This facility provides the most powerful computational platform ever assembled by a higher institution in Hong Kong, providing fuel for computation-intensive and experimental research.

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