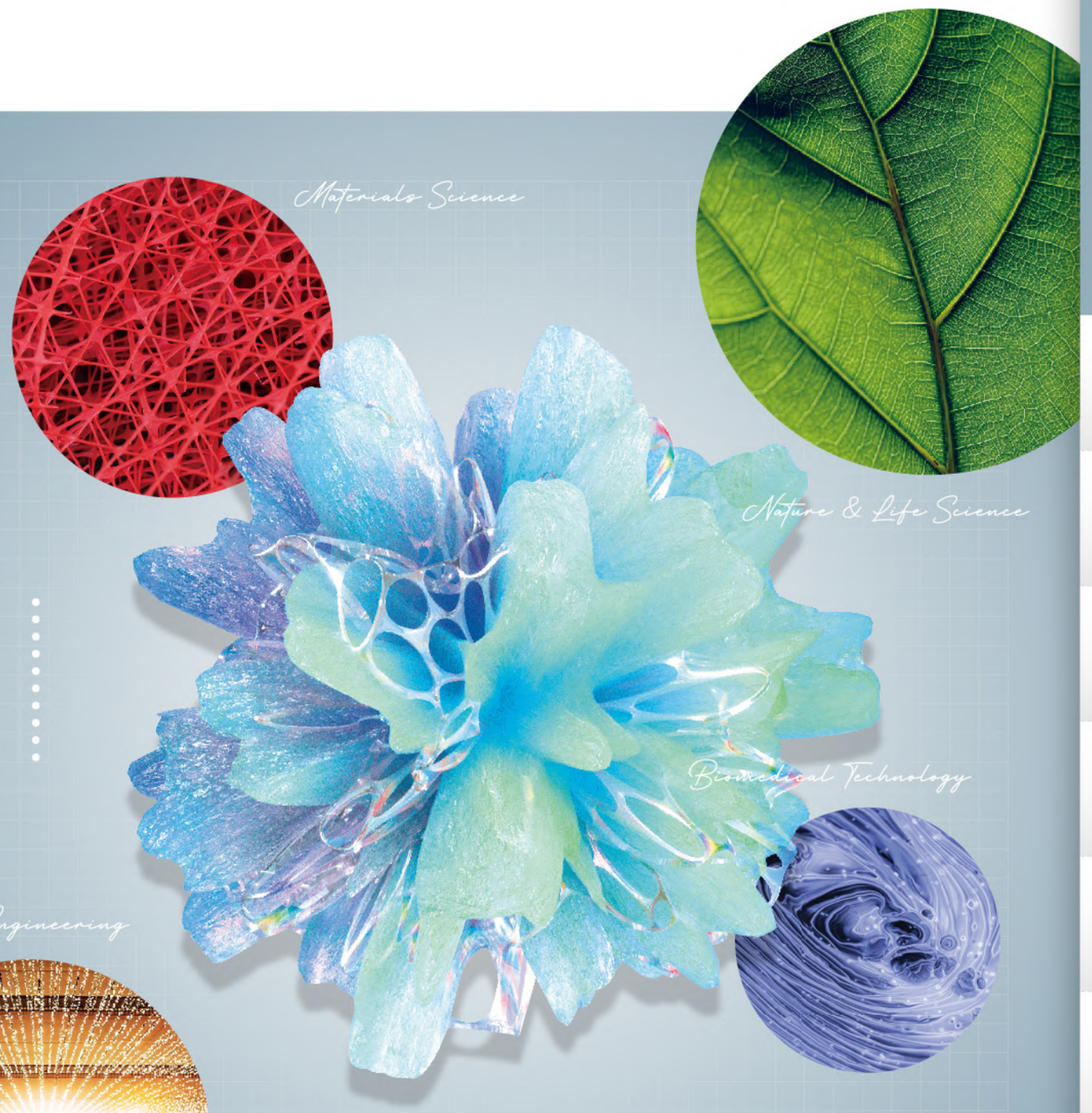

2021/2022
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

About NTHU

Message from the President

R&D Facts and Figures

Nature and Life Science

Engineering

Biomedical Technology

Materials Science

Humanities and Social Sciences

National Tsing Hua University

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http : //www.nthu.edu.tw/
https : //www.facebook.com/nthu.tw/

About NTHU

National Tsing Hua University (NTHU) has a long and proud history. First established as the Tsing Hua Academy at Tsing Hua Garden in Beijing in 1911, the Academy was renamed as National Tsing Hua University in 1928 as its curricula expanded to that of comprehensive university.

In 1956, NTHU was reinstalled on its current campus in Hsinchu, Taiwan. Since its reinstallation, NTHU has developed from an institute focusing on nuclear science and technology to that of a comprehensive research university offering degree programs ranging from baccalaureate to doctorate in science, technology, engineering, humanities and social sciences as well as management.

NTHU has been consistently ranked as one of the premier universities in Taiwan and is widely recognized as the best incubator for future leaders in industries as well as academics. Such stellar records are particularly exemplified by the outstanding achievements of our alumni, including two Nobel laureates in physics Drs. Cheng-Ning Yang and Tsung-Dao Lee, one Nobel laureate in chemistry Dr. Yuan-Tseh Lee and one Wolf Prize winner in mathematics Dr. Shiing-Shen Chern. On the first of November 2016, NTHU formally incorporated the National Hsinchu University of Education. This merger further diversifies and expands its curricula include arts and education to better prepare our students to take on the challenge of a changing world.

Message from the President

President

Dr. W. John Kao

National Tsing Hua University, Hsinchu, Taiwan
November 2022

National Tsing Hua University (NTHU) is a research-intensive university with a long and proud tradition. Since the reestablishment in Hsinchu in 1956, NTHU is known for academic excellence, stellar research output as well as outstanding alumni.

NTHU 's core values are shared governance, academic freedom and inclusivity- equality-diversity. NTHU values academic freedom and provides a diverse environment within which our faculty can offer quality teaching and conduct innovative research. Regarded as one of the top tier research universities, our research activities emphasize fundamental discoveries at the forefront of basic sciences and exploration of breakthrough technologies with high impact. These are reflected in our publications in preeminent journals, international patents received, and technology transferred. In the 2021-2022 R&D annual report, we highlight several important breakthroughs in five fields and also provide the facts and figures related to other important R&D activities.

This volume provides a glimpse into our recent achievements. Hopefully, this can serve as a catalyst for further interactions, exchange of ideas, and establishment of collaborations.

We believe that everyone deserves an opportunity to explore and to realize their unique potential. NTHU will uphold our core values—inclusivity, equality, and diversity in everything we do. We will diligently safeguard academic freedom and shared governance as an integral part of our social responsibility and sustainable development.

R&D Facts and Figures

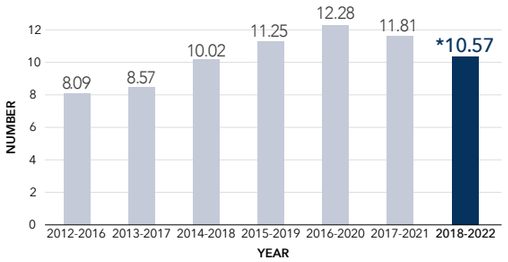
2021 World Rankings

Rankings	Rank
THE Emerging Economies University Rankings	32
QS Asia University Rankings	33
THE Asia University Rankings	54
THE Impact Rankings	201–300

2022 QS World University Rankings by Subject

Top 50 - 100	Top 100 - 150
Linguistics (65)	Engineering & Technology (101)
Materials Sciences (78)	Chemistry (108)
Physics & Astronomy (82)	Statistics & Operational Research (120)
Electrical & Electronic Engineering (90)	Computer Science & Information Systems (123)
Mechanical (98)	Natural Sciences (128)
Chemical Engineering (100)	Modern Languages (133)

Citations Per Paper



Highly Cited Papers

* Last updated November 10,2022
* Data covers a 10-year and 8-month period: January 1, 2012 - August 31, 2022

2021 Highly Cited Researchers

- Professor. Yi-Hsien Lee (Department of Materials Science and Engineering)
- Professor. Horng-Tay Jeng (Department of Physics)

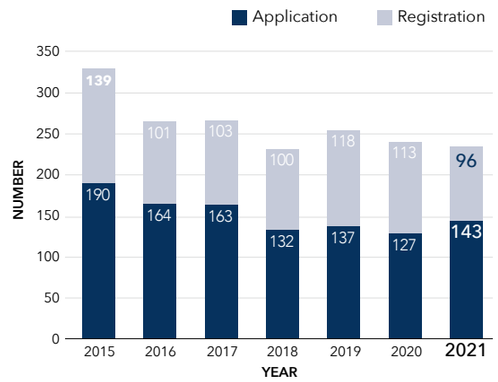
2021 Ranking of U.S. patents

World Ranking 2021 **No.46**

Taiwan Ranking 2021 **No.1**

Technology transfer income	100M+ TWD/ year
Total number of U.S. patents	2800+

International Patent Application and Registration (2015-2021)



Incubation Programme *Grow fast, Grow global*

Number of Startups in 2022	Accumulative Startups	Survival Rate in 3 Years	Faculties to Students ratio	Number of IPO
50	2017-2021 105	91.7%	58%	6

IPO		
	Optoelectronics industry	AIPTEK INTERNATIONAL INC.
		UC&GN INTERNATIONAL CORP.
	Communications industry	GEMTEK TECHNOLOGY CO., LTD.
	IC industry	ADVANCED ANALOG TECHNOLOGY, INC.
		RICH CIRCLE DEVELOPMENT CO., LTD.
		KEY WARE ELECTRONICS CO., LTD.

01

Nature and Life Science

Uncovering The Mystery of Nuclear Size Maintenance

Giant Bubbles Blown by Past Jet Activity of The Galaxy's Central Black Hole

Astronomers Discover A Rare "Black Widow" Binary, with The Shortest Orbit Yet

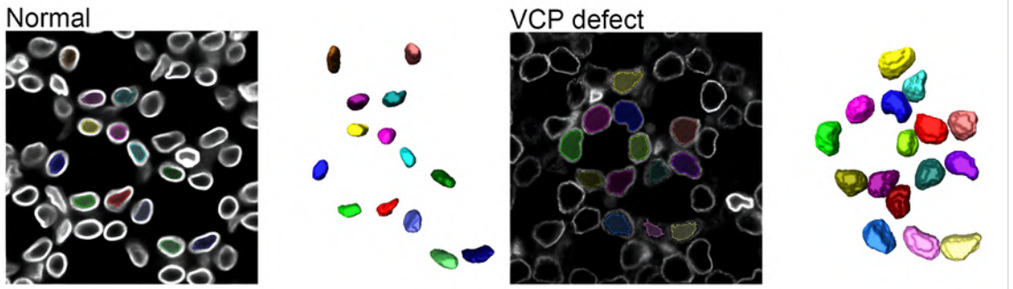
Organic Materials Evolve Differently Around Binary Stars

Uncovering The Mystery of Nuclear Size Maintenance

Professor Tzu-Kang Sang
tksang@life.nthu.edu.tw

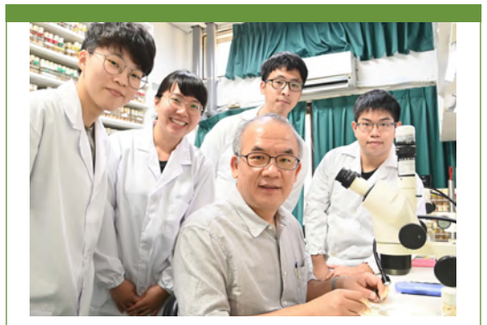
VCP, a multifunctional AAA ATPase, is required to maintain nuclear size. Disruption of fly VCP homolog TER94 causes aberrant expansion of the nucleus. This phenotype is due to the loss of TER94 function could lead to retarded removal of Mu2, the fly ortholog of an essential DDR (DNA damage response) scaffold protein MDC1 (mediator of DNA damage checkpoint protein 1), which results in the accumulation of DNA lesion.

Ubiquitinated proteins accumulate inside the nucleus of TER94 dysfunction cells, and the extent of accumulation correlates positively with the degree of nuclear enlargement. VCP can interact with MDC1 and decrease MDC1 levels, suggesting that MDC1 is a VCP substrate. Indeed, ectopic expression of Mu2 phenocopies the nuclear size increase defect. Mu2 RNAi and overexpression modify this TER94-associated nuclear size increase. These observations link genomic instability and associated nuclear size increase responses together. In addition, we found that accumulated MDC1 could stabilize p53A, and this specific isoform could impair autophagy flux, leading to a TER94^{K2A}-associated nuclear size increase. Together with a previous report that p53A disrupts autophagic flux, we propose that the stabilization of p53A in TER94K2A-expressing cells likely hinders the removal of nuclear content, resulting in aberrant nuclear size increase.



Confocal images show regular (left) and enlarged (right, VCP defect) nuclear size by labeling lamina, a scaffold protein complex lining the nuclear envelope. The corresponded volumetric reconstructions are marked with pseudocolors.

Moreover, we observed that the increase of autophagic proteins, Atg8a and Atg5, in the nucleus correlates well with nucleus expansion. In addition, TER94 dysfunction, in a Mu2- and p53-dependent manner, causes accumulation of p62, a well-known indicator of disrupted autophagic flux. This finding suggests that nuclear structure is tied to autophagy regulation and is likely involved in the cyto-nucleoplasmic translocation of key autophagy components, unlike previous studies on autophagy that only centered on the cytoplasm. However, there are still many unexplored functions in ATG proteins, especially how they operate within the nucleus. We hypothesize three interconnected pillars: genome integrity, autophagy, and nuclear structure, which generate signal cascades essential to maintaining homeostasis following genotoxic stress. Our study may aid in exploring the mechanism of the proposed three pillars for controlling genome stability and shed light on aging and several related disease conditions, including cancer, progeria, and neurodegeneration.



(from left) Pei-Shin Liang, Ting-Yi Huang, Professor Tzu-Kang Sang, Yu-Xiang Peng, Bo-Hua Yu.

Research Output

- Chang Y.-C., Peng Y.-X., Yu B.-H., Chang H.-C., Liang P.-H., Huang T.-Y., Shih C.-J., Chu L.-A., Sang T.-K.*. (2021) VCP Maintains Nuclear Size by Regulating the DNA Damage-associated MDC1–p53–autophagy Axis in Drosophila. *Nature Communications* (12): 4258.

Giant Bubbles Blown by Past Jet Activity of The Galaxy's Central Black Hole

Professor Hsiang-Yi Karen Yang
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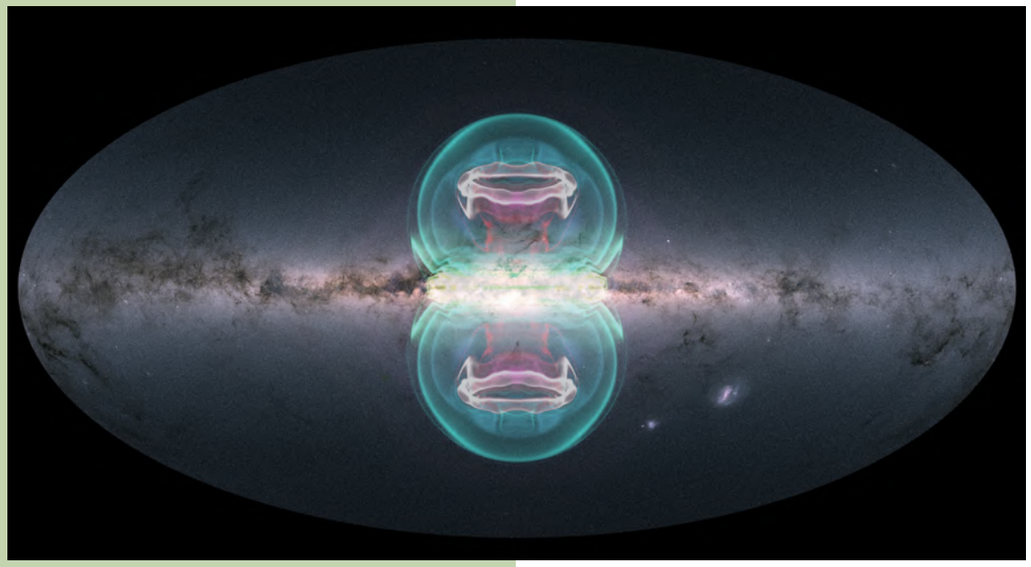
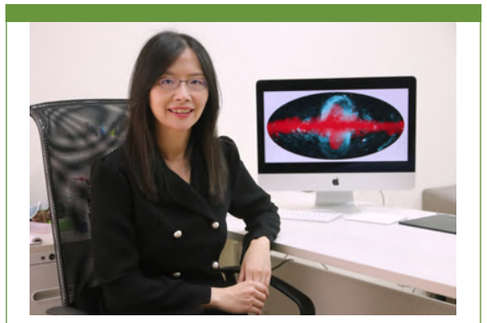


Simulated Fermi/eRosita bubbles overlaid with Gaia's image of our Milky Way Galaxy. Cyan contours show the simulated X-ray emission produced by the forward shock driven by the black hole activity. White/red contours represent the distributions of high-energy particles, which produce the gamma-ray emission that is observed as the Fermi bubbles. (Credit: NASA visualization team; ESA/Gaia/DPAC, CC BY-SA 3.0 IGO)

In our recent work led by NTHU, we performed cutting-edge numerical simulations and showed that the eRosita and Fermi bubbles could be simultaneously explained by a single event of jet activity from the central supermassive black hole a few million years ago. Our simulations included modeling of the high-energy particles carried by the black hole jets, the thermal gas within the Milky Way, as well as the interactions between them. As a result, we could predict the gamma-ray emission generated by these high-energy particles as they interact with photons in the Galaxy. We could also compute the X-ray emission produced as the gas is compressed by the shock wave driven by the jet activity. We showed that our model successfully reproduced the morphology and multi-wavelength spectra of the observed Fermi and eRosita bubbles. We have also obtained important constraints on this activity, including when it occurred, how long it lasted, and how much energy is required, etc. We found that the central supermassive black hole needs to be active about 2.6 million years ago for 0.1 million years. During its active period, the black hole needs to consume ~1,000 to 10,000 solar masses of materials in order to convert a fraction of the accreted energy into a pair of relativistic jets. The energetics and timescales of such an activity are also consistent with an independent measurement of ionization features in the Magellanic Stream, giving further support of an elevated activity of the Galactic center black hole. This study serves as an important step forward in our understanding of the past Galactic center activity of our Milky Way Galaxy, and may bring valuable insights into the broader picture of supermassive black hole-galaxy co-evolution in the context of galaxy formation.



Professor H.-Y. K. Yang.

Research Highlights

- Fermi Cycle 13 Guest Investigator Program
- Highlight talk at the 27th European Cosmic Ray Symposium
- Invited talk at the Tenth International Fermi Symposium

Research Output

- Yang, H.-Y. K., Ruszkowski, M., Zweibel, E. Fermi and eRosita bubbles as relics of the past activity of the Galaxy's central black hole, 2022, Nature Astronomy, 6, 584
- Yang, H.-Y. K., Ruszkowski, M. & Zweibel, E. G. Unveiling the Origin of the Fermi Bubbles, 2018, invited review in the Galaxies special issue, 6, 29
- Yang, H.-Y. K. & Ruszkowski, M. The Spatially Uniform Spectrum of the Fermi Bubbles: the Leptonic AGN Jet Scenario, 2017, ApJ, 850, 2

Astronomers Discover A Rare "Black Widow" Binary, with The Shortest Orbit Yet

Professor Albert Kong
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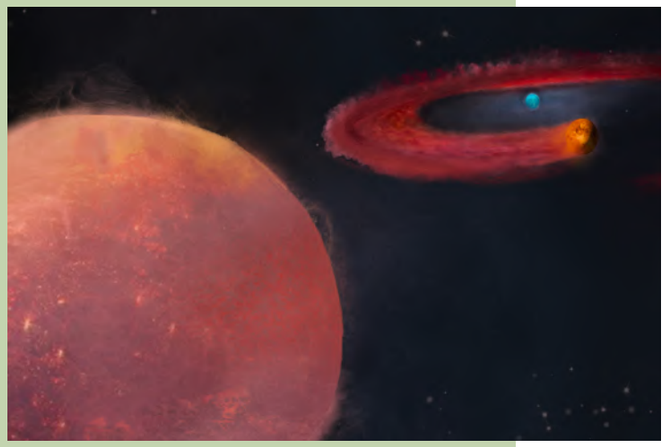
Since 2016, National Tsing Hua University has joined the Zwicky Transient Facility (ZTF) as the founding members under the support of the Ministry of Science and Technology. ZTF is a 1.2m robotic telescope with a very wide-field camera (currently the world's largest camera in use) owned by Caltech. This is a very significant improvement over all other similar facilities and ZTF has been playing a key role in optical follow-up of gravitational wave events and transients in general. In addition to the famous gravitational wave event, the double neutron star merger GW170817/GRB170817A for which ZTF makes significant contribution, ZTF also discovers many interesting celestial objects.



An artist concept view of a black widow binary in a triple system. (Credit: Wan-Yi Chang, NCKU)

Black widow binary is a binary stellar system with a rapidly spinning neutron star, or pulsar, that is circling and slowly consuming a smaller companion star. Comparing to our Sun-Earth system, the orbital period of black widow binary is less than 1 day. Hence, the distance between the pulsar and the companion star is very small, about 1/100 of the Sun-Earth system. Because of the strong high-energy radiation, the companion star will be ablated. Black widow systems are rare and astronomers know of about two dozen black widow binaries in the Milky Way. With ZTF, the team discovered a new black widow binary candidate lying 3000 light-years from Earth. This system has the shortest orbital period yet identified, with the pulsar and companion star circling each other every 62 minutes. The unique feature of this black widow system is that it has a third star orbiting the two inner stars every 10000 years. The NTHU team helped confirm that this system does not emit X-ray and gamma-ray radiation making this the only black widow binary found only in visible light. This "triple" black widow raises questions about how such a system could have formed. Based on its observations, the team proposed an origin story: As with most black widow binaries, the triple system likely arose from a dense constellation of old stars known as a globular cluster. This particular cluster may have drifted into the Milky Way's center, where the gravity of the central black hole was enough to pull the cluster apart while leaving the triple black widow intact.

Professor Albert Kong.

Research Highlights

- Awarded the 2021 Outstanding Research Award by the Ministry of Science and Technology
- Leading Taiwan to participate the first gravitational wave observation with the underground gravitational wave detector KAGRA in Japan
- NTHU as a partner of the Zwicky Transient Facility collaboration to search for cosmic transients

Research Output

- Burdge, K.B. et al. (including Kong, A.K.H.), "A 62-minute orbital period black widow binary in a wide hierarchical triple", Nature, 605, 41–45 (2022)
- Long, J.S., Kong, A.K.H., Wu, K., Takata, J., Han, Q., Hui, D.C.Y., Li, K.L., "XMM-Newton and NuSTAR Observations of the Compact Millisecond Pulsar Binary PSR J1653-0158", The Astrophysical Journal, 934, 17 (2022)
- Reusch, S. (including Kong, A.K.H.), "Candidate Tidal Disruption Event AT2019fdr Coincident with a High-Energy Neutrino", Physical Review Letters, 128, 221101 (2022)
- Abbott, R. (including Kong, A.K.H.), "Search for Gravitational Waves Associated with Gamma-Ray Bursts Detected by Fermi and Swift during the LIGO-Virgo Run O3b", The Astrophysical Journal, 928, 186 (2022)

Organic Materials Evolve Differently Around Binary Stars

Professor Daniel Harsono
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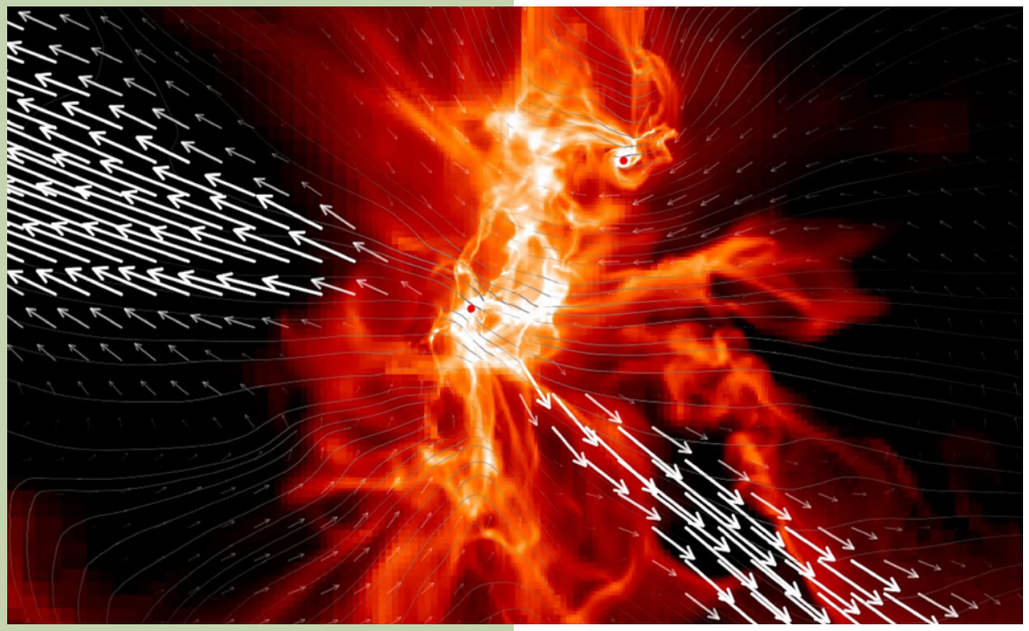
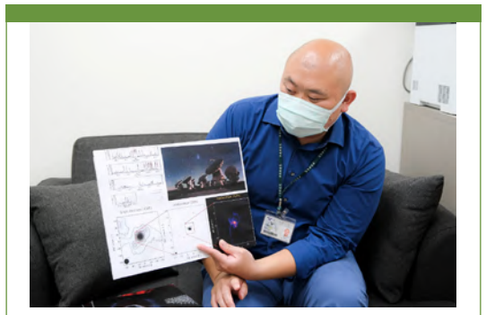
Stars in the universe are born with companions. Most stars are in binary systems where two stars orbit around each other. One of the major questions in astronomy is whether planets can form around binary stars and how the planet-forming materials can differ from the Solar System. In the past year, the stars and planet formation group at National Tsing Hua University has become interdisciplinary by investigating the chemical composition of the gas of planetary cradles. By searching for water and complex organic molecules around the binary star IRAS 2A, we can start to understand how the materials around binary stars differ from that of single stars like the Sun.



Simulated evolution of a binary star involving the surrounding dust and gas (colors) and the ejected material (white solid line) due to the interaction.

Using the Atacama Large Millimeter/sub-millimeter Telescope (ALMA), the NTHU team and international collaborators in Denmark and Michigan found that planetary systems around binary stars are indeed different. The very young binary system IRAS 2A is located about 1000 light years away within the Perseus star-forming regions. It formed roughly about 10,000 years ago. By analyzing the emission spectra of water, methanol, and other molecules, the motion around the binary star is very chaotic. As astronomical observations only show one snapshot of the stars' life, a suite of magnetohydrodynamic simulations is employed to investigate how the binary systems evolve to the current state. The binarity influences the evolution of the planetary cradle around the primary star. Therefore, the molecules that are essential for life as we know it and the materials that will form comets will evolve differently before they are incorporated into the planets. How different will these systems be as compared to the Solar System? We still do not know since many binary stars drift apart with time. Future observations with ALMA and the James Webb Space Telescope of other binary systems will allow us to be closer to the answer.



Dr. Daniel Harsono.

Research Highlights

- PI of a general observer program with *James Webb Space Telescope* (NASA grant – 80k USD)
- Partial Yu-Shan fellowship from MoE, 2021-2026
- ALMA large program to study complex organics

Research Output

- Jes K. Jørgensen, Rajika L. Kuruwita Jørgensen, J. K., Kuruwita, R. L., Harsono, D. et al., "Binarity of a protostar affects the evolution of the disk and planets", Nature 606, 272 (2022).

02

Engineering

Large-Scale Multiple Microfluidic Device System for Desktop Chemical Plant

Neuromorphic Intelligent Visual System

A Hierarchical Hand Gesture Recognition Framework for Sports Referee Training

Two-Stage Evolutionary Neural Architecture Search For Transfer Learning

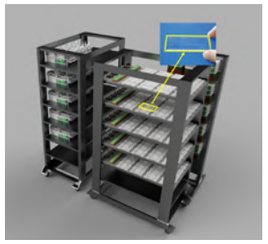
Large-Scale Multiple Microfluidic Device System for Desktop Chemical Plant

Professor Takehiko Kitamori
kitamori@mx.nthu.edu.tw

Our microfluidic device is something like an integrated circuit of liquids fabricated on a glass substrate. We were one of the founders of this technology in the early 1990's, and proved to integrate a chemical laboratory or experiment on a chip which is called as microfluidics now. Our concept of a desktop chemical plant DTP is combining many microfluidic devices serially and parallelly to achieve long and complicated chemical processes and to increase production at the industrial level. A university-industry collaboration (UIC) with Daicel which is a Japanese chemical company launched from 2021 September at NTHU, and a spinoff company from NTHU, IMT-Taiwan, established in 2021 June. The Daicel Joint R&D Center was organized in October 2021 at NTHU, and IMT-Taiwan joined it. The first DTP was completed by IMT-Taiwan and delivered to the customer in May 2022, and its superior performance for chemical synthesis was reported.

The University of Tokyo, UTokyo, is also a major constituent of this project and takes on the role of pursuing chemical process on a serial connection of microfluidic devices while NTHU develops large-scale parallelization of it. Thus, this project is a real international UIC aiming at global innovation and pioneering new industry in Taiwan.

A typical example of a microfluidic device for chemical synthesis is shown in the figure. This device is made of glass which can use acid, base, and organic solution. The white lines seen in the device are microchannels working as test tubes, flasks, pipets, and other kinds of glass apparatus of chemistry, and therefore, this device can operate mixing reaction and purification like chemical experiments. Thus, a microfluidic device works as an integrated chemical laboratory. Multiple microfluidic devices can be connected in serial to achieve long complicated chemical processes for synthesizing chemical compounds and purifying them. The example of the figure is four device serial connections. The size of the channels typically ranges from several 10-100 nm, and concentration and temperature distribution in channels homogenize quickly. This spatiotemporal homogeneity is quite important for precise control of chemical processes, and that is the reason why the microfluidic device system can produce chemical compounds highly effectively and precisely, and therefore, high-quality chemicals can be produced effectively. However, the quantity of each device is under mL, therefore, large-scale parallelization in 100, 1000, and even 10,000 parallels are needed for industrial production quantity in ton/year. We call this large-scale microfluidic device system in serial and parallel combination as a desktop chemical plant DTP.



Schematics of a DTP which consists of 120 microfluidic devices, and a photo of an example of a microfluidic device. The details of the system and the device are described in the research description.

We have organized the international R&D formation with NTHU, UTokyo and Daicel, and founded a spinoff startup IMT-Taiwan (北森微流體研發股份有限公司) for speedy industrial implementation. The roles of each constituent in this international innovation team are described in the summary. The first experimental DTP was designed for synthesizing an important chemical for the semiconductor industry by using 120 microfluidic devices. The design schematics are shown in the figure. The world's first DTP which consists of large-scale multi devices was collaboratively designed based on experimental investigations by this team and completed in the IMT-Taiwan in the end of May 2022. It took just ten months from the beginning of design to line off by applying Taiwanese flexibility and diversity. This DTP performed well as designed, and based on this promising first run, we are planning and designing subsequent successor DTPs.

Our design method of the devices and the systems are flexible and can respond to a variety of requirements from the global chemical industry. Our team will provide DTPs to not only Taiwan and Japanese chemical industries but also to the global market which can be roughly estimated as more than 10BUSD. DTPs will develop from 100 device systems to 1,000 and even 10,000 device systems to satisfy these requirements at ton/year production. To construct the DTPs, many kinds of microfluidic components including pump and flow sensors are needed, and therefore, this project may create the supply chain of microfluidic components as well as open a new market. Thus, the DTP may create a new industry in Taiwan. The DTP system can highly save space and energy, and can respond to on-demand variable and on-site production. The chemical industry in the world needs production innovation to meet the demand for carbon neutral. Our collaborator Daicel is highly expecting DTP to overcome this challenge, and not a few companies in Taiwan and Japan are approaching us to learn DTP more. We take pride in challenging this project to contribute carbon neutral and SDGs as well as giving academic impact.

The main photo is the IMT-Taiwan and Daicel members. The front center is Prof. Takehiko Kitamori at iNEMS/PME. The system buried in the people is the first DTP. From the left-hand side of the inserted photos are Prof. Chihchen Chen and Prof. Kyojiro Morikawa at NTHU (iNEMS/PME), and Prof. Shimizu, Prof. Ohta, and Dr. Smirnova at The University of Tokyo.

Research Highlights

- International UIC project with Daicel (2021 September).
- International Joint R&D Center with Daicel and IMT-Taiwan (2021 October).
- Spinoff startup company IMT-Taiwan (2021 June).
- First DTP (2022 May).
- College of Engineering, Excellent UIC Award (2022 July)
- NTHU Excellent UIC Award (2022 September)

Research Output

- http://webpark1390.sakura.ne.jp/cms/?lang=en

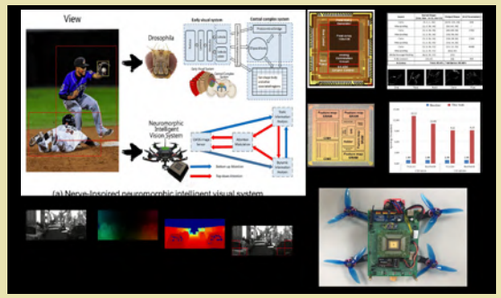
Neuromorphic Intelligent Visual System

Professor Kea-Tiong Tang
kttang@ee.nthu.edu.tw

Our team learn from drosophila and developed a bionic vision chip AI chip system, allowing mobile devices to achieve the effect of real-time image analysis with low power consumption. We hope to solve the problem of the high energy consumption of the current smart imaging system so as to prolong the working time on the mobile device. The overall application is divided into image recognition and dynamic obstacle avoidance. The key techniques used for these two different applications are described below.

1. Image recognition

In image recognition, the smart image sensor with array-level image signal processing developed by our team and the deep learning accelerator of the in-memory computing architecture are integrated. The smart image sensor with array-level image signal processing can operate at the lowest voltage of 0.5V, has the best FoM (Figure b), and uses convolution computation to achieve the feature extraction part of the feature. In the future, the in-memory computing deep learning accelerator (Figure c) that supports the sparsity algorithm and the dense kernel mapping method can be used to skip meaningless calculations, reduce the number of memory overloads and reduce the bandwidth burden, and greatly accelerate the overall image recognition inference. Compared with the non-sparsity aware mechanism, it can achieve a speedup of more than 10 times without causing any drop in accuracy.



Neuromorphic intelligent visual system and four features

2. Dynamic obstacle avoidance

In dynamic obstacle avoidance, the obstacle detection neural network in this project and the developed ARC & FPGA-based drone and drone chip are integrated. Through the Flowdep (depth-from-motion) algorithm and IQIF (Integer Quadratic Integrate-and-Fire) neuron in the obstacle detection neural network (Figure d), a bionic neural network is constructed. First, receive the input of dynamic images and IMU (Inertial measurement unit), then calculate the dense optical flow, and finally obtain the depth information through the calculation of flowdep, and the depth information can be used to reconstruct the 3D map, calculate the current position, detect obstacles and make use of the depth information. The drone (vehicle) acts to avoid obstacles. Then, through the self-developed drone and drone chip (Figure e), the obstacle avoidance algorithm and the self-designed algorithm are integrated to create a flight control system to execute obstacle avoidance flight commands and realize remote control flight.

Through the key technologies of image recognition and dynamic obstacle avoidance independently developed by our team, in addition to being applied to smart drones to assist in disaster relief and inspection, it can also be widely used in smart agriculture, smart robots, and smart homes to create high value and a better living environment in the future.


(from left) Professor Chih-Cheng Hsieh, Professor Chung-Chuan Lo, Professor Kea-Tiong Tang, Professor Ren-Shuo Liu

Research Highlights

National Program Participation (selection)

- 2018~2022: Principal Investigator, National Flagship Program, Moonshot Project, MOST, Taiwan.
- 2016~2012: Principal Investigator, National Program on Intelligent Electronics, MOST, Taiwan.
- 2010~2008: Principal Investigator, National Program for System-on-Chip, MOST, Taiwan.

AWARDS and HONORS (selection)

- 2021&2019: Futuristic Breakthrough Technology Award, Ministry of Science and Technology (MOST), Taiwan.
- 2021~2011: Golden Silicon Awards (2011, 2013, 2014, 2015, 2017, 2018, 2019, 2021), Macronix Education Foundation, Taiwan.
- 2021~2012: National Innovation Award (2012, 2014, 2015, 2016, 2019, 2021), Institute for Biotechnology and Medicine Industry, Taiwan.
- 2020: Outstanding Industrial Research Award, Taiwan.
- 2020: Invited Speaker, International Solid-State Circuits Conference (ISSCC), Top Circuit Design Conference of IEEE.

Research Output

Journals

1. Hung-Yi Hsieh and Kea-Tiong Tang*, "VLSI implementation of a bio-inspired olfactory spiking neural network", IEEE Transactions on Neural Networks and Learning Systems, vol.23 (7). 2012, pp. 1065-1073.
2. Chih-Heng Pan, Hung-Yi Hsieh, and Kea-Tiong Tang*, "An Analog Multilayer Perceptron Neural Network for a Portable Electronic Nose", Sensors, 2013, 13, 193-207
3. Hung-Yi Hsieh and Kea-Tiong Tang*, "A Hardware Friendly Probabilistic Spiking Neural Network with Long-term and Short-term Plasticity", IEEE Transactions on Neural Networks and Learning Systems, vol. 24, no. 12, pp. 2063-2074, 2013
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Conference

1. Zuo-Wei Yeh, Chia-Hua Hsu, Alexander White, Chen-Fu Yeh, Wen-Chieh Wu, Cheng-Te Wang, Chung-Chuan Lo, and Kea-Tiong Tang, "POPPINS: a Population-Based Digital Spiking Neuromorphic Processor with Integer Quadratic Integrate-and-Fire Neurons", 2021 International Symposium on Circuits and Systems (ISCAS)
2. P-C. Wu, J-W. Su, Y-L. Chung, L-Y. Hong, J-S. Ren, F-C. Chang, Y. Wu, H-Y. Chen, C-H. Lin, H-M. Hsiao, S-H. Li, S-S. Sheu, S-C. Chang, W-C. Lo, C-C. Lo, R-S. Liu, Chih-Cheng Hsieh, K-T. Tang, C-I. Wu, M-F. Chang, A 28nm 1Mb Time-Domain Computing-in-Memory 6T-SRAM Macro with a 6.6ns Latency, 1241GOPS and 37.01TOPS/W for 8b-MAC Operations for Edge-AI Devices, 2022 IEEE International Solid-State Circuits Conference (ISSCC), Feb. 2022.

Patent

1. Patent name: FEEDBACK TYPE VOLTAGE REGULATOR
   Patent family
   >Republic of China: 1560538 >United States: 9,753,475
2. Patent name: METHOD AND SYSTEM FOR INTEGRATING PROCESSING-IN-SENSOR UNIT AND IN-MEMORY COMPUTING UNIT
   Patent family
   >United States:11,048,650
3. Patent name: QUANTIZATION METHOD BASED ON HARDWARE OF IN-MEMORY COMPUTING AND SYSTEM THEREOF
   Patent family
   >Republic of China: I737228 >United States: US-2021-0294874-A1 >China: CN113496274A

A Hierarchical Hand Gesture Recognition Framework for Sports Referee Training

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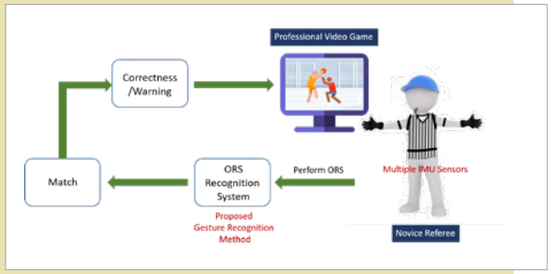
In recent years, multimedia technology has been widely used to analyze sports data and to aid the sports training process. Professional leagues such as MLB, NBA, and NHL introduced systems to track the players, analyze the performance of each player, summarize game highlights, and even predict the possibility of match-fixing. Moreover, with the advance of wearable sensor technology, trainers in different kinds of sports have started utilizing the aid of wearable sensors to improve the skills of the athletes. There is no doubt that multimedia technology has become indispensable to facilitate sports training, which also brings tremendous business opportunities to the sports industry.

To become a professional and convincing referee, one has to experience being the referee of several real and formal sports games to practice not only his/her immediate reaction but also the familiarity with the official referee's signals (ORSs). However, it is a rare opportunity for a new learner to be the referee of professional games because each game has only limited (one to three) referees and no team would like to be judged by a novice referee. Therefore, we aim to develop an ORS training system for the novice referees with the aid of sEMG and IMU. To understand the practical requirements for sports referees and what kind of aspects they would be particularly concerned with, we conducted semi-structured interviews with both novice referees and professional referees. According to the interviews, referee training should achieve an important goal, that is, the trainee can immediately react when a violation/foul occurs and make a correct gesture for his/her judgment. The user wears the armband sensor and watches pre-recorded videos of professional sports games annotated with ORS ground truth. When watching the video, the trainee can make an ORS freely according to his/her own judgment at any time, and our ORS recognition technique will detect and classify the trainee's gestures. The novice referees can repeatedly practice how to judge and perform correct ORSs by using this training system, which contains several pre-recorded videos of basketball games and the corresponding ground truth of judgments. After matching the recognized gesture with the annotated ground truth, the training system will report the correctness to the trainee and give a warning if the trainee misses a violation or a foul event. According to the recognition results, the trainee can realize whether the judgment is correct or not, and then try to improve himself/herself to become a better referee.



Usage Scenario of the Proposed Sports Referee Training System.

The proposed system can correctly recognize a set of gestures related to ORSs and another set of gestures used to intuitively interact with the system. These two gesture sets involve both large motion and subtle motion gestures, and the existing sensor-based methods using handcrafted features do not work well on recognizing all kinds of these gestures. We utilize deep belief networks (DBNs) to learn more representative features for hand gesture recognition and combine selective handcrafted features with the DBN features to achieve more robust recognition results. Moreover, a hierarchical recognition scheme is designed to first recognize the input gesture as a large or subtle motion gesture, and the corresponding classifiers for large motion gestures and subtle motion gestures are further used to obtain the final recognition result. Moreover, the Myo armband consists of eight-channel surface electromyography (sEMG) sensors and an inertial measurement unit (IMU), and these heterogeneous signals can be fused to achieve better recognition accuracy. We take basketball as an example to validate the proposed training system, and the experimental results show that the proposed hierarchical scheme considering DBN features of multimodality data outperforms other methods.

Group photo of the research team participating in the CVGIP meeting.

Research Highlights

- 2021 Sports Technology Application Award, Silver Award

Research Output

- Tse-Yu Pan, Wan-Lun Tsai, Chen-Yuan Chang, Chung-Wei Yeh, and Min-Chun Hu, A Hierarchical Hand Gesture Recognition Framework for Sports Referee Training Based on EMG and Accelerometer Sensors, IEEE Transactions on Cybernetics, vol.52, no.5, pp. 3172-3183, May 2022.
- Tse-Yu Pan, Chen-Yuan Chang, Wan-Lun Tsai, and Min-Chun Hu, Multisensor-Based 3D Gesture Recognition for a Decision-Making Training System, IEEE Sensors Journal, vol.21, no.1, pp. 706-716, January 2021.
- Wan-Lun Tsai, Tse-Yu Pan, and Min-Chun Hu, Feasibility Study on Virtual Reality Based Basketball Tactic Training, IEEE Transactions on Visualization and Computer Graphics, vol.28, no.8, pp. 2970-2982, August 2022.
- Wan-Lun Tsai, Li-Wen Su, Tsai-Yen Ko, Tse-Yu Pan, and Min-Chun Hu, Feasibility Study on Using AI and VR for Decision-Making Training of Basketball Players, IEEE Transactions on Learning Technologies, vol.14, no.6, pp. 754-762, December 2021.

Two-Stage Evolutionary Neural Architecture Search for Transfer Learning

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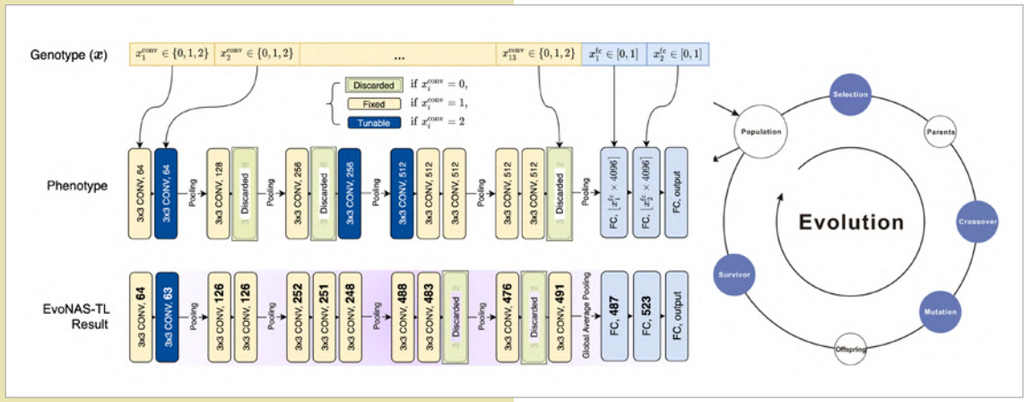
Transfer learning has been used extensively to enhance deep learning models for learning from low-resource tasks. Despite many successful applications, one notable concern about transfer learning is the potential inefficiency of neural architecture, as the transfer techniques focus on tuning parameters for the target task but seldom modify the neural architecture of the source model. This issue impedes those real-world applications with a limitation on model size or inference latency, such as automatic optical inspection in manufacturing. This study proposes EvoNAS-TL, a two-stage bi-objective evolutionary system that performs structure search followed by local enhancement for transfer learning tasks. The structure search manipulates the source model over the structure by layer as a coarse-grained architectural search, while the local enhancement attempts to remove unfavored filters and neurons as fine-grained architectural optimization. For structure search, we propose two representations that encode different levels of structural information.



Selective representation in EvoNAS-TL and its resultant model of transferring from ImageNet to CIFAR-10.

The performance of EvoNAS-TL was examined and compared with three baseline methods and state-of-the-art methods over three transfer learning scenarios. The experimental results showed that, by automatically tailoring neural architecture for the target tasks, the proposed EvoNAS-TL improved classification performance and significantly reduced the model size. Using the minimal-error selection in both stages, EvoNAS-TL improved the testing accuracy of VGG-16 by 6.9% in transferring to the CIFAR-10 dataset and 0.7% in transferring to the NEU dataset; meanwhile, it removed 52% to 85% of the parameters from the source model. This strategy benefits applications that seek high classification performance. Moreover, by selecting the knee model in structure search and the minimal-error model in local enhancement, EvoNAS-TL can strike a balance between test accuracy and model size. On the Office-31 dataset, EvoNAS-TL achieved average accuracy and model size comparable to or better than state-of-the-art domain adaptation methods. These satisfactory outcomes validate that the proposed EvoNAS-TL, which aims to optimize neural architecture in transfer learning tasks, shows promise in advancing the effectiveness and efficiency of the transferred models.

(from left) Dr. Yu-Wei Wen, Sheng-Hsuan Peng, and Prof. Chuan-Kang Ting

Research Highlights

- Editor-in-Chief, IEEE Computational Intelligence Magazine (IF=11.356, Rank=7/139 in CS, AI)
- Editor-in-Chief, Memetic Computing (IF=5.900, Rank=27/139 in CS, AI)
- World's Top 2% Scientists 2020

Research Output

- Y.W. Wen, S.H. Peng, and C.K. Ting*. Two-stage evolutionary neural architecture search for transfer learning. IEEE Transactions on Evolutionary Computation, 25(5):928–940, 2021.
- R.T. Liaw and C.K. Ting. Evolutionary manytasking optimization based on symbiosis in biocoenosis. In Proceedings of the 2019 AAAI Conference on Artificial Intelligence (AAAI), 2019.
- C.C. Liao and C.K. Ting*. A novel integer-coded memetic algorithm for the set k-cover problem in wireless sensor networks. IEEE Transactions on Cybernetics, 48(8):2245–2258, 2018.
- C.K. Ting*, X.L. Liao, Y.H. Huang, and R.T. Liaw. Multi-vehicle selective pickup and delivery using metaheuristic algorithms. Information Sciences, 406:146–169, 2017.
- C.H. Liu and C.K. Ting*. Computational intelligence in music composition: A survey. IEEE Transactions on Emerging Topics in Computational Intelligence, 1(1):2–15, 2017.

03

Biomedical Technology

Tornado-Inspired Acoustic Vortex Technology for Advanced Medical Applications

Helical Structure Motifs Made Searchable for Functional Peptide Design

Fish Out Infected type of Bacteria for Bacteremia Through Multi-functional Microfluidic Poles

Highly Effective Removal of Microplastics by Microalgae Scenedesmus Abundans

Tornado-Inspired Acoustic Vortex Technology for Advanced Medical Applications

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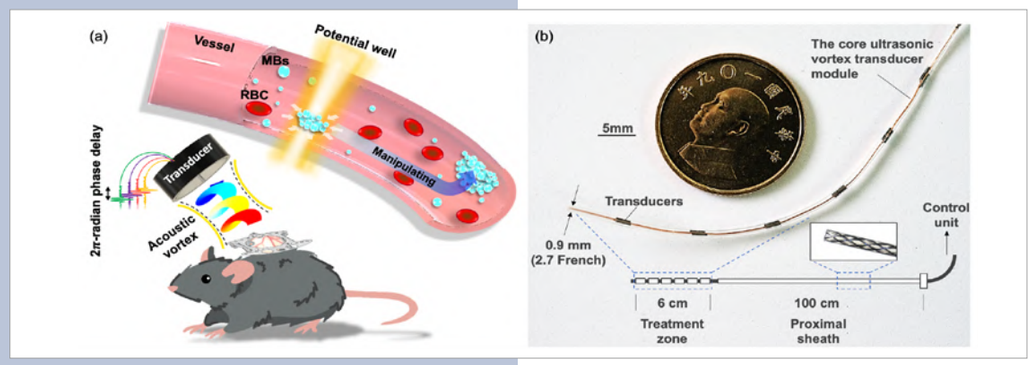
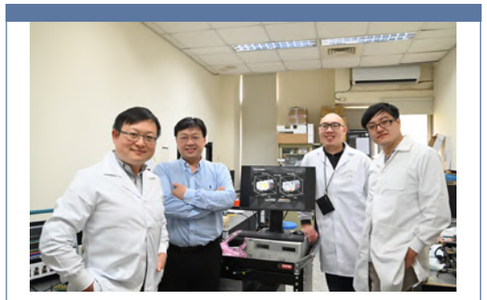
Spatially concentrating and manipulating biotherapeutic agents within the circulatory system for effective targeted drug delivery is a longstanding challenge due to the high velocity of blood flow. We have developed tornado-inspired acoustic vortex technology that performs as a "tweezer" to trap and manipulate lipid-shelled gaseous microbubbles (MBs) in both static and flow conditions, providing effective drug retention in the targeted region for precise medical applications such as treatments on solid tumors and intravascular therapies. With acoustic vortex technology, drug dosage is greatly reduced, allowing more efficient and safer therapy.

Besides trapping and manipulating MBs, the applications of the acoustic vortex technology can be further extended to the treatment of cardiovascular diseases, for instance, thrombolysis for pulmonary embolism (PE) and deep vein thrombosis (DVT). PE and DVT have global prevalence of 10 million new cases annually, with risk factors covering a variety of aspects such as genetics, surgery, injury, life style factors (e.g., aging, reduced mobility), cancer therapies, and pregnancy. Besides, the tight connection of PE and DVT (DVT is the main cause of PE) and the high motility rate of PE (up to 65%) have make such diseases more difficult to tackle. As the current treatment options do not consider both high treatment efficiency and high safety, many adverse effects such as hemorrhage risks is still a big issue for patients. We have developed a solution based on acoustic vortex technology to solve the problem. Working with industrial partners, we developed a catheter-based device for intravascular thrombolysis, with proprietary ultrasonic vortex transducers embedded in a core module designed at a diameter of 0.9 mm (2.7 French). The ultrasonic vortex transducers can generate tornado-like vortex and create a strong turbulent around the thrombus, increasing penetration of thrombolytic drugs and resulting in very effective thrombolysis. The residue of the dissolved thrombus is measured 6-7 μm and is evaluated with very low possibility to cause secondary thromboembolism. Animal studies have shown results of 60% thrombus shrinkage in the mice brain after applying ultrasonic vortex for ten minutes, demonstrating the potential of fast treatment. What's more, the feedback property of ultrasound can be used for real-time treatment monitoring.



(a) Tornado-inspired acoustic vortex technology is used as a "tweezer" to generate a potential well for noninvasive intravascular trapping and manipulation of lipid-shelled gaseous microbubbles (MBs) in the circulatory system. RBC: red blood cell. (b) The core ultrasonic vortex transducer module for the treatment of pulmonary embolism (PE) and deep vein thrombosis (DVT). The diameter of the module is 0.9 mm (2.7 French).

The next development of the acoustic vortex technology will cover noninvasive thrombolysis in the brain, noninvasive treatments of brain and neurovascular diseases, neuromodulation, treatments of neurological disorders such as Parkinson's disease and epilepsy, and combination of MBs or nanoparticles for controlled drug release and advanced localized therapies.



The development team of the acoustic vortex technology. (from left to right) Dr. Chun-Yen Lai, Professor Chih-Kuang Yeh, Dr. Wei-Chen Lo, and Dr. Zong-Han Hsieh.

Research Highlights

- From IP To IPO Program (FITI) Award
- 2021 Future Tech (FUTEX) Award
- 2021 National Innovation Award
- The 17th Tien Te Lee Biomedical Foundation Award

Research Output

- W. C. Lo, C. H. Fan, Y. J. Ho, C. W. Lin, and C. K. Yeh*, "Tornado-Inspired Acoustic Vortex Tweezer for Trapping and Manipulating Microbubbles," Proceedings of the National Academy of Sciences of the United States of America, 118(4), 11794-11819, 2021. (Selected as feature article "In This Issue")
- W. C. Lo, Y. L. Huang, C. H. Fan, and C. K. Yeh*, "3D Ultrafast Ultrasound Imaging of Microbubbles Trapped Using an Acoustic Vortex," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 68(12), 3507-3514, 2021.

Helical Structure Motifs Made Searchable for Functional Peptide Design

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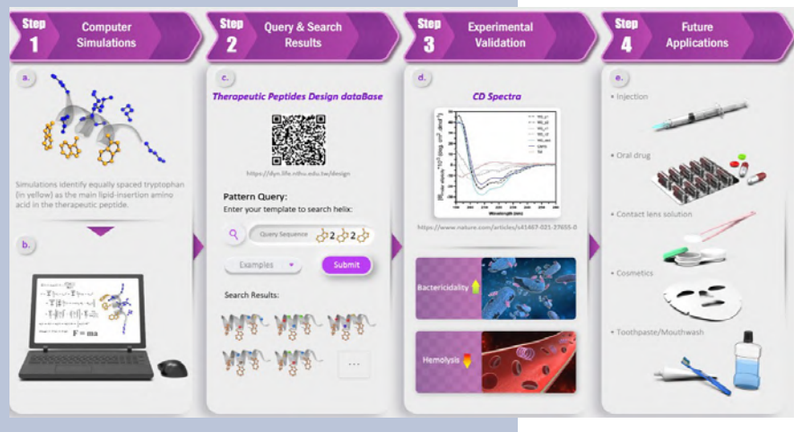
From the point of view of protein design, either to design a better helical antimicrobial peptide (AMP) or to propose stronger interface blockers for therapeutic purposes, it is not an easy task to allow constituent residues to address physicochemical needs, meeting a specific sequence pattern, while maintaining the required structural integrity. Suitable tools need to be developed to facilitate the process. In this study, we showcased the design of a new antifungal/antimicrobial peptide, helix-helix interface blockers that suppress hepatocellular carcinoma, and a diagnostic reporter to detect Helicobacter pylori (H. pylori) infection with the use of a new pattern-based search engine and a helical peptide database (TP-DB) housing 1.7 million experimentally determined helical peptides.

To demonstrate the utility of our secondary structure search engine - finding patterns without considering residues' evolutionary similarity, we would like to identify sequences matching a queried pattern which can only be found by our TP-DB but not by other tools, such as PHI-BLAST. We demonstrated how a known purification-tag-specific antibody was identified and repurposed into a diagnostic kit for Helicobacter pylori.

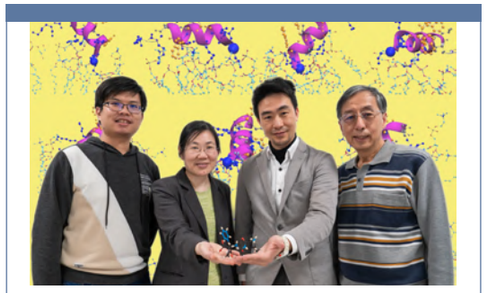
In the design of a new amphiphilic helical antimicrobial peptide (AMP), we first selected two previously reported AMPs as templates whose helicity was confirmed by our CD experiments and MD simulations starting from a fully extended conformation. MD revealed that a stretch of three equally spaced tryptophans are critical in the membrane insertion process. With the understanding, "three equally spaced tryptophans" (W**W**W) were queried in TP-DB and 11 unique helical stretches containing the pattern were found. A segment "WKCWARWRL" in Zinc-dependent metalloprotease (PDB:3ZUK), having relatively high positive charges and helical propensity, was found. By flanking this core segment by two lysine residues at both N- and C-terminus as those in the original template AMPs, we successfully designed a novel helical peptide, W3_db5, which exhibited improved antibacterial (E. coli) and antifungal (Candida albicans) activities and 40-fold less cytotoxicity as compared to their template peptides containing the same pattern. We also found that the helical peptide obtained from our database revealed high helicity verified by circular dichroism spectroscopy in isolation compared to the counterpart obtained from PHI-BLAST as negative controls, indicating the good use of TP-DB equipped with both pattern-based and BLAST-based search engines.



Therapeutic Peptide Design dataBase (TP-DB; https://dyn.life.nthu.edu.tw/design) facilitates the design of new therapeutic helical peptides.

We further demonstrate the third design case of helical blockers to prevent disease-related protein-protein interaction for anti-cancer therapy. Sgo1-PP2A complex is implicated in maintenance of centromere during early mitosis, where Sgo1 is viewed as potential therapeutic target for hepatocellular carcinoma (HCC) due to its up-regulated expression. The helical domain of recruit protein PP2A interacting with Sgo1 are utilized as template pattern ("K***G**Y") confirmed by in silico alanine scanning using MD simulations, for the design of protein-protein blockers. Total 69 unique sequences were found in TP-DB, and seven among them exhibiting higher affinity with Sgo1 supported by MD-derived binding free energy, serving as potential anti-tumor peptides.

In summary, TP-DB houses experimentally-determined helical amino-acid stretches in proteins of PDB, equipped with task-specific search engines and evaluations of helical propensity and 3D contacts of resulting peptides, which can facilitate researchers' functional peptide design in a wide spectrum of applications.



(from left) Mr Cheng-Yu Tsai (the leading first author; a NTHU alumnus who is now a PhD candidate in the NTU hospital), Professor Hua-Wen Fu, Professor Lee-Wei Yang (leading corresponding author), Professor Chung-Yu Lan.

Research Highlights

- Ta-You Wu Memorial Award, 2017
- International Collaboration Research of IPR, Osaka University (funding: 400,000 JP Yen), 2017-2018

Research Output

- In silico design of peptides equilibrated in a lipid bilayer with partition free energies indicating probability of antimicrobial activity U.S Pat. 10,810,329; R.O.C Pat. I557587; P.R.C. Pat. 3376320
- Cheng-Yu Tsai, Emmanuel O Salawu, Hongchun Li, Guan-Yu Lin, Ting-Yu Kuo, Liyin Voon, Adarsh Sharma, Kai-Di Hu, Yi-Yun Cheng, Sobha Sahoo, Lutimba Stuart, Chih-Wei Chen, Yuan-Yu Chang, Yu-Lin Lu, Ximai Ke, Christopher Llynard D. Ortiz, Bai-Shan Fang, Chen-Chi Wu, Chung-Yu Lan*, Hua-Wen Fu*, Lee-Wei Yang* (2022) Helical Structure Motifs Made Searchable to Facilitate the Functional Peptide Design. Nature Communications 13:102
- K K DurgaRao Viswanadham, Roland Böttger, Lukas Hohenwarter, Anne Nguyen, Elham Rouhollahi, Alexander Smith, Yi-Hsuan Tsai, Yuan-Yu Chang, Christopher Llynard Ortiz, Lee-Wei Yang, Liliana Jimenez, Siyuan Li, Chan Hur, Shyh-Dar Li (2021) An Effective and Safe Enkephalin Analog for Antinociception. Pharmaceutics, 13, 927

Fish Out Infected type of Bacteria for Bacteremia Through Multi-functional Microfluidic Poles

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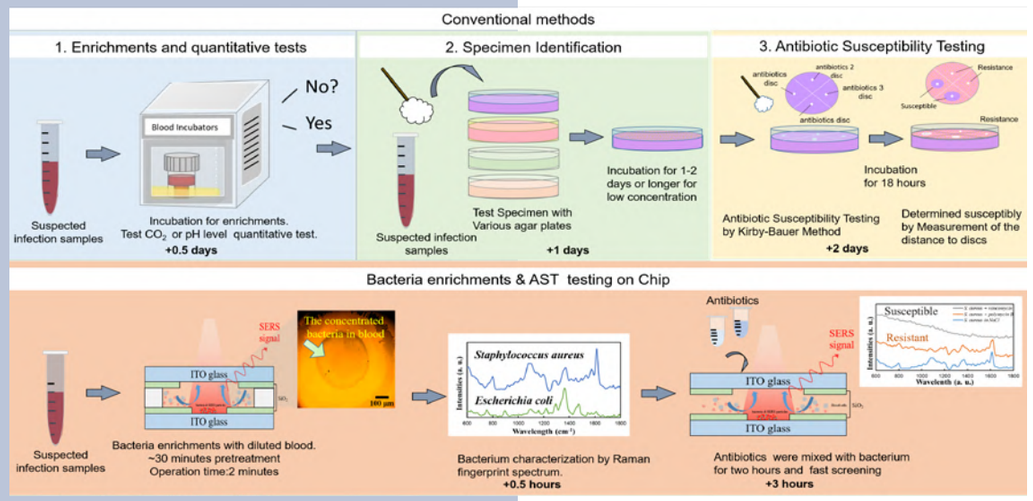
When bacteria was founded in the vascular system, it means an abnormal situation to the immune system and may induce life-threatening sepsis which may cause death within a day. Doctors raced against time to diagnose the infection in order to give the antimicrobial administration and inhibit infection as fast as possible. However, the traditional method for AST such as disk diffusion, gradient diffusion, and agar/broth dilution, usually needed 29-130 hours, which made the schedule really tight. To overcome aforementioned problems, Professor Tseng's group cooperated with Professor Hwan-You Chang, proposed a tiny all-in-one microsystem using three dimensional Alternative Current Electrokinetic/Surface Enhanced Raman Scattering (3D-ACEK/SERS) techniques. It combines multiple functions which can concentrate bacteria from whole blood, identify bacterial species, and determine antibiotic susceptibilities of the bacteria rapidly. The system consists of a hybrid electrokinetic mechanism, integrating AC-electroosmosis (AC-EO) and dielectrophoresis (DEP) that allows thousand-fold concentration of bacteria, including S. aureus, Escherichia coli, and Chryseobacterium indologenes, in the center of an electrode with a wide range of working distance (hundreds to thousands of μm), while exclusion of blood cells through negative DEP forces. By employing SERS assay, the identity of bacteria were determined only in approximately 2 min with a limit of detection of 3 CFU/ml, 5 orders of magnitude lower than that using standard centrifugation−purification process. Finally, label-free antibiotic susceptibility testing has been successfully demonstrated on the platform using both antibiotic-sensitive and multidrug-resistant bacterial strains illustrating a potential utility of the system to clinical applications.



The Schematic comparison between the conventional method (top) and our microfluidic(3D-ACEK/SERS) chip (bottom).

Professor Fan-Gang Tseng

Research Output

- Chen, K. H., Lee, S. H., Kok, L. C., Ishdorj, T. O., Chang, H. Y., & Tseng, F. G. (2022). A 3D-ACEK/SERS system for highly efficient and selectable electrokinetic bacteria concentration/detection/antibiotic-susceptibility-test on whole blood. Biosensors and Bioelectronics, 197, 113740.

Highly Effective Removal of Microplastics by Microalgae Scenedesmus Abundans

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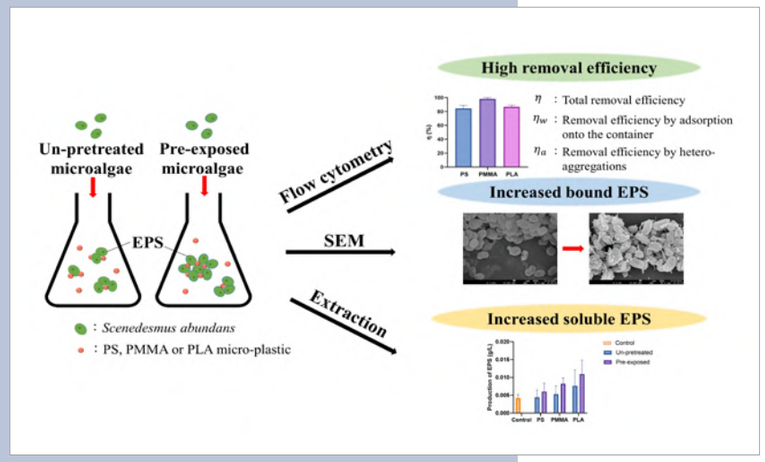
The micro-plastics (MP) discharged from sewage have caused serious threats to the marine ecological environment and potential harms to human health. However, apart from the use of filtration technology to remove MP, which is demanding on the equipment and costs, effective technology has yet to be established. Therefore, this study is committed to exploring the possibility of using microalgae to achieve effective, economically viable, and environmentally friendly removal of MP. The extracellular polymeric substances (EPS) on the surface of microalgae can form self-settling hetero-aggregations with micro-plastics, which does not require energy-consuming centrifugation or filtration to collect. This study aims to establish the technology for removing micro-plastics using microalgae and a standardized process to quantify the removal efficiency. The highly effective removal of multiple kinds of micro-plastics by microalgae Scenedesmus abundans was accomplished and the main mechanism of the MPs removal was identified as hetero-aggregation. The accurate quantification of removal efficiency was achieved by quantifying free suspended micro-plastics before and after the microalgae treatment. *S. abundans* was tested against three kinds of plastics, including polystyrene (PS), poly(methyl methacrylate) (PMMA), and polylactide (PLA). When *S. abundans* were exposed to micro-plastics for a long duration (pre-exposure), the total removal efficiency of all micro-plastics can be higher than 84%. Among these MPs, *S. abundans* were highly effective for removing PMMA micro-plastics (η = 98%). Prolonged pre-exposure increases the total removal efficiency of PS and PLA by 1.18 to 2.35 times. SEM images show that the significant increase of EPS on the surface of *S. abundans* stimulated by micro-plastics promotes the formation of hetero-aggregations, leading to a much higher fraction of MPs removed by aggregations (greater than 70%). On the contrary, if MPs exposure is short, enhanced adsorption onto solid surfaces can play an important role in the MPs removal, especially in the case of PLA. In this aspect, the abundance of soluble EPS was proportional to the amount of MPs adsorbed onto the container wall. The zeta potential on the particle surface also affects the repulsive force between the particle and container wall, resulting in different adsorption efficiencies on the solid surface. These results suggest that the *S. abundans* can effectively remove a variety of micro-plastics, and this is the first study that can count suspended micro-plastics and achieve accurate quantification of removal efficiency.

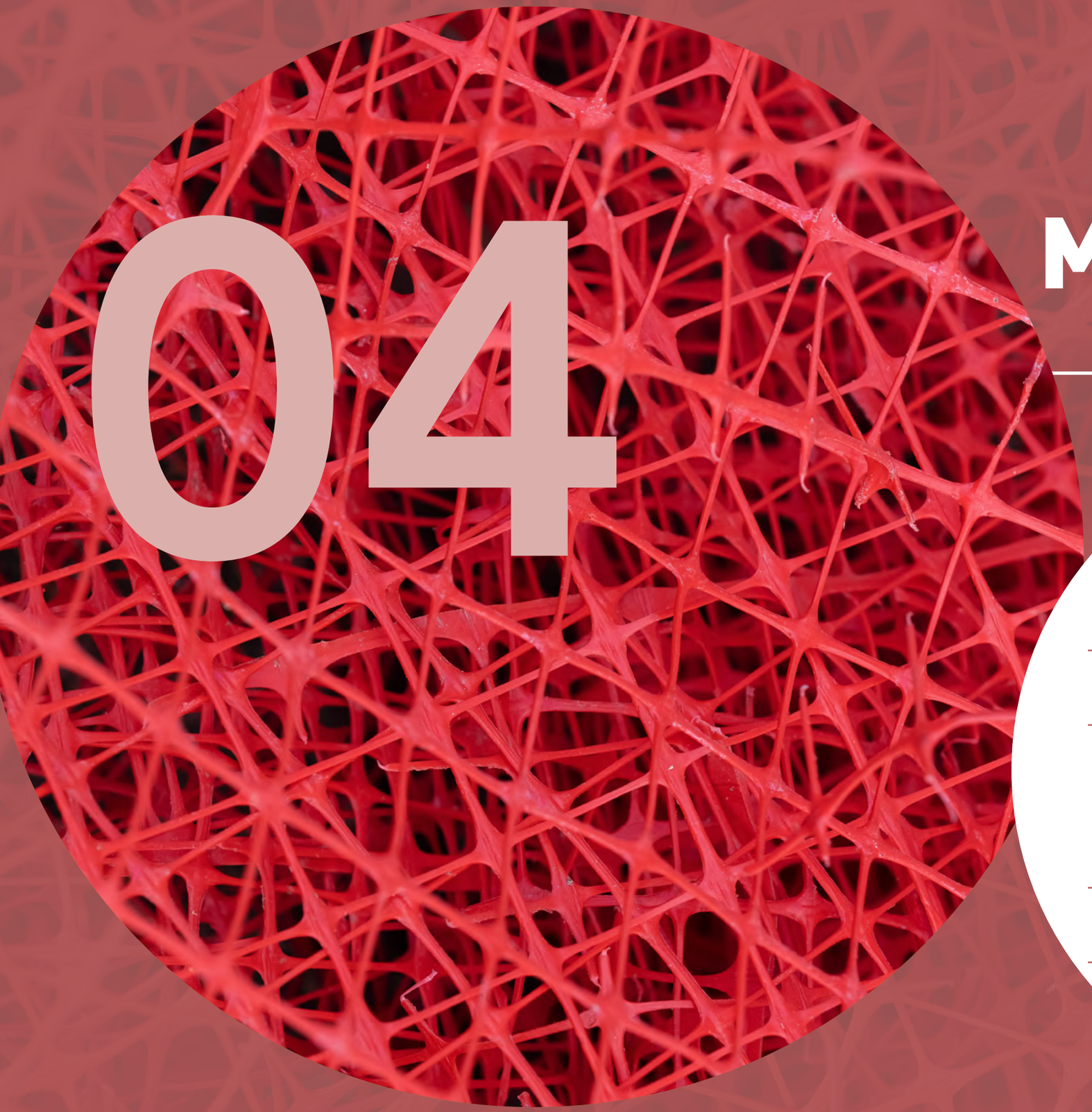


A Taiwan indigenous microalgae strain, *Scenedesmus abundans*, is highly effective for removing multiple kinds of microplastics (MP) in the waterbody. The effective MP removal is owing to the increased extracellular polymeric substances, either bound or soluble, secreted by the cell when challenged by the microplastics.

(from left) Professor Jo-Shu Chang (National Cheng Kung University, Microalgae Strain Provider), Professor Hsiang-Yu Wang (National Tsing Hua University, Principle Investigator), Yu-Ru Cheng (National Tsing Hua University, Master Student), Dr. Shih-Hsien Liu (Industrial Technology Research Institute, Funding Agency).

Research Output

- Yu-Ru Cheng, Hsiang-Yu Wang, "Highly Effective Removal of Microplastics by Microalgae Scenedesmus Abundans." Chemical Engineering Journal, 435, Part 2, 135079, ISSN 1385-8947 (2022).



04

Materials Science

New Strategy for High Strength and Ductility Through High Slip-Plane Density

Polypeptide Biomaterials for Tissue Engineering and Drug Delivery

Rational Design on Wrinkle-Less Transfer of Transition Metal Dichalcogenide Monolayer and Complementary Metal–Oxide–Semiconductor (CMOS) Compatible 2D Layered Film-Based Gas Sensors

Boosting the Performance of Fuel Cell Catalyst from Above

New Strategy for High Strength and Ductility Through High Slip-Plane Density

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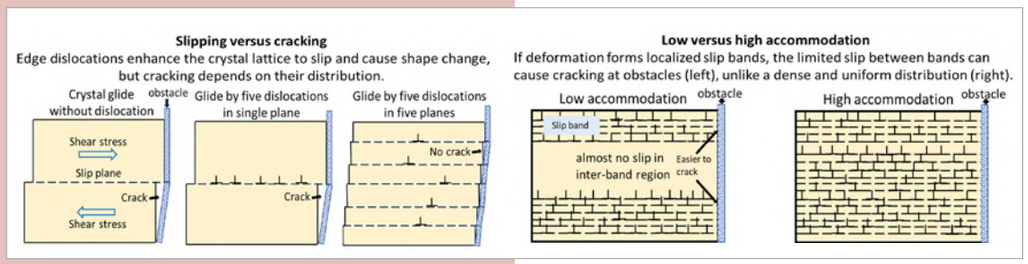
This article provides new strategy with insights and future perspectives. It may seem counterintuitive that crystal defects such as dislocations, stacking faults, and twin boundaries can impart favorable mechanical properties to metals. Dislocations allow crystals to glide and deform under a shear stress that can be several orders of magnitude less than the theoretical shear strength of a perfect crystal. Dislocations also allow a polycrystalline metal to be ductile because the crystal glide in dislocation-free grains would actually be prone to cause fracture at grain boundaries. Thus, dislocations allow metals to be shaped into various forms (such as flattening a sheet with rolling presses) with much less stress and expended power. However, ductile materials can fail if an internal crack develops during plastic deformation under an applied stress. Metal alloys are thus designed to exhibit sufficient plasticity, formability, and workability to enable their processing and sufficient toughness to avoid catastrophic failures in their intended applications.

High strength is often achieved with methods that inhibit dislocation motion (such as precipitation hardening), but this approach often decreases ductility. Many research efforts have been directed to reverse this trend. For example, the strategy suggested by the Considère criterion for necking, higher strain-hardening rates lead to a higher tensile strength and uniform elongation, is useful in the development of transformation-induced plasticity alloys and twinning-induced plasticity alloys. They are promising in structural applications requiring high specific strength and impact resistance. In this article, another strategy is proposed, enhancing the formation of more dislocations along denser and more uniform active slip planes of an alloy during plastic deformation would accommodate more strain and thus increase both strength and ductility. In this "high-accommodation strategy," low stacking-fault energy, lattice distortion, small grain size, dislocation cell structure, nanoprecipitates, dense stacking faults, and nanotwins could enhance the accommodation of higher densities of slip planes. Combining such positive factors of high accommodation strategy could provide high strength along with large ductility. If all positive factors are fully used and each factor gives its best contribution for an alloy, the strength and ductility combination could attain the highest level.

Under this guidance, further research on medium-entropy and high-entropy FCC alloys with different amounts of stacking fault energy to achieve superior properties are required in order to find the best stacking fault energy. In addition, more methodologies including composition design and process design are need to be invented in order to create the best high accommodation structure with small grain size, dislocation cell structure, nanoprecipitates, dense stacking faults, and nanotwins.



Showing the origin of cracking due to dislocation pile-up and the high accommodation capability of high slip-plane density in reducing strain concentration.

Professors S. J. Lin (middle), J. W. Yeh (right 2) and C. W. Tsai (right 1) with lab. members.

Research Highlights

- Invent the concept of high-entropy alloys and high-entropy materials, and drive it to become an emerging field. The concept is a revolution of compositions, breaking through the traditional compositions based on one major element.
- Exceptional Contribution Award of First World Congress on High Entropy Alloys (HEA 2019) in Seattle, USA.
- The highest-level award in Taiwan's science and technology - Executive Yuan Outstanding Science and Technology Contribution Award, 2021.
- Ranking of scientific impact is at the third in the world and the first in Chinese in the field of materials, among the top 2% of top scientists, approximately 160,000 around the world. (A standardized citation metrics author database annotated for scientific field by The Meta-Research Innovation Center at Stanford. Published: 20 October 2021 Version 3, DOI:10.17632/btchxktzyw.3)

Research Output

- JW Yeh*, SK Chen, SJ Lin, JY Gan, TS Chin, TT Shun, CH Tsau, and SY Chang, "Nanostructured High-entropy Alloys with Multi-Principal Elements—Novel Alloy Design Concepts and Outcomes", Advanced Engineering Materials, 6(5)(2004), pp. 299-303.
- KY Tsai, MH Tsai, JW Yeh*, "Sluggish diffusion in Co–Cr–Fe–Mn–Ni high-entropy alloys", Acta Materialia, 61(2013), pp. 4887-4897.
- Kuan-Hao Lin, Chieh-Min Tseng, Chu-Chun Chueh, Shou-Yi Chang, Yu-Chieh Lo, Chun-Chieh Wang, Su-Jien Lin, Jien-Wei Yeh*,''Different lattice distortion effects on the tensile properties of Ni-W dilute solutions and CrFeNi and CoCrFeMnNi concentrated solutions'', Acta Materialia, Volume 221, December 2021, 117399.
- Jien-Wei Yeh*, "Strength through high slip-plane density", Science, 19 Nov., issue 6570, 374(2021), pp. 940-941.

Polypeptide Biomaterials for Tissue Engineering and Drug Delivery

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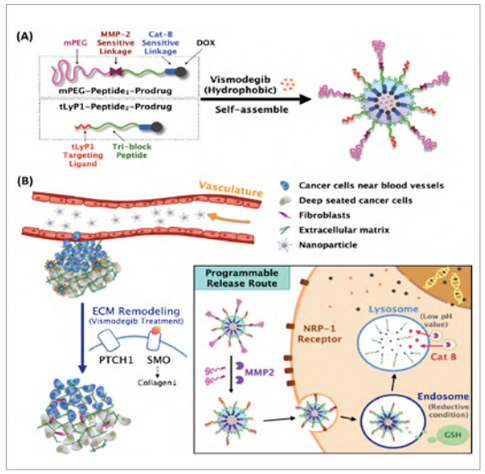
The research expertise of Prof. Wang is whithin the fields of Functionalized Biomaterials Development, Tissue Engineering and Regenerative Medicine, Drug Delivery for Theranostics, and Bioinspired Technology in Nanomedicine. The research topics in Prof. Wang's Lab can be covered in cutting-edge directions and main themes, including self-assembly nanopeptide hydrogel, multiple stimuli-responsive nanoparticle, biomimetic extracellular matrix scaffold, etc. Of note is that the research team also entends and broadens their developed materials or tools to regulate stem cell fate by physical, chemical, or biological methodologies.

For self-assembling peptides (SAPs), we propose the design of functionalized SAPs that demonstrate β-sheet secondary structure, spontaneously organizes into nanofibers network, and construct a functionalized hydrogel scaffold. The peptide secondary structure, nanostructure and mechanical property can be controllable by the adjustment of microenvironmental factors such as pH value and ions concentration. The in vivo assessment of optic tectum neural tissue healing process and regenerative possibility reveals that implanted angiogenic functionalized hydrogel could regulate cellular process, leading to the potential in promotion of angiogenesis, neurogenesis and the enhancement of visual field recovery. The highlights of these research studies are : 1) The mechanical property and the stability of fSAP hydrogel could be enhanced after endogenous transglutaminase enzyme mediation, 2) The designer fSAPs are injectable with self-healing property and possess the ability to form hydrogel in situ, 3) The adoption of proteoglycan serves as protecting carrier for sequestering multiple growth factors and maintains their release locally at injected site, 4) The designer bioinspired fSAP hydrogel is an attractive and promising therapeutic modality for minimally-invasive surgery, ischemic tissue disorders and chronic wound healing.



(A) Formation of self-assembled polypeptide nanoparticle by two main amphiphilic sequences. (B) Illustration of programmable dissociation of polypeptide nanoparticles through the breakdown of dual stimuli-sensitive (enzyme and redox) linkages around tumor region.

For cancer therapy, the tailored-design polypeptide-based nanoparticles with self-assembling and programmable stimulus-responsive properties are designed with advantages including 1) be stable in physiological blood stream environment with a low level of drug loss and effectively release the encapsulated drug with pH variations according to the tumor microenvironment extracellularly and intracellularly, 2) specifically target to hard-to-treat breast cancer cells and activated endothelial cells (tumor region), 3) significantly inhibit the growth and prevent from malignant metastasis of cancer cells in consonance with promising anti-tumor efficacy, and 4) keep tumors stick to localized position so that these confined solid tumors can be more accessible by different treatment modalities and patients may have better treatment outcome and satisfactory quality of life.

Group Photo - The Wang Lab

Research Highlights

- *IUMRS Frontier Materials Young Scientists Award* by International Union of Materials Research Societies (2022)
- *Research Scholar Award & Biomedical Engineering Award* by Prof. Chau-Jean Lee Biomedical Engineering Development Foundation, Society of Biomaterials & Control Release, Taiwan (2020, 2022)
- *"Outstanding Young Scholar Research Grant"* by NSTC (2015-2018, 2019-2022, 2022-2025)

Research Output

- Hsieh PH, Huang WY, Wang HC, Kuan CH, Shiue TY, Chen Y, Wang TW*. Dual-responsive Polypeptide Nanoparticles Attenuate Tumor-associated Stromal Desmoplasia and Anticancer through Programming Dissociation. Biomaterials 2022; 284:121469
- Huang LC, Wang HC, Chen LH, Ho CY, Hsieh PH, Huang MY, Wu HC, Wang TW*. Bioinspired Self-assembling Peptide Hydrogel with Proteoglycan-assisted Growth Factor Delivery for Therapeutic Angiogenesis. Theranostics 2019; 9(23): 7072-7087
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- Cheng TY, Chen MH, Chang WH, Huang MY, Wang TW*. Neural stem cells encapsulated in a functionalized self-assembling peptide hydrogel for brain tissue engineering. Biomaterials 2013; 34(8): 2005-2016

Rational Design on Wrinkle-Less Transfer of Transition Metal Dichalcogenide Monolayer and Complementary Metal–Oxide–Semiconductor (CMOS) Compatible 2D Layered Film-Based Gas Sensors

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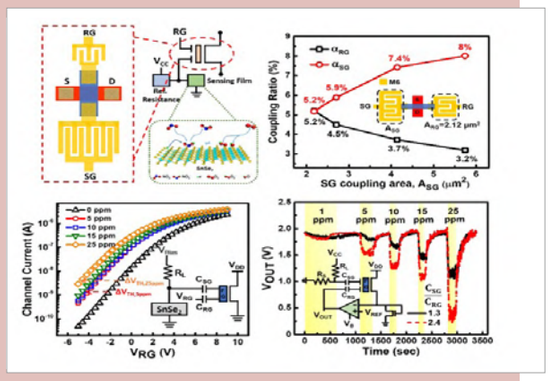

Figure 1 demonstrates the conventional transfer method and AWAT method. The wettability is the critical parameter for achieving a wrinkle-less TMDC monolayer during the wet transfer method. In the AWAT method, alcohol was added to pure DI water, which is the transfer media, to reduce its polarity.

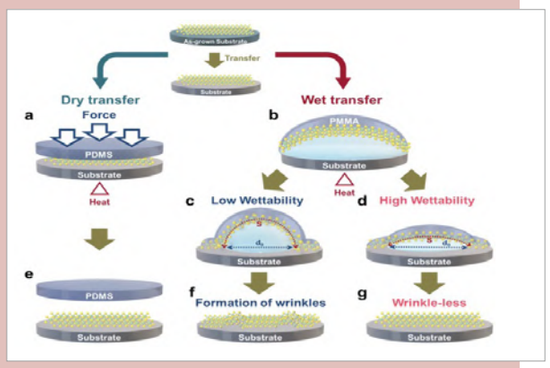

Figure 2 shows a schematic of the gas-sensitive floating-gate FET and the sensing mechanism of TMDC materials. The proposed sensor exhibited a sensitivity of 102 mV/ppm in the range of 1-25 ppm of NOx, owing to the FG structure and high surface-area-to-volume ratio of $SnSe_2$.

An adjustable wettability-assisted transfer (AWAT) method, which is a modified wet transfer process, is designed and developed to achieve a uniform and wrinkle-less TMDC monolayer on arbitrary substrates. To decrease transfer-induced defects, the transfer solution is adjusted to enhance the wettability of the target substrate, thus making the TMDC monolayer to cover the target substrate smoothly. In the AWAT method, alcohol was added to pure DI water, which is the transfer media, to reduce its polarity. By decreasing the polarity of the transfer media, the degree of wetting increases when the transfer medium comes in contact with the target substrate. With this method, the density of wrinkles can be decreased by ~15–20 % compared with the conventional transfer method by pure DI water. The transferred MoS2 monolayer with the AWAT method can achieve enhanced carrier mobility from ~20 to ~35 $cm^2V^{-1}s^{-1}$ in average, which is 30 times larger than that transferred with the conventional transfer method by the pure DI water.

A novel embedded sense amplifier and readout scheme was developed for a 2D-layered $SnSe_2$ CMOS-compatible gas sensor featuring high and adjustable sensitivity. The synthesis process of the $SnSe_2$ layered films as the sensing films can operate at low temperatures, and can be measured at room temperature, which is suitable for low-power applications. A self-balanced readout circuit was developed with a negative-feedback operational amplifier. The sensitivity of the readout circuit reached 102 mV/ppm for a NO_2 concentration of 1-25 ppm. Furthermore, the sensing range can be adjusted using the bias voltage (V_{REF}) of the operational amplifier. With this flexibility, the readout circuits are able to account for inevitable process variations. By adjusting the coupling capacitors and film thickness, the proposed gas sensor can be adapted to the ambient level of the targeted gas in the environment. Moreover, the calibration method and peripheral circuits proposed in this research endow low error, high density, and high sensitivity responses. The performance of the proposed detector is comparable to that of the other state-of-the-art gas sensors.

Group photo of Prof. Yu-Lun Chueh, Co-PI:Prof. Ya-Chin King and Prof. Po-Wen Chiu

Research Highlights

- Establish a transfer method to reduce the transfer-induced defects of transition metal dichalcogenide materials synthesized by chemical vapor deposition
- Combine the $SnSe_2$-based gas sensor and floating gate FinFET to achieve a highly sensitive, wide, and adjustable dynamic ranges with a real-time response of the sub-ppm detection limit on NO_2 gas.
- Cooperate with TSMC (TSMC JDP project)

Research Output

- Ying-Chun Shen, Yu-Ting Wu, Ling Lee, Jyun-Hong Chen, Sumayah Shakil Wani, Tzu-Yi Yang, Chih Wei Luo, Ming-Deng Siao, Yi-Jen Yu, Po-Wen Chiu*, and Yu-Lun Chueh*, "Rational Design on Wrinkle-Less Transfer of Transition Metal DSichalcogenide Monolayer by Adjustable Wettability-Assisted Transfer (AWAT) Method", *Advanced Functional Materials*, 2021, 2104978.
- Po-Hung Tan, Che-Hao Hsu, Ying-Chun Shen, Chien-Ping Wang, Kun-Lin Liou, Jiaw-Ren Shih, Chrong Jung Lin, Ling Lee, Kuangye Wang, Hong-Min Wu, Tsung-Yu Chiang, Yue-Der Chih, Jonathan Chang, Ya-Chin King*, Yu-Lun Chueh*, "Complementary Metal–Oxide–Semiconductor Compatible 2D Layered Film-Based Gas Sensors by Floating-Gate Coupling Effect", *Advanced Functional Materials*, 2022, 32(13), 2108878.

Boosting the Performance of Fuel Cell Catalyst from Above

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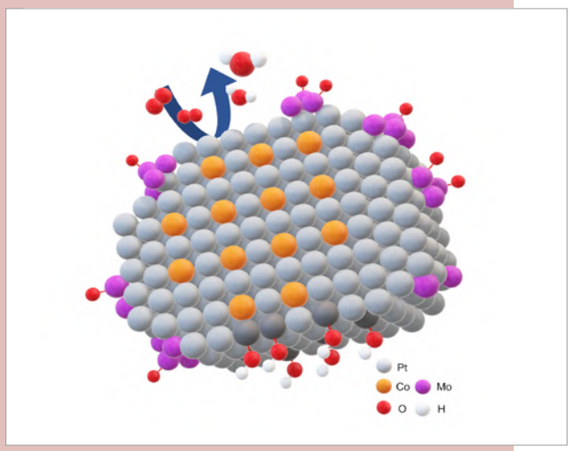
Polymer electrolyte membrane fuel cells (PEMFC), an essential component in the hydrogen economy, suffer from the high cost of platinum (Pt) precious group metal (PGM) catalyst used on the electrodes. The reduction of Pt usage is critical for the success of commercializing the technology, particularly when the demand gets higher and higher. However, lowering Pt loading results in insufficient performance and durability, posting a great challenge for large-scale deployment.
To mitigate the aforementioned issues, we have developed a highly active and durable catalyst for low-PGM PEMFC through atomic scale engineering. First, we have prepared an intermetallic Pt-Co catalyst with a facile impregnation method. The atomic scale ordering of Pt and Co significantly increases the activity towards oxygen reduction reaction (ORR) and stability against Co dissolution, when compared with disordered structures. The intermetallic Pt-Co catalyst, therefore, shows nearly 3 times enhancement in mass activity compared with commercially available Pt/C catalysts. To further enhance performance and durability, ultrafine Mo-O_x species were decorated onto the intermetallic Pt-Co catalyst. These Mo-O_x promoters further boosted a 30% enhancement in mass activity which was effective throughout the lifetime analysis.
To decipher the origin of the observed compelling electrochemical behaviors, synchrotron-based X-ray absorption spectroscopy and density functional theory calculation (DFT) were carried out to acquire further understanding of the boosting effect of the Mo-O_x promoters. The X-ray absorption near edge structure (XANES) spectra showed the continuous weakening of Pt-O bonds as the Pt catalyst was sequentially modified by Co alloying/ordering and the Mo-O_x promoters. As the adsorption of oxygen is generally considered to be too strong on Pt surfaces, a weaken Pt-O bond would favor the progression of ORR on the catalyst surface and hence leading to the observed activity enhancement. From a theoretical point of view, DFT calculation revealed the modification of d-band electronic structure by the Mo-O_x promoters leading to a downshift of the *d*-band center energy. The lowered *d*-band center would result in a downshift of the anti-bonding orbital, with respect to the Fermi level, when the Pt surface hybridizes with the adsorbed oxygen molecule. The anti-bonding orbital thus has a higher probability to be filled with electrons and decreases the Pt-O bond strength.



Boosting Pt catalyst inside out: Alloy and ordering Co atoms inside the Pt nanoparticle and having Mo-O_x promoters decorating the surface makes it a very active catalyst towards oxygen reduction reaction for low-PGM PEMFC.

The developed Pt-Co intermetallic ORR catalyst equipped with the Mo-O_x promoter was also evaluated under practical fuel cell testing conditions in a membrane electrode assembly (MEA). The enhanced mass activity was verified and enabled the low humidity operation of fuel cells due to the sufficient self-generated water. As low humidity conditions post great advantages in drive cycle durability, our developed catalyst may open new opportunities for new modes of operation for fuel cell vehicles.

(from left) Hanna Ilyani Zulhaimi, Yi-Hung Huang, Liang-Chen Lin, Ren-Hao Yang, Yun-Sheng Cheng, Syu-Cheng Ye, Prof. Yung-Tin Pan, Wei-Chieh Liao, Qing-Yun Chou, Ding-Huei Tsai, Cheng-Yang Chang, Lu-Yu Chueh, Yu-Mei Huang

Research Highlights

- Young Scholar Fellowship (Einstein Program), Ministry of Science and Technology

Research Output

- L-C. Lin, C-H. Kuo, Y-H. Hsu, L-C. Hsu, H-Y. Chen, J-L. Chen, Y-T. Pan*, High-Performance Intermetallic PtCo Oxygen Reduction Catalyst Promoted by Molybdenum, *Appl. Catal. B.* 2022 (in press)
- W-C. Liao, D-H. Tsai, W-Z. Hong, Y-H. Huang, L-C. Lin, Y-T. Pan*, Enabling Direct CO_2 Electrolysis by Alkali Metal Cation Substituted Membranes in a Gas Diffusion Electrode Reactor, *Chem. Eng. J.*, 2022, 134765.
- Y-H. Huang, Y-H. Hsu, Y-T. Pan*, Fabrication of Catalyst Layers with Preferred Mass and Charge Transport Properties through Texture Engineering, *ACS Appl. Energy Mater.*, 2022, 5, 2890-2897.
- L-C. Lin, Y-S. Cheng, C-H. Kuo, Y-C. Chen, W-C. Liao, L-Y. Chueh, S-C. Ye, H-Y. Chen, H-Y. Tiffany Chen,Y-T. Pan*, Armoring the Pt/C Catalyst with Fine Atomic-Scale Tungsten Species to Increase Tolerance against Thermal and Fuel Cell Stresses, *ACS Appl. Energy Mater.*, 2021, 4, 11448-12457

05

Humanities and Social Sciences

The Decisive Role of Subordination in Social Hierarchy in Weanling Mice and Young Children

Western Technologies and China's Industrial Development: Steamship Building in 19Th Century China

The Valuation and Determinations of Brand Names

Barriers to Academic Data Science Research in The New Realm of Algorithmic Behavior Modification by Digital Platforms

The Decisive Role of Subordination in Social Hierarchy in Weanling Mice and Young Children

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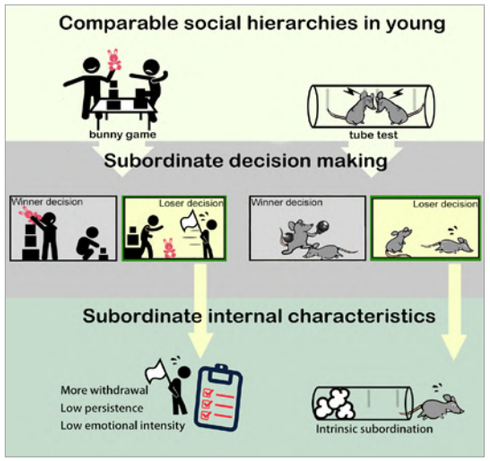
Humans are social animals who naturally form social hierarchies during social interactions from their time as preschoolers to adults. When playing in groups, some preschoolers naturally become the leaders without being appointed. These children issue commands, determine the content and methods of play, and become core figures in their class; some other children seem to be natural followers, following orders without questioning and do not participate in decision-making. The animal world works similarly. Social animals, such as a pack of wolves or a troop of monkeys, also compete and fight to form social hierarchies. While the concept of social dominance has been investigated extensively in both the fields of social sciences and life sciences, there were not too many studies focusing on humans and animals simultaneously. Under the support of National Tsing Hua University's cross-discipline research grant, team led by Dr. Yu-Ju Chou from the Department of Early Childhood Education and Dr. Tsung-Han Kuo from the Institute of Systems Neuroscience compared the social behaviors of young children and young mice to explore the nature of social dominance behaviors and the underlying neurophysiological mechanisms in humans and animals.

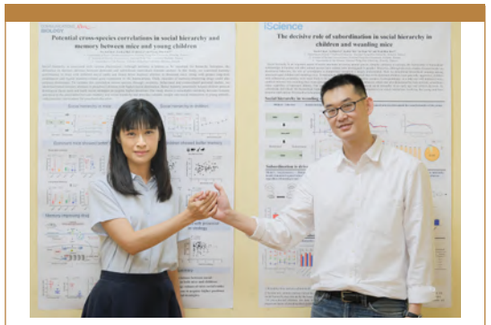
For mouse study, the tube test, in which one mouse forces its opponent backward out of a tube, was applied to evaluate social hierarchy. Unexpectedly, the conflicts in tube test between young mice are not resolved by winner approach but by loser retreat. Behavioral and surgical manipulations further indicated that the loser withdrawal is mainly determined by intrinsic subordinate status regardless of opponent identity. Meanwhile, temperament assessment in young children suggested that children with lower ranking are generally less persistent, low emotional intensity and withdrew easily. Identifying the importance of subordinate characteristics in the formation of children social hierarchy is therefore similar to the finding in mice.



In both children and mice, subordinate characteristics play decisive role in the formation of social hierarchy.

Intriguingly, in the follow-up research, the team found that there is a positive correlation between memory and social hierarchy in both mice and children. Behavioral, inventory and event-related potential studies indicated that memory ability could potentially affect children's acquisition of social positions directly through processing dominant facial cues and indirectly through social strategy learning.

These findings provided an important reminder to our educators. The silent formation of a social hierarchy implied that subordinate children may easily lose their opportunities to class resources without being noticed. And the relatively few resources and poor interaction quality may in turn lead to frustration and fewer opportunities to encounter cognitive stimuli, consequently leading to poor development. To assist young children in achieving better social adaptation, more attention should be paid to subordinates in the classroom. Rather than just provide moral education or behavioral requirements, we should take the level and limitations of children's cognitive development into account and ensure that every child has the opportunity to access the learning resources.



(from left) Associate Professor Yu-Ju Chou and Assistant Professor Tsung-Han Kuo conducted cross-species research and achieved important outcomes.

Research Highlights

- Successful cross-species research cooperation between the Department of Early Childhood Education and the Institute of Systems Neuroscience.
- Identify the importance of subordinate characteristics in the formation of social hierarchy
- Highlight the importance of appropriate distribution of educational resources
- Feature in several public media in Taiwan including *Liberty Times, China Times and United Daily News.*

Research Output

- Yu-Ju Chou, Yi-Han Lu, Yu-Kai Ma, Yu-Shan Su and Tsung-Han Kuo. **The decisive role of subordination in social hierarchy in weanling mice and children.** *iScience, 24*(2), 102073 (2021).
- Yu-Ju Chou, Yu-Kai Ma, Yi-Han Lu, Jung-Tai King, Wen-Sheng Tasi, Shi-Bing Yang and Tsung-Han Kuo. **Potential cross-species correlations in social hierarchy and memory between mice and young children.** *Commun Biol.*, 5(1):230 (2022)

Western Technologies and China's Industrial Development: Steamship Building in 19th Century China

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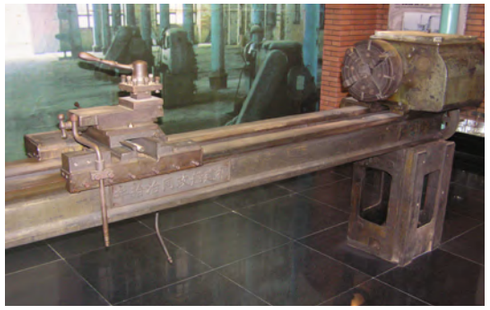
How might China have developed modern technology? China's economic power and technological advancement today is impressive, in the nineteenth century the middle kingdom could barely match the military strength and technological prowess of Western powers. Why? My research offers a partial answer to the big question.

After the defeats in the two Opium Wars (1839-1842, 1856-60) by British and French forces, the Qing government of China launched a series of measures, including establishing modern arsenals and shipyards, to import Western military technologies into China. Nevertheless, the humiliating defeat in the Sino-Japanese War (1894-95) seems to suggest that all these measures were failures. Historians often blame China's conservatism for such failures. They may also accuse Western imperialistic aggression for hampering Chinese technological development. None of these arguments really looks into the key issues of science and technology.
The steam engine, which China had to import, was at the heart of the Industrial Revolution. Its invention had to do with Europe's machine tool tradition and the scientific discoveries of atmospheric pressure, the study of heat, and mathematised physics. China had no strong tradition in any of these fields

After the discovery of steam power during the two Opium Wars, senior Qing government officials established arsenals that were equipped with machine tools to produce firearms and to build steamers. Yet, they ignored that steam-engine technology was science-based, especially when thermodynamics had become essential in engine design after the 1850s. Foreign missionaries started to translate texts into Chinese to introduce elementary level scientific concepts to Chinese readers. Some of the texts were used as textbooks in schools that taught foreign languages. These texts were far from adequate for training engineers. Although more translations, including engine-room manuals, were produced by the Translation Department (est. 1868) of the Jiagnan Arsenal (est. 1865), the problem of properly translating the concept of energy hampered the efforts of introducing the new science. The only institution in nineteenth-century China that successfully introduced steamship building technology from its scientific principles to its technical applications was the Fuzhou Navy Yard (est. 1866), which recruited French technicians and teachers. The Navy Yard trained Chinese workers with modern technical skills and taught Chinese students with physics, mathematics, and thermodynamics. In the 1880s, the Navy Yard technicians were able to design and build steam warships on their own. Unfortunately, due to an arm race with Japan, which was triggered by the Japanese invasion of Taiwan in 1874, the Qing government diverted funds to the purchase of advanced warships from Western Europe, allowing the domestic shipbuilding industry to lag behind the new development in technology after the 1880s.



Fuzhou Navy Yard's lathe

To conclude, radical institutional reforms was essential in developing science and technology. Unlike Japan that started its reforms after the Meiji Restoration (1868), China only initiated similar changes in the early twentieth century. Unfortunately, it was too late when science and technology was advancing in a neck-breaking speed.

Professor. Hsien-ch'un Wang

Research Highlights

- This is the first book that explores the scientific and technical issues of importing steam engine technology into China between the 1840s and 1890s.
- This book examines how translation might have achieved in bringing new understanding of heat to late Qing Chinese literati.
- This book shows how China's first engineering school was established to train shipbuilding workers and engineers.

Research Output

- **Contested Tracks to Modernity: Negotiating Narratives at Taiwan's Railway Department Park. *Technology and Culture*, 62:2 (Apr. 2021) 573-583.**
- Merchants, Mandarins, and the Railway: Institutional Failure and the Wusong Railway, 1874-1877. *International Journal of Asian Studies*, 12:1 (Jan. 2015), 31-53.
- Discovering Steam Power in China, 1840s-1860s. *Technology and Culture*, 51:1 (Jan. 2010), 31-54.

The Valuation and Determinations of Brand Names

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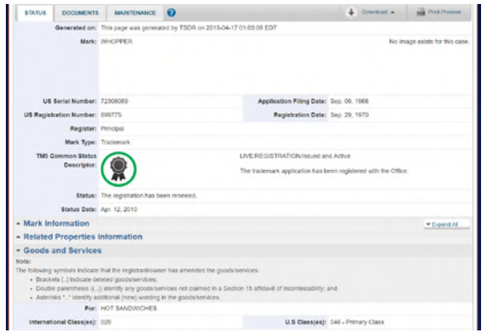
One important and promising agenda of my research is to understand the interaction between brand names and financial markets. My analyses along this direction expand the knowledge domain of the economics and finance literature about intellectual property, and deliver policy implications on governments' industrial policies and security regulations. I briefly talk about my three publications in this area as follows:

Contribution #1: Valuation of New brands
Brand names s are notoriously difficult to value. I and my coauthors propose to track the stock returns of firms with different levels of intensity in launching new trademarks. Together with my coauthors Dongmei Li (U. South Carolina), Qin Li (Hong Kong Polytechnic U.), Siew Hong Teoh (UCLA) and Kevin Tseng (National Taiwan U.), we find that firms launching more new trademarks are more profitable; however, such profitability is underestimated by stock analysts. Such an underestimation can be attributed to analysts' (and investors') pessimism about market uncertainty of and lack of attention to new brands. We conclude that stock investors underestimate the value of new brands due to lack of attention and/or limited information processing ability.

Contribution #2: Brands in Merger and Acquisitions
An important question in the mergers and acquisitions (M&As) literature is how product market synergies are achieved. Together with my coauthors Kai Li (UBC), Hong Wu (Fudan U.), Xing Liu (UBC), we propose to use trademark data to measure product competition and show that companies facing greater competition are more likely to be acquirers. We further show that acquirers consolidate their product offerings by discontinuing more existing trademarks and launching fewer new trademarks. We thus use trademark data to highlight that M&As create product market synergies by cutting overlapping product offerings to achieve cost efficiency.



An example of trademark - Whopper (Registration no. 899775)

Contribution #3: Board Structure and New Brands
Staggered boards, also known as classified boards, are a board structure that requires more than one year to be replaced. This structure is argued to offer stability in corporate governance and management, which is beneficial to firms' long-term investment. Together with my coauthors I-Ju Chen (Yuan Ze U.) and Yanzhi Wang (National Taiwan U.), we examine if such a board structure influences the development of brand names require long-term marketing input. We show that a legislation change in Massachusetts that forced the adoption of staggered boards in 1990 makes affected Massachusetts-incorporated firms perform better in product innovations measured by new trademarks and product-related patents.


Professor Po-Hsuan Hsu.

Research Highlights

- TPRI Fellow, Technology Policy & Research Initiative, Boston University, 2022-present
- Associate Editor, Journal of Banking & Finance
- Advisory Editor, Research Policy
- Research has been covered by the following international media: Wall Street Journal, Harvard Law School Forum on Corporate Governance, Duke Law School FinReg Blog, NBER homepage, etc.

Research Output

- "Innovation strategy of private firms," with Huasheng Gao and Kai Li (UBC), Journal of Financial and Quantitative Analysis, 53 (1), 1-32, February 2018 (lead article).
- "Innovative originality, profitability, and stock returns," with David Hirshleifer and Dongmei Li, Review of Financial Studies, 31(7), 2553-2605, July 2018.
- "Natural disasters, technology diversity, and operating performance," with Hsiao-Hui Lee, Shu-Cing Peng, and Long Yi, Review of Economics and Statistics, 100(4), 619-630, October 2018.
- "More cash, less innovation: The effect of the American Jobs Creation Act on patent value," with Heitor Almeida, Dongmei Li, and Kevin Tseng, Journal of Financial and Quantitative Analysis, 56(1), 1-28, February 2021 (lead article).
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Barriers to Academic Data Science Research in The New Realm of Algorithmic Behavior Modification by Digital Platforms

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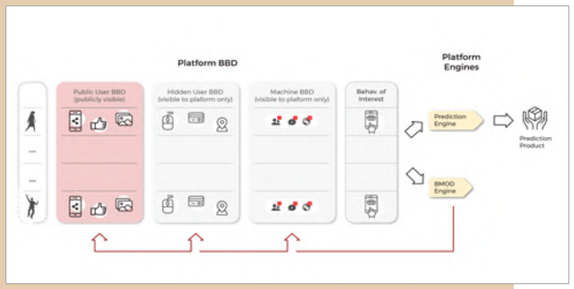
The era of *behavioral big data* has created new avenues for data science research, with many new contributions stemming from academic researchers. Yet data controlled by platforms have become increasingly difficult for academics to access (Lazer et al., 2020; Sadowski et al., 2021). This isolation of academic researchers results from their lack of access to human behavioral data and, crucially, to both the data on machine behavior (Rahwan et al., 2019) that triggers and learns from the human data and the platform's behavior modification mechanisms. Our central claim in Greene, Martens, and Shmueli (2022) is that investigating the nature, causes, and effects of scientifically and socially important topics is increasingly difficult for anyone except researchers at platforms or academics affiliated with prestigious institutions with platform connections.

Platforms such as Facebook, TikTok and YouTube now routinely use algorithmic behavior modification, implemented via machine learning techniques such as reinforcement learning, to manipulate users' behavior. Platforms employ behavior modification to, for example, provide personalized services, increase user engagement, "hook" users by habit formation, generate further behavioral big data, and more. Behavior modification techniques derive from principles of behaviorist psychology and include nudging, herding, and operant conditioning, among others (Zuboff, 2019). Such techniques, when integrated into digital platforms, are commonly termed *persuasive technology* (Fogg, 2002).

Behavior modification interventions range in transparency: some are observable to users (e.g. chatbots, recommendations, and app notifications) while others are less so (e.g. A/B testing, feed filtering and comment moderation on social networks, and deceptive interface design choices.) The employment of opaque forms of behavior modification on platforms greatly complicates the ability to research human and machine behavior (Milano et al., 2021).



Human users' behavioural data and related machine data used for behaviour modification and prediction. Rows represent users. Academic researchers typically can only access Public User BBD (e.g., shares, likes, posts), while Hidden User BBD (e.g., webpage visits, mouse clicks, payments, location visits, friend requests), Machine BBD (e.g., displayed notifications, reminders, news, ads) and Behaviour of Interest (e.g., click, dwell time) are generally unknown or unavailable. Black arrows show how these data are used as inputs for prediction and behaviour modification. Red arrows show how these data feed back into the behaviour modification mechanism, thereby generating new human and machine BBD.

Given the impact of platform-based behavior modification on individual and societal well-being, we discuss the consequences for data science knowledge creation, and encourage academic data scientists to take on new roles in producing research to promote (1) platform transparency and (2) informed public debate around the social purpose and function of digital platforms.

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Top: Galit Shmueli (left), David Martens (center), Travis Greene (right) / Bottom: David Martens (left) and Galit Shmueli (right)

Research Highlights

- 2022 Hou De Association Outstanding Research Award, National Tsing Hua University
- 2021 Outstanding Research Award, Taiwan Ministry of Science & Technology (MOST)
- 2021 E.SUN Bank Academic Award
- 2020 Inaugural Teaching Innovation Award, INFORMS Information Systems Society
- 2020 Elected Fellow, Institute of Mathematical Statistics (IMS)

Research Output

- Shmueli, G., and Tafti, A. (2022), How to "Improve" Prediction Using Behavior Modification, International Journal on Forecasting, accepted.
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