19 '20

2019/2020
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

National Tsing Hua University

No. 101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan 30013, R.O.C.
Tel : +886-3-571-5131
E-mail : rd@my.nthu.edu.tw
http ://www.nthu.edu.tw/
https ://www.facebook.com/nthu.tw/

19'20
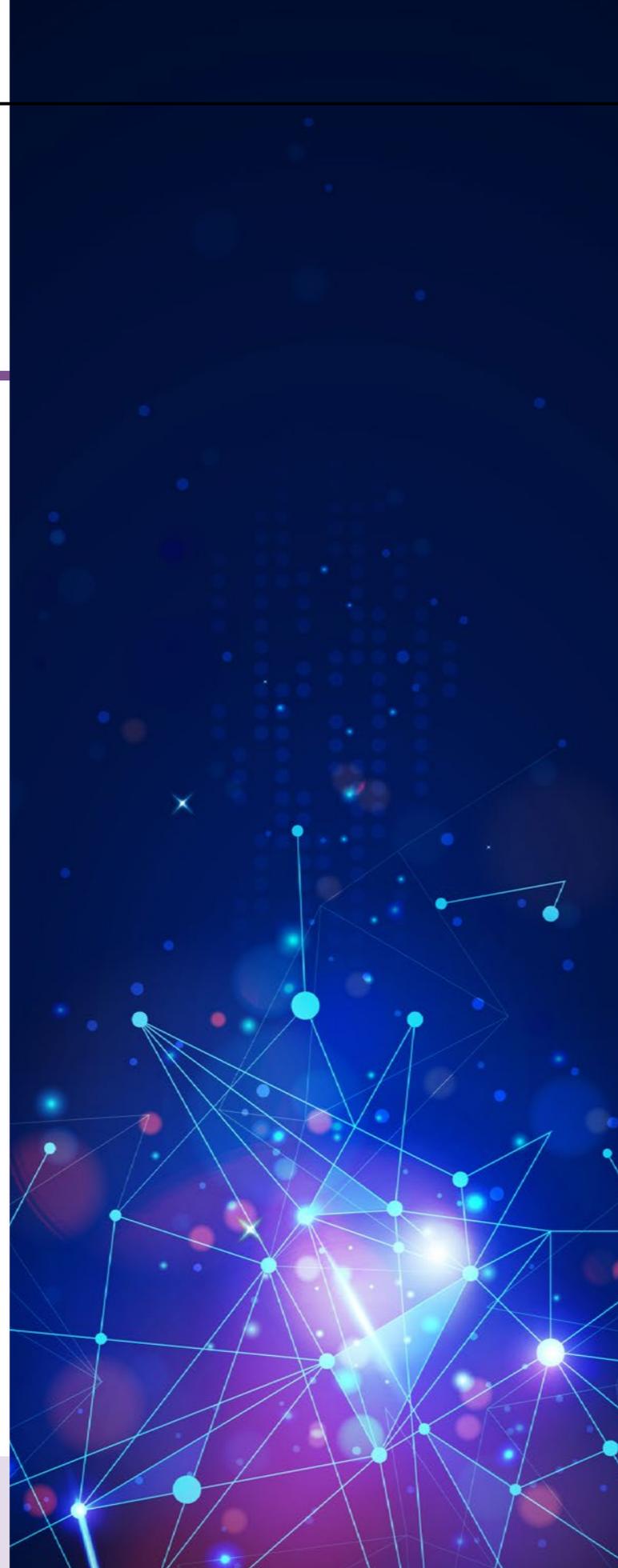**NATIONAL TSING HUA UNIVERSITY**
R&D REPORT

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

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

NTHU provides a stimulating and nurturing environment within which our faculty can offer quality teaching and conduct innovative research. Regarded as one of the toptier research universities, our research activities emphasize fundamental discoveries at the forefronts of basic sciences and exploration of breakthrough technologies with a high potential for applications. These are reflected in our publications in the world's preeminent journals, international patents received, and technology transfered. In the 2018-2019 R&D annual report, we highlight several important breakthroughts in five fields and also provide the facts and figures related to other important R&D activities. This volume is undoubtedly too limited to give the full scope of R&D at NTHU but a glimpse into our recent achievements. Hopefully, this can serve as a catalyst for further interactions, exchange of ideas, and establishment of collaborations.

Built on our proud heritage, NTHU will continue to promote excellent teaching and innovative research with the goal of achieving important scientific discoveries and innovative technologies. I hope that you will find this R&D annual report informative and will give us your precious opinions and suggestions.
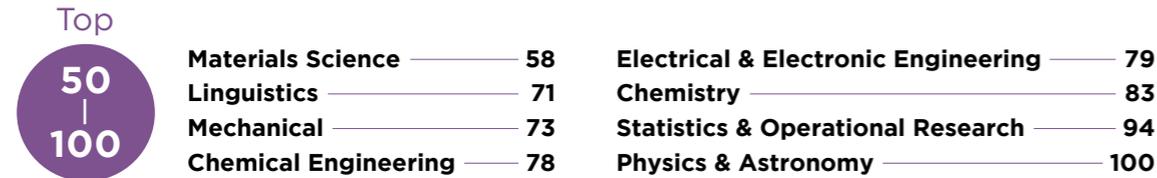
Dr. Hong Hocheng
President

National Tsing Hua University
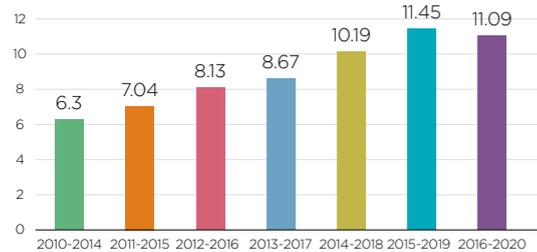*Hsinchu, Taiwan*
November 2020

19'20 NATIONAL TSING HUA UNIVERSITY
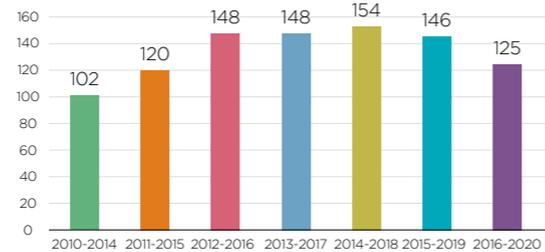**R&D REPORT**

R&D Facts and Figures

2020 QS World University Rankings by Subject

Top **50 | 100**

Materials Science — 58	Electrical & Electronic Engineering — 79
Linguistics — 71	Chemistry — 83
Mechanical — 73	Statistics & Operational Research — 94
Chemical Engineering — 78	Physics & Astronomy — 100

Citations Per Paper

Period	Value
2010-2014	6.3
2011-2015	7.04
2012-2016	8.13
2013-2017	8.67
2014-2018	10.19
2015-2019	11.45
2016-2020	11.09

Highly Cited Paper

Period	Value
2010-2014	102
2011-2015	120
2012-2016	148
2013-2017	148
2014-2018	154
2015-2019	146
2016-2020	125

2019 Highly Cited Researchers:

Professor. Yi-Hsien Lee (Department of Material Science)
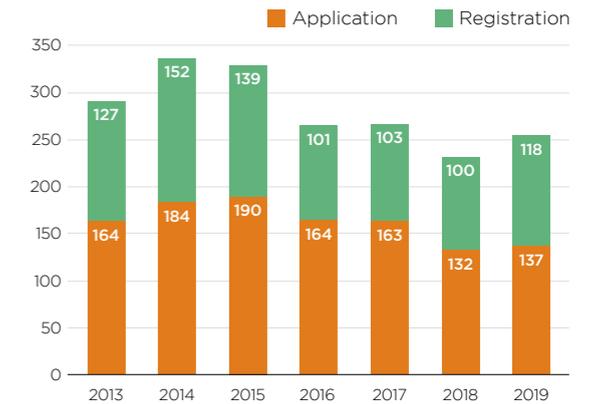**Professor. Horng-Tay Jeng (Department of Physics)**

2019 Ranking of Top Universities in Greater China (ARWU)

Rank	Institution
1	Tsinghua University
2	Peking University
3	The Chinese University of Hong Kong
4	Zhejiang University
5	The University of Hong Kong
6	University of Science and Technology of China
7	Shanghai Jiao Tong University
8	Fudan University
9	**National Tsing Hua University**
10	National Taiwan University

Number of Awarded US Patents

Taiwan Ranking No. 1 **2013-2019**							
2013	2014	2015	2016	2017	2018	2019	
World Ranking							
15	11	15	25	23	24	31	
Taiwan Ranking							
2	*NO.1*						

International Patent Application and Registration (2013-2019)

Legend: Application (orange), Registration (green)

Year	Application	Registration
2013	164	127
2014	184	152
2015	190	139
2016	164	101
2017	163	103
2018	132	100
2019	137	118

Incubation Programme Grow fast, Grow global

Number of Startups in 2020	Accumulative Startups	Survival Rate	Faculties & Students ratio	Number of IPO
46	since 2000 214	75%	49%	8

Programme

Short Term	Mid Term	Long Term
Accelerate-To-Market Programme (ATM)	**Soft-Landing Programme**	**Overseas Market Expansion Programme**

Nature and Life Science

Real-time mass spectrometry combined with urea-urease clock reaction enables observation of protein folding (graphic by G.R.D. Prabhu and C.-M. Chang)

Professor Pawel Urban
urban@mx.nthu.edu.tw

Smart Chemical Analysis: Development of Novel Tools for Detection of Small and Large Molecules

The team led by Assoc. Prof. Pawel Urban carries out research toward development of tools for chemical analysis of small and large molecules. In one branch of our research activities, we focus on detection of volatile organic compounds (VOCs) in a variety of matrices. This kind of chemical analysis is relevant to environmental science, food science, and biomedicine. For example, some VOCs are flavor components in foodstuffs. They can be analyzed using instruments such as chromatographs, mass spectrometers, and ion-mobility spectrometers. However, before analyses of complex samples can be accomplished, the samples need to be first prepared in a proper way. The analyzed VOCs need to be isolated from liquid and solid matrices, and transferred to the gas phase. In fact, sample preparation is one of the most laborious and time-consuming steps in chemical analysis. Therefore, we aim to develop efficient and automated sample preparation tools to expedite analysis of VOCs.

Some of the developed methods take advantage of effervescence phenomenon. For example, in the so-called 'fizzy extraction', a gas is dissolved in the sample, and the sample chamber is abruptly decompressed. The sudden decompression leads to the release of VOCs from the liquid sample, which are immediately transferred to chromatograph or mass spectrometer. Alternatively, an effervescent tablet is introduced to the liquid sample. An acid-base reaction leads to formation of gas bubbles, which extract VOCs.

In the second branch of our research, we develop methods for interrogation of protein structural changes. In fact, protein molecule structure is critical to protein function in biological systems. Thus, there are efforts to understand the conditions in which protein molecules undergo changes. The methods developed in our lab rely on fluorescence spectroscopy and mass spectrometry. In the former case, protein molecules are interrogated with light

beam, and the emitted light is measured to get an insight into momentary structure. In the latter case, protein molecules are brought to the gas phase and ionized. The ions are separated according to their mass-to-charge ratios, which provide information on the folding status of the analyzed proteins.

In the third branch of our research, we develop miniature probes and sensing devices for analysis compounds adsorbed on surfaces. These may include skin excretion components or residues left on the surfaces of furniture. For example, we have developed methods for sampling and profiling skin metabolites. Such skin excretions are first sampled into hydrogel micropatches, and such specimens are analyzed by sensitive mass spectrometric methods. The obtained information can be used to track a disease and recovery process. Alternatively, the analytes sampled into hydrogel are subjected to an in-gel reaction, which is then followed by optical detection.

Finally, in most our projects, we take advantage of prototyping technology such as 3D-printing and universal electronic modules. We are not just users of the existing instrumentation. We also devise our own analytical instruments to address challenging tasks. Thus, our students obtain interdisciplinary training, not only in analytical chemistry but also in ancillary areas, what we refer to as 'analytical science'.

Research Output

- Prabhu G.R.D., Yang T.-H., Hsu C.-Y., Shih C.-P., Chang C.-M., Liao P.-H., Ni H.-T., Urban P.L.* 2020, Facilitating chemical and biochemical experiments with electronic microcontrollers and single-board computers. Nature Protocols 15:925-990.
- Liao P.-H., Yang H.-H., Wu P.-C., Abu Bakar N.H., Urban P.L.* 2020, On-line coupling of simultaneous distillation-extraction using the Likens-Nickerson apparatus with gas chromatography. Analytical Chemistry 92:1228-1235.
- Chang C.-M., Prabhu G.R.D., Tseng C.-M., Urban P.L.* 2019, Temporal analysis of conformers in the course of pH scan directed by urea-urease reaction – a "protein clock". Analytical Chemistry 91:8814-8819.
- Yang H.-C., Urban P.L.* 2019, On-line coupling of fizzy extraction with gas chromatography. Analytical and Bioanalytical Chemistry 411:2511-2520. (selected as a "Paper in Forefront")
- Urban P.* 2019, 3D-printed lab parts can contaminate experiments. Nature 566:326. (correspondence)

Assoc. Prof. Pawel Urban (middle, seventh from the left) and his team

Using Statistical Models to Tackle a Longstanding Issue in Forest Ecology

Professor Anne Chao
chao@stat.nthu.edu.tw

ECOLOGY LETTERS

WILEY · cnrs

The methodology article appears as the cover article in the 2019 November issue of Ecology Letters.

(from left) Dr. Simon Thorn and professor Anne Chao

Forests all around the world are increasingly affected by natural disturbances, such as wildfires, windstorms, or outbreaks of insect pests. Subsequent salvage logging, a widespread management practice conducted predominantly to recover economic capital, produces further disturbance and impacts biodiversity at a global scale. Salvage logging can have particularly negative effects on specialized species which inhabit the disturbed forest. A longstanding issue in forest ecology is how to estimate retention benchmarks for the proportion of naturally disturbed forests that should to excluded from salvage logging so as to conserve biodiversity.

Our approach utilizes a proportional mixture of two within-habitat rarefaction/extrapolation curves to analytically predict biodiversity changes in landscapes when a specified proportion of its original habitat is transformed. The two within-habitat rarefaction/extrapolation curves depict, respectively, the estimated species accumulation relationships for unlogged disturbed plots and salvaged logged plots. When a proportion of an unlogged disturbed area is salvage logged, the between-habitat compositional difference can be incorporated into the proportional mixture model to predict the resulting diversity change due to salvage logging.
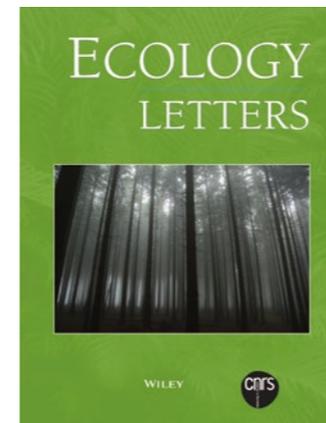
The methodology we developed enables us to estimate logging benchmarks, i.e., the proportion of naturally disturbed forests that must be retained from salvage logging to maintain a specified percentage of its unique species. For example, based on our

analysis, we recommend retaining three quarters of a given disturbed forest to maintain 90% of its specialized species. By contrast, salvage logging of half of a disturbed forest deceases species diversity by one quarter. We also developed the software "miNEXT" (mixed iNterpolation/EXTrapolation) to facilitate all computations and graphics.

The research was started in 2018 when Dr. Simon Thorn (Field Station Fabrikschleichach, Biocenter, University of Würzburg, Germany), supported by the Humboldt-Foundation and the MOST Research fellowship, visited Taiwan to work with Anne Chao for three and a half months on methodology issues. In 2019, Anne Chao visited Field Station Fabrikschleichach, and the Bavarian forest to examine Dr. Thorn's experimental sites and sampling designs. Then forest ecologists around the world contributed their datasets to this project; a total of 201 datasets from various species groups were selected and used to estimate retention benchmarks based on our methodology. This project was truly a collaborative effort, with scholars from wide ranging disciplines bringing unique and complementary capabilities to address the research question. Collaboration among ecologists and statisticians is essential to tackling complex and challenging issues in ecology.

During the early stages of this research, it was determined that most available statistical methods are not sufficient to resolve the retention benchmark issue, since natural disturbances occur unplanned and complicate standardized scientific designs. In order to forecast the biodiversity change when a disturbed forest is progressively salvage logged, generalization of traditional diversity analyses from one habitat-type to a mixture of two habitats (salvage logged and unlogged) is required. That is, a more general theoretical issue was how to forecast biodiversity changes under landscape transformation from one habit-type to another.

In this research, we developed a proportional mixture of two rarefaction/extrapolation curves derived from within-habitat biodiversity sample data from two distinct habitat types. This blended curve can then be used to analytically predict the composite biodiversity of a landscape comprising different proportions of original and transformed habitats. We also derive analytic formulas to forecast compositional change, i.e. to track the number of shared species and unique species in a mixed landscape. Based on the species unique to the original habitat, retention benchmarks can be obtained to maintain a given percentage of species unique to the original habitat. Furthermore, we propose a bootstrap method for assessing the sampling uncertainty of our estimators/formulas.

After we developed the methodology, Dr. Thorn started to compile relevant datasets from all across the world, ranging among the pine forests in the Rocky Mountains, spruce forests in Central Europe, and mountain ash forests in southern Australia. These data also cover different species groups, including birds, insects, plants, and fungi. An international team of 30 coauthors and a total of 201 datasets were involved. Our research provides an example that multi-national and cross-disciplinary research can lead to practically useful methodologies and also theoretically sound resolutions to some ecological and environmental issues.

Research Highlights

- The methodology article appears as the cover article in the 2019 November issue of Ecology Letters.
- One of the application paper (appearing in Nature Communications) was covered in 10 news outlets.
- Relevant statistical and ecology papers have been cited > 26900 times in Google Scholar, and > 14400 times in SCIE (Web of Science) accessed on Oct. 8, 2020. Six papers are listed as highly cited in Web of Science.
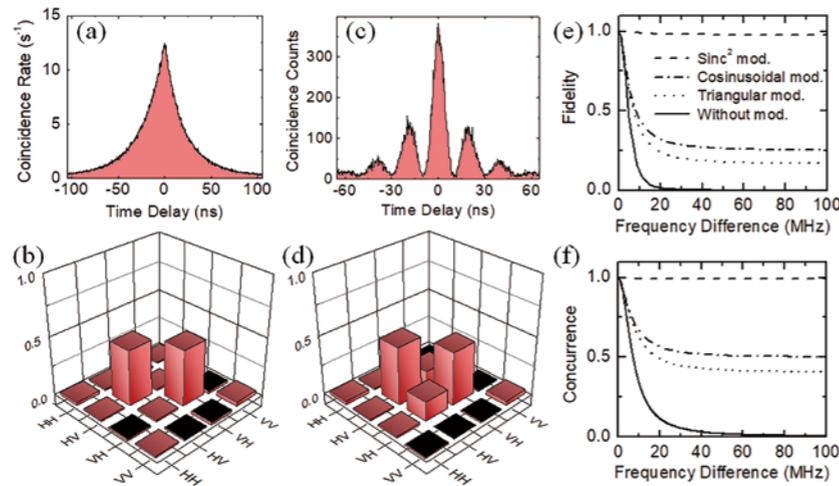
Research Output

- Chao, A., Colwell, R. K., Gotelli, N. J. and Thorn, S. (2019) Proportional mixture of two rarefaction/extrapolation curves to forecast biodiversity changes under landscape transformation. *Ecology Letters* 22, 1913-1922.
- Georgiev, K. B., Chao, A., Castro, J., Chen, Y-H, Choi, C-Y, Fontaine, J. B., Hutto, R. L., Lee, E-J., Müller, J., Rost, J., Żmihorski, M. and Thorn, S. (2020) Salvage logging changes the taxonomic, phylogenetic and functional successional trajectories of forest bird communities. *Journal of Applied Ecology*, 57, 1103-1112.
- Thorn, S., Chao, A., Georgiev, K. B., Müller, J., Bässler, C., ..., Leverkus, A. B. (a total of 30 coauthors) (2020) Estimating retention benchmarks for salvage logging to protect biodiversity. *Nature Communications* https://www.nature.com/articles/s41467-020-18612-4

19'20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Professor Chih-Sung Chuu
cschuu@phys.nthu.edu.tw

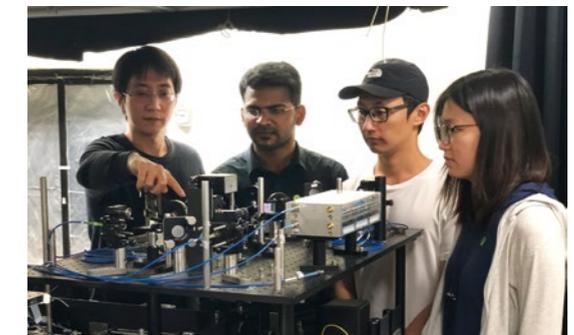# Revival of Quantum Interference and Entanglement

(a) Temporal wavepacket and (b) measured density matrix of the unmodulated two-photon wavepacket. (c) Temporal wavepacket and (d) measured density matrix of the modulated two-photon wavepacket. The reappearance of the coherence terms indicates the revival of the polarization entanglement. Our calculation shows that the (e) fidelity and (f) concurrence of the entangled state can be fully recovered to perfect level.

Quantum optics and quantum information science are enriched by the possibility to manipulate the wavepackets of single photons or biphotons. In our recent work, we demonstrate another fascinating use of wavepacket manipulation: by modulating the biphotons' wavepacket, we restore the quantum interference and post-selected entanglement that would otherwise be destroyed by the photons' distinguishability. Quantum interference and entanglement, apart from the fundamental interest, are at the heart of photonic quantum technologies with examples ranging from quantum communication and quantum computation to quantum random number generation. To generate entanglement, two-photon interference has

been the workhorse in many quantum optics experiments and applications. By sending non-polarization-entangled biphotons onto a beam splitter, one may entangle the photons exiting through different ports in the polarization degree of freedom. However, if the frequencies of the biphotons are dissimilar, the interference visibility diminishes; the entanglement then declines or even disappears. In our experiment, biphotons are first generated by doubly resonant parametric down-conversion in a monolithic KTP crystal, with a temporally long wavepacket allowing the arbitrary shaping of the waveforms. The orthogonally polarized photon pairs are then entangled in the polarization degree of freedom by selecting pairs exiting through different ports of the beamsplitter. The frequency difference of the biphotons, which can be tuned via the phase-matching condition by adjusting the pump frequency and crystal temperature, determines the distinguishability in two-photon interference as well as the degree of entanglement. To precisely control the frequency difference, time-resolved two-photon interference is carried out to measure the beat frequency. When

the biphotons are degenerate, the beat vanishes and the indistinguishability in the two-photon interference through the beamsplitter results in a polarization-entangled state. To characterize the entanglement, we exploit the concurrence as the measure. When the frequency difference increases, the concurrence and the degree of entanglement declines rapidly. Similar decline of entanglement can also be observed in the violation of the Clauser-Horne-Shimony-Holt inequality, which requires quantum entanglement to explain the correlations or nonlocality. To demonstrate that the lost entanglement or nonlocality can be restored by shaping the biphotons, we modulate each photon of the pair synchronously with electro-optic modulator at half of the frequency difference of the pair so that the biphoton wavepacket is modulated by the convolution of these modulation functions at the frequency of pair's frequency difference. By tomographically reconstructing the density matrix, we observe the increase in both the concurrence and purity of the quantum state, thus manifesting the revival of entanglement. The revival of quantum interference, entanglement, or nonlocality by shaping the photons' wavepacket can be understood in the following ways. From the time-domain point of view, the modulation at the frequency of biphoton's frequency difference ensures a constant phase between the two-photon states in two-photon interference. From the frequency-domain point of view, the modulation at the frequency of biphoton's frequency difference generates signal (or idler) photons at the carrier frequency or sidebands of the idler (or signal) photons. In both viewpoints, the indistinguishability in two-photon interference increases as a consequence of modulation, thus improving the quality of entanglement and the ability to observe nonlocality. While biphotons are used in our work, the modulation may also be applied to restore the two-photon interference and entanglement

between independent nondegenerate photons. The distinction between restoring the quantum interference or entanglement of single photons and biphotons is that the former necessitates well-defined time origin for the modulation while the latter does not.

(from left) Professor C.-S. Chuu, Dr. R. Chinnarasu, Dr. C.-H. Wu, Y.-M. Su.
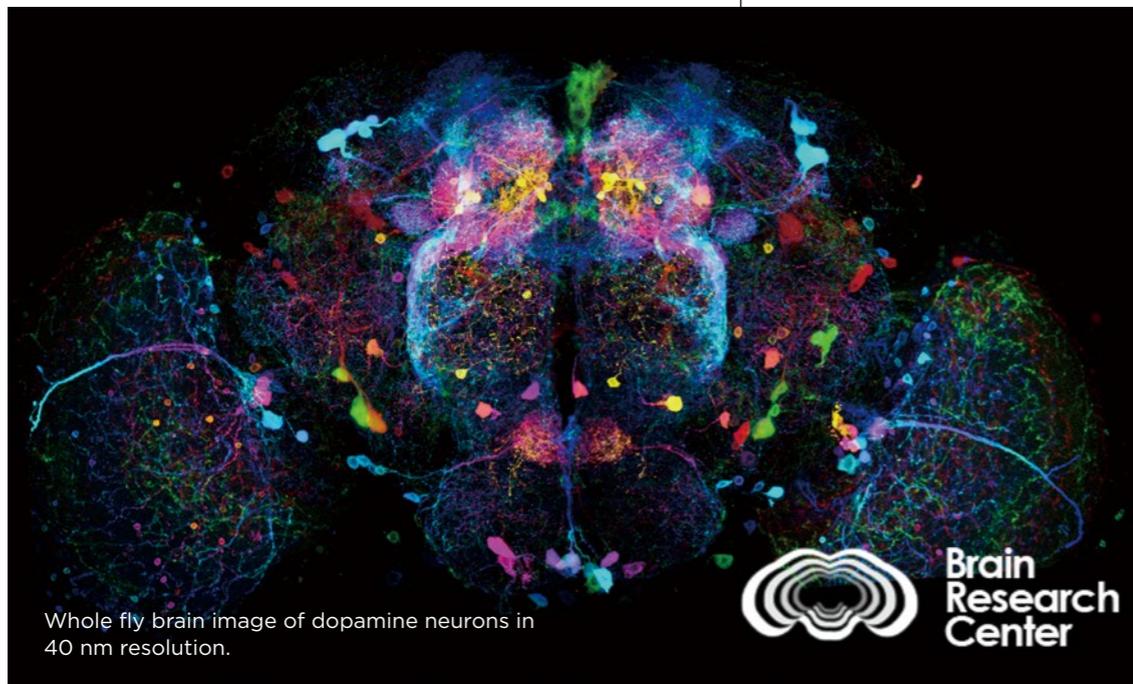
Research Highlights
• 科技部十大科學研究之破壞性創新論文

Research Output
• C.-H. Wu, C.-K. Liu, Y.-C. Chen, and C.-S. Chuu, "Revival of Quantum Interference by Modulating the Biphotons," Phys. Rev. Lett. 123, 143601 (2019).
• S.-W. Feng, C.-Y. Cheng, C.-Y. Wei, J.-H. Yang, Y.-R. Chen, Y.-W. Chuang, Y.-H. Fan, and C.-S. Chuu, "Purification of single photons from room-temperature quantum dots," Phys. Rev. Lett. 119, 143601 (2017).
• C.-H. Wu, T.-Y. Wu, Y.-C. Yeh, P.-H. Liu, C.-H. Chang, C.-K. Liu, T. Cheng, and C.-S. Chuu, "Bright single photons for light-matter interaction," Phys. Rev. A 96, 023811 (2017).

19 '20 NATIONAL TSING HUA UNIVERSITY R&D REPORT

Professor Ann-Shyn Chiang
aschiang@life.nthu.edu.tw

Whole fly brain image of dopamine neurons in 40 nm resolution.

Imaging the Whole Fly Brain at Nanoscale Resolution

Visualizing memory is the holy grail in the field of neuroscience. In 2012, we first identified two neurons storing long-term memory in the Drosophila brain (Science, doi: 10.1126/science.1212735). To resolve how neural activity allocates new proteins to specific synaptic ensembles requires single-molecule localization in the whole brain. Though modern electron microscopy can achieve nanoscale resolution, visualizing multiple labeled proteins produced during memory consolidation in a large volume is unpractical. On the other hand, recent advances in super-resolution microscopy have allowed single-molecule localization within individual

(from left) Professor Ann-Shyn Chiang (NTHU), Professor Li-An Chu (NTHU), Dr. Wei-Kun Chang (NTHU), Professor Bi-Chang Chen (Academia Sinica), Professor Shi-Wei Chu (NTU)

> *Using spontaneous blinking fluorophores to label proteins of interest, we resolved the morphology of most, if not all, dopaminergic neurons in the whole adult brain of Drosophila melanogaster at the nanoscale resolution and high imaging speed.*

cells, but not within large tissues. Last year, we have established three independent methods for super-resolution imaging of the whole Drosophila brain, providing 30 nm resolution for all the targeted neurons and proteins (See publication list). We believe that visualizing single proteins with cutting-edge super-resolution imaging system will not only have a great impact for our understanding memory formation, but also for many other biomedical research in general.

Research Highlights

- Higher Education Sprout Grant funded by the Ministry of Science and Technology and Ministry of Education in Taiwan (Ann-Shyn Chiang)
- MOST brain technology grant (Shi-Wei Chu)
- The 18th Y. Z. Hsu scientific paper award (Bi-Chang Chen)
- MOST best research paper award for postdoctoral fellows (Li-An Chu)
- MOST Einstein grant (Li-An Chu)

Research Output

- Li-An Chu#, Chieh-Han Lu#, Shun-Min Yang, Yen-Ting Liu, Kuan-Lin Feng, Yun-Chi Tsai, Wei-Kun Chang, Peilin Chen, Ting-Kuo Lee, Yeu-Kuang Hwu, Ann-Shyn Chiang*, Bi-Chang Chen*, "Rapid single-wavelength lightsheet localization microscopy for clarified tissue", Nature Communications, Oct 18, 2019, 10:4762 (Impact factor: 12)
- Han-Yuan Lin#, Li-An Chu#, Hsuan Yang, Kuo-Jen Hsu, Yen-Yin Lin, Keng-Hui Lin*, Shi-Wei Chu*, and Ann-Shyn Chiang*, "Imaging through the whole brain of Drosophila at $\lambda/20$ super-resolution", iScience, 26, April 26, 2019, 14:164-170 (Impact factor: 4.447)
- Patent, TW I702420 B. Axicon-based Bessel Beam for Cone-shell Illumination in Epi-fluorescence Single-molecule Localization Microscopy for Tissues.
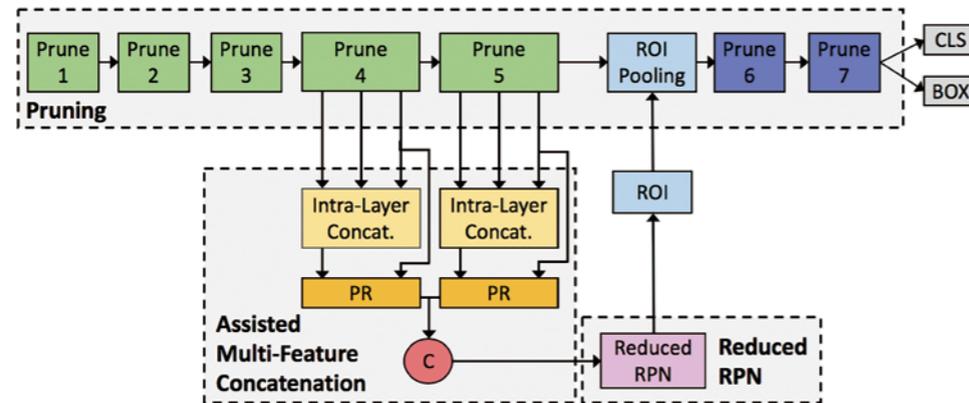
Engineering

- *Real-Time Object Detection With Reduced Region Proposal Network via Multi-Feature Concatenation*

- *Intrusion Detection in Distributed Frequency Control of Isolated Microgrids*

- *Empower Taiwan Industrial Migration and Digital Transformation via Industry 3.5*

- *Junctionless Poly-GeSn Ferroelectric Thin-Film Transistors with Improved Reliability by Interface Engineering for Neuromorphic Computing*

Professor Ching-Te, Chiu
chiusms@cs.nthu.edu.tw

Real-Time Object Detection With Reduced Region Proposal Network via Multi-Feature Concatenation

Overall architecture, which includes pruning, reduced RPN, and assisted multi-feature concatenation. ML: Max-Pooling. *SL_i*: sub-layer i, where i=1,2,3.

This research is based on Faster R-CNN, the most widely used two-stage architecture. The goal is to improve the running speed to achieve real-time object detection without affecting accuracy. We first use the pruning method while reducing the number of parameters and calculations. It can be expected that pruning will cause a decrease in accuracy. Therefore, we propose a Multi-Feature Assisted Region Proposal Network to improve the accuracy, which includes the Assisted Multi-Feature Concatenation Module combining the features of different convolutional layers, and then combined feature is used as the input of the Reduced Region Proposal Network. The proposed architecture can more accurately find the candidate regions and compensate for the accuracy of the loss due to pruning.

In the channel pruning part, we reduce the number of output channels of the convolutional layer and the fully connected layer to compress the parameter amount. The multi-feature connection auxiliary area candidate network is mainly composed of three parts, namely Concatenation part, Intra-Layer Concatenation part and Proposal Refinement part. First of all, the reason why we use concatenation instead of summation is mainly because we want to ensure the independence of each feature map. On the other hand, concatenation also has better flexibility, so we use concatenation to summarize data. In Intra-Layer Concatenation, we first read out the feature maps in the fourth and fifth convolutional layers and perform concatenation, but if the feature maps are directly concatenation, it will cause

computational problems due to too many output channels, and then the speed is affected, so we use a convolutional layer with a kernel size of 1, adjust the number of channels to 16, and then summarize the data. The last part is Proposal Refinement. The design of this part is because we want to improve on the subsequent Reduced RPN, so we use two convolutional layers to further process the feature map, and concatenation with the previous convolutional layer output. Later, we convert the feature map into ROI related data.

RPN is the most important part of Faster R-CNN. The design of RPN allows us to make full use of the power of deep learning to find ROIs (Region of Interest), so we can solve ROI tasks and detection tasks in the same network. Looking further at the RPN architecture, we can find that its architecture is actually very simple, but it has a very large impact on accuracy. In other words, if we improve RPN, it is equivalent to improving accuracy. As mentioned in the previous paragraph, when we are pruning, the reduction of accuracy is inevitable. Therefore, we designed a reduced area candidate network to improve the accuracy of RPN and reduce its size as much as possible. In Reduced In RPN, we use two convolutional layers to operate. In the first layer, we first use a convolutional layer with a kernel size of 1 to adjust the input channel dimension. The purpose is to compress the parameters in the RPN. In the second layer, we use dilated convolution to expand our receptive field. The outputs from the last convolution in the fourth and fifth convolutional blocks are taken as the first layer of dilated convolution respectively, and then the information is connected to the second layer of dilated convolution in Reduced RPN. It can expand its receptive field to the same effect as three convolutional layers, and it does not increase the number of parameters and can improve the accuracy of the ROI.

Professor C.T. Chiu

19 '20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Proposed control diagrams for individual distributed interface converters.

Intrusion Detection in Distributed Frequency Control of Isolated Microgrids

Professor Chia-Chi Chu
ccchu@ee.nthu.edu.tw

The main contributions of this work are two-fold. First, the full MG network dynamics, including power flow dynamics and droop controlled distributed interface converters (DICs), are considered. The problem of minimizing the frequency error and ensuring a proportional power sharing operation simultaneously is formulated as a consensus optimization problem. Assuming connected communication graph among DICs, we adopt the partial primal-dual (PPD) algorithm to solve the steady-state problem in closed-form. Interestingly, parts of the proposed update rules boil down to network power flow dynamics and thus are seamlessly implemented by the physical system itself. Hence, the proposed control design

only requires the exchange of a few variables, while its stability follows directly from the PPD algorithm. Distinct from most of the previous work, the proposed control design can guarantee the MG stability through the selection of optimization step-size. Secondly, the PPD-based design with localized dual variable information can be further utilized to improve the capability to attack detection. Earlier attack detection work for general distributed consensus methods typically requires system-wide information collection and accordingly has a very high computational burden. To overcome these limitations, we have developed the metrics for detection and identification by using local physical measurements and neighboring dual variable

information. The centralized energy management system (EMS) collects all this information to decide the attack scenarios, as motivated by standards on cyber networks for integrating DER into power systems, and also by practical work studying cybersecurity framework in supervisory control and data acquisition systems (SCADA) of modern power systems. Different layers of protection schemes for managing cyber/physical security have been considered to evaluate intrusion probability for preventing possible cyber attacks. Accordingly, the proposed implementation is very scalable. Compared with previous work where the cyber-security of the MG has not been addressed, we have provided analytical understanding and mitigation strategies for cyber intrusions.

> *Model-based anomaly detection and localization strategies are developed by exploring the dual variable-related metrics.*

Group Photo of Professor Chia-Chi Chu (Central).

19'20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Empower Taiwan Industrial Migration and Digital Transformation via Industry 3.5

Chair Professor Chien, Chen-Fu
cfchien@mx.nthu.edu.tw

Nature (vol. 577, 15 January 2020, https://www.nature.com/articles/d41586-020-00060-1): "Taiwan's time to transform", From plastic toys to Industry 4.0: How Taiwan is using science to upgrade its manufacturing via joint efforts empowered by the AI grand projects of Ministry of Science and Technology, Taiwan.

Nature, Vol. 577, 2020.
https://www.nature.com/articles/d41586-020-00060-1

Leading nations have reemphasized smart manufacturing and agile supply chains to compete for the dominant positions in restructuring global supply chains after COVID-19. However, the industry structure of most emerging countries including Taiwan may not be ready for direct migration of Industry 4.0, or for facing other challenges.

As the Director of Artificial Intelligence for Intelligent Manufacturing Systems (AIMS) Research Center that is one of four AI centers sponsored by Ministry of Science & Technology, Taiwan, I have led my Decision Analysis Laboratory (DALab) associates and affiliated teams to empower smart manufacturing and digital transformation for Taiwan industries using big data analytics, artificial intelligence, optimization, and digital decision.

Industry 3.5 is a hybrid strategy via disruptive technologies to address fundamental objectives for smart manufacturing to empower humanity, create high-value jobs, and maintain economic growth in the ongoing industrial revolution. We developed effective solutions based on AI, big data analytics, cloud computing, Internet of Things (IoT), optimization and digital decision that are validated through in-depth industrial collaborations with leading companies in different industries. We have derived critical insights from cross-validation of developed solutions in various industrial settings and have thus constructed solid fundamentals for advanced research.

We developed the UNISON Decision Framework and PDCCCR that enable coordination of manufacturing strategic decisions including pricing, demand planning, capacity configuration, capital expenditure, and cost structuring to optimize revenue and profitability for smart production. Also, we have developed big data analytics solutions to extract effective manufacturing intelligence for yield management in the most complex semiconductor manufacturing processes. For example, since high-tech manufacturing system is increasing complicated, we developed solutions to derive specific improvement direction and decision rules for the most suitable intervals of the parameters to effectively reduce the production cycle time. Furthermore, as wafer fabrication is reaching nano-technology nodes, linewidth is increasingly complicated for semiconductor manufacturing. The teams have developed a novel approach integrating a feed-forward Run-to-Run controller and the proposed mini-max regret tool dispatching rule to determine tool affinity to hedge the variation between the photolithography for pattern development and the etching process to effectively reduce the etching bias caused by tool misalignment.

We promote corporate digital transformation to lead small-medium business to proactively participate in the ongoing industrial revolution. To realize this vision of Dr. Fab to support SME, we also span off a startup, DALabx (DALab Solutions x Associates Co., Ltd.), in NTHU Incubation Center that was also selected by MOST as a paradigm for germination based on MOST sponsored projects. With the innovative solutions AIMS has developed, Taiwan shall be able to play a leadership role in the new manufacturing paradigm of Industry 3.5 and share our experiences with other emergent countries (such as ASEAN countries) facing similar issues.

(from left) Minister Liang-Gee Chen, Professor Chen-Fu Chien

Research Highlights

- 《Industry 3.5》has been selected as one of most influential scientific publication by MOST in 2020, while it is also one of bestselling books in 2019.
- Nature (Vol. 577, 2020) interview as a paradigm for Taiwan industrial transformation; APO Chairman Dr. Ha Minh Hiep also invited me for APO Top Talk (https://youtu.be/won5saQsSQQ), showing international influence of Industry 3.5 strategy.
- Establish Zhen Ding-Tsing Hua Joint Research Center to support smart manufacturing for PCB industries.
- Developed solution "AI & Big Data Analytics for Energy Saving and Chiller Configuration Optimization," receives the 2020 National Innovation Award.
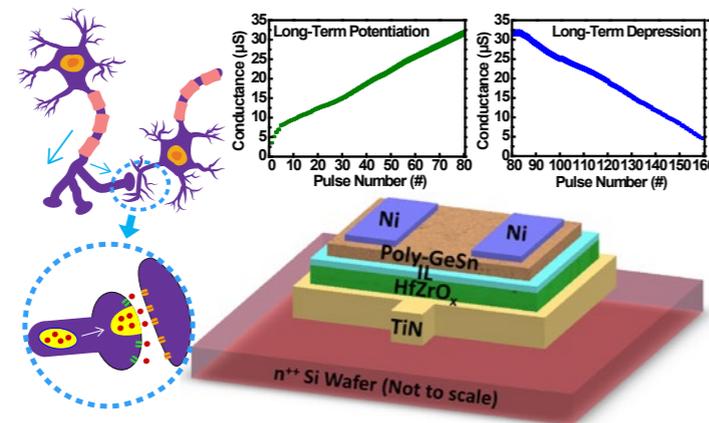
Research Output

- Chien, Chen-Fu, Lin, Y.-S., and Lin, S.-K. (2020), "Deep reinforcement learning for selecting demand forecast models to empower Industry 3.5 and an empirical study for a semiconductor component distributor," International Journal of Production Research, 58(9), 1 -21. (SCI) (2018 Impact Factor: 3.199)
- Chien, Chen-Fu, Kuo, C.-J., and Yu, C. (2020). "Tool allocation to smooth work-in-process for cycle time reduction and an empirical study," Annals of Operations Research, 290, 1009–1033. (SCI) (2019 Impact Factor: 2.583)
- Khakifirooz, M., Chien, Chen-Fu, and Chen, Y.-J. (2020), "Dynamic Support Vector Regression Control System for Overlay Error Compensation With Stochastic Metrology Delay," IEEE Transactions on Automation Science and Engineering, 17(1), 502-512. (SCI) (2018 Impact Factor: 5.224)
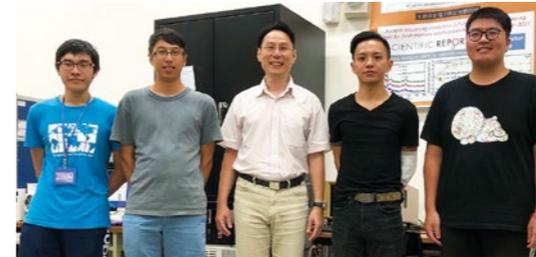
Professor Yung-Hsien Wu
yunhwu@mx.nthu.edu.tw

Junctionless Poly-GeSn Ferroelectric Thin-Film Transistors with Improved Reliability by Interface Engineering for Neuromorphic Computing

Junctionless poly-GeSn ferroelectric thin-film transistors that implement the behaviors of synaptic devices by showing long-term potentiation and depression

Brain-inspired neuromorphic computing system is one of the essential elements to fuel artificial intelligence (AI) technology. Such system requires massively parallel processing, high connectivity, large bandwidth and fast links for energy efficient communication among neuron layers. Vertically integrated monolithic 3D IC which sequentially builds and stacks two or more layers of CMOS devices without using through silicon via (TSV) provides an excellent approach to meet the requirements since the device density can be continuously increased while reducing power consumption and enhancing operating frequency due to the rich vertical connectivity between the strata that shortens the interconnect length. The major challenge for monolithic 3D IC lies in achieving good performance of the top-layer devices within the thermal budget. Thin film transistors (TFTs) with process temperature within the thermal budget is a viable technology to realize monolithic 3D

IC. Among the possible TFTs technologies, oxide semiconductor such as IGZO and IZO have been widely investigated. Nevertheless, IGZO and IZO are n-type semiconductors which is not capable to implement p-channel devices, making it difficult to achieve low-power circuits since CMOS devices are not available. On the other hand, due to the potential to be processed at low temperature, the capability to form both n-channel/p-channel devices and the process compatibility with incumbent VLSI technology, polycrystalline IV-group semiconductor received much attention as the monolithic 3D IC technology. Poly-Ge TFTs recently have aroused significant interest due to its superior mobility and lower process temperature as compared to poly-Si. Recently, junctionless (JL) poly-GeSn p-channel TFTs, the successor of poly-Ge TFTs, manifest

(from left) Mr. H. K. Peng, Mr. T. H. Kao, Professor Y. H. Wu, Mr. C. P. Chou, and Mr. G. T. Lai

desirable I_{ON}/I_{OFF} ratio and mobility with low thermal budget. In addition, n-channel GeSn devices have also been demonstrated, making poly-GeSn TFTs a promising technology for monolithic 3D IC. It is essential to extend the capability of the TFTs technology for neuromorphic computing based on deep neural network (DNN) to empower AI chips. Employing HfZrO$_x$ (HZO)-based ferroelectric FETs (Fe-FETs) as synaptic devices for neuromorphic computing have been extensively explored and demonstrate the great eligibility for AI chips.

Based on the background, it is a prerequisite to develop HZO-based Fe-TFTs on poly-GeSn film for high-performance AI chips. In this work, besides the optimal process development for HZO-based JL poly-GeSn Fe-TFTs by interface engineering, its application to synapse devices and pattern recognition were also explored. The core values of this work include (1) much improved reliability in terms of robust endurance and good retention can be achieved by 2-stage interface engineering such as NH$_3$ plasma treatment of poly-GeSn and growth of Ta$_2$O$_5$ interfacial layer (IL), (2) larger remnant polarization (Pr) of ferroelectric-HZO on poly-GeSn than that on poly-Ge TFTs is obtained which is beneficial to implement more conductance (G) states, and (3) demonstration of Fe-TFTs as synaptic devices for deep neural network (DNN) with more than 80 analog states, non-volatility up to 10 years, high endurance up to 10^6 cycles, symmetric potentiation/depression, moderate Gmax/Gmin of 9.6 and recognition accuracy of handwritten digits up to

91.4 %. Furthermore, spiking neural network (SNN) with the learning algorithm of spike-timing-dependent plasticity (STDP) is also realized.

Research Highlights

- IET Fellow
- 2016 Lifetime Achievement Award（國際傑出發明家發明終身成就獎）by Taiwan International Invention Award Winners Association
- 2019 "Outstanding Young Scholar Research Grant"（優秀年輕學者計畫）by the Ministry of Science and Technology, Taiwan.

Research Output

- Chuan-Pu Chou, Yan-Xiao Lin, Yu-Kai Huang, Chih-Yu Chan, and Yung-Hsien Wu*, "Junctionless Poly-GeSn Ferroelectric Thin-Film Transistors with Improved Reliability by Interface Engineering for Neuromorphic Computing," ACS Appl. Mater. Interfaces, vol. 12, no. 1, pp. 1014-1023, 2020.
- Chi-Yu Chan, Kuen-Yi Chen, Hao-Kai Peng and Yung-Hsien Wu*, "FeFET Memory Featuring Large Memory Window and Robust Endurance of Long-Pulse Cycling by Interface Engineering Using High-k AlON," in Symp. VLSI Tech., 2020.
- Kuen-Yi Chen, Yen-Hua Huang, Ruei-Wen Kao, Yan-Xiao Lin, and Yung-Hsien Wu*, "Dependence of Reliability of Ferroelectric HfZrOx on Epitaxial SiGe Film with Various Ge Content," in Symp. VLSI Tech., pp. 119-120, Honolulu, USA, 2018.
- Kuen-Yi Chen, Pin-Hsuan Chen, and Yung-Hsien Wu*, "Excellent Reliability of Ferroelectric HfZrOx Free from Wake-Up and Fatigue Effects by NH3 Plasma Treatment," in Symp. VLSI Tech., pp. 84-85, Kyoto, Japan, 2017.
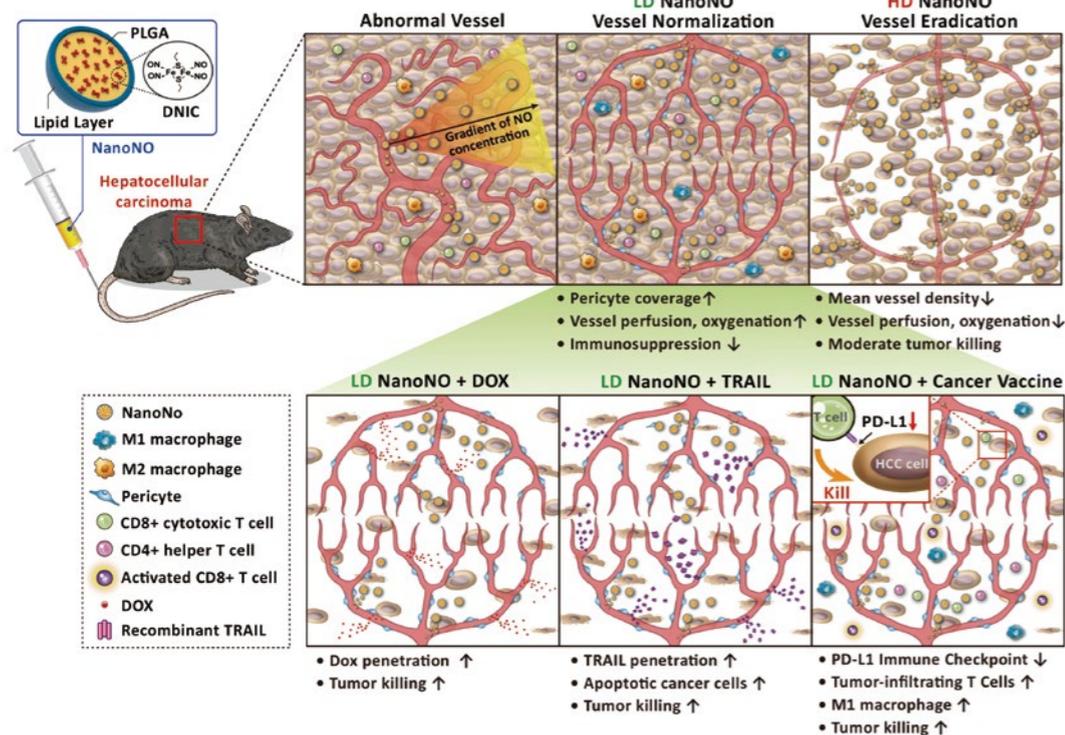
Biomedical Technology

- *Delivery of Nitric Oxide with a Nanocarrier Promotes Tumour Vessel Normalization and Potentiates Anti-Cancer Therapies*

- *Face Mask Use in The General Population and Optimal Resource Allocation During The Covid-19 Pandemic*

- *Dengue and Zika Virus Domain III-Flagellin Fusion and Glycan-Masking E Antigen for Prime-Boost Immunization*

- *Rapid Diagnostic System for Predicting Upcoming Respiratory Failure and Cytokine Release Syndrome in Covid-19 Patients*
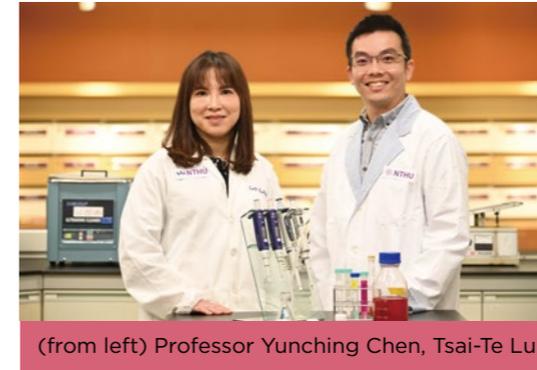
Professor Yunching Chen
yunching@mx.nthu.edu.tw

Professor Tsai-Te Lu
ttlu@mx.nthu.edu.tw

Delivery of Nitric Oxide with a Nanocarrier Promotes Tumour Vessel Normalization and Potentiates Anti-Cancer Therapies

(from left) Professor Yunching Chen, Tsai-Te Lu

A research team led by Professor Yunching Chen and Tsai-Te Lu of the Institute of Biomedical Engineering, National Tsing Hua University have recently developed a new treatment for cancer, in which blood vessels within malignant tumors are normalized by injecting a specially developed nanodelivery system for nitric oxide (NanoNO), which also facilitates the delivery of cancer drugs and immunocytes into the tumor. This research has recently been published in the prestigious journal *Nature Nanotechnology*.

The cancer treatment currently in use, such as chemotherapy and target drugs, mainly work by killing the cancer cells or tumorous blood vessels, but cause abnormalities in the functions and structure of the blood vessels; moreover, if any of the cancer cells survive the treatment, they become recalcitrant, like hardened ruffians, increasing the chances of a relapse or metastasis. Nitric oxide (NO), which is a multifunctional signaling molecule, plays a crucial role in mediating cancer formation and progression. NO synthesized in endothelial cells not only mediates angiogenesis but also maintains vascular homeostasis and endothelial function. Creation of perivascular NO gradients may normalize tumor vessels, resulting in improved response to anti-cancer treatment. Despite the potential of this therapy for cancer treatment, developing a pharmacological NO-based therapy that has clinical utility to treat cancer remains a

major challenge. Because of the short lifetime of nitric oxide, it is mostly used to treat acute symptoms, and is ineffective for chronic diseases like cancer.

The research team developed a polymer-based nanodelivery system consisting of lactic acid and glycolic acid to stabilize the biomimetic dinitrosyl iron complex (DNIC) that releases NO, thereby extending the time in which NO are effectively released from a few minutes to several days, allowing them to accumulate in tumorous tissues, and restoring the abnormal blood vessels to normal. At this point, anti-cancer drugs and immune cells can penetrate into the tumor, destroying the cancer cells in one fell swoop. Immunotherapy has become a leading topic in cancer treatment research in recent years, but getting the immunocytes to the location of the cancer cells has been problematic. The newly developed nitric oxide nanocarriers combined with immunotherapy can eliminate liver tumors in mice.

Research Highlights

- Young Investigator Award, TienTe Lee Biomedical Foundation, Taiwan
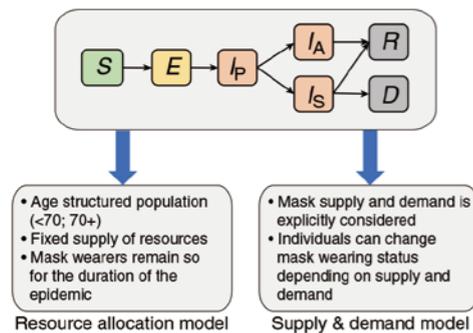- Promising Women in Science Award, Taiwan

Research Output

- Delivery of Nitric Oxide with a Nanocarrier Promotes Tumour Vessel Normalization and Potentiates Anti-Cancer Therapies. Nature Nanotechnology, 14, 1160–1169. (2019)
- Highly Efficient and Tumor-Selective Nanoparticles for Dual-Targeted Immunogene Therapy against Cancer. Science Advances, 6(3), eaax5032. (2020)
- NANOPARTICLE, PREPARATION PROCESS AND USES THEREOF" U.S. Pat. US 10,675,250

NO released from NanoNO creates perivascular NO gradients and facilitates the alteration of the tumour microenvironment. 1) NanoNO at low doses normalizes tumour vessels characterized by the enhanced pericyte coverage of tumour vessels, increased vessel perfusion, and reduced tumour hypoxia. 2) NanoNO at low doses enhances the delivery of small-molecule anti-cancer drugs and macromolecular therapeutics and synergistically suppresses tumour progression in combination with small molecule chemotherapy (DOX) and macromolecular therapeutic agents (recombinant TRAIL protein). 3) NanoNO downregulates the expression of the immune checkpoint protein PD-L1, suppresses polarization of TAMs to immunosuppressive M2-like phenotype and increases T cell tumour infiltration in HCC. 4) NanoNO at low doses synergistically suppresses tumour progression in combination with immunotherapy using cGM-CSF modified whole-cell cancer vaccines. LD: low dose; HD: high dose.

19'20
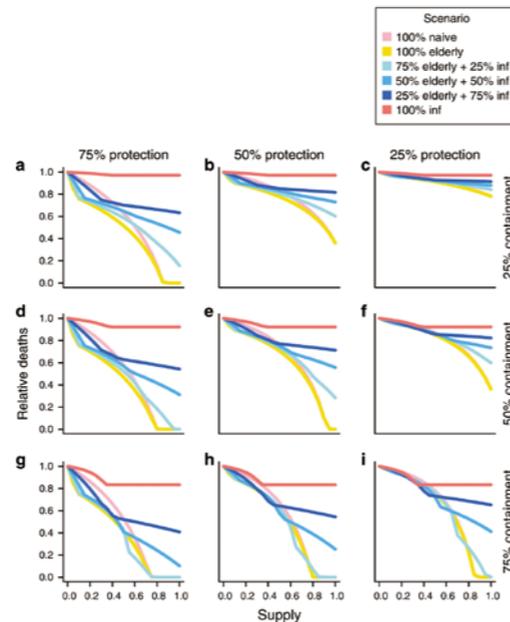NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Professor Hsiao-Han Chang
hhchang@mx.nthu.edu.tw

Face Mask Use in The General Population and Optimal Resource Allocation During The Covid-19 Pandemic

> **Face mask use, particularly for a pathogen with relatively common asymptomatic carriage, is an effective intervention strategy, while optimized distribution is important when resources are limited.**

The structure of the mathematical model.

Reduction in total deaths under each distribution strategy for a range of mask availability levels.

The ongoing novel coronavirus disease (COVID-19) pandemic has already infected millions worldwide and, with no vaccine available, non-therapeutic interventions to mitigate transmission are urgently needed. Dr. Hsiao-Han Chang's group constructed mathematical models that were parameterized by empirical data to study the spread of COVID-19 and investigate and compare the effectiveness of different intervention methods, including mask wearing and travel restrictions. In a recent study published in Nature Communications, Dr. Chang and her collaborator from Broad Institute of MIT and Harvard, Dr. Colin Worby, modelled face mask use in the general population and identified optimal resource allocation during the COVID-19 pandemic. This study is of great interest among epidemiologists, policy makers, and the general public, and was mentioned in National Institute of Health (NIH) of USA director's blog on August 25th (https://directorsblog.nih.gov/2020/08/25/).

While there is broad agreement that travel restrictions and social distancing are beneficial in limiting the spread of SARS-CoV-2, recommendations around face mask use are inconsistent. While mask use is common and widely recommended in East and Southeast Asia, Western countries have been slower to encourage any adoption of masks. Using mathematical modeling, Dr. Chang's group and Dr. Worby examined the impact of face mask use in limiting morbidity and mortality, and explored the optimal distribution of masks when resources are limited. They found that even with a limited protective effect, face masks can reduce total infections and deaths, and can delay the peak time of the epidemic. However, random distribution of masks is generally suboptimal. Prioritized coverage of the elderly improves outcomes, while retaining resources for detected cases provides further mitigation under a range of scenarios. In addition, they modeled public demand in tandem with epidemic dynamics, and found that panic buying can lead to a rapid depletion of resources in the early stages of the outbreak and managing demand and rationing supplies can reduce total infections over the course of the epidemic. They concluded that face mask use, particularly for a pathogen with relatively common asymptomatic carriage, is an effective intervention strategy, while optimized distribution is important when resources are limited.

In the following years, Dr. Chang will keep studying the spread and evolution of pathogens, including malaria parasites, dengue virus, and coronavirus, using both epidemiological and genomic approaches.

(from left) Professor H.H. Chang, Dr. Colin Worby

Research Highlights
- Yushan Young Scholar
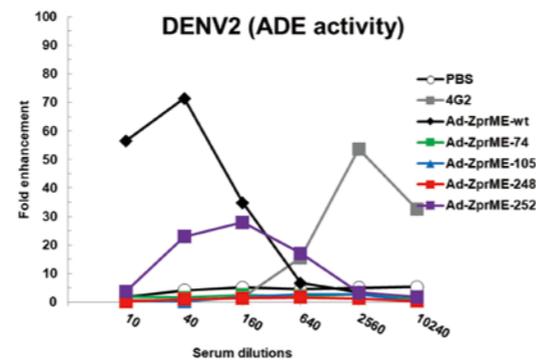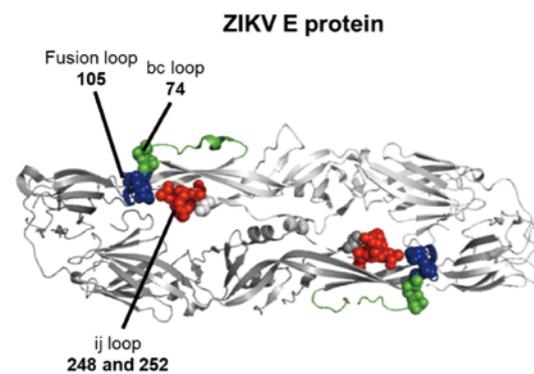- Young Scholar Fellowship (Columbus Program), Ministry of Science and Technology

Research Output
- Worby, C.J., Chang, H. Face mask use in the general population and optimal resource allocation during the COVID-19 pandemic. Nat Commun 11, 4049 (2020). https://doi.org/10.1038/s41467-020-17922-x (This study was mentioned in NIH director's blog: https://directorsblog.nih.gov/2020/08/25/)

19 '20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Professor Suh-Chin Wu
scwu@mx.nthu.edu.tw

Dengue and Zika Virus Domain III-Flagellin Fusion and Glycan-Masking E Antigen for Prime-Boost Immunization

ZIKV E protein

Fusion loop 105 bc loop 74

ij loop 248 and 252

DENV2 (ADE activity)

To abolish the production of cross-reactive ADE-facilitating antibodies by ZIKV prime-boost immunizations, we constructed four glycan-masking Ad-ZprME mutants by introducing additional N-linked glycosylation motifs in the DII region of ZIKV E protein. To investigate whether these glycan-masking mutations can abolish the ADE activity, these antisera were tested in K562 cells against DENV2 virus infections. The results indicated that antisera from the Ad-ZprME and Ad-ZprM-74 immunized groups and the 4G2 mAb group showed a peak of 70-, 30-, and 60-fold enhancements against DENV2 infections in K562 cells. However, antisera from the glycan-masking Ad-ZprME-105 and Ad-ZprME-248 mutations did not induce ADE activity in K562 cells against DENV2 infection.

The viral E proteins of dengue virus (DENV) and Zika virus (ZIKV) are the major viral proteins involved in receptor binding and fusion, and for the induction of protective antibodies against viral infections. E protein is the major viral protein involved in receptor binding and fusion, and is formed as a head-to-tail dimer on the surfaces of viral particles. E protein consists of three distinct domains: a central beta-barrel domain I (DI), an extended finger-like dimerization domain II (DII), and an immunoglobulin-like domain III (DIII). DIII of the E proteins is an independent domain and stretches out on the virion surface that can elicit type-specific neutralizing antibodies. Here, the DIII of the E genes of DENV and ZIKV were fused with
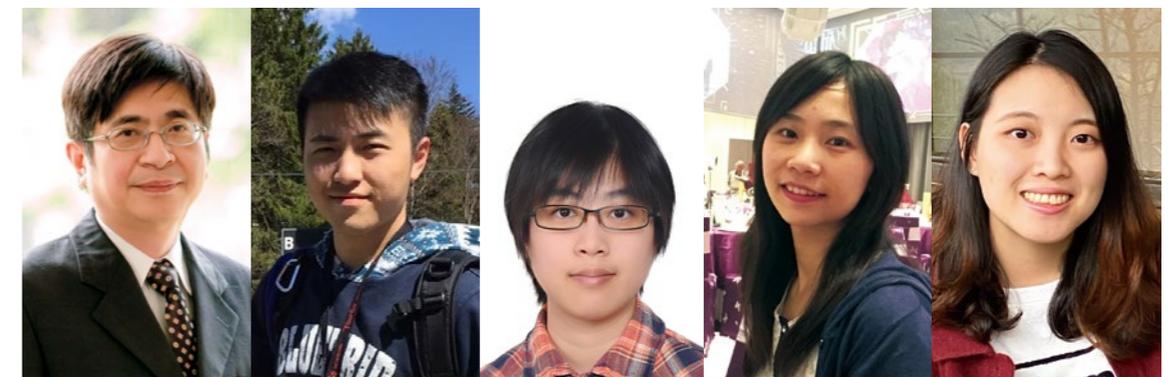
Salmonella typhimurium bacterial fliC gene for the expression of flagellin-DIII (FliC-DIII) fusion proteins. Prime-boost immunization strategies by the second-dose booster of four DENV serotype or ZIKV FliC-DIII fusion proteins were used to investigate the induction of neutralizing antibodies and protection against viral infections. We showed that inclusion of a bivalent live-attenuated vaccine with a FliC-DIII booster is superior in eliciting neutralization titers and protection in vivo against all four-serotype DENVs. We also demonstrated that recombinant adenovirus vectors encoding four-serotype DENV prMEs with a FliC-DIII prime-boost scheme is capable of eliciting good antibody responses.

The sequence analysis of E protein previously demonstrated that DENV and ZIKV are more phylogenetically close to each other than other flaviviruses. It was initially proposed for use in DENV infections for disease-enhancing antibody-dependent enhancement (ADE) activity. Therefore, the development of safe and effective vaccines is needed to abolish the elicitation of cross-reactive non-neutralizing antibodies between DENV and ZIKV. To abolish the elicitation of cross-reactive ADE-facilitating antibodies, we constructed a series of glycan-masking mutations on DII
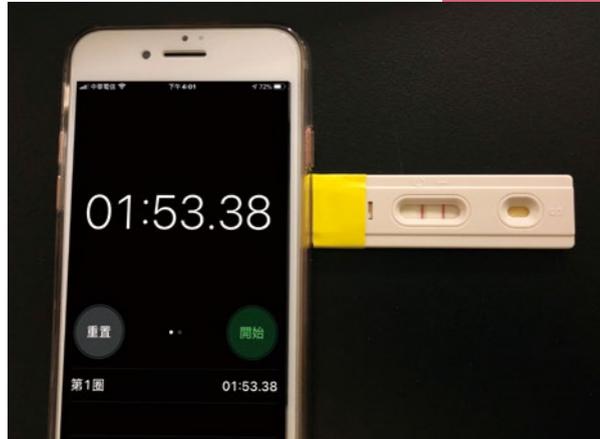
region of ZIKV E protein. The ij loop is located on the DII of E protein nearby the fusion loop. Our results indicated that the glycan-masking mutation on the ZIKV E protein ij loop (E-248NHT) resulted in abolishing the elicitation of cross-reactive antibodies for DENV and ZIKV infection enhancements. Our findings can provide useful information for designing novel immunogens and vaccination strategies in an attempt to develop a safe and efficacious DENV or ZIKV vaccine.

Research Output

- Lin HH, Yang SP, Tsai MJ, Lin GC, Wu HC, Wu SC. Dengue and Zika virus domain III-flagellin fusion and glycan-masking E antigen for prime-boost immunization. Theranostics 2019 Jul;9(16):4811-4826.
- US Patent 10,124,054; Taiwan Patent I625393. Vaccine combination against multiple dengue virus serotypes and preparation and application thereof.
- US Patent 10,501,529. Taiwan Patent I658848. Zika virus vaccine composition and application thereof.

(from left) Professor S.C. Wu, G.C. Lin, Dr. H.H. Lin, M.J. Tsai, S.P. Yang.

19 '20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Our IL-6 Test Strip for COVID-19

Rapid Diagnostic System for Predicting Upcoming Respiratory Failure and Cytokine Release Syndrome in Covid-19 Patients

Professor Chao-Min Cheng
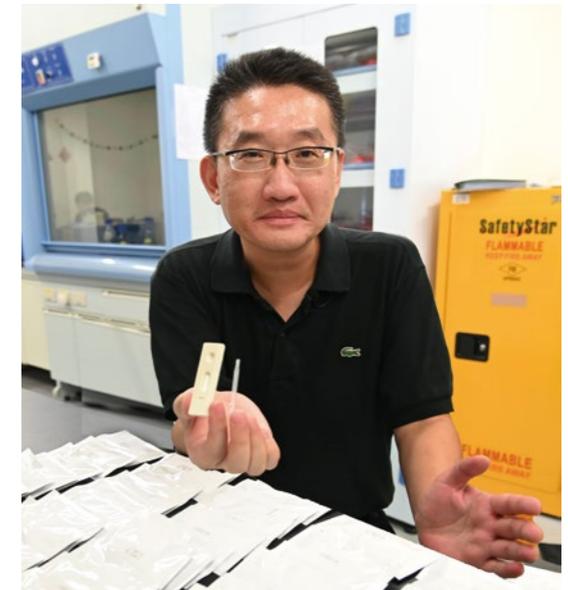*chaomin@mx.nthu.edu.tw*

Taiwanese researchers have developed a test kit that can detect potentially severe cases of COVID-19 in just two minutes, and it is now in the clinical trial phase.

The prototype of the rapid test kit was developed by National Tsing Hua University, Cheng Chao-Min（鄭兆珉）, a professor at the university's Institute of Biomedical Engineering, said during a presentation of the research project. While people usually experience mild influenza-like symptoms in the early stages of COVID-19, they can quickly become seriously ill, therefore, it is crucial to identify those who are likely to develop severe COVID-19, to prevent death. The COVID-19 severity test strip is based on lateral flow immunoassay, which may help the clinicians to assess the severity of COVID-19 patients. The test strip targets a

cytokine in patient serum known as Interleukin-6 (IL-6). Researches have shown that IL-6 may play an important role in development of respiratory failure, shock, multi-organ dysfunction, or even cytokine storm. Compared to mild COVID-19 cases, patients with severe infections of the disease have significantly higher levels of serum interleukin (IL-6), a cytokine that triggers the body's immune and inflammatory response to fight infections. Therefore, taking serum IL-6 as the targeting biomarker, can help predicting disease progression. High levels of IL-6 can cause the immune system to begin attacking itself, unleashing a cytokine storm, which has been linked to the death of a number of COVID-19 patients. As a result, the gold nanoparticles accumulate on the test line to perform color signal. Two red lines on the test kit mean high levels of IL-6, thus signaling a possible

severe COVID-19 infection, while one red line means low IL-6 levels and likely mild symptoms. Through test strip modification and in coordination with a reader, a cutoff value can be defined which is related to the color signal. In clinical situation, if the testing value reaches the cut-off value, this means that the patient may be in danger of respiratory dysfunction, and immediate actions such as intubation is required. The result of the test strip is further being recorded by the reader in order to digitalize into numerical data, which refers to the amount of IL-6 in patient serum. The two-minute test works by measuring levels of IL-6 in human serum and can be used to help identify patients who are more likely to develop severe COVID-19 illness. Clinicians can be able to predict disease progression through test strip result and decide whether to take further action such as intubation.

The research team is working with Italian hospitals and medical institutions to carry out clinical trials of the test. The team has also filed an application with the U.S. Food and Drug Administration for emergency use authorization (EUA) of the test kit, based on the results of the clinical trials. In a statement, National Tsing Hua University said it is looking forward to collaboration with business sector to mass produce the test kit.

Prof. Chao-Min Cheng

Research Output

- Y.-C. Wang, Y.-T. Lee, T. Yang, J.-R. Sun, C.-F. Shen and C.-M. Cheng*, Bioengineering and Translational Medicine, 2020 (https://doi.org/10.1002/btm2.10177)

> *The result of the test strip is further being recorded by the reader in order to digitalize into numerical data, which refers to the amount of IL-6 in patient serum.*
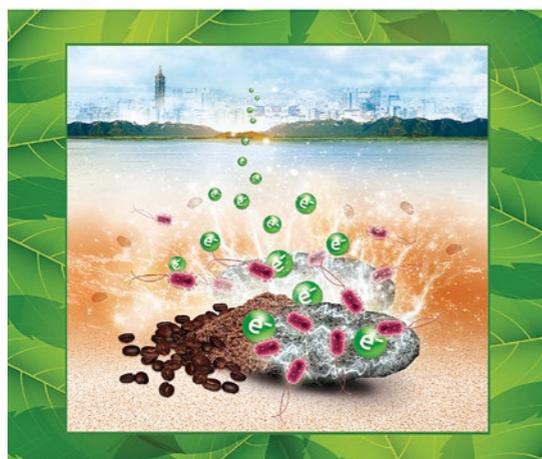
Material Science

- *Advanced and Sustainable Electrode Materials for Lithium-Ion Batteries, Hybrid Energy Storage Devices, and Microbial Fuel Cells*

- *Efficient Cesium Lead Halide Perovskite Solar Cells through Alternative Thousand-Layer Rapid Deposition*

- *Gel Polymer Electrolyte with Lithium-Ion-Conducting Channel for Lithium Ion Battery*

- *Composition-Balanced Trimetallic MOFs as Ultra-Efficient Electrocatalysts for Oxygen Evolution Reaction at High Current Densities*

Professor Han-Yi Chen
hanyi.chen@mx.nthu.edu.tw

Advanced and Sustainable Electrode Materials for Lithium-ion Batteries, Hybrid Energy Storage Devices, and Microbial Fuel Cells

Renewable Coffee-Waste-Derived Porous Carbons as Anode Materials for High-Performance Sustainable Microbial Fuel Cells

Because of the increasing demand for portable devices, renewable energy systems, and electric vehicles, energy storage systems have been developed intensively recently. Lithium-ion batteries (LIBs) which have high energy density, no memory effect, and good cycling stability, become important to the development of electric vehicles. Polyoxometalates (POMs) are transition metal oxide clusters, and they have multiple redox reactions as a molecular cluster. We utilized an electron/ion sponge-like $Na_7H_2[PV_{14}O_{42}]$ (NPV) as anode material for LIBs. This V-based POM was synthesized through a simple solution process, and it exhibited a high reversible specific capacity up to 687 mA h g^{-1} as well as a good cycling stability of 80% after 150 cycles, demonstrating this anode material is suitable for energy storage applications. In operando measurements such as X-ray Absorption Spectroscopy and X-ray diffraction was also conducted to study the charge storage mechanisms of this V-based POM. The charge storage mechanism of NPV is proposed that Li ions insert into the polyanions $[PV_{14}O_{42}]^{9-}$ continuously which is like an electron/ion sponge storing at least 30 electrons per molecule. It demonstrates that NPV is a promising anode material for LIBs.

SWCNT-NCMH nanohybrids have been successfully synthesized via a facile hydrothermal process and utilzied as a promising electrode material for hybrid energy storage devices. The NCMH nanospheres/nanoflakes electrode exhibited a high specific capacity of 678 C g^{-1} at 1 A g^{-1}, while the SWCNT-NCMH (10:90) nanohybrid electrode possessed even higher capacities of 912 C g^{-1} at 1 A g^{-1}. It is worth mentioning that the SWCNT-NCMH (30:70) nanohybrid electrode, which has similar capacity with NCMH at low rate, shows higher capacity at high rate (435

C g^{-1} at 50 A g^{-1}), indicating the improvement in electrical conductivity by combining with the SWCNTs. Furthermore, the SWCNT-NCMH (30:70) nanohybrid electrode displays well cycle stability with capacity retention of ~70 % after 10000 cycles. The SWCNT-NCMH (30:70)// SWCNT asymmetric hybrid energy storage device exhibits high flexibility under folding, indicating the improvement of mechanical properties by combining with SWCNTs. These encouraging findings reveal that SWCNT-NCMH nanohybrid materials are promising electrode candidates for flexible hybrid energy storage devices.

Microbial fuel cells (MFCs) provide the electric energy by collecting the electrons generated from the microbes. However, the low power density and the high costs of electrode materials are the main limitations for the development of MFCs. In this study, the MFC fabricated with the coffee-waste-derived anode (CWAC) exhibited considerably higher performance than previous reported E. coli-based MFCs with modified anode materials. The CWAC anode with a large amount of macropores and some mixed meso/micropores exhibited the high power density of 3927 mW m^{-2}. The surface area and pore size distribution of CWAC were suitable for biofilm formation, thus enhancing the electron transfer ability. In addition, a higher proportion of the graphitic structure in CWAC, resulting from the carbonization process, led to improvement in the electronic conductivity. Furthermore, the MFC with CWAC anode exhibited a self-powering/self-recharging ability. Overall, the high performances of MFCs with CWAC anodes demonstrate the potential of CWAC for sustainable energy applications as well as the development of a green and circular economy.
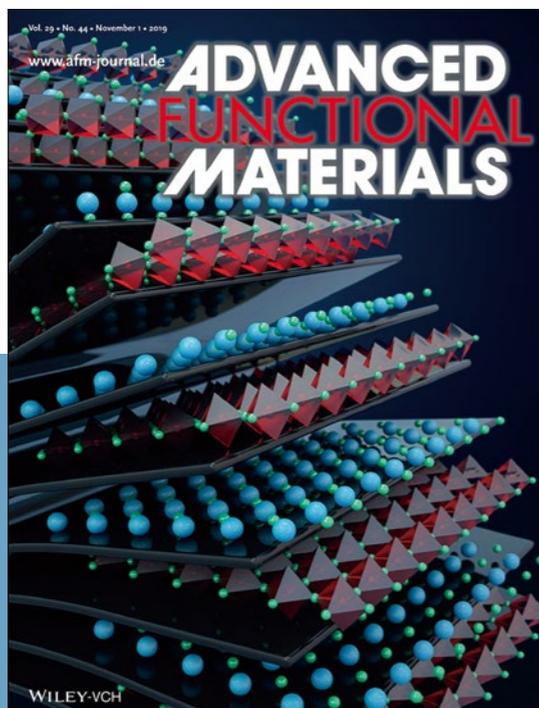
Research Highlights
- 108 學年度國立清華大學工學院新進人員研究獎
- MOST Young Scholar Fellowship（科技部年輕學者養成計畫－愛因斯坦計畫）
- 109 學年度國立清華大學新進人員研究獎

Research Output
- Shao-Chu Huang, Chia-Ching Lin, Chih-Wei Hu, Yen-Fa Liao*, Tsan-Yao Chen*, Han-Yi Chen*, "Vanadium-based Polyoxometalate as Electron/Ion Sponge for Lithium–Ion Storage", Journal of Power Sources, 2019, 435, 226709. [IF: 8.247]
- Yu-Hsuan Hung, Tzu-Yin Liu,* and Han-Yi Chen*, "Renewable Coffee-Waste-Derived Porous Carbons as Anode Materials for High-Performance Sustainable Microbial Fuel Cells", ACS Sustainable Chemistry & Engineering, 2019, 7, 20, 16991-16999. [IF: 7.632]
- Kun-Ju Tsai, Chung-Sheng Ni, Han-Yi Chen*, Jin-Hua Huang*, "Single-walled carbon nanotubes/Ni-Co-Mn layered double hydroxide nanohybrids as electrode materials for high-performance hybrid energy storage devices", Journal of Power Sources, 2020, 454, 227912. [IF: 8.247]
- "微生物燃料電池及其製造方法"，洪瑜萱，陳翰儀，劉姿吟（中華民國專利申請號 108126520）

Professor Han-Yi Chen's group (CEM lab).

Illustration showing the alternatively stacked cesium halides and metal halides in the three-dimensional metal halide perovskites. Reproduced from Adv. Funct. Mater. 29, 1905163 (2019) with permission.

Efficient Cesium Lead Halide Perovskite Solar Cells through Alternative Thousand-Layer Rapid Deposition

Professor Hao-Wu Lin
hwlin@mx.nthu.edu.tw

Recently, metal halide perovskites have attracted extensive attention due to their extraordinary optical and electrical properties. Classic organic lead halide perovskites are usually solution-processed because organic halides exhibit gaseous characteristics and would build-up in the vacuum chamber, making it difficult to control the reaction between organic halides and deposited metal halides. However, by replacing the organic halides with cesium halides, the issues related to organic halides in the vacuum process can be mostly prevented because of the conventional physical vapor deposition characteristics of cesium halides.

In this work, Prof. Hao-Wu Lin and his group members develop a layerwise vacuum deposition method to deposit Cs-based lead halide perovskites with a thousand-layer structures, approximating the structures of three-dimensional cesium lead halide perovskites in which Cs^+ and PbX_6^{4-} octahedrons were stacked alternatively. In short, a vacuum chamber was divided into two equal parts by a baffle, and a sample holder was rotated directly above the baffle. When the sample holder was rotating, cesium halide and lead bromide could be alternatively deposited on the substrate. The thickness of each layer can be controlled by adjusting the deposition rate of each precursor together with the rotation speed of the sample holder, with the thicknesses of which the cesium halide and the lead bromide are stoichiometrically balanced could be calculated using the molecular weights and the density of each species. After the precursor deposition was conducted, the films were annealed to ensure that cesium halides and lead halides reacted and were completely transferred to perovskite.

We found that when the 400-nm $CsPbI_2Br$ were made with 660 pairs of CsBr and PbI_2, which imitated the thicknesses of CsBr and PbI_2 in the $CsPbI_2Br$ perovskite unit cell, they exhibited smooth surface morphology and high crystallinity. Their solar cell integrating with vacuum-deposited small molecule carrier-transporting layers also delivered the highest power conversion efficiencies of up to 13.0%, with an open-circuit voltage of 1.13 V, a short-circuit current of 15.6 mA cm^{-2}, a fill factor of 0.74, and a stabilized power conversion efficiency of 12.8%. The use of these devices for environmental light energy harvesting also exhibited a high power conversion efficiency of 33.9% under fluorescent light illumination of 1000 lux and a promising lifetime. The device maintained 96% of its power conversion efficiency with encapsulations for 90 days.

Compared to the traditional codeposition method, the composition of perovskites depositing using this method could be controlled more easily and precisely owing to the separation of the half-chamber, which enables the thickness sensors to monitor the deposition rates of both precursors respectively. The process used in this study not only demonstrated a new method for efficient perovskite solar cell fabrication but also provided a novel approach for obtaining widely applicable high-quality perovskite thin films for various optoelectronic devices.

Research Highlights
- The research is featured on the inside front cover of Advanced Functional Materials.
- International Advisory Board member of Advanced Energy & Sustainability Research.
- MOST Outstanding Research Award.

Research Output
- Efficient Cesium Lead Halide Perovskite Solar Cells through Alternative Thousand-Layer Rapid Deposition, H.-Y. Lin, C.-Y. Chen, B.-W. Hsu, Y.-L. Cheng, W.-L. Tsai, Y.-C, Huang, C.-S. Tsao, H.-W. Lin, Adv. Funct. Mater. 29, 1905163 (2019).
- All-Vacuum-Deposited Stoichiometrically Balanced Inorganic Cesium Lead Halide Perovskite Solar Cells with Stabilized Efficiency Exceeding 11%, C.-Y. Chen, H.-Y. Lin, K.-M. Chiang, W.-L. Tsai, H.-W. Lin, Adv. Mater. 29, 1605290 (2017).
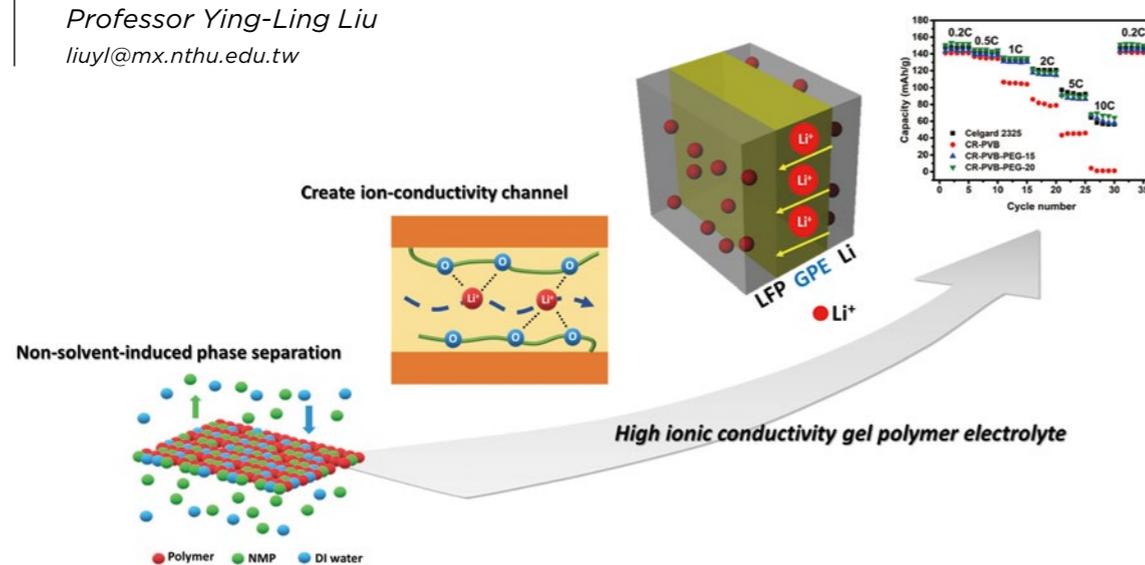

Professor Hao-Wu Lin (center of the first row) and his group members

19 '20

NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Gel Polymer Electrolyte with Lithium-Ion-Conducting Channel for Lithium Ion Battery

Professor Ying-Ling Liu
liuyl@mx.nthu.edu.tw

Gel Polymer Electrolyte with Lithium-Ion-Conducting Channels Lithium Ion Battery

fabricate porous membrane in the NIPS process with water as a coagulant, the hydrophilic PEG segments of the copolymer move to the water-rich phase and expose on the pore walls. In addition to the hydrophilicity, PEG also shows the ability to coordinate with lithium ion. Accompany with the movement of PEG segment, it shows a good transporting ability of lithium ion. Therefore, the PEG segments residing on the pore walls of porous membrane of GPEs could contribute to create the continuous PEG-rich channels for lithium-ion transportation. The lithium ion batteries assembled with PVB-g-PEG based GPEs exhibit rapid charge-discharge ability at 10C. This work proves that PVB-g-PEG copolymer is one of the potential candidates of next generation gel polymer electrolyte.

> *The PEG segments form ion-conducting channels in the pores to facilitate the transportation of lithium-ions through gel polymer electrolytes. The lithium ion battery possessing this class of gel polymer electrolyte demonstrates high charging rate and long cycle stability.*

One of the major issues of gel polymer electrolytes for lithium-ion batteries to be address is their relatively low charge-discharge rate, as high C-rate is highly demanded for high energy output devices, such as electric vehicles. The work provides a convenient and efficient strategy to build up lithium-ion-conducting channels in gel polymer electrolytes for lithium ion batteries.

Poly(ethylene glycol) (PEG)-grafted poly(vinyl butyral) (PVB-g-PEG) copolymer is employed as the raw material for preparing the porous membranes through non-solvent-induced phase separation (NIPS) process. In the NIPS process, the hydrophilic PEG segments appear at the pore walls not only increasing the liquid electrolyte uptake of the membrane but also forming a hydrophilic domain and lithium-ion-conducting channels, consequently to enhance lithium ion transportation through the membrane.
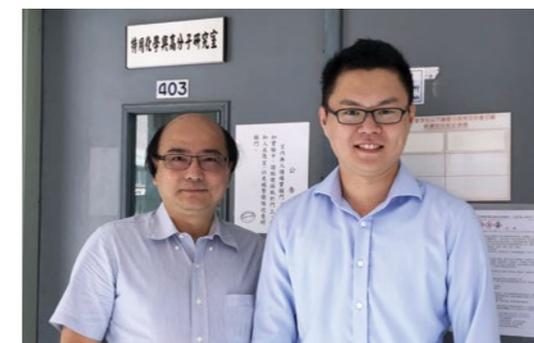
The creation of lithium-ion-conducting channels in porous GPEs is interesting. NIPS process has been employed for creating lithium-ion-conducting channels in porous membrane by using amphiphilic polymers. While using PVB-g-PEG copolymer to

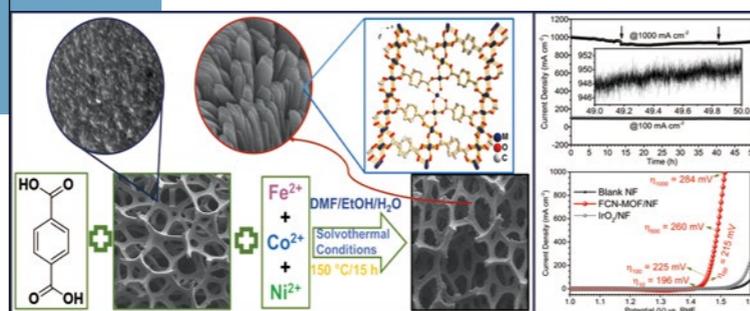(from left) Professor Y.-L. Liu, Mr. C.-Y. Tsai

Research Output

- Tsai, C. Y.; Peng, K. J.; Wang, C. F.; Liu, Y.L. Creation of Lithium-Ion-Conducting Channels in Gel Polymer Electrolytes through Non-Solvent-Induced Phase Separation for High-Rate Lithium-Ion Batteries. ACS Sustainable Chem. Eng., 2020, 8, 2138-2146.

Composition-Balanced Trimetallic MOFs as Ultra-Efficient Electrocatalysts for Oxygen Evolution Reaction at High Current Densities

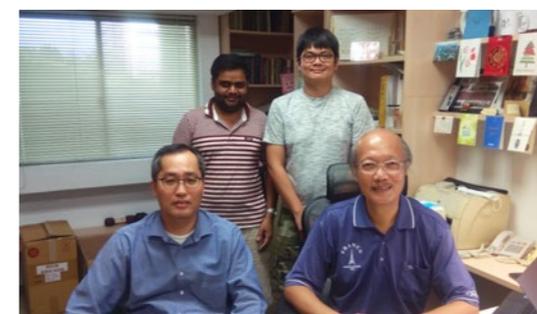*Professor Shih-Yuan Lu*
sylu@mx.nthu.edu.tw

Hydrogen plays a key role in deep decarbonization to tackle the two–degree–scenario (2DS) set by the Paris Climate Agreement. It has been proposed that decarbonization through hydrogen economy could achieve half of the reduction in carbon dioxide emission required to realize the 2DS. Presently, the most popular and economical commercial process for H_2 production is steam–methane reforming, which uses fossil fuels as the raw material and produces comparable amounts of CO_2 as the by–product. It is definitely an environmental unfriendly and a non–sustainable H_2 production process, and development of green H_2 production is in urgent need. In this regard, renewable energy driven electrolytic water splitting has been gaining rapidly increasing popularity and is considered by many the most promising green H_2 production process for future hydrogen economy infrastructure. It is also considered a necessary energy storage approach to resolve the detrimental unreliability and intermittency issues of renewable energies. The high cost of electricity however severely limits the prevailing of this technology, and cost–effective highly efficient and stable

Schematic illustration of one-step in situ growth of Fe, Co, Ni based trimetallic MOF thin nanoslabs on skeleton surfaces of nickel foam and OER performances.

electrocatalysts, aiming to reduce the necessary working potential for cost competiveness, are critically important for the prevailing of the technology. For catalyst development, unary systems have been exhaustively explored and multi–component systems have advanced drastically, benefitting from the synergistic effects between constituent components. In this regard, maximizing the synergistic effects between constituent components is a promising way to enable breakthrough development in catalyst design. On the other hand, metal-organic framework (MOF), possessing versatile catalytic activities, remarkable structural diversity, high surface areas, and tunable pore structure, was recently demonstrated an outstanding catalyst for oxygen evolution reaction (OER), the bottleneck reaction of water splitting. The above two

observations motivate us to develop multi-metal-based MOFs as OER catalysts. There however are lacking guidelines for composition design of multi-component catalysts. In this regard, we proposed a maximized-entropy concept to maximize the synergistic effects for maximum enhancements in electrocatalytic efficiencies of multi-component catalysts. The basic concept of the maximized-entropy approach is to maximize the randomness of the distribution of the constituent active species of a catalyst to gain maximum synergistic effects among the constituent active species to achieve maximum enhancements in electrocatalytic performances. To induce synergistic effects, the participating active species should be in intimate contact. A way to ensure the maximum extent of interactions between participating active species is to maximize the randomness of the species distribution, which can be achieved by maximizing the molar configuration entropy of the system. Accordingly, equimolar iron, cobalt, and nickel based trimetallic MOFs grown in-situ on nickel foam, were developed and demonstrated outstanding OER performances with ultra-low overpotentials of 196 and 284 mV at current densities of 10 and 1,000 mA cm^{-2}, respectively, as well as an ultra-low Tafel slope of 29.5 mV dec^{-1} in alkaline aqueous media. The stability of the electrocatalyst was also outstanding at large current densities, experiencing only 5% loss in current densities,

when chronoamperometrically tested at an ultra-high and industrially relevant current density of 1,000 mA cm^{-2} for over 50 hours.

Research Highlights

- Fellow, Royal Society of Chemistry (UK)
- Fellow, International Association of Advanced Materials (Sweden)
- Tsing Hua Chair Professor

Research Output

- Duraisamy Senthil Raja, Xui-Fang Chuah, Shih-Yuan Lu,* 2018, "In situ Grown Bimetallic MOF as Highly Efficient Bifunctional Electrocatalyst for Overall Water Splitting with Ultrastability at High Current Densities," Adv. Energy Mater., 8, 1801065. (inside back cover)
- Duraisamy Senthil Raja, Hao-Wei Lin, and Shih-Yuan Lu,* 2019, "Synergistically Well-Mixed MOFs Grown on Nickel Foam as Highly Efficient Durable Bifunctional Electrocatalysts for Overall Water Splitting at High Current Densities," Nano Energy, 57, 1-13.
- Hao-Wei Lin, Duraisamy Senthil Raja, Xui-Fang Chuah, Cheng-Ting Hsieh, and Shih-Yuan Lu,* 2019, "Bi-metallic MOFs Possessing Hierarchical Synergistic Effects as High Performance Electrocatalysts for Overall Water Splitting at High Current Densities," Appl. Catal. B. – Environ., 258, 118023.
- Cheng-Ting Hsieh, Chun-Lung Huang, Yu-An Chen, Shih-Yuan Lu,* 2020, "NiFeMo Alloy Inverse-Opals on Ni Foam as Outstanding Bifuctional Catalysts for Electrolytic Water Splitting of Ultra-Low Cell Voltages at High Current Densities," Appl. Catal. B. – Environ., 267, 118376.

(front left) Prof. YongMan Choi, Prof. Shih-Yuan Lu, (back left) Dr. Duraisamy Senthil Raja, Dr. Chun-Lung Huang.

Humanities and
Social Sciences

—

- *Social Welfare for Marginal Ethnic Groups: Chinese NGOs in Southwest China*

- *Fostering Students' 21st Literacy and Competence*

- *Mental Calculation in Bilinguals: Lost in Translation or Calculation?*

- *The Valuation of Brand Names and Trademarks*

- *The Rule of Law in Times of Technological Uncertainty*

- *Green Transformation: Lessons from the Fuel Cell Innovation System in Taiwan*

19'20
NATIONAL TSING HUA UNIVERSITY
R&D REPORT

Professor Shu-min Huang
smhuang@gate.sinica.edu.tw

Social Welfare for Marginal Ethnic Groups: Chinese NGOs in Southwest China

"

Findings in this study confirm the argument that in spite of the unique governance systems in China, Chinese NGOs in the Mainland are more akin to global NGOs owing to their shared charitable and altruistic concerns.

"

Based on previous discussion, we can draw a few concluding remarks about growth of NGOs in China and their impact on civil society building. First, the proliferation of NGOs has been astronomical, and the trend will continue along with the current economic growth and the rising middle class. Sustained economic growth in China during the past three decades has contributed to the improved living standard, especially among urban dwellers along the coast. Enhanced education levels over the same period have also contributed to a new sense of citizens 'awareness. The rise of the middle class, albeit small in number and percentage for the entire population, signals for a fundamental structural change in Chinese society. Demands for legal rights and protections, such as consumers' rights, environmental conservation, and industrial workers ' protection from work-related injuries , will generate more grassroots movements that accelerate the civil society building processes. The announcement of incorporating entrepreneurs into the Communist Party by the then President Jiang Zemin in 2000 clearly signals for the awareness of the top echelon of the Party-State that change is inevitable, and democratization will

become China's mainstream development in the years to come.

Second, in considering the relationships between NGOs and civil society building in China, we should include the organizations initiated by the Party-State as genuine NGOs. Both the Chinese Communist Party and the Chinese society are going through rapid changes. Owing to the all encompassing and permeating nature of the Communist Party before the reform era, it would be next to impossible to expect the automatic formation of citizens' voluntary associations after 40 years of oppressive rules. Under this condition it would not be unusual to find the best organized and best operated social groups outside of the Party-State bureaucracies established by the Party-State as fronts to appease certain segments of the society. The increased liberty given to citizens from the top has underscored a new dialogical relationship between the Party-State and society. It is under this condition that we will find members of the Party-State initiated NGOs deciding to disassociate themselves from the Party-State

apparatus, and transform their organizations into genuine NGOs to serve societal goals.

It is along the same vein that we can conclude that while Habermas' general theory of civil society building seems to be appropriate in explicating the civil society building processes in China, there are also discrepancies that must have been taken into considerations about the unique history and cultural heritage in China. Among the major differences are: first, the lack of a religious institution that sets outside the state-society dichotomy. Without an institutional alternative or mediator between them, the state-society division may become more sharpened and contentious as seen in political riots in Taiwan in 1970s and China in 1980s. The shortened feedback loops between state and society, however, also make their changing balances more direct and observable. In other words, the retrenchment of the state power will entail the dramatic increase of grassroots organizations, even when such organizational formats are newly imported from the outside and not a part of the cultural tradition.

Professor Shu-min Huang

Research Highlights

- Research supported by Taiwan's Ministry of Science & Technology.
- Paper presented at the 8th International Asian Forum in Lanzhou, China, October 26, 2019.
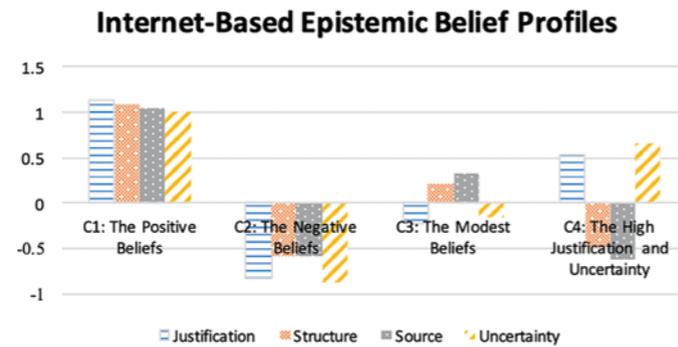
Fostering Students' 21st Literacy and Competence

Internet-Based Epistemic Belief Profiles

Internet epistemic beliefs can be categorized into justification, structure, source, and uncertainty. Cluster 1 (positive beliefs) has congruent positive scores in all belief constructs. Cluster 2 (negative beliefs) has congruent negative scores in all belief constructs. The epistemic belief scores for Cluster 3 (C3) centers around the factor score of zero (modest beliefs). Cluster 4 (high justification and uncertainty) has more positive scores on justification and uncertainty and more negative scores on structure and source.

Professor Yuan-Hsuan Lee
yuanhsuanlee@mx.nthu.edu.tw

Insights Gained from the Large-Scale International Assessment

My research agenda focused on enhancing people's 21st literacy. With the exploration of Programme for International Student Assessment (PISA) database, my collaborator and I found potential digital divide in the frequency of classroom use of ICT as well as in empowering students to use ICT to achieve their goals (Lee & Wu, 2012). We further exhibited that social-reading negatively predicted students' metacognitive knowledge, which in turn was associated with poorer reading literacy regardless in print or in electronic format; nevertheless, information-seeking activities positively predicted metacognitive knowledge, which in turn was associated with better reading in both the printed and electronic formats (Lee & Wu, 2013). Findings from the large-scale international survey demonstrated the trends of students' literacy performance and factors that were related with their literacy.

Developing Pedagogical Supports for Online Science Reading

Lessons learned from the PISA research led to me to develop the Collaborative Questioning, Reading, Answering, and Checking (C-QRAC) collaboration script as objective guidelines to foster students' metacognition and to empower them in using these competences to achieve their goal in active online learning. Through a series of research (Lee, 2015; 2018), I tested the effectiveness of the C-QRAC script on university students' collaborative science reading literacy. Results showed that the C-QRAC script enhanced participants' critical thinking and helped close the gender gap in science reading in the computer-mediated environment (Lee, 2015). Moreover, students who followed the C-QRAC script performed better on the delayed advanced multiple-choice items than those in the control group. Higher prior knowledge predicted better scores on delayed basic MC as well as immediate and delayed constructed-response items. The study results confirmed that the C-QRAC collaboration

Professor Yuan-Hsuan Lee

script can be used to facilitate students' critical thinking and enhance their self-directed learning in both computer-mediated and technology-supported flipped learning conditions (Lee, 2018).

Addressing Students' Literacy development from the Perspectives of Teacher Education and Training

The rapid development of ICT has provided great affordances for students to satisfy their social and educational needs. Instructors' perceptions of the use of technology may be related to their classroom teaching practices. Using k-means clustering algorithm, I investigated preservice teachers' epistemic belief profiles based on their beliefs toward the nature of Internet knowledge and process of knowing on the Internet (Lee, 2018). Four epistemic belief groups were derived based on these constructs; and they exhibited differential effects on the validating variables. Cluster 1 was characterized by four positive epistemic beliefs (the positive beliefs), Cluster 2 by four negative epistemic beliefs (the negative beliefs), Cluster 3 by modest scores of the epistemic beliefs (the modest beliefs), and Cluster 4 by positive uncertainty and justification scores as well as negative structure and source scores (the high justification and uncertainty). Findings suggest that intervention targeting pre-service teachers in the negative beliefs and the modest beliefs may be necessary to foster positive epistemic beliefs for better constructivist learning in the online environment.
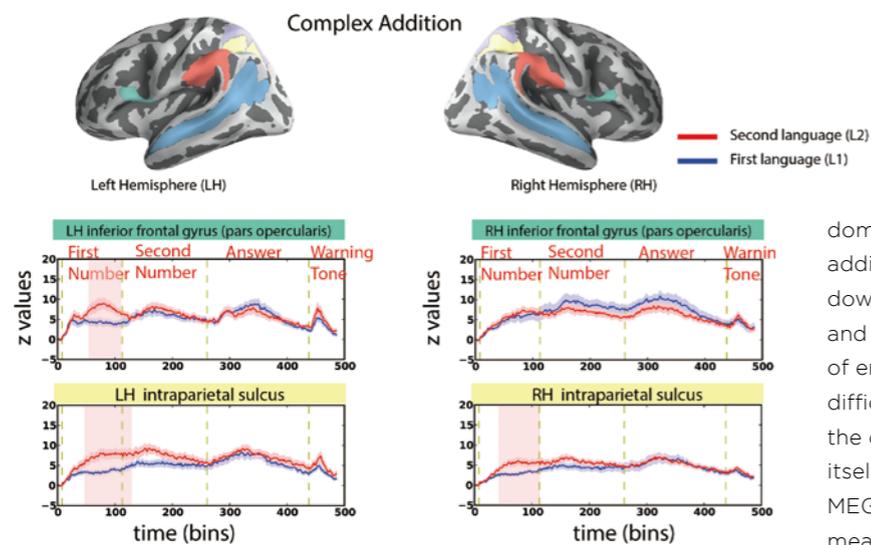
Research Output
- Hong, H. Y., Lin, P. Y., & Lee, Y.-H. (2019). Developing effective knowledge-building environments through constructivist teaching beliefs and technology-integration knowledge: A survey of middle-school teachers in northern Taiwan. Learning & Individual Differences. 76, 101787. doi:10.1016/j.lindif.2019.101787
- Lee, Y.-H. (2018). Internet-based epistemic beliefs, engagement in online activities, and intention for constructivist ICT integration among pre-service teachers. Australasian Journal of Educational Technology, 34(5), 120-134.
- Lee, Y.-H. (2018). Scripting to enhance university students' critical thinking in flipped learning: Implications of the delayed effect on science reading literacy. Interactive Learning Environments, 26(5), 569-582.
- Lee, Y.-H. (2015). Facilitating critical thinking using the C-QRAC collaboration script: Enhancing science reading literacy in a computer-supported collaborative learning environment. Computers & Education, 88, 182-191
- Lee, Y.-H., Ko, C. H., & Chou, C. (2015). Revisiting Internet addiction among Taiwanese students: A cross-sectional comparison of students' expectations, online gaming, and online social interaction. Journal of Abnormal Child Psychology, 43(3), 589-599.

Professor Jo-Fu Lotus Lin
jofulin@mx.nthu.edu.tw

Mental Calculation in Bilinguals: Lost in Translation or Calculation?

Time courses of brain activity extracted from regions of interest on the left and right hemisphere. Selected regions of interest are color-coded and shown on the cortical surface. Stronger brain responses were observed in the L2 compared to L1 Complex Addition task in the left inferior frontal area and bilateral parietal areas. Increased response magnitude was found during the First Number period before calculation can take place. (adapted from Lin et al., 2019, Brain & Cognition)

Numerous behavioural studies reported reduced accuracy and increased response time when bilinguals were tested with arithmetic problems presented in their second language (L2). In real-life situations, new international students and new immigrants often encounter difficulties when numbers and arithmetic problems are given in their L2. Difficulties could arise from the process of translating numbers into L1, the dominant language. This additional process slows down the response time and increases the chance of errors. However, difficulties could arise from the calculation process itself as well. Using the MEG technique, we can measure minute magnetic fields that are associated with electrical activity of neurons in the brain. MEG also provides millisecond-level temporal information. With such fine temporal resolution, we could identify the source and time window when differences between L1 and L2 start to emerge. Using both behavioural and brain measures, our study investigated the underlying cognitive and neural causes of lower performance in L2 mathematical performance.

In our study, bilingual adults were tested with Complex Addition problems while their brain activity was recorded simultaneously with MEG. Behavioral data showed lower accuracy when two-digit addition problems were given in L2 compared to L1. Brain data showed enhanced response magnitude in L2 compared to L1 Complex Addition task. Differences in brain activity were observed in the left inferior frontal areas and bilateral parietal areas during the First Number interval. This is the time period when the first number in the addition problem was presented, before the second number was given. Because only one number was given, no mathematical calculation could take place. This result suggests that differences between languages emerge before calculation starts.

As the government in Taiwan is promoting bilingual education in elementary and secondary schools, the impact of bilingualism on cognitive development and learning cannot be ignored. Our findings can inform practices in bilingual education. As shown in our study, when addition problems were provided in L2, cognitive as well as neural costs were observed. At the behavioral level, bilinguals showed lower behavioral performance when addition problems were provided in their L2, instead of L1. For our participants, L1 is the language they used to learn simple arithmetic and the language they preferred for mental calculation. At the cortical level, performing mental addition in one's L2 required more neural resources. Our finding highlights the importance of language of instruction in bilingual education. When teachers use one language to teach a specific domain of knowledge, the information is then encoded in that specific language. Later, when the language of retrieval does not match the language of encoding, cognitive and neural costs are expected.

Research Output

- Lin J-F L, Imada T, Kuhl PK (2019) Neuroplasticity, Bilingualism, and Mental Mathematics: A behavior-MEG study. Brain and Cognition, 134: 122-134.
- Lin J-F L, Imada T, Kuhl PK (2012) Mental Addition in Bilinguals: an fMRI Study of Task-related and Performance-related Activation. Cereb Cortex, 22, 1851-1861.

(from left) Prof. Patricia Kuhl, Prof. Toshiaki Imada, Prof. Jo-Fu Lotus Lin.

Prof. Lin (right) with members of the Neurolinguistics lab and students from the Institute of Linguistics in the MEG lab of Veterans General Hospital. The magnetoencephalography (MEG) system is located inside the magnetically shielded room (MSR) on the right.

Professor Po-Hsuan HSU
pohsuanhsu@mx.nthu.edu.tw

The Valuation of Brand Names and Trademarks

This figure plots the aggregate number of trademarks registered from 1976 to 2014 by all public firms included in our sample (left vertical axis). It also plots annual stock returns and averaged in each year corresponding to the year of the TRAT measure (right vertical axis).

We find that firms launching more new products (measured by the number of new trademarks) provide significantly higher stock returns in the future. Firms launching more new products are more profitable; however, such profitability is underestimated by stock analysts. We conclude that stock investors underestimate the value of new trademarks due to lack of attention and/or limited information processing ability.

Impact: (1) We find that the market does not efficiently price new trademarks.; (2) new trademark activities represent intellectual property that contributes substantially to firm value

Takeaways: (1) The launch of new trademarks enhances firm value; (2) Stock investors discount the value created by new trademarks; (3) The values of new trademarks and the new products bearing them are difficult for general investors to assess; (4) Trademarks constitute an important part of intangible assets of firms; and (5) legal protection is important for the value of trademarks.

Implications for governments and accounting regulators; institutional investors; stock analysts; stock investors; and CEOs and board directors: (1) New trademarks are value-enhancing; (2) stock

> ## " The evidence is more consistent with investors' undervaluation of new trademark registrations rather than a risk-based story. "

markets tend to overvalue new trademarks and new products bearing them; (3) intangible assets are notoriously hard to value, and trademarks are no exception; (4) legal protection is fairly important for trademarks.

Novelty: (1) Existing research neglects the asset pricing implication of trademarks; (2) stock markets are inefficient in processing information related to new trademarks; (3) such inefficiency is due to limited investor attention and aversion to uncertainty and complexity; (4) trademarks are an important and widely used form of IP protection; and (5) legal protection influences how stock markets value trademarks.

Professor Po-Hsuan Hsu

Research Highlights

- MOST Outstanding Research Award, 2019
- Best Paper Award, 2018 Conference on the Theories and Practices of Securities and Financial Markets (SFM, National Sun Yat-Sen U.)
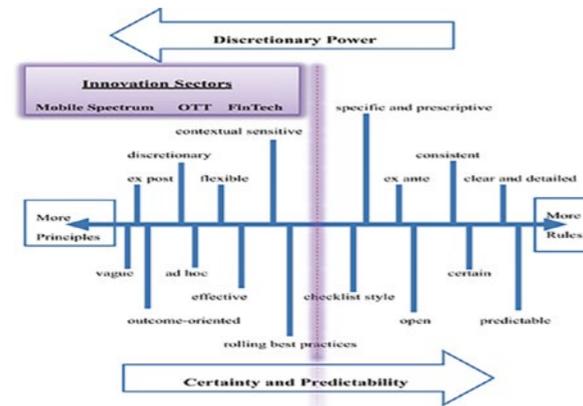
Research Output

- "Valuation of new trademarks," with Dongmei Li, Qin Li, Siew Hong Teoh, and Kevin Tseng, Management Science (a top journal and is included in the Financial Times 50 journal list), forthcoming, 2020.
- "Benchmarking U.S. university patent value and commercialization efforts: A new approach," with David Hsu, Tong Zhou, and Arvids Ziedonis, Research Policy (a top journal and is included in the Financial Times 50 journal list), 50(1), 104076, 2021 (lead article).
- "The Oscar goes to…: High-tech firms' acquisitions in response to rivals' technology breakthroughs," with I-Ju Chen, Micah Officer, and Yanzhi Wang, Research Policy (a top journal and is included in the Financial Times 50 journal list), 49(7), 104078, 2020 (corresponding author).
- "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 (a top journal and is included in the Financial Times 50 journal list), forthcoming, 2019.

The Rule of Law in Times of Technological Uncertainty

Professor Shin-yi Peng
sypeng@mx.nthu.edu.tw

The Principles versus Rules Continuum: An appropriate balance between rules and principles in technology regulations may look quite different from an appropriate balance in other arenas. The appropriate point lies not in the middle, but more toward the left of the continuum: moving toward principles-based approaches.

Professor Shin-yi Peng

WTO National Security Exceptions" (Journal of International Economic Law) represents another compelling example of my effort to examine IEL and domestic law in a coherent way. This article argues that the principle of good faith can help to explain how far "self-judging" power can reach. Exploiting the potential dispute over ICT products as an occasion to explore the trade implications of security measures, the article reveals that fact-finding and evidence gathering are the most troubling elements in the application of the National Security Exceptions.

> **The relevant provisions are not sufficiently forceful in a manner that safeguard due process and counter the potential abuse of administrative power.**

Research Highlights

- Outstanding Research Award, Minister of Science and Technology, Taiwan (2020)
- Outstanding Research Award, National Science Council (now renamed as Ministry of Science and Technology), Taiwan (2010)
- Wu Ta-You Memorial Award, National Science Council (now renamed as Ministry of Science and Technology), Taiwan (2005)
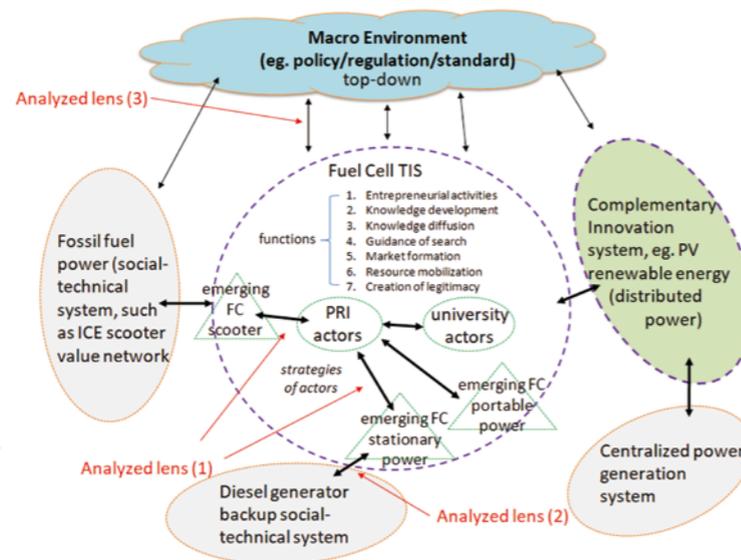
Research Output

- Shin-yi Peng, 2019.03, "The Rule of Law in Times of Technological Uncertainty: Is International Economic Law Ready for Emerging Supervisory Trends?" Journal of International Economic Law, Volume 22, Issue 1, 1-27. (Best of Law, Oxford University Press, 2019 https://academic.oup.com/journals/pages/best-of-law)
- Shin-yi Peng, 2018.10, ""Private" Cybersecurity Standards? Cyberspace Governance, Multistakeholderism, and the (Ir)relevance of the TBT Regime" Cornell International Law Journal, Volume 51, Number 2, 445-469.
- Shin-yi Peng, 2015.06, "Cybersecurity Threats and the WTO National Security Exceptions" Journal of International Economic Law, Volume 18, Issue 2, 449-478.

Legal scholars are now showing greater interest in the relationship between international and domestic law. In my view, domestic regulation is essential to achieve legitimate policy objectives intertwined with trade in services, because the markets do not always work perfectly and cannot always yield desired results by themselves. Regulatory interference with the market may be motivated by the need to accomplish economic objectives such as market competition, or non-economic social goals such as privacy, security and cultural protection. Should trade liberalization trump national regulatory autonomy? Conversely, can WTO members legitimately claim they retain formal autonomy to enact whatever privacy or cybersecurity legislation they deem appropriate? How can we carefully balance the rights and obligations that comprise the WTO Agreement?

How can we establish an appropriate trade regime to address non-economic interests? Most of my work offers contextual and systemic arguments regarding the linkages between IEL and domestic regulation. For example, "The Rule of Law in Times of Technological Uncertainty: Is International Economic Law Ready for Emerging Supervisory Trends?" (Journal of International Economic Law) argues that in light of technological uncertainty, a move toward more discretionary practices has been discernible across sectors. Yet technology regulations increasingly take the form of vague language that requires regulators to engage in interpretation and "translation." The article identifies regulators' increasing discretionary practices in the innovation sectors and examines whether IEL is ready for supervisory trends. The article "Cybersecurity Threats and the

Professor   Hu, Mei-Chih
mchu@mx.nthu.edu.tw

Green Transformation: Lessons from the Fuel Cell Innovation System in Taiwan

(from left) Professor Tommy Tsung-Ying Shih, Professor Mei-Chih Hu, Dr. Justin Che-Ping Chou

The background structure of fuel cell TIS analysis for the system functions and interactions among innovation actors, emergent and incumbent technologies, as well as the external effect from policies and regulations.

The study of Taiwan's fuel cell innovation system sought to identify the institutions and mechanisms that drove the fuel cell innovation during the period of 2000 - 2016. The study adds empirical evidence to the concept of an innovation system that involves interactive and dynamic learning by doing (Rothwell, 1977, Lundvall, 1985, Kline and Rosenberg, 1986) with an in-depth investigation on the "build-up" process of the emerging FCT in Taiwan.

The analysis of Taiwan's fuel cell innovation system contributes real test cases for the TIS framework (Markard & Truffer, 2008) with empirical data to demonstrate the build-up process of an emergent technology. Building on earlier fuel cell TIS literature which focused on western countries (Markard, 2008; Suurs et al., 2009; Andreasen and Sovacool, 2015), this study examined the phenomenon of a latecomer

nation (Taiwan) in an East Asian setting. The embedded case study of FCT development in Taiwan illustrates how actors encountered difficulties and barriers in the course of fuel cell innovation and the kind of strategies they adopted to navigate various challenges and opportunities. Various actors would form different innovation strategies such as different niche applications to gain accessible resources. Actors competed, but they were also required to unite around a network. These actors would thereafter form alliances to influence the macro-structure (landscape) in order to survive. The decisions to form coalitions and to solicit resources via the network mechanism, were not a long-term strategy. When the policy

landscape started to withdraw some of its support and resources, new strategies were needed. The fuel cell firms could no longer rely on the domestic support structures. Our examples showed how some actors chose to seek other markets and collaborate with international actors in order to survive.

The non-linear behavior with respect to managerial practices and illustrated by the actors reactive response to government policy and end user preferences, implies the needs for stability in an innovation system. Some degree of government foresight and guidance as well as consistency might be required. Such efforts however, need to be balanced with the networks that are being formed aimed towards influencing politics rather than technology development.

This study provides an empirical account of the emergence of fuel cell innovation in Taiwan. As many other latecomer nations like China, India, the Philippines, Malaysia, and Indonesia are presently investing in the development of green energy, the current study can aid policy makers in understanding the dynamics in the innovation systems. The role of policy is important and government actions can both support and offset development. Against this understanding, we suggest that an important role for the government is to provide a stable environment, clear and consistent policy, and to offer guidance of the search.

Research Output

• "Chou, J., Mathews, J.A., 2017. Taiwan's Green Energy Transition Under Way. The Asia-Pacific Journal: Japan Focus, 15 (21), 1-10.

• Hu, M.C., Mathews, J.A., 2005. National Innovation Capacity in East Asia. Research Policy 34 (9), 1322-1349.

• Hu, M.C. and Mathews, J.A. 2016. Taiwan's green shift – prospects and challenges. The Asia-Pacific Journal: Japan Focus 14 (19/2), available on-line on October 1, 2016 at: http://apjjf.org/2016/19/Hu.html

• Hu, M.C. and Mathews, J.A. (2016). Taiwan's green shift. Taipei Times, October 24, 2016, Taiwan. http://www.taipeitimes.com/News/feat/archives/2016/10/24/2003657797/3

• 2019 Taiwan Innovative Business Model Patent: Smart plant eco-system tank for oxygen generation and air purification (Patent Number: M579261)

• 2020 Taiwan Patent: Air Purifier (Patent Number: M592064)

• 2020 Taiwan Patent: Smart Aquaponics Environmental Management System (Application Number: 109201887)