CENTER FOR RELIABILITY SCIENCES AND TECHNOLGIES

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Signing of Taiwan Space Industry Alliance-

Taiwan Consortium of Space Radiation Environment Testing on July 21, 2020

Combining Taiwan's superior electronic industries to drive the development of the domestic space industry and enter the international space market is an important goal of the third phase of my country's national space technology long-term development plan. In order to assist local electronics manufacturers to upgrade their technologies and promote Taiwan’s transition from a major semiconductor industry country to a supplier of space-level radiation electronic components, the National Space Center of the National Experimental Research Institute (National Academy of Sciences Space Center) and domestic radiation testing and analysis units, including "Chang Gung Medical Linkou Chang Gung Memorial Hospital" (referred to as Chang Gung Memorial Hospital), "Chang Gung University/Linkou Chang Gung Memorial Hospital Institute of Radiation Medicine" (referred to as Chang Gung University), "Institute of Nuclear Energy, Executive Yuan Atomic Energy Commission" (referred to as Nuclear Research Institute), "IST "Technology Co., Ltd." (referred to as iST), "Academia Sinica Institute of Physics" (referred to as the Institute of Physics, Academia Sinica) and "National Tsinghua University Atomic Science and Technology Development Center" (referred to as Tsinghua

University Science and Technology Center), together form the "Taiwan Space "Radiation Environment Testing Alliance", representatives of the seven units jointly signed a memorandum of cooperation at the Space Center of the National Research Institute on July 21, which is a big step forward to complete China's space environment testing energy. CReST is also invited in this initiative to perform reliability test and statistical analysis of various components tested under different radiation conditions.

Prof Cher Ming Tan featured in Research Outreach journal

Research Outreach publication is produced on a bi-monthly basis, featuring a true mixture of wonderful research found around the globe. It publishes each edition as a physical hard copy and also publish digitally.

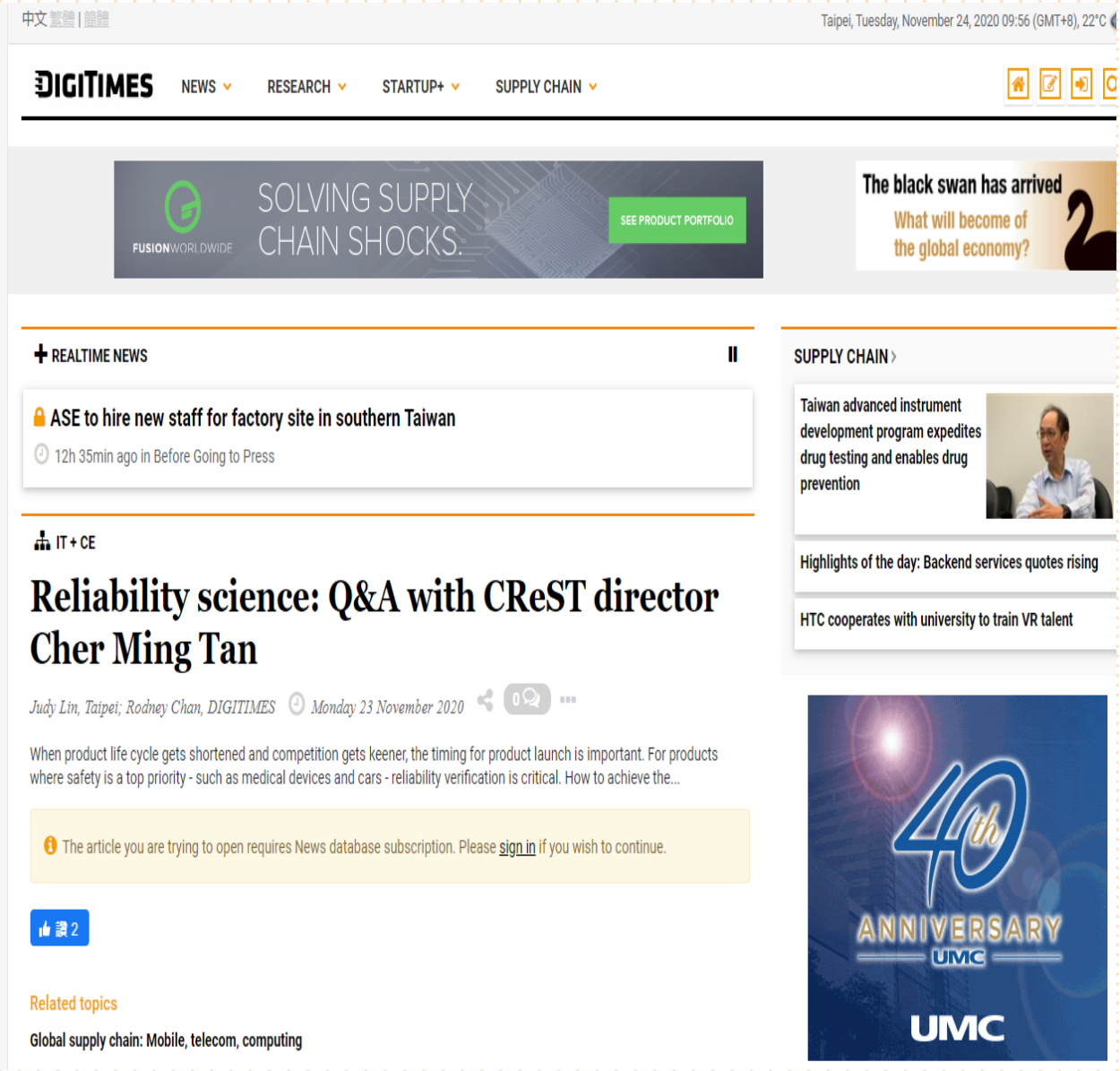
Each edition features between 15 to 30 research teams. Research Outreach publication is distributed to over 110,000 contacts globally. Each article you see within the publication is also used to create a bespoke web page feature, which allows us to promote individual articles, as well as the publication as a whole.

In its recent edition, Prof Tan was invited to present his views on degradation physics studies and reliability analysis. The article was titled as "Physics of degradation- The difference between reliability engineering and reliability science".

Abstract:

Quality and reliability are key factors for a product's commercial success. Reliability testing usually occurs at the final product, using destructive methods. This implies that there might be added costs and delays if reliability tests fail. Looking at reliability sciences from the physics of degradation and the identification of degradation mechanisms, Prof Cher Ming Tan from the Research Center on Reliability Sciences and Technologies in Taiwan is proposing an innovative approach. He studies the reliability of products based on a physics, chemistry and materials sciences level, before the assembly of the final product. Combining experimental data and simulations, he can predict the reliability of the final product under various operational conditions, saving precious time and money.

Prof Cher Ming Tan featured in DIGITIMES



More information can be found from: https://www.digitimes.com/news/a20201120PD214.html

Prof. Hsiao-Chien Chen joined CReST Lab

Hsiao-Chien Chen received his Ph.D in Chemical and Materials Engineering from Chang Gung University, and then was a postdoctoral fellow in Taipei Medical University, National Taiwan University and National Cheng Kung University. Because of owning both background of engineering training and experience of science research, he is experienced and learn many great skills in interdisciplinary researches, including material modification, biosensor design, green energy, water science, electrocatalyst and *in-situ* methodology. His current research interest is focused on the development of *in-situ* multi-probing measurements for reliability and failure analysis.

Prof Kun-Mu Lee received MOST award

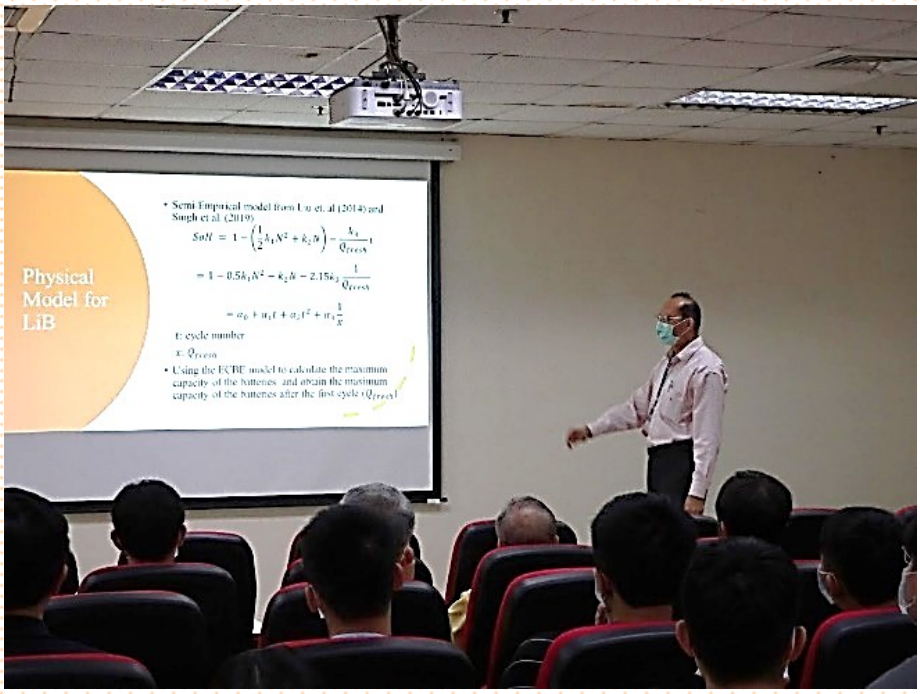
CReST member Prof K M LEE received 2020 Ta- You Wu Memorial award for his outstanding research outcomes for the year 2019-20. We congratulate Prof K M Lee and wish him more success in the coming future.

Bio-Asia exhibition – 22nd – 26th July, 2020

BIO Asia–Taiwan 2020 brought together biotechnology and pharmaceutical executives and investors from North America, Europe and Asia to meet and explore business opportunities with Taiwan's emerging biotech sector in both online and live settings. The five-day event features rich programming, online company presentations from Asia and around the world, BIO One-on-One Partnering™ meetings, online seminars and workshops, and an online exhibition. And online meeting lounges and other social media-type activities will facilitate and replicate the social and networking elements so important to the typical conference experience. Prof Cher Ming Tan demonstrated his work on prognosis and health management for dialysis machine in the exhibition.

The 29th South Taiwan Statistics Conference, Chiayi, Taiwan, August 20, 2020

This is a nationally important academic seminar on probability statistics. It has been held for 25 sessions since 1981. Past papers have been published and the participants have been very enthusiastic. In recent years, more than 300 people have participated in each edition. It can be regarded as the longest and most grand academic seminar on probability statistics held every year in Taiwan. Another feature of the Southern District Statistics Seminar is to provide a platform for graduate students and doctoral students to publish their research work, so that new blood in the field of probability statistics and senior scholars and experts can have a more extensive exchange of ideas, and provide veterans and rookies in the field of probability statistics. A valuable opportunity to know and pass on. Prof Cher Ming Tan delivered an invited talk in the conference titled “Application of statistics in Reliability and failure analysis in electronics”.



Invitation for Induction Program 2020, Assam Kaziranga University

Prof Cher Ming Tan was invited to be the Guest Speaker on the occasion of Induction Day, organized by Kaziranga University's School of Engineering and Technology and School of Computing Sciences, which is held on the 19th of October, 2020 from 11:00 am onwards.

Kaziranga University's School of Engineering and Technology and School of Computing Sciences aspires to meet the needs of 21st century learners, while enabling their students with the right kind of knowledge, values and skills. Their programmes are industry-aligned, designed and delivered in collaboration with some of the top industry experts in the country and abroad. This commitment is manifested through innovative and trademark attention to the trinity of professional education: Purpose, Pedagogy and Progress.

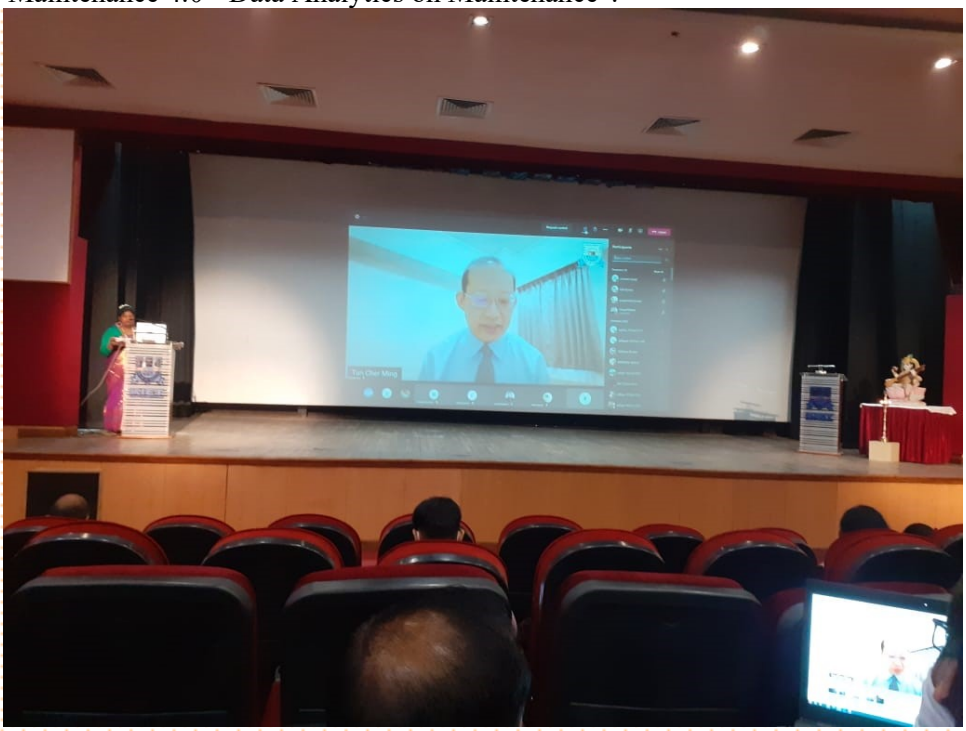
The Induction day on the 19th of October marks the induction of new students into the School of Engineering and Technology and School of Computing Sciences. These are students from all over the North-East, who will begin their academic journeys into the world of Engineering and Technology. Prof Tan’s success and extensive experiences in the industry have convinced that his words will tremendously inspire the students.

Virtual Conference on Innovative Applications of Computational Intelligence on Power Energy and Control with their impact on Humanity (VCIPECH) in Delhi, India

6th – 7th November 2020

VCIPECH 2020 has been organized three times successfully in year 2014, 2016 and 2018 by the Department of Electrical and Electronics Engineering, KIET Group of Institutions, Ghaziabad, Uttar Pradesh, India. There are multiple tracks in this virtual conference covering the areas of the conference theme.

VCIPECH 2020 is a platform to share ideas for nurturing smart ideas by discussing technological scopes in areas of computational intelligence and applications, control systems and applications, power electronics, drives and electromechanical energy conversion, power system technology, applied technologies in renewable energy and smart grids, emerging trends in on-chip communications, recent technological developments in VLSI design and tool automation, measurement, automation and sensing technology and topics related to the technology benefiting humanity and society. Prof Cher Ming Tan delivers a keynote talk titled “Maintenance 4.0 - Data Analytics on Maintenance”.



Session chair in 2020 International Electron Devices and Materials Symposium (IEDMS 2020)

CGU, Taiwan

On 15th – 16th Oct, 2020

The conference offers a common forum for researchers, scientists, engineers, and practitioner throughout the world to present their latest research findings, ideas, developments, and applications in the areas of semiconductor materials and devices. The technical program will consist of oral presentations and poster sessions. Prof Cher Ming Tan is invited to be a session chair for one of the session in the conference.

PCM conference aims to provide a forum for academic experts and participants to exchange their experiences and share research results about all aspects of Polymer and Composite Materials and discuss the encountered practical challenges and the adopted solutions. The conference program consists of Keynote Speech, Invited Speech, Oral Presentation and Poster Presentation. Every year, BEST oral and poster presentations will be selected and awarded with free registration to the next conference.

Prof Cher Ming Tan delivered his invited talk on "A composite material for interconnections in advanced electronics".

Abstract: VLSI Interconnects are essential as billions of transistors in an IC are interconnected to form a working circuit specific to achieve certain functions. With the advent of IC technology, the line-width of VLSI interconnects is shrinking and hence their reliability is deteriorating significantly. Copper (Cu) has remain a prime choice for an interconnection material in Semiconductor Industries for years owing to its best balance of conductivity and performance. However, Cu interconnects are running out of steam, but complete replacement of Cu is not trivial due to many considerations to be considered. There has been proposal of using Carbon Nanotubes, 2D materials like Graphene, etc. as alternatives but these proposals presented difficult challenges to be answered. Scalability, manufacturability, ability to be integrated in current semiconductor process are some of the major challenges. Owing to the excellent properties of Graphene, including electrical and thermal conductivities, high current density tolerance and high electromigration reliability on Graphene Interconnects, Graphene is likely to be the most suitable candidate for future interconnections. This work presents our proposal on the novel composite material which is a copper interconnect with Graphene sandwiched in between. The synthesis method and its performance as well as reliability are proven experimentally by our group and will be presented. With such a composite material as interconnections, the VLSI-IC industry and even printed circuit board industry can enjoy high performance and highly reliable interconnections.

Epistar invited talk, 19th August, 2020

Epistar Corp. is the largest manufacturer of light-emitting diodes (LEDs) in Taiwan. The company was established in 1996, and its headquarters are in Hsinchu, In 2009 it had an annual turnover of NT$10 billion. Epistar specializes in high-brightness LED products, which are used in general lighting, traffic signals, and various consumer products such as mobile phones and laptop computers. The company supplies the LED backlighting for Samsung liquid crystal displays.

It is the world's largest manufacturer of red and yellow LEDs, and holds over 3000 patents. It has a history of patent disputes with competitor Philips Lumileds, now Lumileds, over the use of AlInGaP LED technology. However, in September, 2009, Philips Lumileds signed an agreement to license AlInGaP technology to Epistar. Prof Cher Ming Tan is invited to deliver a talk demonstrating the use of simulation and statistic in failure analysis of high power LEDs and shared his experience and research outcomes with the Epistar members.

National Chiao Tung University, Taiwan invited talk

25th November, 2020

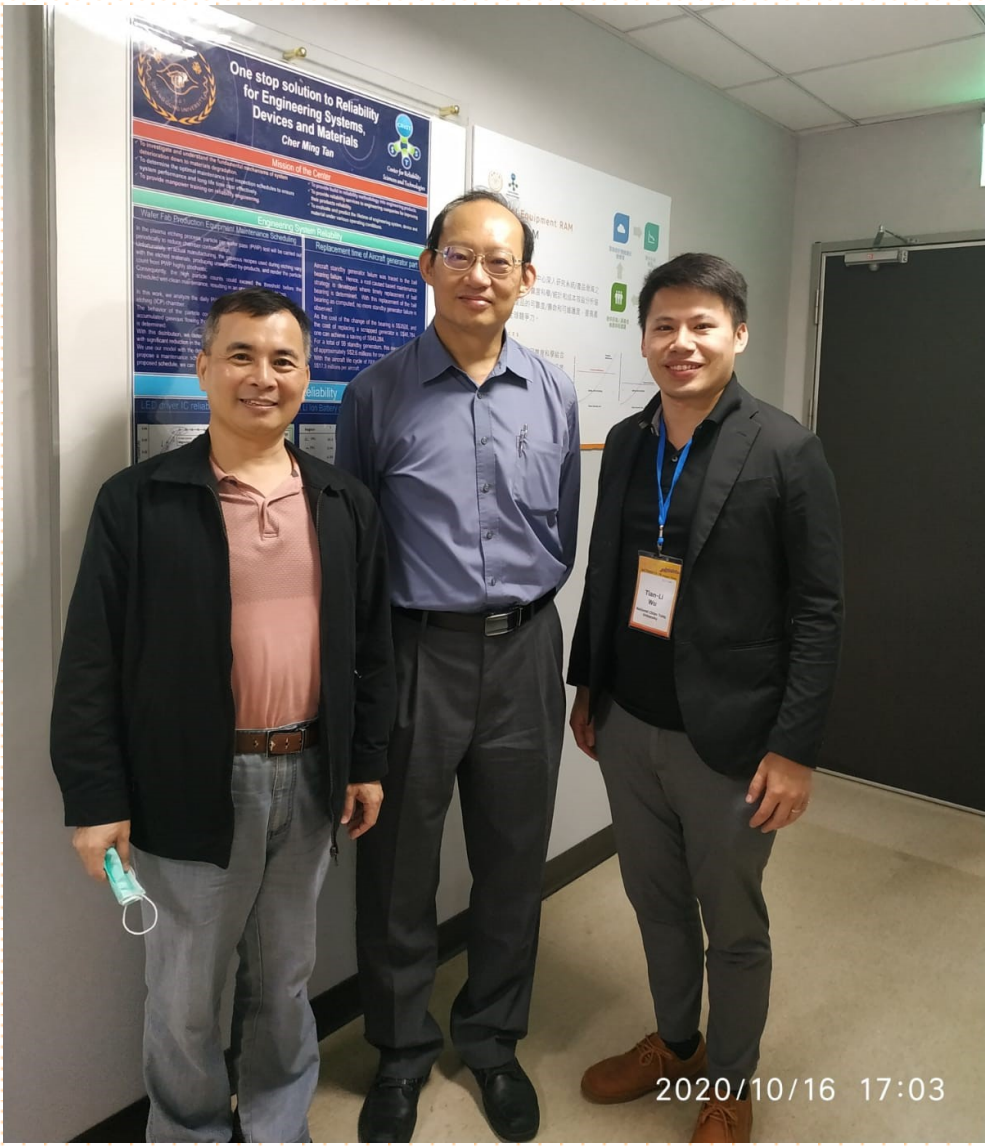
The International College of Semiconductor Technology (ICST) was founded as the first of its kind in 2015 to nurture cross-disciplinary talents with global mobility for the semiconductor industry. ICST is nurtured as per the guidance of Taiwan government and industrial elites, along with teaching excellence and research capability from college of electrical and computer science as foundation. Building on the basis of electrical engineering, material science, mechanical engineering, the curriculum is spread over college of electronic engineering, college of engineering (department of material science and mechanical engineering) and college of science (department of electro-physics and applied chemistry). The vertical cross-disciplinary professions combined through colleges comes together in ICST to nourish international industrial elites in the semiconductor field.

Prof Cher Ming Tan delivers a talk on "Evaluation of Integrated circuits reliability" to the esteemed professors along with students of ICST which will motivate them to take up this challenge.

Integrated circuit (IC) reliability is of increasing concern in present-day IC technology where the interconnect failures significantly increases the failure rate for ICs with decreasing interconnect dimension and increasing number of interconnect levels. Electromigration (EM) of interconnects has now become the dominant failure mechanism that determines the circuit reliability. This brief addresses the readers to the necessity of 3D real circuit modelling in order to evaluate the EM of interconnect system in ICs, and how they can create such models for their own applications. A 3-dimensional (3D) electro-thermo-structural model as opposed to the conventional current density based 2-dimensional (2D) models is presented at circuit-layout level.

Prof Wen-Kuan Yeh (Director General, Taiwan Semiconductor Research Institute (TSRI), Taiwan) visits CReST

The Taiwan Semiconductor Research Institute (TSRI) under the National Applied Research Laboratories (NARLabs) is a consolidation of the National Chip Implementation Center (CIC) and National Nano Device Laboratories (NDL). An integrated research environment for related fields of study in Taiwan is urgently required to enhance the overall cultivation of quality talents in response to the introduction of the 3-nm node; rapid development of new applications (e.g., artificial intelligence, quantum computers, next-gen magnetic random access memory, high-speed computers, and 5G network); and challenges posed by countries including European countries, the United States, Japan, and South Korea. It is great honour for Prof Yeh, Director General of TSRI, Acting Vice President of NARLabs (on the left side of Prof Tan) to visit CReST on 16th Oct 2020. On the right side of Prof Tan is Prof Wu from NCTU.



Prof Hao-Chung Kuo, NCTU, Taiwan visited CReST

It was a great honor for CReST to invite Prof H C Kuo to CReST on 16th Oct, 2020. HAO-CHUNG KUO (Fellow, IEEE) received the B.S. degree in physics from National Taiwan University, Taipei, Taiwan, the M.S. degree in electrical and computer engineering from Rutgers University, New Brunswick, NJ, USA, in 1995, and the Ph.D. degree from the University of Illinois at Urbana–Champaign, Urbana, IL, USA, in 1999. He has an extensive professional career both in academic research and industrial research institutions, which include a Research Assistant at Lucent Technologies and Bell Laboratories, from 1993 to 1995, and a Senior Research and Development Engineer of the Fiber-Optics Division, Agilent Technologies, from 1999 to 2001, and LuxNet Corporation, from 2001 to 2002. Since October 2002, he has been a Faculty Member with the Institute of Electro-Optical Engineering, National Chiao Tung University (NCTU), Hsinchu, Taiwan. He is currently the Associate Dean of the Office of International Affairs, NCTU. He has authored or coauthored 300 international journal articles and two invited book chapters, and holds six granted and 12 pending patents. His current research interests include semiconductor lasers, VCSELs, blue and UV LED lasers, quantum-confined optoelectronic structures, optoelectronic materials, and solar cells. He was elected as an OSA Fellow and the SPIE Fellow in 2012. He was a recipient of the Ta-YouWu Young Scholar Award from the National Science Council Taiwan in 2007 and the Young Photonics Researcher Award from the OSA/SPIE Taipei Chapter in 2007. He is an Associate Editor of the IEEE/OSA JOURNAL OF LIGHTWAVE TECHNOLOGY and was a Guest Editor of the of the Special Issue on Solid-State Lighting of the IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS in 2009.

Statistic Professors meet in CReST, 13th Nov, 2020

A group of Professors from various Taiwan Universities who are working on reliability statistics visits CReST to seek for collaboration with Prof Tan on reliability Science. The list of professors is as follows:

Department of Mathematics, National Cheng Kung University	Yufen Huang	Professor
Department of Statistics, National Cheng Kung University	Shuen-Lin Jeng	Associate Professor
Department of Statistics, National Cheng Kung University	Hsing-Ming Chang	Assistant Professor
Department of Mathematics, Tamkang University	Chih-Chun, Tsai	Associate Professor
Institute of Statistical Science, Academia Sinica	Chien-Yu Peng	Associate researcher
Institute of Statistical Science, Academia Sinica	Hsueh Fang Ai	Postdoctoral fellow
Department of Statistics and Informatics Science, Providence University	Ming-Yung Lee	Associate Professor
Department of Mathematics, National Chung Cheng University	Yi-Fu Wang	Assistant professor
Graduate Institute of Statistics, National Central University	Yi-Shian Dong	PhD student
Institute of Statistics, National Tsing Hua University	Hung-Ping, Tung	PhD student

Fault tree analysis (FTA) hands on training in MOXA Inc., 17th Nov, 2020

Prof Cher Ming Tan had given a detailed lecture on FTA and its effectiveness to explore the causes of system level failures. After the lecture, a hands-on training session was organized where Prof Tan teaches the company employees how to construct FTA for a complex real time problem.

Patents

CReST Lab have filed 3 new patents for their technology which are stated below.

1. The protein measurement apparatus and operation method thereof

   The invention is to provide a protein measurement apparatus and operation method thereof, including power supply, electromagnetic-wave generator, electromagnetic-wave detection circuit, micro-controller and display, and method thereof.

2. Gallium nitride transimpedance amplifier

   The present invention is a gallium nitride transimpedance amplifier, as an essential electronic circuit in the proton beam therapy. Because gallium nitride withstands the radiation generated during the proton beam therapy, it has high reliability and increases the reliability of the overall system.

3. A method for measuring the health and residual service life of lithium-ion batteries

   The invention is a method for measuring the health and residual service life of lithium-ion batteries, and is suitable for lithium-ion batteries under different operating conditions, including different ambient temperatures and different discharge rates. The health and remaining life of lithium-ion batteries is predicted correctly and in real-time by the invention.

Journal papers

1. Venkateswarlu, S., Lin, Y. D., **Lee, K. M**., Liau, K. L., & Tao, Y. T. (2020). Thiophene-Fused Butterfly-Shaped Polycyclic Arenes with a Diphenanthro [9, 10-b: 9′, 10′-d] thiophene Core for **Abstract:** Highly Efficient and Stable Perovskite Solar Cells. *ACS Applied Materials & Interfaces*.

   Two polycyclic heteroarene derivatives, namely, **V-1** and **V-2**, with a diphenanthro[9,10-*b*:9′,10′-d]thiophene (DPT) core tethered with two diphenylaminophenyl or diphenylamino groups were first synthesized and used as hole-transporting materials (HTMs) in perovskite solar cell (PSC) fabrication. The novel HTMs exhibit appropriate energy-level alignment with the perovskite so as to ensure efficient hole transfer from the perovskite to HTMs. **V-2** with the diphenylamino substituent on DPT exhibited impressive photovoltaic performance with a power conversion efficiency of 19.32%, which was higher than that of **V-1** (18.60%) and the benchmark 2,2′,7,7′-tetrakis-(*N*,*N*-di-*p*-methoxyphenyl-amine)-9,9′-spirobifluorene (spiro-OMeTAD) (17.99%), presumably because of a better hole extraction, higher hole mobility, and excellent film-forming ability, which were supported by steady-state photoluminescence (PL), time-resolved PL, the hole mobility experiment, scanning electron microscopy, and atomic force microscopy measurements. Meanwhile, **V-2**-based PSCs exhibited better long-term durability than that with **V-1** and the state-of-the-art spiro-OMeTAD, which is ascribable to the excellent surface morphology and hydrophobicity of the film. This systematic study suggests that DPT-based molecules are good potential candidates as HTMs for achieving high-performance PSCs.

2. Wu, M. C., Lin, Y. T., Chen, S. H., Jao, M. H., Chang, Y. H., **Lee, K. M**., ... & Su, W. F. (2020). Achieving High-Performance Perovskite Photovoltaic by Morphology Engineering of Low-Temperature Processed Zn-Doped TiO2 Electron Transport Layer. *Small*, *16*(41), 2002201.

   Abstract: Perovskite solar cells (PSCs) have become one of the most promising renewable energy converting devices. However, in order to reach a sufficiently high power conversion efficiency (PCE), the PSCs typically require a high-temperature sintering process to prepare mesostructured TiO_2 as an efficient electron transport layer (ETL), which prohibits the PSCs from commercialization in the future. This work investigates a low-temperature synthesis of TiO_2 nanocrystals and introduces a two-fluid spray coating process to produce a nanostructured ETL for the following deposition of perovskite layer. The temperature during the whole deposition process can be maintained under 150 °C. Compared to the typical planar TiO_2 layer, the perovskite layer fabricated on a nanostructured TiO_2 layer shows uniform compactness, preferred orientation, and high crystallinity, leading to reproducible and promising device

performance. The detail mechanisms are revealed by the contact angle test, morphology characterization, grazing incident wide angle X-Ray scattering measurement, and space charge limited currents analysis. Finally, optimized device performance can be achieved through adequate Zn doping in the TiO_2 layer, demonstrating an average PCE of 19.87% with champion PCE of 21.36%. The efficiency can maintain over 80% of its original value after 3000 h storage in ambient atmosphere. This study suggests a promising approach to offer high-efficiency PSCs using the low-temperature process.

3. **Chiu, H. C**., Liu, C. H., Kao, H. L., Wang, H. C., Huang, C. R., Chiu, C. W., ... & Chang, K. J. (2020). Low-Mg out-diffusion of a normally off p-GaN gate high-electron-mobility transistor by using the laser activation technique. *Materials Science in Semiconductor Processing*, *117*, 105166.

   Abstract: A low- Magnesium (Mg) out-diffusion normally off p-GaN gated AlGaN/GaN high-electron-mobility transistor (HEMT) was developed using a low-temperature laser activation technique. Conventionally, during the actual p-GaN layer activation procedure, Mg out-diffuses into the AlGaN barrier and GaN channel at high temperatures. In addition, the Al of the AlGaN barrier layer is injected into GaN to generate alloy scattering and to suppress current density. In this study, the GaN doped Mg layer (Mg:GaN)was activated using short-wavelength Nd:YAG pulse laser annealing, and a conventional thermal activation device was processed for comparison. The results demonstrated that the laser activation technique in p-GaN HEMT suppressed the Mg out-diffusion-induced leakage current and trapping effect and enhanced the current density and breakdown voltage. Therefore, using this novel technique, a high and active Mg concentration and a favorable doping confinement can be obtained in the p-GaN layer to realize a stable enhancement-mode operation.
4. Jao, M. H., Chan, S. H., **Wu, M. C**., & Lai, C. S. (2020). Element Code from Pseudopotential as Efficient Descriptors for a Machine Learning Model to Explore Potential Lead-Free Halide Perovskites. *The Journal of Physical Chemistry Letters*, *11*, 8914-8921.

   Abstract: The rapid development of machine learning has proven its potential in material science. To acquire an accurate and promising result, the choice of descriptor plays an essential role in dictating the model performance. In this work, we introduce a set of novel descriptors, Element Code, which is generated from pseudopotential. Using a variational autoencoder to perform unsupervised learning, the produced Element Code is verified to contain representative information on elements. Attributed to the successful extraction of information from pseudopotential, Element Code can serve as the primary descriptor for the machine learning model. We construct a model using Element Code as the sole descriptor to predict the bandgap of a lead-free double halide perovskite, and an accuracy of 0.951 and mean absolute error of

0.266 eV are achieved. We believe our work can offer insights into selecting lead-free halide perovskites and establish a paradigm of exploring new materials.

5. **Kao, H. L**., Cho, C. L., Chang, L. C., Chen, C. B., Chung, W. H., & Tsai, Y. C. (2020). A Fully Inkjet-Printed Strain Sensor Based on Carbon Nanotubes. *Coatings*, *10*(8), 792.

   Abstract: A fully inkjet-printed strain sensor based on carbon nanotubes (CNTs) was fabricated in this study for microstrain and microcrack detection. Carbon nanotubes and silver films were used as the sensing layer and conductive layer, respectively. Inkjet-printed CNTs easily undergo agglomeration due to van der Waals forces between CNTs, resulting in uneven films. The uniformity of CNT film affects the electrical and mechanical properties. Multi-pass printing and pattern rotation provided precise quantities of sensing materials, enabling the realization of uniform CNT films and stable resistance. Three strain sensors printed eight-layer CNT film by unidirectional printing, rotated by 180° and 90° were compared. The low density on one side of eight-layer CNT film by unidirectional printing results in more disconnection and poor connectivity with the silver film, thereby, significantly increasing the resistance. For 180° rotation eight-layer strain sensors, lower sensitivity and smaller measured range were found because strain was applied to the uneven CNT film resulting in non-uniform strain distribution. Lower resistance and better strain sensitivity was obtained for eight-layer strain sensor with 90° rotation because of uniform film. Given the uniform surface morphology and saturated sheet resistance of the 20-layer CNT film, the strain performance of the 20-layer CNT strain sensor was also examined. Excluding the permanent destruction of the first strain, 0.76% and 1.05% responses were obtained for the 8- and 20-layer strain sensors under strain between 0% and 3128 με, respectively, which demonstrates the high reproducibility and recoverability of the sensor. The gauge factor (GF) of 20-layer strain sensor was found to be 2.77 under strain from 71 to 3128 με, which is higher than eight-layer strain sensor (GF = 1.93) due to the uniform surface morphology and stable resistance. The strain sensors exhibited a highly linear and reversible behavior under strain of 71 to 3128 με, so that the microstrain level could be clearly distinguished. The technology of the fully inkjet-printed CNT-based microstrain sensor provides high reproducibility, stability, and rapid hardness detection.

6. Jin, H., Chien, C. Y., Li, E. S., **Li, C. Y**., & Chin, K. S. (2020). Design of wideband CPW bandpass filters using phase comparison method and oblique air bridges. *Journal of Electromagnetic Waves and Applications*, *34*(16), 2079-2093.

   Abstract: This work presents two wideband coplanar-waveguide bandpass filters using open-circuited stubs (Design 1) and short-circuited stubs (Design 2), respectively. The electrical lengths of stubs were accurately determined by a phase comparison method. In Design 1, a spurious resonance was found at the high band edge of the passband. The problem was solved by introducing oblique air bridges to ruin the undesired resonance path for the suppression of the spurious resonance. Design 1 achieves bandwidth of 38.1% and low insertion loss of 0.7

dB. Another CPW filter, Design 2, was constructed with short-circuited stubs for compact size, which can achieve a very wide bandwidth of 70.8% and insertion loss of 0.9 dB.

7. Sze Li Harry Lim, Duong Pham, Hyunseok park, Preetpal Singh, **Cher Ming Tan** and Nagarajan Raghavan "Assessing Multi-Output Gaussian Process Regression for Modeling of Non-Monotonic Degradation Trends of Light Emitting Diodes in Storage", Microelectronics Reliability, accepted 2020.

   Abstract: Light emitting diodes (LEDs) exhibit different degradation physics under different environmental conditions of humidity, temperature and electrical loading, leading to complex degradation models – a common behavior with several other electronic devices. While most researches focus on degradation under active use, degradation models in storage are often not well established. Large fleet storage of components, in the absence of a degradation model, requires laborious continuous inspections despite the preservation under similar environmental conditions. Leveraging on training data from other LEDs within the fleet, stored under similar conditions, this study investigates the utility of multi-output Gaussian Process Regression (MOGPR) with limited test data, to model the complex degradation curve of LEDs in storage, as a proxy for electronic components. We further explore the choice of detrending means and training data sets, to enhance the prediction of degradation curves and residual storage life (RSL). Additional training data sets are observed to give diminishing returns for prediction accuracy.

8. **Tan, C. M.**, Singh, P., & Chen, C. (2020). Accurate Real Time On-Line Estimation of State-of-Health and Remaining Useful Life of Li ion Batteries. *Applied Sciences*, *10*(21), 7836.

   Abstract: Inaccurate state-of-health (SoH) estimation of battery can lead to over-discharge as the actual depth of discharge will be deeper, or a more-than-necessary number of charges as the calculated SoC will be underestimated, depending on whether the inaccuracy in the maximum stored charge is over or under estimated. Both can lead to increased degradation of a battery. Inaccurate SoH can also lead to the continuous use of battery below 80% actual SoH that could lead to catastrophic failures. Therefore, an accurate and rapid on-line SoH estimation method for lithium ion batteries, under different operating conditions such as varying ambient temperatures and discharge rates, is important. This work develops a method for this purpose, and the method combines the electrochemistry-based electrical model and semi-empirical capacity fading model on a discharge curve of a lithium-ion battery for the estimation of its maximum stored charge capacity, and thus its state of health. The method developed produces a close form that relates SoH with the number of charge-discharge cycles as well as operating temperatures and currents, and its inverse application allows us to estimate the remaining useful life of lithium ion batteries (LiB) for a given SoH threshold level. The estimation time is less than 5 s as the combined model is a closed-form model, and hence it is suitable for real time and on-line applications.

9. Loganathan MK, Mishra B, **Tan CM**, Kongsvik T, Rai RN. Multi-Criteria decision making (MCDM) for the selection of Li-Ion batteries used in electric vehicles (EVs). Materials Today: Proceedings. 2020 Aug 10.

   Abstract: Battery-operated electrical vehicles are gradually replacing combustion engine-based vehicles. However, this is happening at a very slow pace as the development of better performing batteries are still underway. Rapid charging, long range driving, longest battery life and low cost are the stringent requirements to be met in developing battery technology. The most widely used Lithium-ion (Li-ion) batteries have managed to deliver a reasonable performance, but with high cost and shorter life span. The materials used for electrodes play a vital role in deciding the battery performance, cost, and life. The Li-ion batteries, which are currently in use, are classified based on the material used in making electrodes. The practical issue is that the EV manufacturers do find it difficult to select a best Li-ion battery, in order to strike a trade-off between performance, cost, and life. In this paper, an MCDM based methodology for the selection of Li-ion batteries that are categories based on cathode/ anode material, is proposed. The method is useful for the EV OEMs (Original Equipment Manufacturers) in selection of the best battery, and to optimize the cost, and the performance of the EVs.

10. Wang, Q., Periasamy, K., Fu, Y., Chan, Y. T., **Tan, C. M.**, Bajalovic, N., ... & Loke, D. K. (2020). Analytical modeling electrical conduction in resistive-switching memory through current-limiting-friendly combination frameworks. *AIP Advances*, *10*(8), 085117.

    Abstract: Resistive-switching memory (RSM) is one of the most promising candidates for next-generation edge computing devices due to its excellent device performance. Currently, a number of experimental and modeling studies have been reported to understand the conduction behaviors. However, a complete physical picture that can describe the conduction behavior is still missing. Here, we present a conduction model that not only fully accounts for the rich conduction behaviors of RSM devices by harnessing a combination of electronic and thermal considerations via electron mobility and trap-depth and with excellent accuracy but also provides critical insight for continued design, optimization, and application. A physical model that is able to describe both the conduction and switching behaviors using only a single set of expressions is achieved. The proposed model reveals the role of temperature, mobility of electrons, and depth of traps, and allows accurate prediction of various set and reset processes obtained by an entirely new set of general current-limiting parameters.

University social responsibility program, REDeX

Prof Cher Ming Tan is also continuously involved in social service programs. He was recently a part of the social service program where university teachers visited old age people living in remote mountains and how teachers can provide their services via technology to improve the living of those people.

All professors met patients in those places and discuss their problems and the facilities provided for their welfare.

CReST Lab Celebrates Annual Diwali celebration

All students, faculty, and staff gathered in CReST Lab conference room to celebrate the annual Diwali festival tree lighting on Thursday, 25th November 2020.

Prof Cher Ming Tan, Director of the Center said that it was a wonderful opportunity to come together as a faculty, staff, and students, to celebrate this Diwali season. Dr Sandeep also shared the meaning behind Diwali celebration as members of the center belong to different religions and cultures.