

產品可靠性暨系統安全研發中心 CENTRE FOR ADVANCES IN RELIABILITY AND SAFETY

## JANUARY 2021 ISSUE CAIRS NEWSLE

香港電子業是香港最大的產

品出口創匯行業,根據香港

政府及貿發局資料顯示,香

港電子業佔香港2019年總出

口68.3%,截至2020年1月

至5月總出口總值超過一萬億

港元。電子與日常生活息息

相關,產品可靠及系統安全

基本上是關乎於生活的每一

環。成立超過四十年的香港

電子業商會(HKEIA)一向

致力服務香港電子業,協助

業界發展應用科技及開拓業

務,所以HKEIA去年支持香

港理工大學發展香港成為環



香港電子業商會會長吳自豪博士 Dr CH Ng, Chairman of the Hong Kong Electronic Industries Association

球科研合作中心,成立了「產品可靠性暨系統安全研發中心」 (CAiRS),與業界攜手研發產品可靠性和系統的安全。

Hong Kong's electronics industry is the territory's largest merchandise export earner, accounting for 68.3% of total exports in 2019. According to the Census and Statistics Department and HKTDC, the value of total export is over one trillion Hong Kong dollars from January to May in 2020. Product reliability and system safety are fundamentally related and important to all electronics products and our daily life. With aims to serve Hong Kong electronics industry and promote applied technology, the Hong Kong Electronics Industry Association (HKEIA) in the past 40 years supports the Hong Kong Polytechnic University to establish the Centre for Advances in Reliability and Safety (CAiRS) last year to develop Hong Kong as the hub for global research collaboration with industries in Hong Kong.

香港電子業總會(HKEIC)致力 推動業界應用科技,支持研發 成果落地。我們了解到本港業 界對產品可靠及系統安全是非 常重視,所以去年支持香港理 工大學發展成為環球科研合作 中心,成立了「產品可靠性暨 系統安全研發中心」(CAiRS), 希望能夠與業界攜手共同協作 研發產品可靠性和系統安全的 產品及方案。

Hong Kong Electronics Industry Council (HKEIC) commits in promoting



香港電子業總會主席莊子雄先生 Mr Steve Chuang, Chairman of Hong Kong Electronics Industry Council

application of cutting-edge technologies and their commercialisation. We recognize the importance of product reliability and system safety for all industries. Therefore, we support the establishment of the Centre for Advances in Reliability and Safety (CAiRS), initiated by the Hong Kong Polytechnic University last year. We hope CAIRS will work and collaborate with the industry to provide innovative solutions for product reliability and system safety.

產品可靠性暨 系統安全研發中心(CAiRS) 總監及執行董事 容錦泉教授 Prof Winco Yung, Centre Director of CAiRS



要打造香港製造成為全球享負盛名的國際品牌,產品可靠性及系統安全是關鍵焦點,因此「產品可靠性暨系統安全研發中心」(CAiRS)的成立旨 為業界進一步提升產品可靠性及系統安全水平作準備,為香港工業打造國際品牌。

我們利用人工智能、大數據及深度學習模型等先進技術與業界協作,共同研發可靠性和安全性的項目。我們擁有世界知名及高水平的專業團隊, 研究範圍適用於香港的不同行業包括:公共服務、交通運輸、電子、關鍵性零部件、數據及軟件等所有重視可靠性及系統安全的行業。

The Centre for Advances in Reliability and Safety (CAiRS) is to make Hong Kong known and respected for high quality, reliable and safe products, systems and infrastructure. To do this, we will address the scientific and technological electronics reliability and safety challenges of national interest by advancing the symbioses between mathematics, engineering, computing, and data science; launch new interdisciplinary communities; and develop the future national workforce.

The mission of CAIRS is to link up academic and industrial counterparts to introduce and implement new artificial intelligence methods and deep learning techniques with reliability modelling, with the goal of improving the products reliability and systems safety of critical components and devices, products, systems and sub-system designed, commissioned and/or manufactured by Hong Kong companies and enterprises. Our research is readily applicable to different industries (e.g., Public Utilities, Transportation, Electronics Industries, Critical Parts & Components, Data and Software etc.) in Hong Kong with high potential Technology and Commercial impacts. The research would also serve as technology enabler to the development of Smart City in Hong Kong.

# RESEARCH FOCUS

#### DEVELOPMENT OF CANARIES FOR CATASTROPHIC FAILURE PREVENTION FOR BATTERIES

In the past, canaries provided an early warning of toxic gases for coal miners. In the event of such danger, the canaries would be killed prior to the miners, which gave them an early signal to evacuate from the hazard.



Figure 1. Canary in a coal mine<sup>[1]</sup>

**In today's engineering systems,** Fibre Bragg Grating (FBG) sensor are a potential "modern canary" in assessing the Remaining Useful Life (RUL) of the components to which they are attached. FBG sensors are formed from an optical fiber with a periodic variation in the refractive index of the fiber core. According to Bragg's law, a FBG sensor reflects only a fraction of wavelengths of light and transmits all the others when illuminated by a broadband light source (Figure 2). The reflected wavelength (also known as the Bragg wavelength) is dependent on the change of physical properties such as temperature, pressure, strain, etc. <sup>[2]</sup> Thus, by noting the shifts in wavelength, it is possible to deduce the corresponding change in physical properties.

## **RESEARCH FOCUS**



Figure 2. Principle of FBG sensor

FBG sensors are small in size and resistant to electromagnetic interference. These attributes allow them to monitor the physical properties and assess the health status of the components in many engineering systems, such as structural health monitoring applications. While they may be applied in many domains, one of CAiRS's main focuses is on electrochemical batteries (Figure 3), in which the chemical reactions happening inside the cells are difficult to directly observe.

- Blanca J., (2020). The canary in the mine. https://bigpondmoney.com.au/uncategorized/the-canary-in-the-mine/
- [2] Bonefacino J., ChengX., TseM. V. and Tam H., (2017). Recent Progress in Polymer Optical Fiber Light Sources and Fiber Bragg Gratings. IEEE Journal of Selected Topics in Quantum Electronics, 23(2), 252-262.



Figure 3. Different size of Batteries

The implantation of FBG sensors inside battery cells has enabled researchers to measure the internal strain, temperature, and pressure changes in a non-destructive manner <sup>[3], [4], [5]</sup>. Recently, Huang et al. (see Abstract below) successfully used FBG sensing signals to understand the electrochemical reactions within the cells to deduce the growth of solid electrolyte interface (SEI) within Na-ion cells <sup>[5]</sup>.



## **RESEARCH FOCUS**

#### Abstract :

## Operando decoding of chemical and thermal events in commercial Na(Li)-ion cells via optical sensors <sup>[5]</sup>

Abstract: Monitoring the dynamic chemical and thermal state of a cell during operation is crucial to making meaningful advancements in battery technology as safety and reliability cannot be compromised. Here we demonstrate the feasibility of incorporating optical fibre Bragg grating sensors into commercial 18650 cells. By adjusting fibre morphologies, wavelength changes associated with both temperature and pressure are decoupled with high accuracy, which allows tracking of chemical events such as solid electrolyte interphase formation and structural evolution. We also demonstrate how multiple sensors are used to determine the heat generated by the cell without resorting to microcalorimetry. Unlike with conventional isothermal calorimetry, the cell's heat capacity contribution is readily assessed, allowing for full parametrization of the thermal model. Collectively, these findings offer a scalable solution for screening electrolyte additives, rapidly identifying the best formation processes of commercial cells and designing battery thermal management systems with enhanced safety.

CAIRS is currently active in applying the above research to battery industry. By correlating the physical measurements with the parasitic chemical reactions and interfacial growth dynamics within battery cells, it opens up a new window for the industry to study the real-time internal electrochemical reactions in batteries. Subsequently, the findings can be applied to evaluate the state of health and make predictions on RUL. It is anticipated the research work would have a great impact and advancement in the safety and reliability in battery design.

- [3] Cheng, X., & Pecht, M. (2017). In situ stress measurement techniques on li-ion battery electrodes: A review. Energies, 10(5), 591.
- [4] Fortier, A., Tsao, M., Williard, N. D., Xing, Y., & Pecht, M. G. (2017). Preliminary study on integration of fiber optic Bragg grating sensors in Li-ion batteries and in situ strain and temperature monitoring of battery cells. Energies, 10(7), 838.
- [5] Huang, J., Blanquer, L. A., Bonefacino, J., Logan, E. R., Dalla Corte, D. A., Delacourt, C., Gallant B. M. Boles, S. T., Dahn J. R., Tam, H. Y. & Tarascon, J. M. (2020). Operando decoding of chemical and thermal events in commercial Na (Li)-ion cells via optical sensors. Nature Energy, 1-10.



### 產品可靠性暨系統安全研發中心 到訪多家本地企業 CENTRE FOR ADVANCES IN RELIABILITY AND SAFETY (CAIRS) VISITS TO HONG KONG INDUSTRY

為了更了解香港不同企業對產品可靠 性及系統安全的發展及加強溝通,產 品可靠性暨系統安全研發中心(CAiRS) 到訪多家不同本地企業,進行討論及 研究協作事項,希望可以為業界進一 步提升產品可靠性及系統安全水平作 準備。

In order to enhance and strengthen products reliability and systems safety for the Hong Kong Industry, Centre for Advances in Reliability and Safety (CAiRS) visited to local industry to discuss and explore research projects for further collaboration.



到訪德國寶(香港)有限公司 Visit to German Pool (Hong Kong) Limited



到訪保力集團 Visit to ProVista Group



到訪香港電燈有限公司 Visit to The Hongkong Electric Company, Limited (HK Electric)



到訪港機集團 Visit to HAECO Group



到訪金山工業(集團)有限公司 Visit to Gold Peak Industries (Holdings) Limited



到訪金柏科技有限公司 Visit to Compass Technology Company Limited



到訪匯達交通服務有限公司 Visit to Bravo Transport Services Limited





#### 『產品可靠及系統安全』業界面對的挑戰 與 機遇 網上研討會 WEBINAR ON "HOW PRODUCTS RELIABILITY AND SYSTEMS SAFETY HELP LOCAL INDUSTRY TO ADDRESS MARKET NEEDS AND PROMOTE BUSINESS OPPORTUNITIES"

由產品可靠性暨系統安全研發中心主辦、 香港電子業商會、香港電子業總會及香港 科技園支持主辦首場『產品可靠及系統安 全』業界面對的挑戰與機遇網上研討會, 於 2020 年 11 月 26 日下午假「產品可靠 性暨系統安全研發中心」舉行。

是次網上研討會邀請到著名學者及業界代 表出席,包括主講嘉賓 - "產品可靠性暨系 統安全研發中心" (CAiRS)總監及執行董 事 - 容錦泉教授、金山工業(集團)有限公 司執行副總裁 - 李耀祥博士及香港理工大 學副教授 – Dr. Steven Boles。各位嘉賓 從不同角度分享個人見解,引領大家探討 及分析產品可靠及系統安全如何協助業界 面對挑戰及掌握機遇。

主辦機構CAiRS總監及執行董事 - 容錦泉教 授除了介紹本中心,也分享了研究目標、合 作機構和這些研究對行業的益處以及重點 研究的領域。金山工業(集團)有限公司執 行副總裁 - 李耀祥博士指出其公司與「產 品可靠性暨系統安全研發中心」合作,一 方面可提升產品質素,包括是可靠性及系 統安全等;另一方面,能提升業界在國 際市場上建立品牌的競爭力。此外, Dr. Boles 以電池為分享主題,講述電池 存儲設備,電化學存儲(電池),鋰電池 故障機理和異常檢測。

想了解更多關於CAiRS的最新消息及活動 資訊, 歡迎大家到CAiRS網站 www.cairs.hk或關注CAiRS臉書。 Organized by "Centre for Advances in Reliability and Safety" (CAiRS), supported by the Hong Kong Electronic Industries Association (HKEIA), Hong Kong Electronics Industry Council (HKEIC) and the Hong Kong Science & Technology Parks (HKSTP), Webinar on "How Products Reliability and Systems Safety help Local Industry to address market needs and promote business opportunities" was successfully completed on 26 Nov 2020.

In the Webinar, we have invited professional experts and renowned industrialist included Prof. Winco Yung, Centre Director of CAiRS, Dr. Brian Li, Executive Vice President of Gold Peak Industries (Holdings) Limited and Dr. Steven Boles, Associate Professor of The Hong Kong Polytechnic University to share their industrial and research experiences on Products Reliability and Systems Safety and how the industry needs can be addressed, and business opportunities can be promoted.

For more information and details of the webinar or upcoming activities, please visit our CAIRS website www.cairs.hk or follow our facebook #CAIRS.





(From left) Dr Steven Boles, Dr Brian Li and Prof Winco Yung share their industrial and research experiences on Products Reliability and Systems Safety in the Webinar





產品可靠性暨系統安全研發中心 CENTRE FOR ADVANCES IN RELIABILITY AND SAFETY

