PRESS RELEASE / RESEARCH – 24 AUGUST 2020

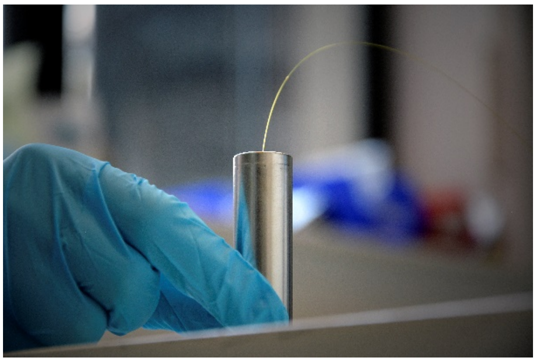
= = UNDER EMBARGO UNTIL 24 AUGUST 2020 - 17h00 (GMT+1) = =

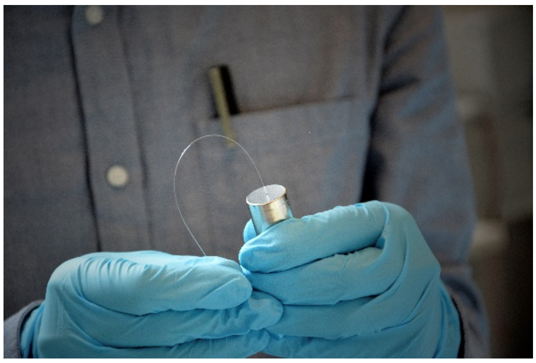
In situ *optical fibers and sensors for smart and more efficient batteries*

As people become more mobile in the 21st century, batteries are essential for a wide range of applications (portable devices, renewable energy storage, electric mobility…) that have become the heart of our interconnected society. Such an increasing societal dependence make battery reliability and performance immensely more important than ever before. Researchers and companies must find new solutions to ensure the safety and reliability of these storage systems by injecting new sensing and monitoring functionalities, but with costs and scalability that render them practical.

An international team (Collège de France, CNRS[1], The Hong Kong Polytechnic University, MIT, Dalhousie University and LRCS) has adopted a transdisciplinary approach that consists of incorporating optical fiber "Bragg" grating (FBG) sensors within 18650 format cells (a standard for commercial batteries). The innovation here is twofold: Firstly with the use of optimized internal structures in the fibers to obtain clear optical signals and secondly with advanced signal analysis to decode the thermal and chemical events taking place within the battery.

In the article published in Nature Energy, the team demonstrates how the information captured from the sensors (wavelength shift) allows for real-time assessment and on-demand analysis of thermal and chemical events (e.g. heat generation and phase transformations) inherent to various battery chemistries.





Experimental setup consisting of an 18650 cell and optical fiber "Bragg" grating (FBG) sensors.

[1] French labs involved in the research: Laboratory of Chemistry of Materials and Energy / Laboratoire de Chimie du solide et de l'énergie (CNRS/Collège de France/Sorbonne Université), Laboratoire de réactivité et chimie des solides (CNRS/Université Picardie Jules Verne), within the French initiative on Electrochemical Energy Storage (RS2E) / coordinated by CNRS.

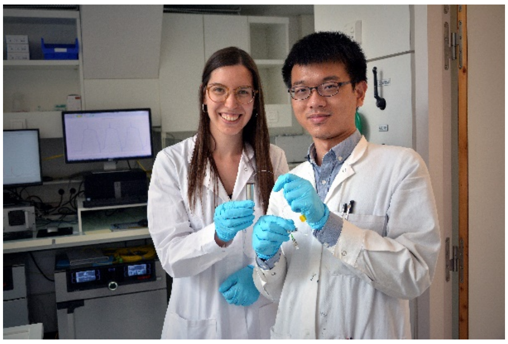
"*Currently, commercialized battery 'packs' are equipped with temperature sensors positioned at the module level (set of cells) and not directly at each cell. This configuration leads to very conservative and ultimately inefficient battery management systems (BMS), since the actual sensors do not inform us what is really happening within the batteries, especially in terms of thermal/chemical events,*" explains Jean-Marie Tarascon, Professor at the Collège de France and senior author of the study.

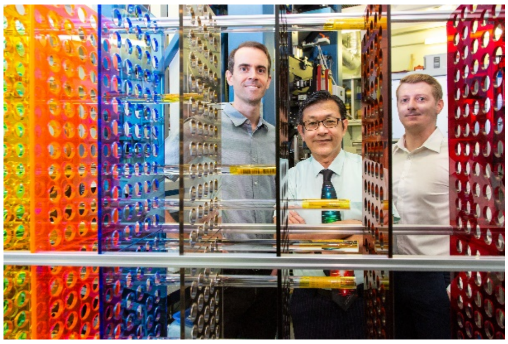
"*By optimizing the positions of three optical sensors, it is possible to obtain not only the internal and surface temperatures, but it further enables us directly calculate with extreme accuracy the battery heat generation and transfers; critical parameters for the design of more efficient cooling/heating systems.*" Consequently, new BMS systems optimized with optical fibers might bring the world one step closer towards the common goal of reaching the theoretical limits of existing technologies.

Unravelling secrets pertaining to the battery private life

The optical sensor inserted within the cell works as a wavelength-selective mirror where the information collected is a reflected wavelength peak. The position of this peak will change in real time due to temperature and/or pressure variations in the vicinity of the sensor. In the study, the researchers demonstrate a novel approach to decouple the temperature and pressure signals by combining a microstructured optical fiber and a normal optical fiber.

"*What is really new is that we use a specific arrangement of three fibers which allows us to quantify the thermodynamic parameters of the battery. The information obtained with our optical calorimetry method are ideal for the optimizing many aspects of the battery, including both active materials and packaging*", says Dr. Jiaqiang Huang, post-doctoral fellow at the Collège de France and first author of the article. "*Moreover, we are now associating these observed changes to specific "chemical" events happening within the battery so that they no longer need to be treated as black boxes*", adds Laura Albero Blanquer, doctorate at the Collège de France and second author.





Picture on the left: Laura Albero Blanquer (left) and Dr. Jiaqiang Huang (right)
Photo on the right: Dr. Steven T. Boles (left), Pr. Hwa-Yaw Tam (center) et Dr. Julien Bonefacino (right)

Particularly, the chemical information retrieved by the researchers allows them to better understand important parasitic reactions affecting the functioning of the battery, namely the formation and composition of the solid electrolyte interphase (SEI). A proper understanding of the SEI formation (in other words, the control of the electrode/electrolyte interphase growth dynamics) is a crucial and expensive step in cell manufacturing because these interfaces ultimately shape the cell's lifetime. The protocols to form them are closely guarded trade secrets among manufacturers. As such, mastering the formation of these interphases is a critical asset for the battery industry.

"*The technical and scientific advances highlighted by this work have been made possible by the convergence of battery science and optical fiber sensor engineering*", says Hwa-Yaw Tam, Chair Professor at the Hong Kong Polytechnic University and specialist in optical fiber sensors. "*The superb chemical stability and ease of scaling/expansion make FBGs ideal for deployment in new applications in the energy industry*."

Indeed, the future is very bright for extending this approach as the team has already started to look to other energy storage devices (such as alkaline batteries, fuel cells, and supercapacitors), as well as other important applications (such as catalysis and water splitting for the production of hydrogen).

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Jean-Marie Tarascon is a Professor at Collège de France. He holds the Chair Chemistry of Materials and Energy and serves as a director to the Laboratory of Chemistry of Materials and Energy / Laboratoire de Chimie du solide et de l'énergie (CNRS/Collège de France/Sorbonne Université) and the French initiative on Electrochemical Energy Storage. He received the CNRS Innovation Medal in 2017.
Crédit : Collège de France / Patrick Imbert

References of the article:

Operando decoding of chemical and thermal events in commercial Na(Li)-ion cells via optical sensors
Jiaqiang Huang, Laura Albero Blanquer, Julien Bonefacino, Eric R. Logan, Daniel Alves Dalla Corte, Charles Delacourt, Betar M. Gallant, Steven T. Boles, Jeff R. Dahn, Hwa-Yaw Tam, jean-Marie Tarascon. *Nature Energy 2020*

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Collège de France – resources and links:

- Pr. Jean-Marie Tarascon – Chair Chemistry of Materials and Energy (access biography and online teachings since 2010) : https://www.college-de-france.fr/site/jean-marie-tarascon

- Pr. Jean-Marie Tarascon –2020-2021 Teaching – Diagnostic techniques and self-repair for the most efficient batteries (starting 2 February 2021) : https://www.college-de-france.fr/site/jean-marie-tarascon/course-2020-2021.htm

- Pr. Jean-Marie Tarascon - Chair Chemistry of Materials and Energy – Short videos (with subtitles) – Les courTs du Collège de France series:

-> Applied electrochemistry: different systems of batteries (2'10s) - https://youtu.be/McnXNn8eqUs
-> Applied electrochemistry: different systems of batteries (6'08s) - https://youtu.be/O1iYZNqNkJs

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