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Characterization of Li-ion battery internal short circuit caused failures using smart nails

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Mary Long

Proposal for 2022 Honors Capstone Research Summer Program

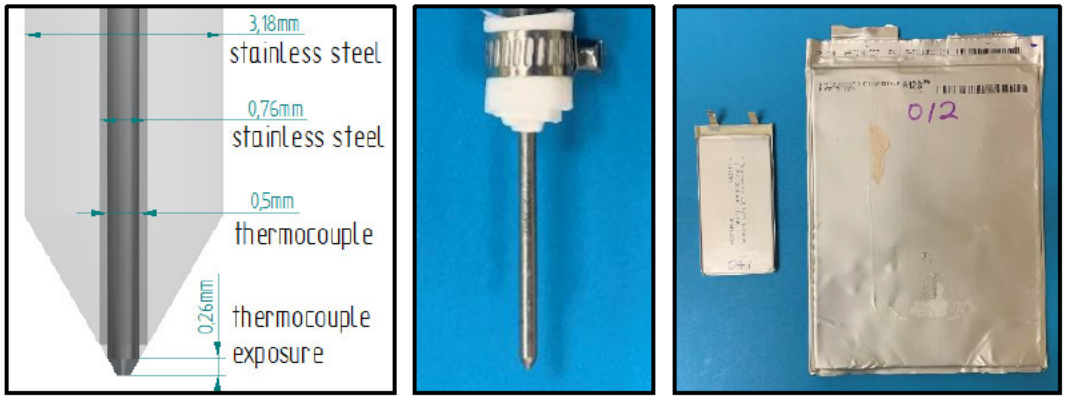
Characterization of Li-ion battery internal short circuit caused failures using smart nails

Student Applicant: Mary Long, Mechanical Engineering, Cumulative GPA: [redacted]
Mentor: Guangsheng Zhang, Assistant Professor, Mechanical and Aerospace Engineering

Project description:

The goal of this project is to investigate the effects of Li-ion cell capacity and nail penetration speed on internal short circuit (ISC) and thermal runaway behaviors, using a smart nail previously developed by the student applicant in their summer 2021 RCEU project. ISC can occur in Li-ion batteries through several kinds of abuse conditions, including fast charging at low temperatures, nail penetration, crushing, overcharging, etc. ISC could lead to thermal runaway, a dangerous condition that can cause fires or even explosions. Since Li-ion batteries are such a pervasive part of society and are so vulnerable to thermal runaway when subjected to ISC, it is vital to understand its mechanisms so that future batteries can be made safer and better.

Efforts in the previous RCEU project have been spent on designing and prototyping smart nails that can measure temperature at the ISC location and have symmetric nail tips while being strong enough to withstand repeated tests of large-format Li-ion cells. Figure 1(a) and Figure 1(b) show a schematic and picture of a smart nail developed in the previous RCEU project. The smart nail has been demonstrated on small-format (3-Ah) Li-ion battery cells as a proof of concept with interesting results obtained.



(a) (b) (c)

Figure 1. (a) Schematic of a smart nail developed in previous RCEU project; (b) Picture of a smart nail developed in previous RCEU project, (c) Picture of a small-format 3-Ah cell for electronics applications and a large-format 20-Ah cell for electric vehicle application.

In this proposed work, a smart nail will be applied to commercial Li-ion battery cells with capacities of 20 mAh, 3Ah and 20 Ah to investigate the effects of cell capacity on ISC behaviors. Figure 1 (c) shows pictures of a 3-Ah cell and 20-Ah cell to be tested. These cells are representative of Li-ion batteries used in electronics and electric vehicles. The smart nail used will be made of stainless steel and have a 3.2mm diameter so that its dimensions are similar to industry standard nails used in traditional nail penetration tests. In addition to testing several types of cells, the speed of penetration will be varied. Tests will be conducted at 0.1 mm/s, 1

mm/s and 10 mm/s. This experiment would allow for the study of the relationship between penetration speed and ISC temperature increase as well as the relationship between cell capacity and ISC.

This project is expected to be the first study about the effects of cell capacity and nail penetration speed on ISC behaviors using a smart nail for in-situ measurement of ISC temperature. It is expected to provide insights on ISC behaviors of Li-ion cells that could be not obtained by conventional nail penetration testing. The findings would be helpful for development of safer and better Li-ion batteries for various applications.

Organization hierarchy: The student applicant will work with the mentor (Dr. Zhang) and a PhD student (Siyi Liu). Weekly meetings will be held for discussion on the project progress.

Potential impacts:

For student: (1) obtaining hands-on experiences with battery research equipment; (2) being professionally trained in doing research and presenting research results.

For mentor : (1) cultivating a new project; (2) obtaining preliminary data for potential external funding which can be used to support this student and more undergraduate students in research.

Remote Plan:

In the event that face-to-face operations are prohibited by COVID-19, but graduate students or the PI are allowed to work in the lab, the remaining tests will be conducted by PhD student Siyi Liu or the PI, and the data will be sent to the student for processing. If all face-to-face operations are prohibited by COVID-19, the student will perform a detailed literature review, focusing on ISC caused failures, and design more advanced smart nails.

Project Timeline and Tasks:

Start Date	5/06/2022	End Date	8/1/2022	Duration	12 weeks
Weeks 1-2	Experimental setup				
Weeks 3-4	Initial experiments				
Weeks 5-6	Preliminary data analysis; New experiment design				
Weeks 7-8	New experiment setup				
Weeks 9-10	Refined experiments				
Week 11-12	Final data analysis; Preparing presentation and manuscript.				

Mentor's signature for approval of this proposal:

1/18/2022