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Quantitative Characterization of Lithium-ion Batteries under Abuse Conditions

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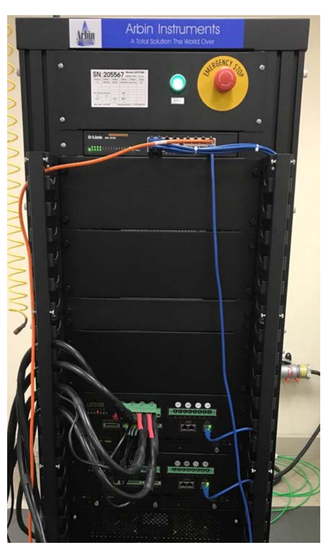
Introduction

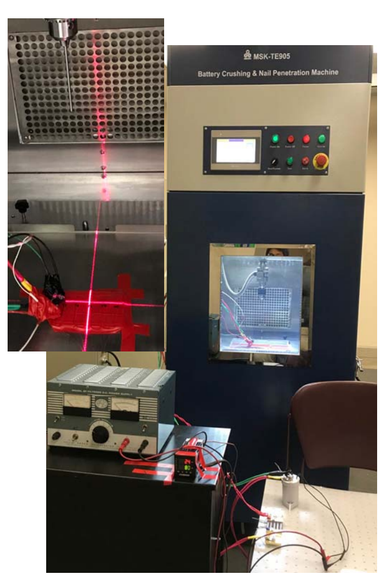
Lithium-ion (Li-ion) batteries are widely used in consumer electronics and increasingly used in electric vehicles. However, under abuse conditions such as short circuit or penetration, they could overheat or even catch fire. With many accidents reported in recent years, Li-ion battery safety has become a critical challenge [1,2]. The objective of this project is to address the challenge by understanding quantitatively the behaviors of Li-ion battery cells under abuse conditions, including external short circuit and internal short circuit caused by nail penetration. The behaviors under abuse conditions are compared with those under normal operations.

2.4 Ah Li-ion cell for test

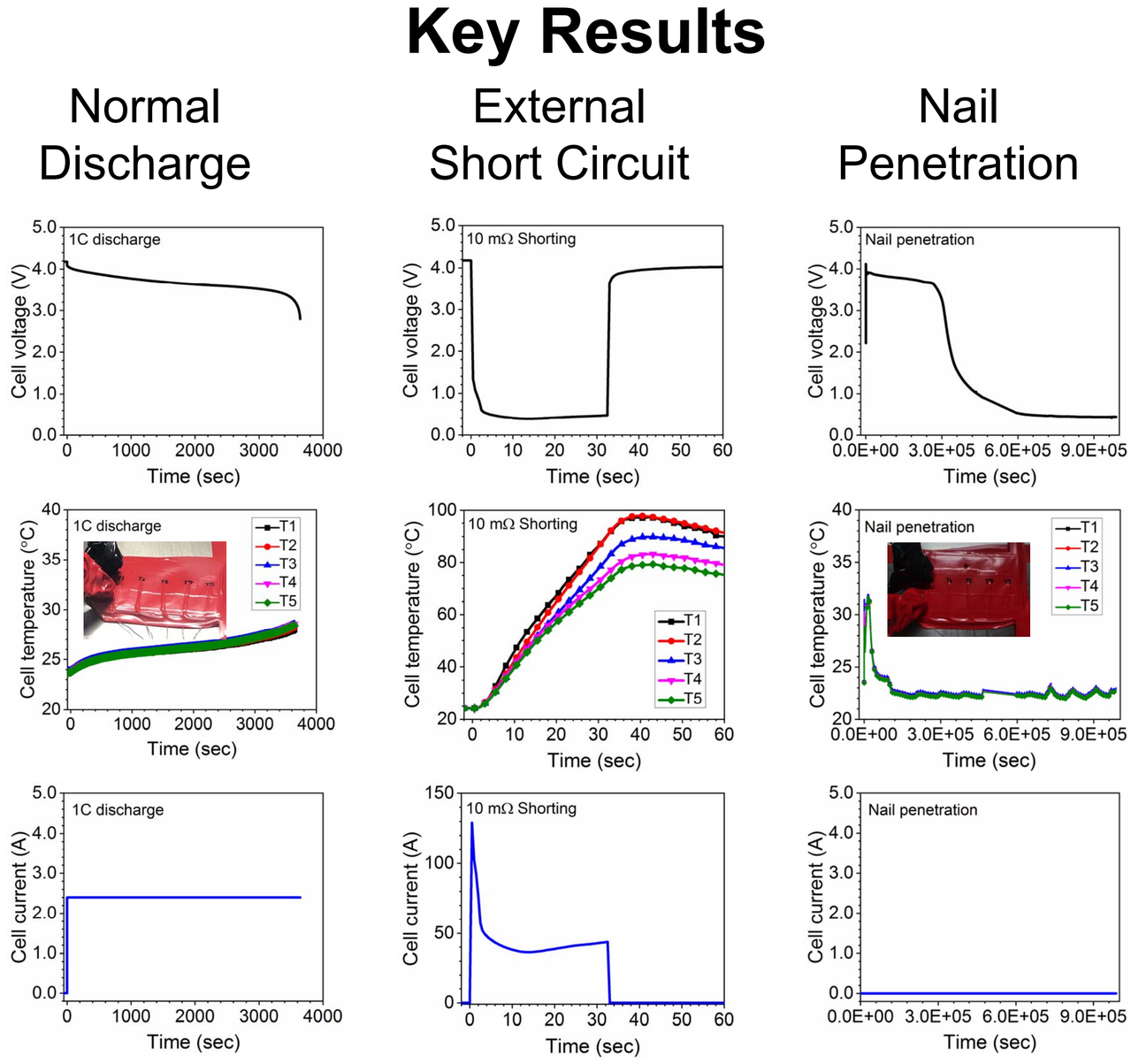
Battery tester



Abuse testing setup



Key Results



1. During normal discharge, cell voltage decreased slowly until 2.8 V (cut-off voltage) and cell temperatures increased <5 ^{o}C in one hour.
2. During external short circuit (stopped when cell surface temperature in the middle, T_3, reached 80 ^{o}C), cell voltage dropped to below 0.5 V and temperatures near tabs (T_1, T_2) increased to ~100 ^{o}C.
3. During internal short circuit by nail penetration, cell voltage dropped to ~2.2 V but quickly recovered and then very slowly decreased until stabilized at ~0.4 V. The cell temperatures only increased slightly at first and then decreased back to room temperature.

Conclusions

1. The cell temperatures increased ~2,000 times faster and the temperature distribution was more non-uniform during external short circuit than during 1C normal discharge.
2. The experimental Li-ion cell did not overheat during nail penetration as expected, which should be further investigated.

Conceptual Framework

1. This research provides preliminary quantitative insights into the behaviors of Li-ion battery cells under abuse conditions.
2. The unexpected thermal behaviors of experimental Li-ion cell during nail penetration suggest the complexity of internal short circuit and the needs of further investigation.

References

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2. A. Abaza, S. Ferrari, H.K. Wong, C. Lyness, A. Moore, J. Weaving, M. Blanco-Martin, R. Dashwood, R. Bhagat. Experimental study of internal and external short circuits of commercial automotive pouch lithium-ion cells, *J. Energy Storage*, 16: 211-217 (2018).

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