Durability and Reliability of EV Batteries under Electric Utility Grid Operations: Bidirectional Charging Impact Analysis

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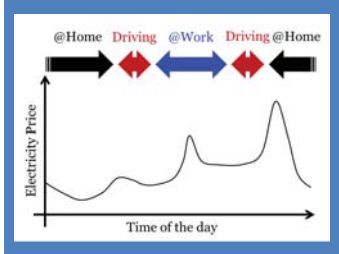
Introduction

Mass adoption of electric vehicles (EVs) could have a number of impacts, including the ability to assist in the integration of renewable energy into existing electric grids by sourcing/sinking energy to/from the grid known as **vehicle-to-grid (V2G)** and **grid-to-vehicle (G2V)**, respectively.

The potential benefits of V2G and G2V have been heavily investigated in recent years. However, their impact on vehicle battery degradation has not been investigated in detail.

The aim of this work is to understand the effect of bidirectional charging on the degradation mechanisms of commercial Li-ion cells used in electric vehicles today and use that knowledge to suggest practices that will improve capacity retention.

Design of experiment



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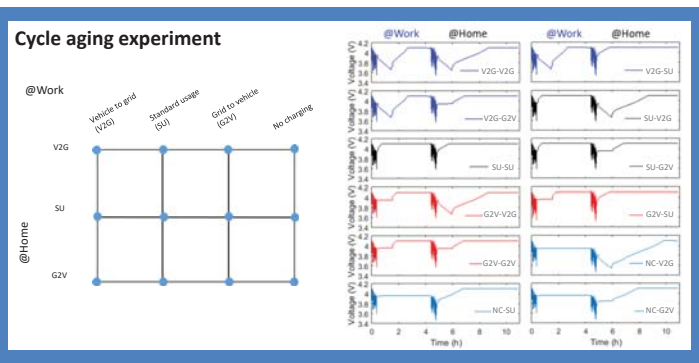
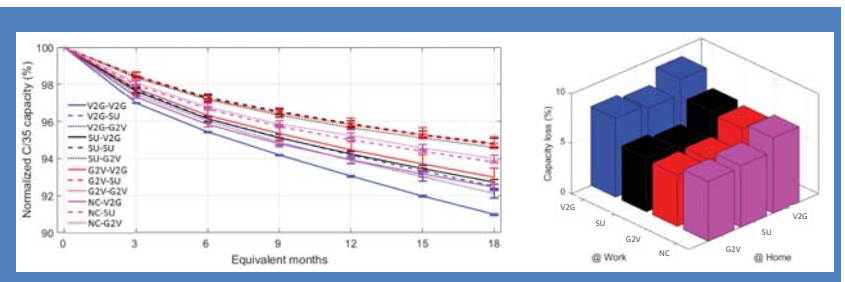
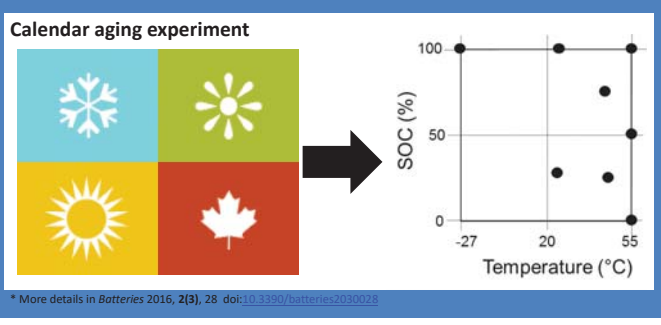
Cycle aging experiment





- Cells lost between 5 and 9% capacity after an equivalent 18 months of driving
- V2G strategy induced 2% extra degradation per daily occurrence (@work and/or @home)

Calendar aging experiment

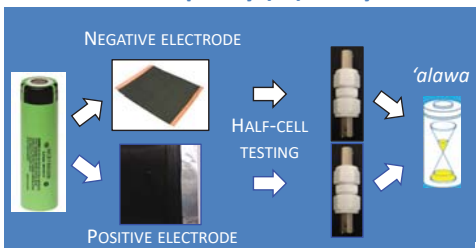


* More details in *Batteries* 2016, **2(3)**, 28 doi:10.3390/batteries2030028

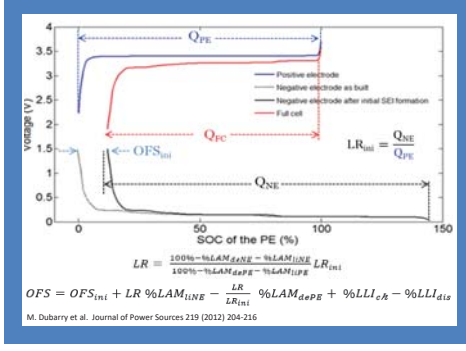
Temperature (°C)	SOC (%)	Capacity loss after 66 weeks
-27	5	1.4%
-27	99	1.5%
25	50	2.8%
25	100	4.5%
45	20	6.1%
45	70	10.1%
55	5	6.5%
55	81.5	13.0%

- Capacity loss associated with the 66 weeks of calendar aging ranged from 1% (-27°C/99% SOC) to 13% (55°C/81.5% SOC)

Incremental capacity (IC) analysis



Evolution of IC curves at slow rate (C/35)
Degradation modes impact on voltage:
- Loss of lithium inventory (LLI),
- Loss of active material (LAM) on the positive and negative electrode (PE and NE, respectively), and
- Kinetic changes (RDF) to each of the electrodes.



$$LR = \frac{100\% - \%LAM_{deNE} - \%LAM_{iiNE}}{100\% - \%LAM_{dePE} - \%LAM_{iiPE}} LR_{ini}$$

$$OFS = OFS_{ini} + LR\ \%LAM_{iiNE} - \frac{LR}{LR_{ini}}\ \%LAM_{dePE} + \%LLI_{ch} - \%LLI_{dis}$$

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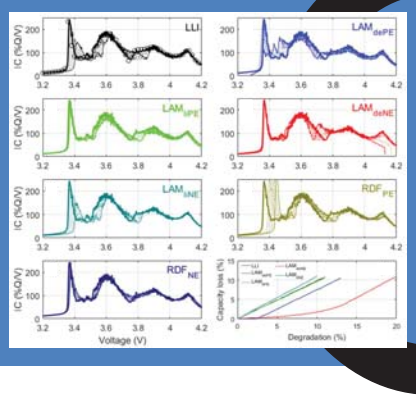
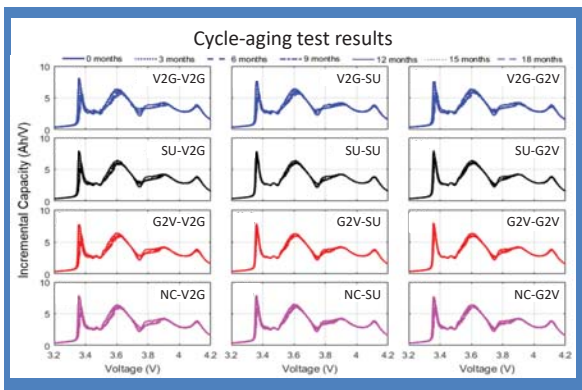
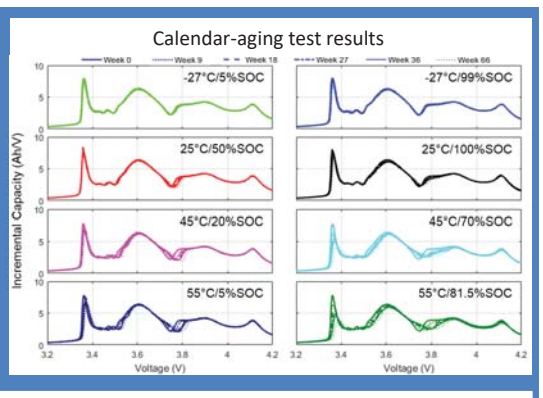
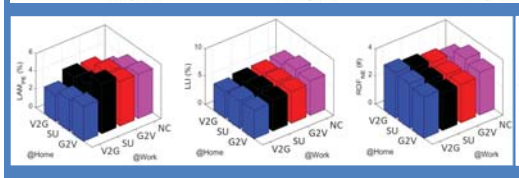


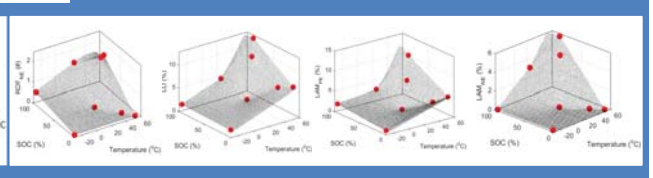
Cycle-aging test results

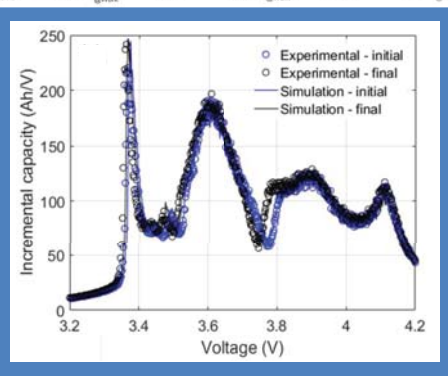


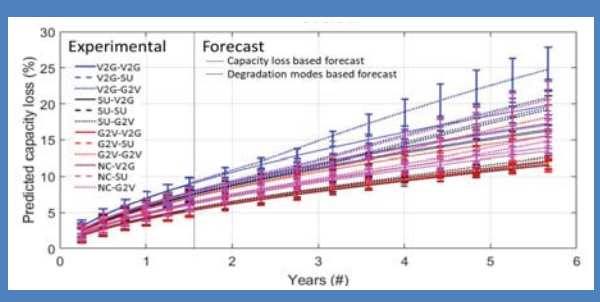
Calendar-aging test results





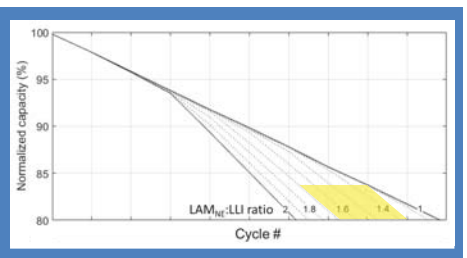


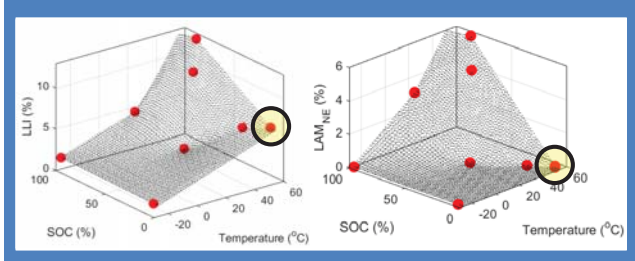




Outlook

LAM_{NE} was faster than LLI in the cycle-aging tests (LAM_{NE} : LLI ratio ≈ 1.5); a sign that the cycled cells will enter an advanced aging stage characterized by the onset of Li plating.



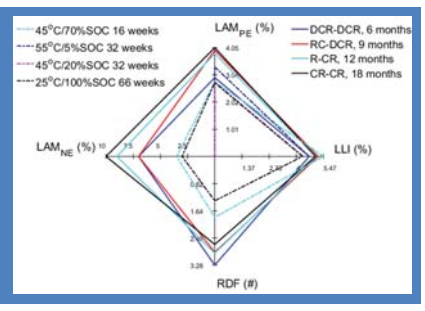


The calendar aging results show resting at low SOCs & high temperatures facilitates LLI and impedes LAM_{NE}. These conditions may prevent Li plating.

- **Rigorous examination of experimental and emulated incremental capacity curves quantified the different degradation modes occurring in cycle- and calendar-aged cells.**

Conclusions

- **Results led to prediction of a second accelerated aging stage characterized by the onset of lithium plating and a revision of the lifetime prognosis.**
- **The accelerated aging stage was induced by the increased rate of the LAM_{NE} relative to the LLI.**
- **Resting at low SOCs & high temperatures facilitates LLI and impedes LAM_{NE} which may avert accelerated aging.**
- **Findings suggest V2G / G2V strategies does not invariably lead to reduced battery lifetimes.**
- **Intelligent control algorithms can be used to adjust duty cycles and rest conditions depending on the battery chemistry to avoid any accelerated aging stage.**



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