# Hoverboards, fires and residential battery storage

The recent personal transportation device craze that is "self-balancing electric scooters" – a.k.a. hoverboards, have been all over the news recently, but for the wrong reasons. It seems these new toys, or more specifically the batteries used, have a tendency to unexpectedly catch fire in a range of situations. The fact that there have also been house fires reported allegedly due to the use of lithium ion batteries leaves us with an even more pressing question: what are the implications for lithium ion battery storage systems for residential applications? Is there a risk that a similar situation will occur in these residential energy storage systems, except on a larger scale?

## The Batteries

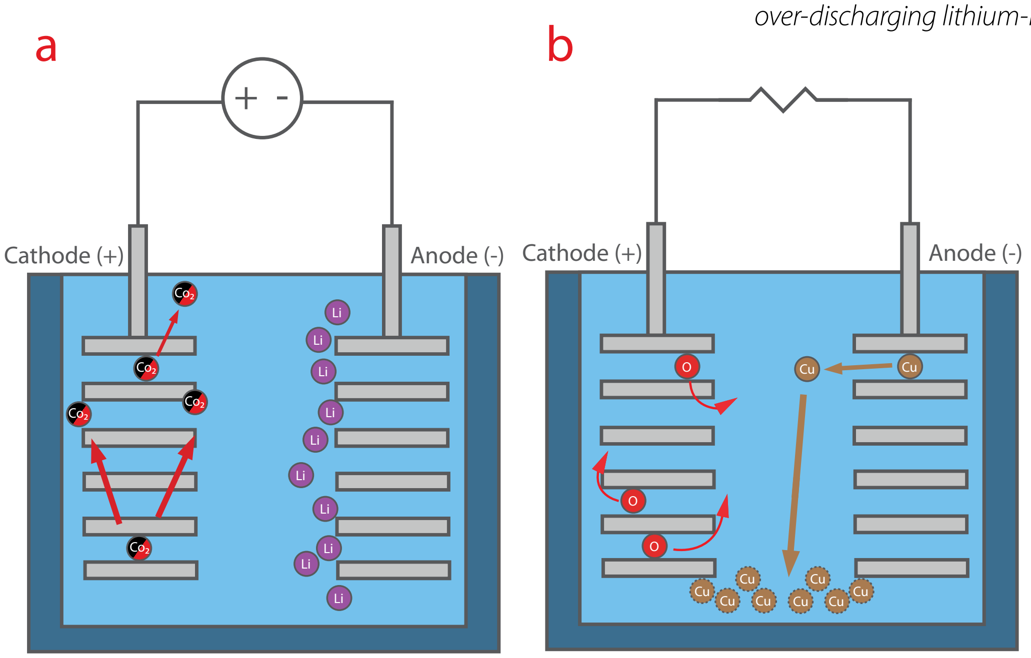
Lithium batteries are compact, relatively lightweight, and energy dense. These qualities make them popular in many devices (particularly where weight is important), but the same chemistry that produces these qualities also makes them very sensitive to environmental conditions and highly volatile. There are several ways that a lithium ion cell can fail catastrophically:

### High and low temperatures

Lithium ion cells are sensitive to temperature. If charged at very cold temperatures the lithium ions plate onto the surface of the anode. These ions form dendrites (ions 'grow' out of the surface of the anode) and have the potential to form a conductive path to the cathode, causing an internal short circuit.

At high temperatures the internal composition of the cell breaks down, resulting in uncontrollable chemical reactions. These reactions produce yet more heat, which increases the rate of reaction, resulting in thermal runaway. The creation of any internal short circuit will also result in thermal runaway.

***Figure 1:*** *Effect of overcharging and over-discharging lithium-ion cells*



### Overcharging and over-discharging

Overcharging and over-discharging of lithium batteries can also cause serious problems. Overcharging causes lithium plating at the anode in much the same way as charging at cold temperatures, and also produces carbon dioxide gas at the cathode, increasing internal pressure (Figure 1a).

Over-discharging is an even greater hazard, as copper that is included in the anode dissolves when the cell reaches a particularly low charge (the charge on the anode normally prohibits this). When charge is restored to the battery the copper becomes solid again and in doing so, falls to the bottom of the cell, creating a potential short circuit (Figure 1b).

### Battery Monitoring Systems and safety features

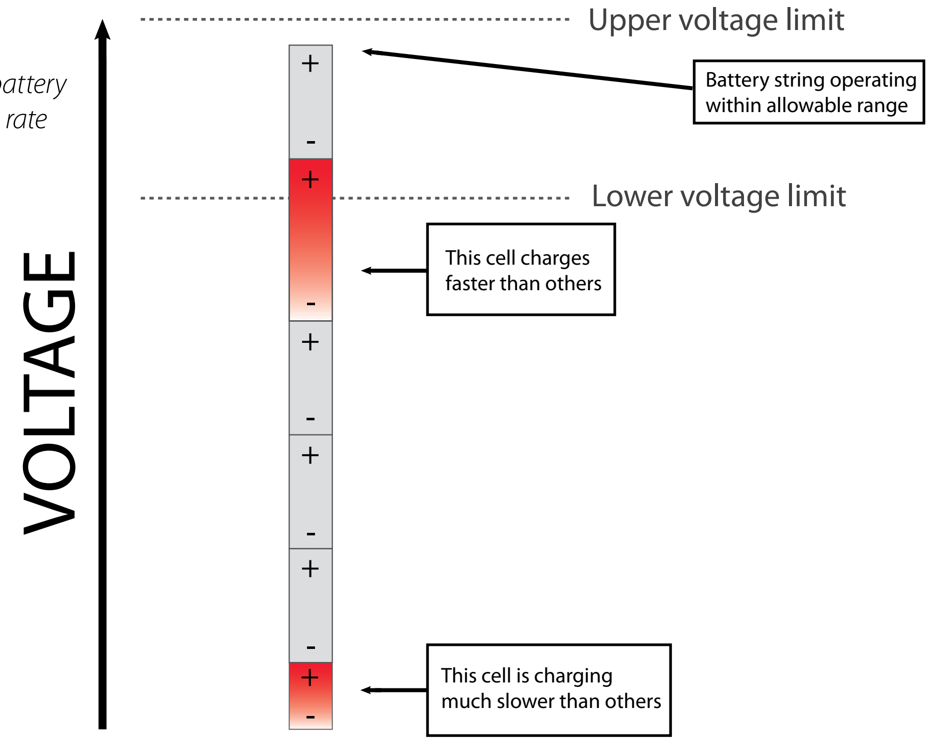
Clearly it's essential that lithium ion cells be monitored carefully to ensure that any temperature extremes, overcharging and over-discharging do not occur. A suitable battery monitoring system (BMS) that monitors the voltage and temperature of cells will provide this protection. Due to slight manufacturing differences, individual cells within the battery bank will charge and discharge at slightly different rates, which, if the voltage of only the whole string is referenced, can lead to a monitoring flaw as depicted in Figure 2: Not all cells in a battery string charge at the same rate below. To ensure that no single cell is operating outside its temperature or voltage window, each cell must be monitored independently. This monitoring method however increases the product cost, so often manufacturers will monitor groups of parallel cells as an alternative.

Lithium ion cells are also generally manufactured to include a number of safety devices to quickly disrupt short circuit currents (e.g. fuses, Current Interrupt Discs, Positive Temperature Coefficient Expansion Discs) and pressure valves to relieve excess pressure build-up in emergencies.

## The Hoverboard Fires

Any of the failure modes described above may have been the root problem of the recent hoverboard fires. The recently reported product failures may have been caused by substandard battery components, poorly designed BMSs, and non-compliant or faulty battery chargers: the correct diagnoses will be known only when any test results are released. However retailers and consumers

***Figure 2:** Not all cells in a battery string charge at the same rate*



should ensure that both the hoverboard and the charger are compliant with AS/NZS3820 (Essential safety requirements for Australia & New Zealand) and carry the following mark:

The most expensive component of self-balancing hoverboards is by far the battery, and therefore this component is the natural target for cost-cutting measures. As the demand for lithium ion batteries has grown, new factories are now producing alternatives to the leading market brands, e.g. Panasonic and Samsung. Any charging or discharging inconsistencies in lithium ion batteries can lead to cells not charging and discharging uniformly, and when any of these problems is coupled with a substandard BMS, it can easily lead to the problems reported. Such a fault would explain the boards that caught alight both during charging and while being used. All battery chemistries may fail if treated incorrectly. Therefore when using a battery type for mobile applications, it is obvious that quality batteries incorporating a suitable BMS provide reliability and performance.

The nature of the electric hoverboards and similar items e.g. scooters and bikes, is such that the device and its battery will experience more physical impacts than a typical battery in other consumer electronic devices. This means that any existing or developing issues in the battery can be exacerbated, particularly if sufficient shock-absorbing materials have not been included in the product's design. A damaged cell or inter-cell connection may be a reason why a battery pack develops charging inconsistencies that leads to cell failure and combustion.

## The implications for distributed stationary storage

Given that many new home battery systems rely on the same chemistry as hoverboard battery packs, what learning do we take from the reported product failures that might apply to the residential market?

The potential for the residential use of lithium ion battery systems to fail in the same way as hoverboards will always be present. There are however some key differences which reduce the likelihood of this happening. Defects due to physical impacts and wear-and-tear in most cases will not be a significant problem: residential units will be stationary without any vibrational stresses and are protected by a casing, which should meet the Building Code of Australia's requirements. Residential systems do not impose the same weight limitations for components as required for mobile uses. Finally, a stationary battery system is designed to perform for 10+ years, and so reliability and longevity are a much more significant design concern.

Residential battery systems should ensure that all components within the system (such as the batteries, the charge controller, and the cables) have been matched, sized and installed correctly. This includes a suitable BMS that has been programmed correctly for the specific battery cells. In addition, installers are responsible for ensuring that the components are of a satisfactory quality, likely to be free from manufacturing defects, and that appropriate safety devices (within the cells and the battery pack as a whole) are present.

## Conclusion

All battery chemistries, of which lithium ion batteries are just one type, are inherently dangerous. Lithium ion batteries used in stationary energy storage products have the same potential to fail as seen recently with the hoverboard products.

- Questions which might be suitable for installers and homeowners to ask could be:
- Is the battery pack monitored at an individual cell level, module level, or pack level?
- What mechanical safety mechanisms are employed within each cell and the battery pack as a whole?
- If there is an internal fault, how is the system owner made aware?
- Does the installation comply with relevant

standards and building codes?

- Does the system come with instruction on how to extinguish a fire (note: care must be taken to use the appropriate method when extinguishing lithium fires) and what equipment is necessary? E.g. type of fire extinguisher and any other protection equipment
- Is it possible for an untrained person to adjust the safety settings of the device (such as changing voltage set points)?

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