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Lithium-ion cell safety improvement with reduced pressure

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Summary

- Preventing Li-ion cell fire and cell explosion with reduced pressure
- Increase of Li-ion cell safety

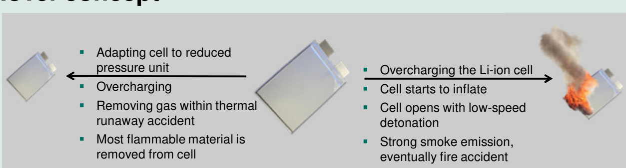
Motivation

- Enhancing the **cell safety** of Li-Ion batteries
- Exploring the **removal** of highly flammable electrolyte solvent and gaseous products during thermal runaway
- Reducing **fire hazard** after cell accident
- Evaluation of the technique in terms of **explosion prevention**

State of the art

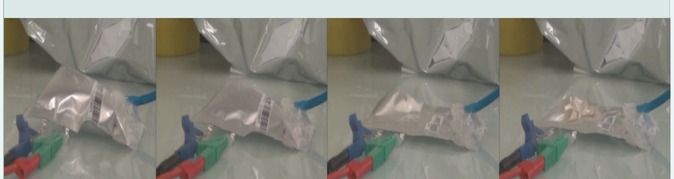
Before thermal runaway	During/after thermal runaway
Use of electrolyte additives (redox shuttle, fire-inhibitors), „safer" electrolyte solvents and gel polymer electrolytes	Pressure relief valve
Solid-state electrolytes	Use of heat-absorbing material around the cell
Use of safer separators (ceramic coated)	Cell and battery cooling system
Electronic devices (battery management system)	Stable cell casing

Novel concept



- 88 mAh pouch bag cell (NMC, graphite, 850 µl EC/DMC + 1M $LiPF_6$ electrolyte, ceramic coated separator) is equipped with tube to vacuum pump or suction unit (manually connectable)
- Overcharging the Li-ion cell with current rate of 5C
- Applying of reduced pressure at the crucial moment of thermal runaway (strong swelling of the cell)
- Remove of the hot gaseous products and solvents from the electrode material

Pouch bag cell during overcharging without protection



Pouch bag cell during overcharging; a vacuum pump is used for applying reduced pressure

Pouch bag cell during overcharging, a suction unit is used for applying reduced pressure

Pouch bag cells after thermal runaway (under reduced pressure)

- All cells remain tightly close and exhibit a cell voltage of 0 V in contrast to Li-ion reference cell without protection
- The electrode foils are dry and the electrode material can easily be detached from the current collector foils (Cu and Al)
- Electrolyte solvents and gaseous products are removed during thermal runaway experiments under reduced pressure
- Formation of gaseous products approx. 0.15 l due to the electrolyte amount
- Strong heat is produced in all cases, but without fire or explosion (see cells after thermal runaway below)
- The outer plastic coating of the pouch bag foil melts and becomes colored due to the heat formation
- Temperature of the outer pouch-bag foil (above electrode sheets) during overcharging increases to >150 °C
- Vacuum pump as well as suction unit both are appropriate to remove the gaseous products reliably
- Increase of cell safety due to the removal of highly combustible solvents and decomposition products inside of the cell
- Technique can be combined with other methods to improve the cell safety (electrolyte, separator, cell casing, etc.)

Pouch bag cell after thermal runaway test

Possible adaption to larger cells

- Electrolyte amount in 20 Ah cell: approx. 80 ml
- This gives rise to ~120 dm^3 gaseous products during thermal runaway
- Gaseous products could be removed via suction unit
- Cell opening pressure can be adjusted by aluminum sealing
- Several single pouch bag cells are enclosed inside a container equipped with a rupture disk which is connected to the suction unit
- In case of a thermal runaway accident, temperature sensors can be used to turn on the suction unit

Conclusions

- Prevention of cell explosion in 88 mAh pouch bag cells (cell remains close)
- Highly volatile and combustible electrolyte solvents are removed under reduced pressure
- Oxygen getting formed during thermal runaway is also removed from the cell
- Strong heat formation without explosion of fire

Outlook

- Quantification of the heat flow during thermal runaway
- Quantification of the mass reduction of highly volatile electrolyte
- Test of the findings in larger cells

References

- Hofmann et al., "*Preventing Li-ion cell explosion during thermal runaway by reduced pressure*", Appl. Thermal Eng., *under revision*.

Acknowledgements

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* C/*n*: current rate when the cell is charged or discharged completely in *n* h