

### Thermal runaway behavior of commercial 18650 Li-Ion batteries

Andrey W. Golubkov\*<sup>1</sup>, David Fuchs<sup>1</sup>, Julian Wagner<sup>2</sup>, Helmar Wiltsche<sup>3</sup>, Christoph Stangl<sup>4</sup>, Gisela Fauler<sup>4</sup>, Gernot Voitic<sup>5</sup>, Alexander Thaler<sup>1</sup> and Viktor Hacker<sup>5</sup>

\*Corresponding author: [andrej.golubkov@alumni.tugraz.at](mailto:andrej.golubkov@alumni.tugraz.at)

<sup>1</sup>VIRTUAL VEHICLE Research Center, Inffeldgasse 21a, 8010 Graz, Austria

<sup>2</sup>Graz Centre for Electron Microscopy, Steyrergasse 17, 8010 Graz, Austria

<sup>3</sup>Institute of Analytical Chemistry and Food Chemistry, Graz University of Technology, Stremayrgasse 9 / III, 8010 Graz, Austria

<sup>4</sup>Varta Micro Innovation GmbH, Stremayrgasse 9, 8010 Graz, Austria

<sup>5</sup>Institute of Chemical Engineering and Environmental Technology, Graz University of Technology, Inffeldgasse 25/C/II, 8010 Graz, Austria

Li-Ion batteries with high energy-density are playing an important role in everyday's life. The aim of this work is to give a better understanding of possible risks that are emanating from those devices.

The possibly most important abusive reaction that a Li-Ion battery can undergo is the so-called thermal-runaway. For commercially available Li-Ion cells, the thermal-runaway reactions can be initiated by heating the cell far beyond the temperature rating that is specified by the manufacturer [1–5].

Data from thermal-runaway experiments covering the temperature evolution and gas production during the abuse tests, as well as analysis of the main gas components will be reported in the present work.

The thermal-runaway experiments were performed using a custom build test rig. The Li-Ion cells were placed inside a pressure-tight heat-able reactor. The heater temperature was increased slowly, starting at room temperature and continuing up to ~300°C. At elevated temperatures several events can occur. These events may include cell venting, cool down by the Joule-Thomson effect, slow thermal-runaway or rapid thermal-runaway.

The presence and magnitude of those effects depend on the cell chemistry and state-of-charge of the cell. Experiments were performed with different types of commercially available consumer Li-Ion cells, of the standardized 18650 format. Tested Li-Ion batteries include those with iron-phosphate and metal-oxide based cathodes.

The authors would like to acknowledge the financial support of the "COMET K2 - Competence Centres for Excellent Technologies Programme" of the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT), the Austrian Federal Ministry of Economy, Family and Youth (BMWFJ), the Austrian Research Promotion Agency (FFG), the Province of Styria and the Styrian Business Promotion Agency (SFG). The project was supported by the following industrial partners: Magna Steyr Battery Systems GmbH & Co OG and by BASF SE.

[1] C.-Y. Jhu, Y.-W. Wang, C.-Y. Wen, and C.-M. Shu, "Thermal runaway potential of LiCoO<sub>2</sub> and Li(Ni<sub>1/3</sub>Co<sub>1/3</sub>Mn<sub>1/3</sub>)O<sub>2</sub> batteries determined with adiabatic calorimetry methodology," *Applied Energy*, pp. 2–6, Jul. 2012.

[2] C.-Y. Jhu, Y.-W. Wang, C.-M. Shu, J.-C. Chang, and H.-C. Wu, "Thermal explosion hazards on 18650 lithium ion batteries with a VSP2 adiabatic calorimeter.," *Journal of hazardous materials*, vol. 192, no. 1, pp. 99–107, Aug. 2011.

[3] P. Ribière, S. Grugeon, M. Morcrette, S. Boyanov, S. Laruelle, and G. Marlair, "Investigation on the fire-induced hazards of Li-ion battery cells by fire calorimetry," *Energy & Environmental Science*, vol. 5, no. 1, p. 5271, 2012.

[4] E. P. Roth and C. J. Orendorff, "How electrolytes influence battery safety," *Electrochemical Society Interface*, vol. 21, no. 2, pp. 45–49, 2012.

[5] D. Doughty and E. P. Roth, "A general discussion of Li Ion battery safety," *Electrochemical Society Interface*, vol. 21, no. 2, pp. 37–44, 2012.