

Benchmarking Graphite Materials Used as Anodes in Lithium-Ion Batteries

P. Onnerud, J. Shi, R. Chamberlain, S. K. Singh, B. Barnett and C. Lampe-Onnerud*
 Arthur D. Little, Inc.
 Acorn Park, Cambridge, MA 02140, USA

Graphite materials remain the dominant active anode material used in lithium-ion batteries. The performance of graphite as a safe and reliable material that provides sufficient energy density for many portable power applications, such as mobile phones and laptop computers, explains this dominance. However, recent safety concerns involving lithium-ion batteries used in laptop computers and increasing power demands of new technology, especially in mobile phones, continues to demand improved performance of battery materials. While research into new active anode materials progresses, improvements to graphite materials help maintain their use in lithium-ion batteries.

In this study, we continue our look at different graphite materials available in today's marketplace for use as the active anode material in lithium-ion batteries. We have previously shown that morphology and structural differences, as elucidated by SEM and XRD, can help explain why graphite materials perform differently when tested electrochemically in lithium-ion cells. For this study, special attention is given towards differences in safety features and energy density offered by these graphite materials.

Differential scanning calorimetry (DSC) and accelerating rate calorimetry (ARC) are used to compare the safety performance of the different graphites. Both lithiated and non-lithiated samples were studied in the common electrolyte system 1 M LiPF₆, 1:1 ethylene carbonate/dimethyl carbonate. Figure 1 compares the energy from the first DSC exotherm at 135 – 140 °C for five different graphite materials. Clearly, differences exist which may have critical effects on overall safety performance of the lithium-ion batteries into which these materials are assembled.

We have also looked at the increased energy density possibilities for different graphite materials. This is accomplished by increasing coating density of the active material in order to increase volumetric energy density. Graphite beads, fibers and flakes were coated to electrode densities varying from 1.3 – 1.8 g/cm³ and the resulting performances in lithium-ion cells were assessed. Dramatic differences exist. For example, graphite flakes clearly show decreasing performance in high rate and long-term cycling capabilities as coated electrode density increases. Figure 2 shows the 2C rate capability (as a percentage vs. C/5) for graphite flakes coated in two different formulations, with and without a conductive carbon additive.

In the end, final choice of active anode material rests on consideration of a number of properties, including safety and energy density. This requires understanding both material properties as well as the end-use application of that material.

Figure 1: DSC analysis of first exotherm (135 - 140 °C) for lithiated graphite materials in 1 M LiPF₆, EC/DMC electrolyte.

Figure 2: 2C rate capability for graphite flake sample coated at three electrode densities for two different formulations: (+) with conductive carbon and (-) without conductive carbon.

