ELECTROCHEMICAL PERFORMANCE OF LAC KNIFE HIGH PURITY FLAKE IN THE ANODE AND CATHODE OF LITHIUM ION BATTERIES

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OUTLINE

- Lac Knife Graphite Project Overview
- Performance of Lac Knife Graphite and Synthetic Graphite in Li Ion Cells
- Long Term Cycling Performance of Lac Knife Graphite
- Production of Expanded Lac Knife Graphite
- Lac Knife Graphite as a Conductivity Additive in Cathodes
- Advantages of Using Lac Knife Graphite in Li Ion Batteries
DRILL RIG & CORES
CLEANING CIRCUIT → FLOTATION CELL
FLAKE PURIFICATION PROCESS

Flotation Concentrate

Concentrate after Polishing

Lac Knife Graphite after Purification

96% Cg

98.3% Cg

99.98%+ Cg
SEM shows flake graphite has been successfully processed to produce spherical particles (SPG).

SPG was coated with carbon to reduce the Specific Surface Area (SSA) to make it suitable for use in Lithium-ion Batteries.

Coating also has the effect of reducing reactivity with the electrolyte further reducing the irreversible capacity loss.
PERFORMANCE OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN Li ION COIN CELLS

Coated Lac Knife Spherical Graphite

Commercial Grade of Synthetic Graphite
Cell # 708, CR2016, counter: Li/Li⁺; Graphite: Standard Grade Uncoated SPG (D50 = 24 µm); Rate: C/20; Electrolyte: 1M LiPF₆ in FEC/EMC (30:70 vol%),

1st Cycle Loss = 4.69%
Fig. 2  INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR STANDARD GRADE OF COATED SPG

SURFACE AREA = 0.48 m²/g  TAP DENSITY = 0.90 g/cc

Voltage, V

Specific Capacity, Ah/kg

1st Cycle Loss – 1.44%

Cell #736. CR2016, counter: Li; Graphite: Standard Grade Surface Coated SPG; Rate: C/20; Electrolyte 1M LiPF6 in FEC/EMC (30:70 vol%)
Fig. 3  INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR FINE GRADE OF COATED SPG

SURFACE AREA = 1.14 m²/g  TAP DENSITY = 0.87 g/cc

1st Cycle Loss – 1.01%

Cell #705. CR2016, counter: Li; Graphite: Fine Grade Surface Coated SPG; Rate: C/20; Electrolyte 1M LiPF6 in FEC/EMC (30:70 vol%)
Fig. 4  INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR SYNTHETIC GRAPHITE #1

ICL = 6.45%

1st Cycle Loss = 6.45%
Fig. 5  INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR SYNTHETIC GRAPHITE #2

1st Cycle Loss = 3.76%

Cell 969, Synthetic Graphite #2
Fig. 6  INITIAL CHARGE-DISCHARGE CURVES FOR LAC KNIFE FLAKE GRAPHITE COMPARED WITH SYNTHETIC GRAPHITE

- SG1: 6.45% ICL
- SG2: 3.76% ICL
- SPG Focus: 0.65% ICL

- Cell 964, Synthetic Graphite #1
- Cell 969, Synthetic Graphite #2
- Cell 705B, Focus Graphite, Fine Grade Coated SPG
Fig. 7  GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR FINE GRADE OF CARBON COATED SPG AT C/20, C/5 AND C/2 RATES IN CR2016 HALF CELLS

Cell #705, CR2016, counter: Li/Li⁺; Graphite: Focus Fine Grade Coated SPG
Rate: C/20, C/5, C/2;
Electrolyte: 1M LiPF₆ in FEC/EMC (30:70 vol%)

Cycling Protocol:
- 3 cycles at C/20
- 2 cycles at C/10
- 1 cycle at C/5
- 20 cycles at C/2
The reduced C/2 Rate values are due to design limitations of the cells and not due to the graphite.

The Lac Knife cell does show a higher specific capacity (256 Ah/kg) at the C/2 Rate than the synthetic cell (204 Ah/kg) at the same rate.
Fig. 9 PERFORMANCE OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN Li ION COIN CELLS

Coated Lac Knife Spherical Graphite

Commercial Grade of Synthetic Graphite
LONG TERM CYCLING PERFORMANCE OF LAC KNIFE GRAPHITE

Formation of a Graphite Sphere

Spherical Graphite
Anodes consisted of graphite, binder and carbon black with a 20µ Cu foil current collector.
Anodes were tested in CR2016 coin cells prepared with 1M LiPF6/EC/DMC electrolyte and Li foil reference/counter electrodes.

Fig. 11  LONG TERM CYCLING PERFORMANCE OF LAC KNIFE GRAPHITE COMPARED WITH TWO COMMERCIAL Li ION GRADES OF FLAKE GRAPHITE

- Speronized Coated Standard Grade of Purified Lac Knife Graphite (Focus Graphite, Inc.)
- Commercial Lithium-Ion Battery Grade of Purified Coated Spheronized Natural Flake Graphite (Supplier #2)
- Commercial Lithium-Ion Battery Grade of Purified Coated Spheronized Natural Flake Graphite (Supplier #1)
Coin cells were cycled between 0.003 and 1.5 volts. Formation was carried out with C/10 current density and cycling was carried out at the same voltage limits at C/10.
Fig. 13  LONG TERM CYCLING PERFORMANCE OF UNCOATED NATURAL Flake GRAPHITE PURIFIED TO DIFFERENT ASH LEVELS

Sample 1 – 0.02% Ash
Sample 2 – 0.80% Ash
PRODUCTION OF EXPANDED LAC KNIFE GRAPHITE

Purified Graphite

Expanded Graphite
Fig.14 PRODUCTION OF EXPANDED LAC KNIFE GRAPHITE

Natural Flake Graphite Precursor

Intercalation (acids, room temp)

Intercalated Natural Flake Graphite

Exfoliation 850-950°C in Air

“Expanded” Natural Flake Graphite “worm”
RESISTIVITY OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN CATHODE MATRIXES OF Li ION BATTERIES
Fig. 15  RESISTIVITIES IN Li ION CATHODE MATRIX:

LiNiMnCoO$_2$

- Premium Quality Synthetic Graphite, $D_{50} = 3.5 \mu$
- Focus' Lac Knife Expanded Graphite, $D_{50} = 15.8 \mu$
- Commercial Flake Graphite, $D_{50} = 6 \mu$

Resistivity, ohm-inch vs. wt% Addition of Graphite in Cathode
ADVANTAGES OF USING LAC KNIFE GRAPHITE IN BATTERIES

Key Properties:

• Near Theoretical Reversible Capacity
• Low Irreversible Capacity Loss
• Reduced Capacity Fade during Long-term Cycling
• High Electrical Conductivity

End User Advantages:

• Higher Capacity
• Increased Power
• Longer Battery Life
• Increased Utilization of Cathode Active Material
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THANK YOU

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