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

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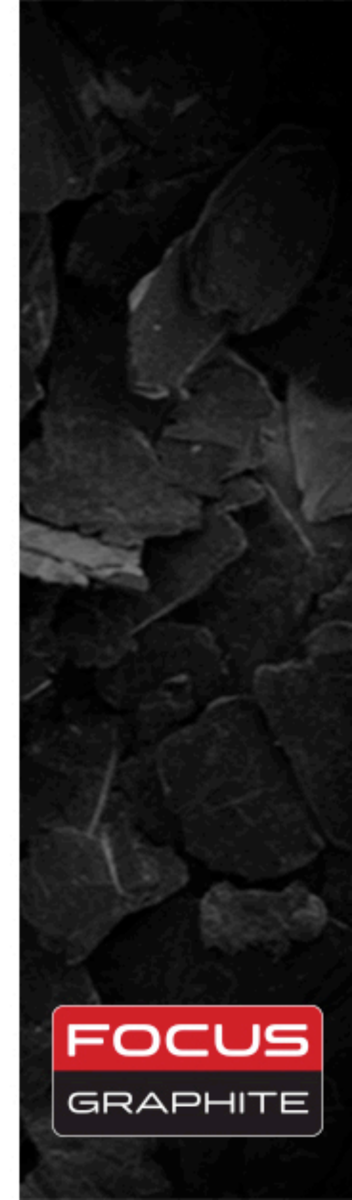
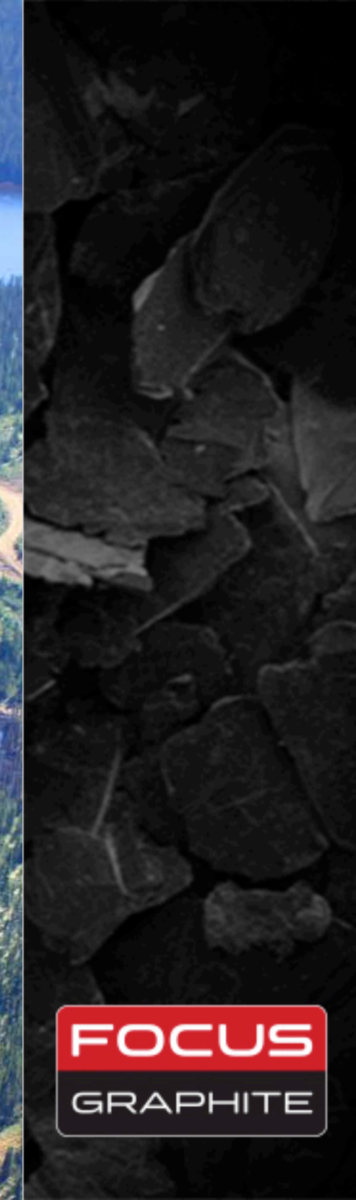
OUTLINE

- 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



LAC KNIFE GRAPHITE PROJECT

Lac Knife, Québec, Canada



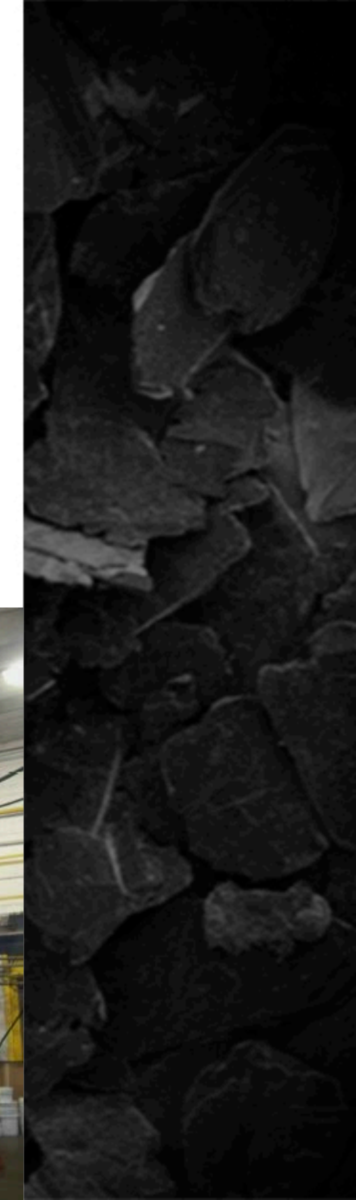
FOCUS GRAPHITE

DRILL RIG & CORES

FOCUS
GRAPHITE

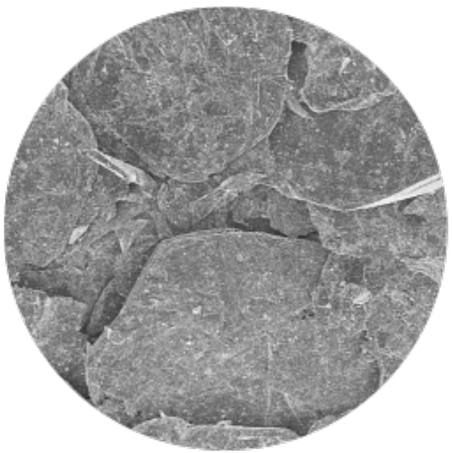
FLOTATION CELL

CLEANING CIRCUIT



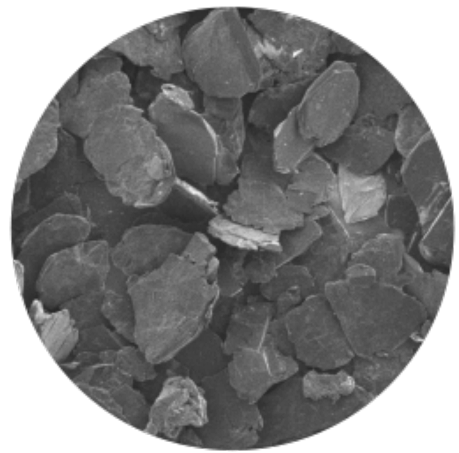
FLAKE PURIFICATION PROCESS

Flotation Concentrate



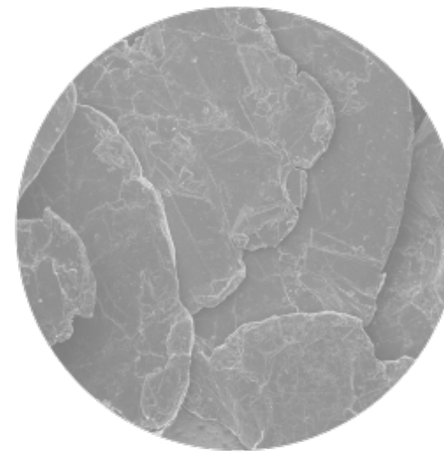
96% Cg

Concentrate after Polishing



98.3% Cg

Lac Knife Graphite after Purification



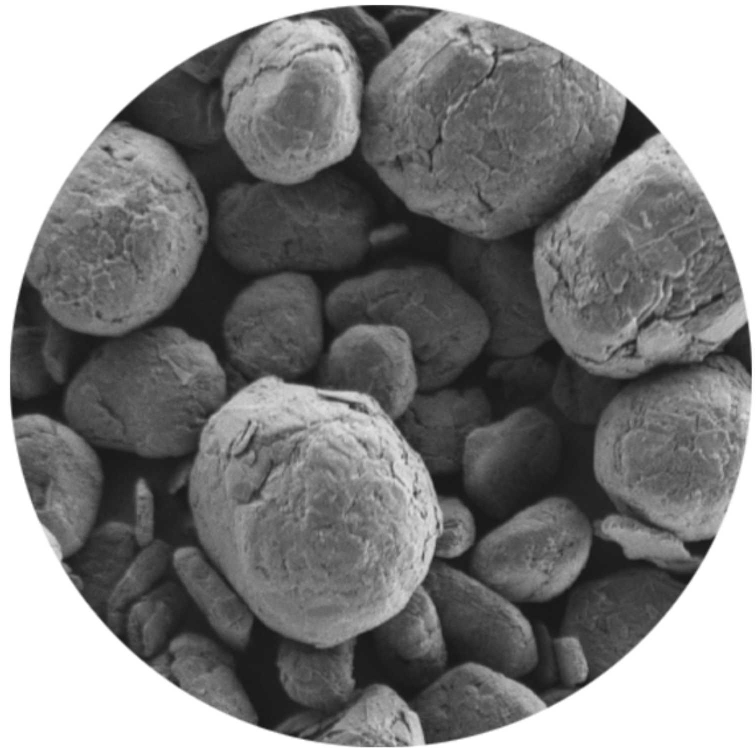
99.98%+ Cg

SCANNING ELECTRON MICROGRAPH (SEM) OF UNCOATED STANDARD-GRADE PURIFIED SPHERICAL

- 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

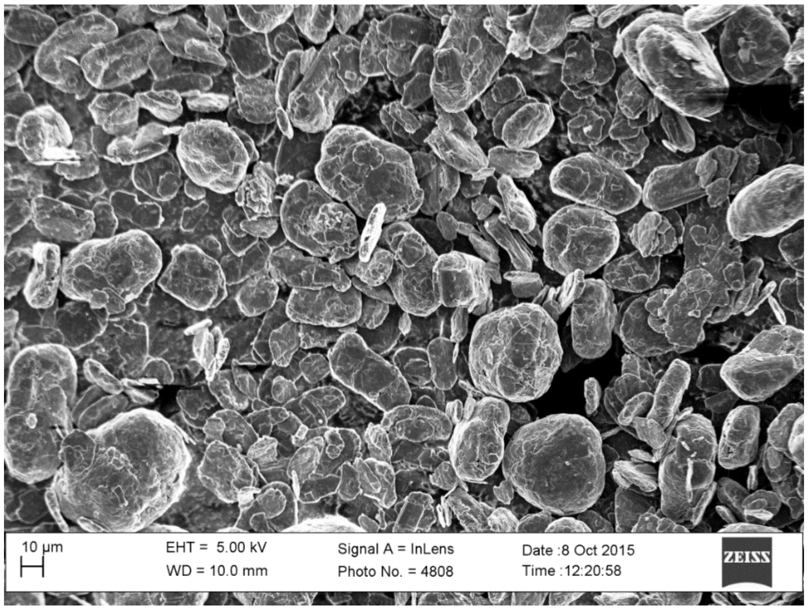
- Coating also has the effect of reducing reactivity with the electrolyte further reducing the irreversible capacity loss



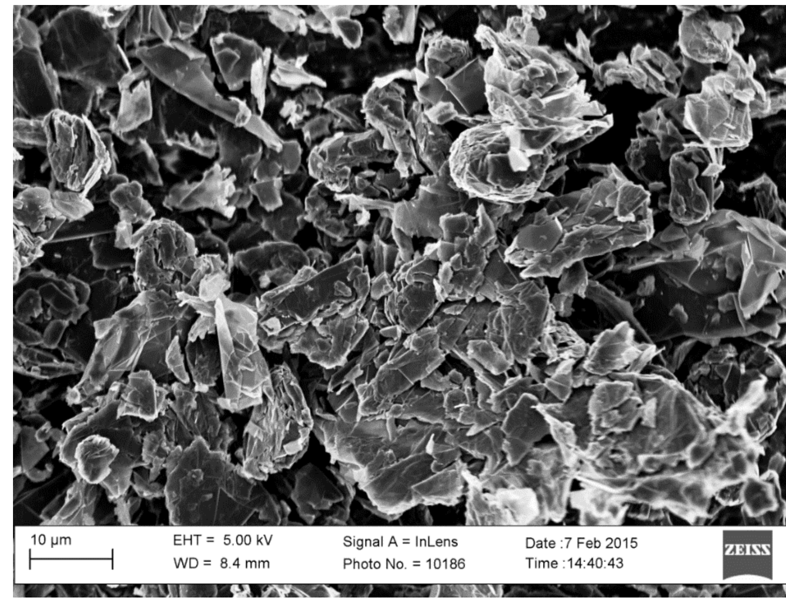
FOCUS GRAPHITE

PERFORMANCE OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN Li ION COIN CELLS

FOCUS GRAPHITE



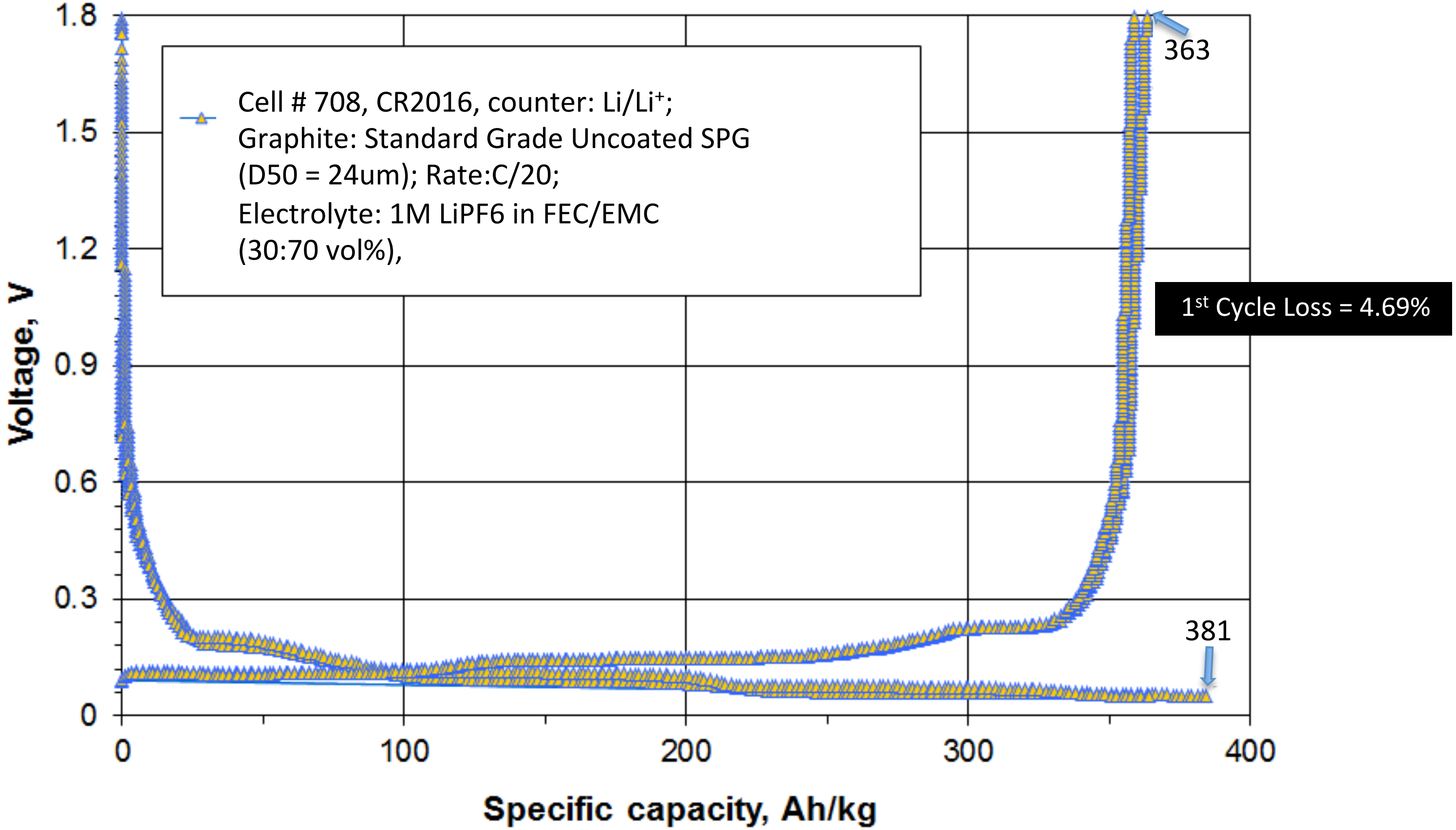
Coated Lac Knife Spherical Graphite



Commercial Grade of Synthetic Graphite

Fig.1 INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR STANDARD GRADE OF UNCOATED SPG

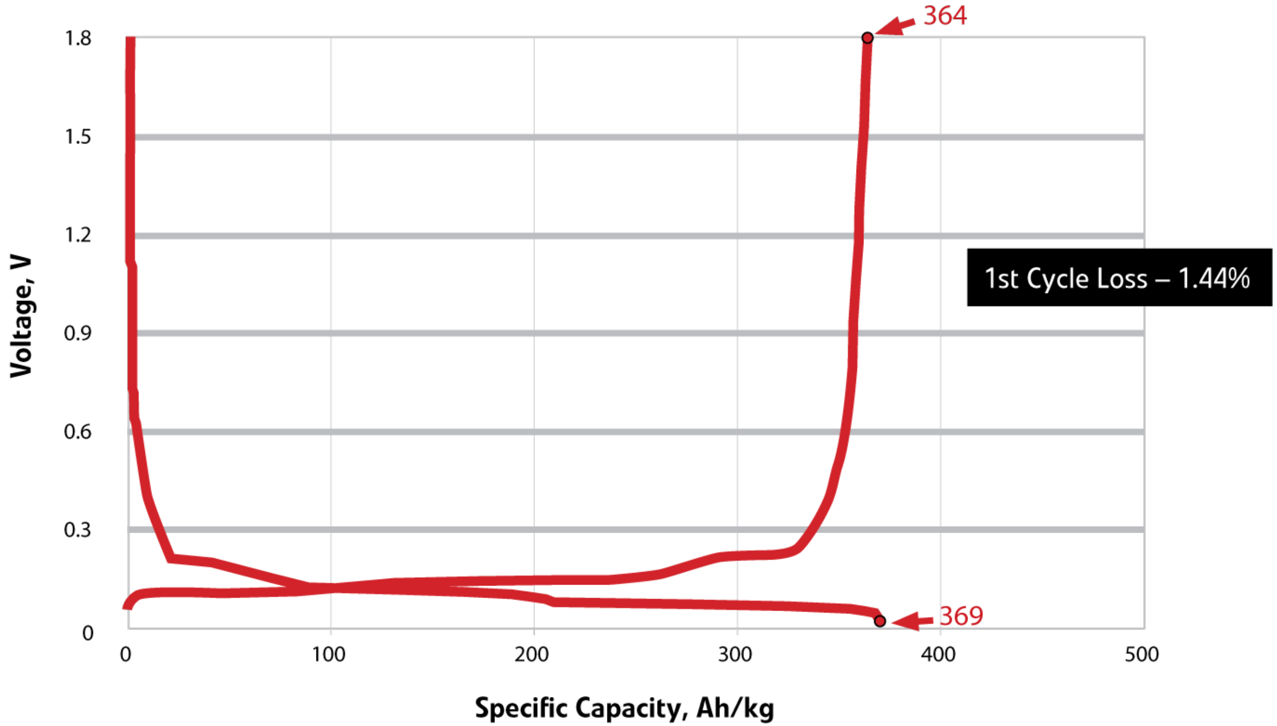
SURFACE AREA = 5.15 m^2/g **TAP DENSITY = 0.96 g/cc**



FOCUS GRAPHITE

Fig.2 INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR STANDARD GRADE OF COATED SPG

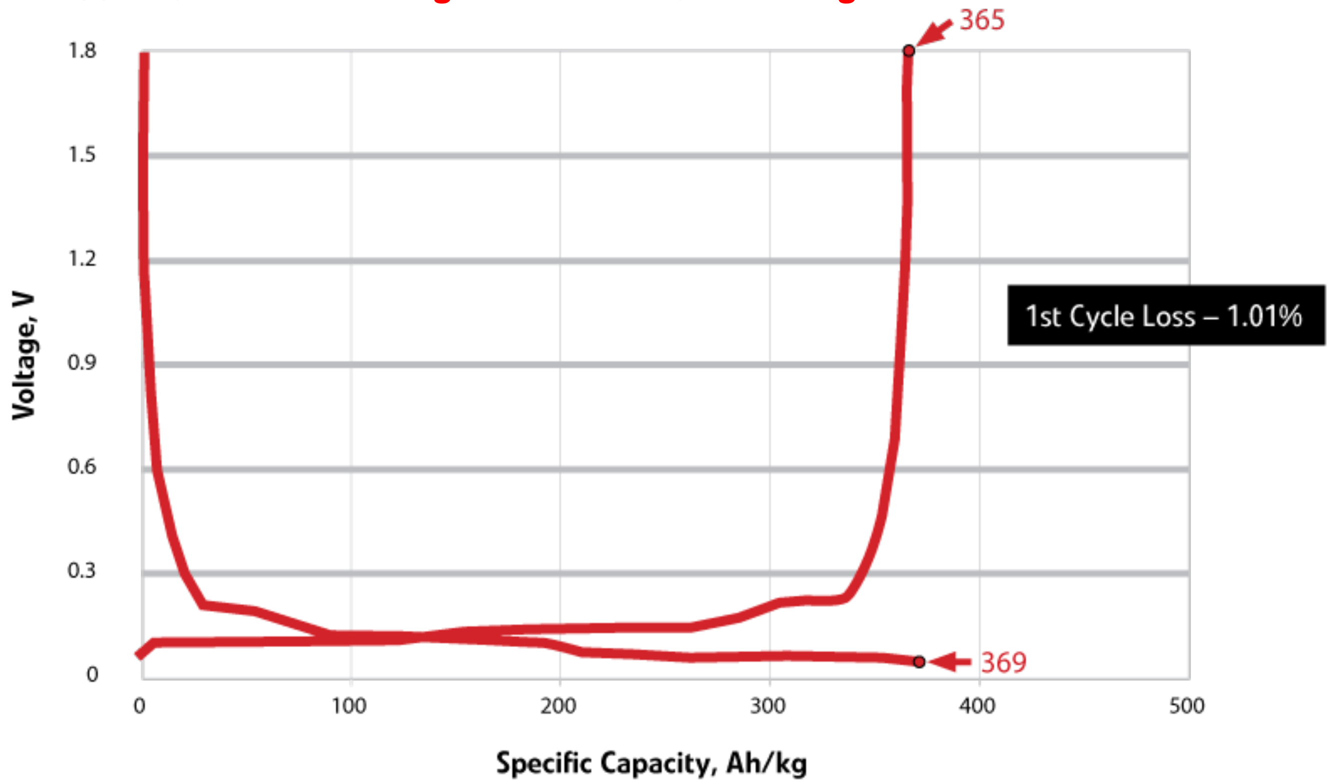
SURFACE AREA = 0.48 m²/g **TAP DENSITY = 0.90 g/cc**



Cell #736. CR2016, counter: Li; Graphite: Standard Grade Surface Coated SPG; Rate: C/20; Electrolyte 1M LiPF6 in FEC/EMC (30:70 vol%)

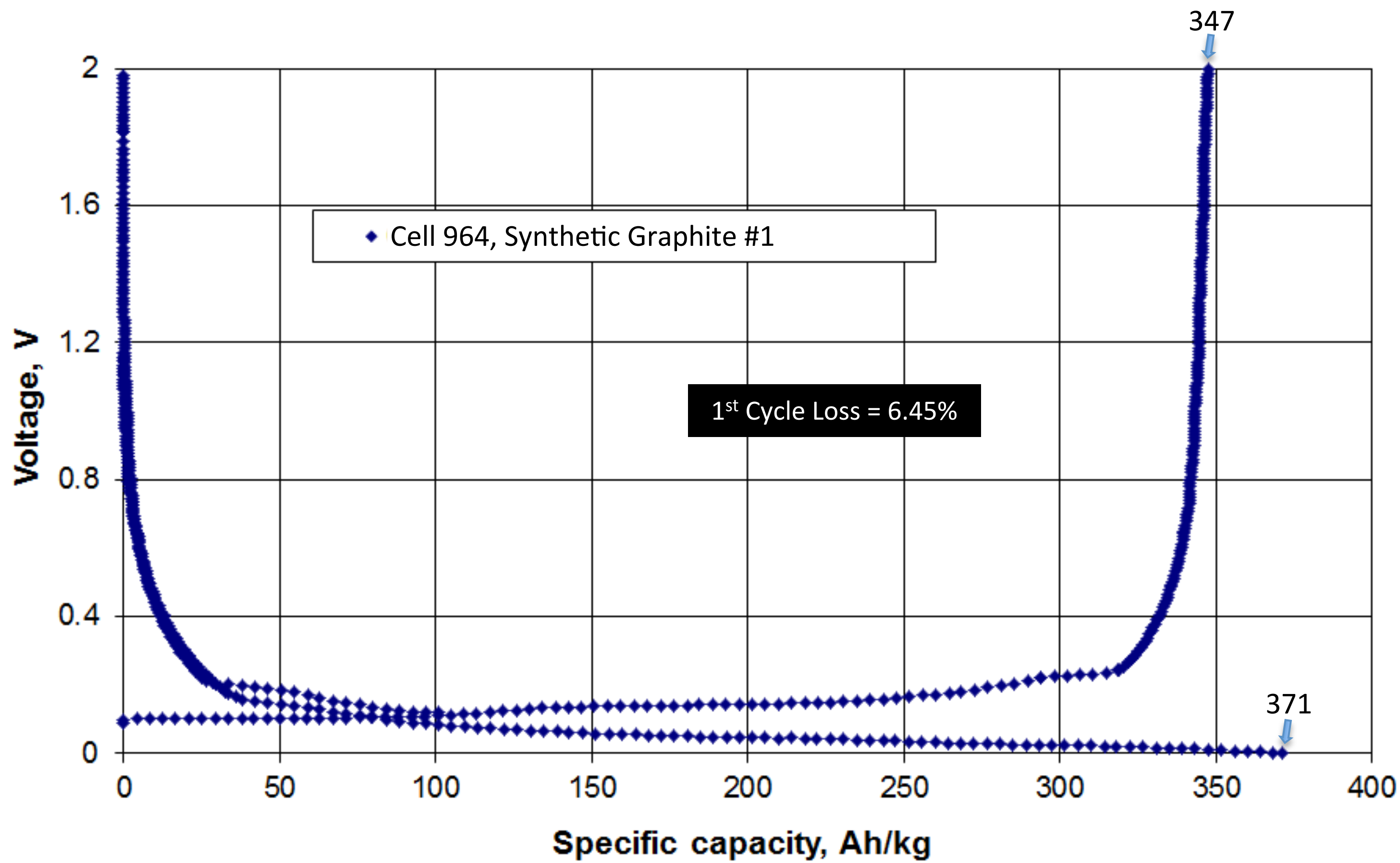
Fig.3 INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR FINE GRADE OF COATED SPG

SURFACE AREA = 1.14 m^2/g TAP DENSITY = 0.87 g/cc



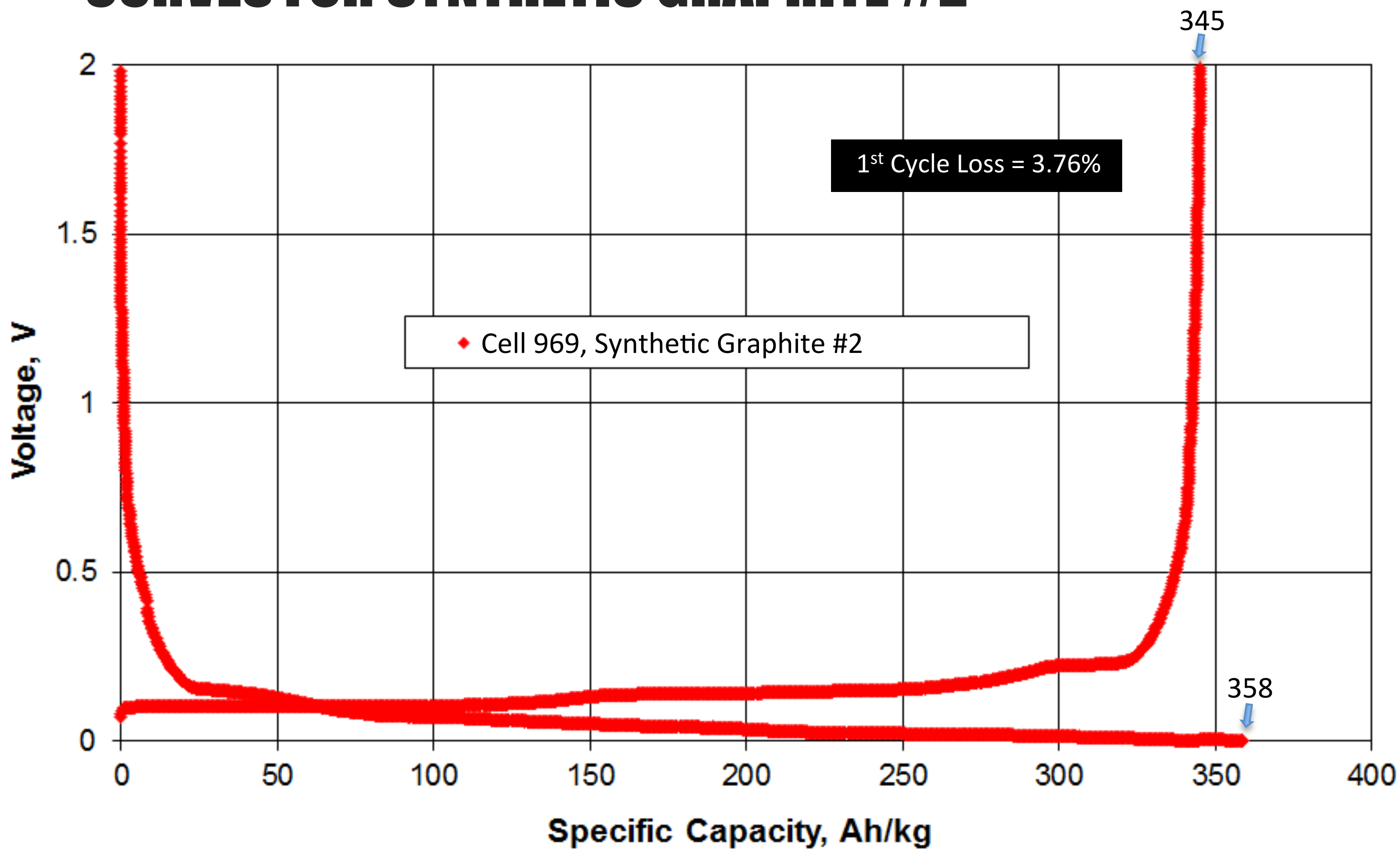
Cell #705. CR2016, counter: Li; Graphite: Fine Grade Surface Coated SPG; Rate: C/20; Electrolyte 1M LiPF6 in FEC/EMC (30:70 vol%)

Fig.4 INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR SYNTHETIC GRAPHITE #1



FOCUS GRAPHITE

Fig.5 INITIAL GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR SYNTHETIC GRAPHITE #2



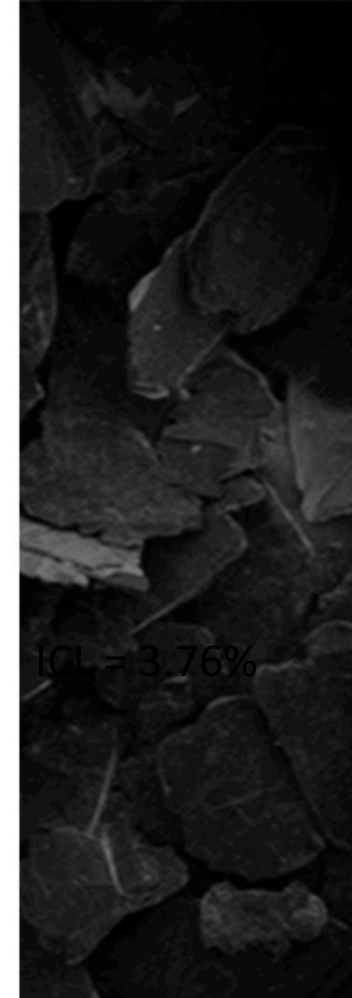
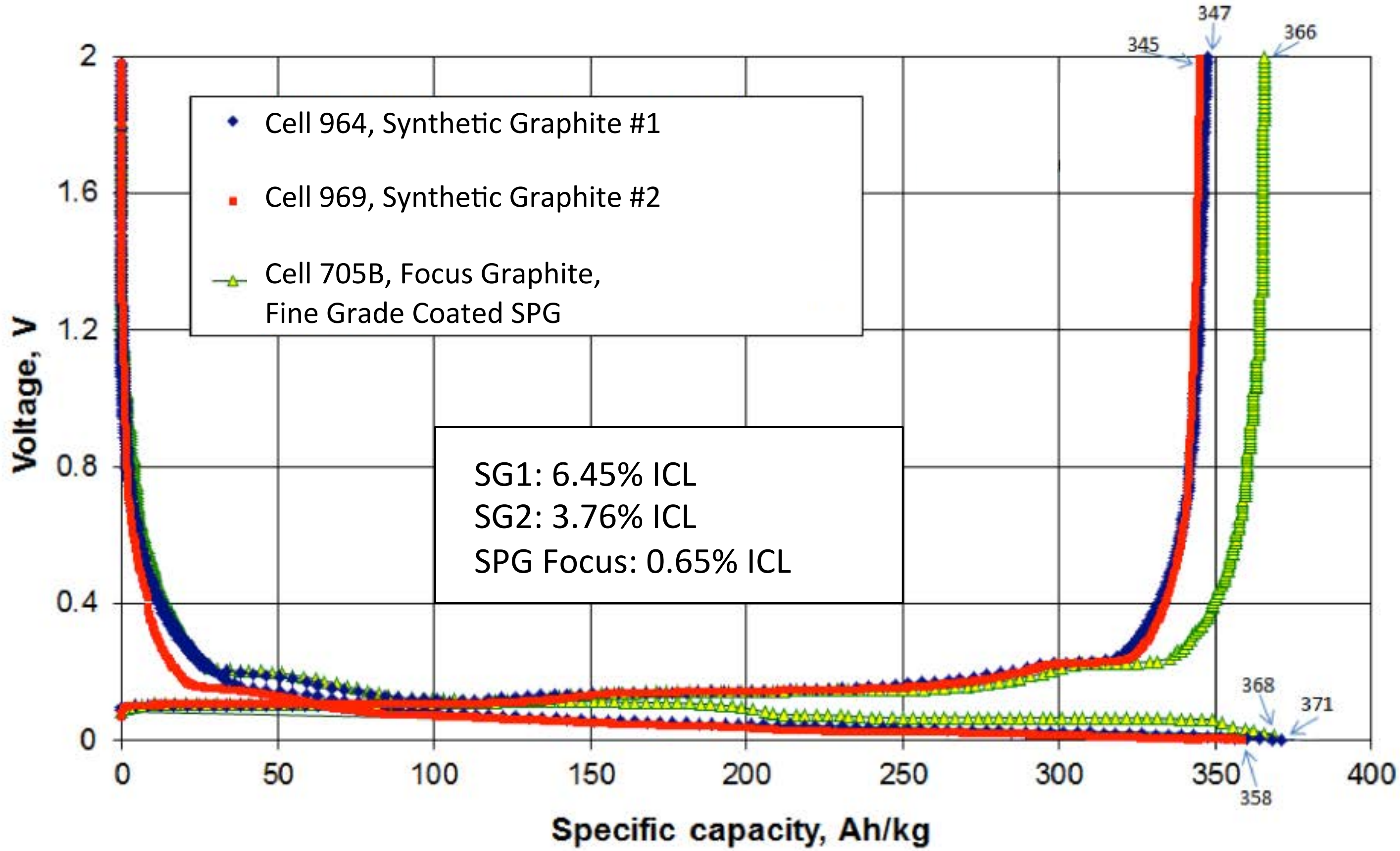


Fig.6

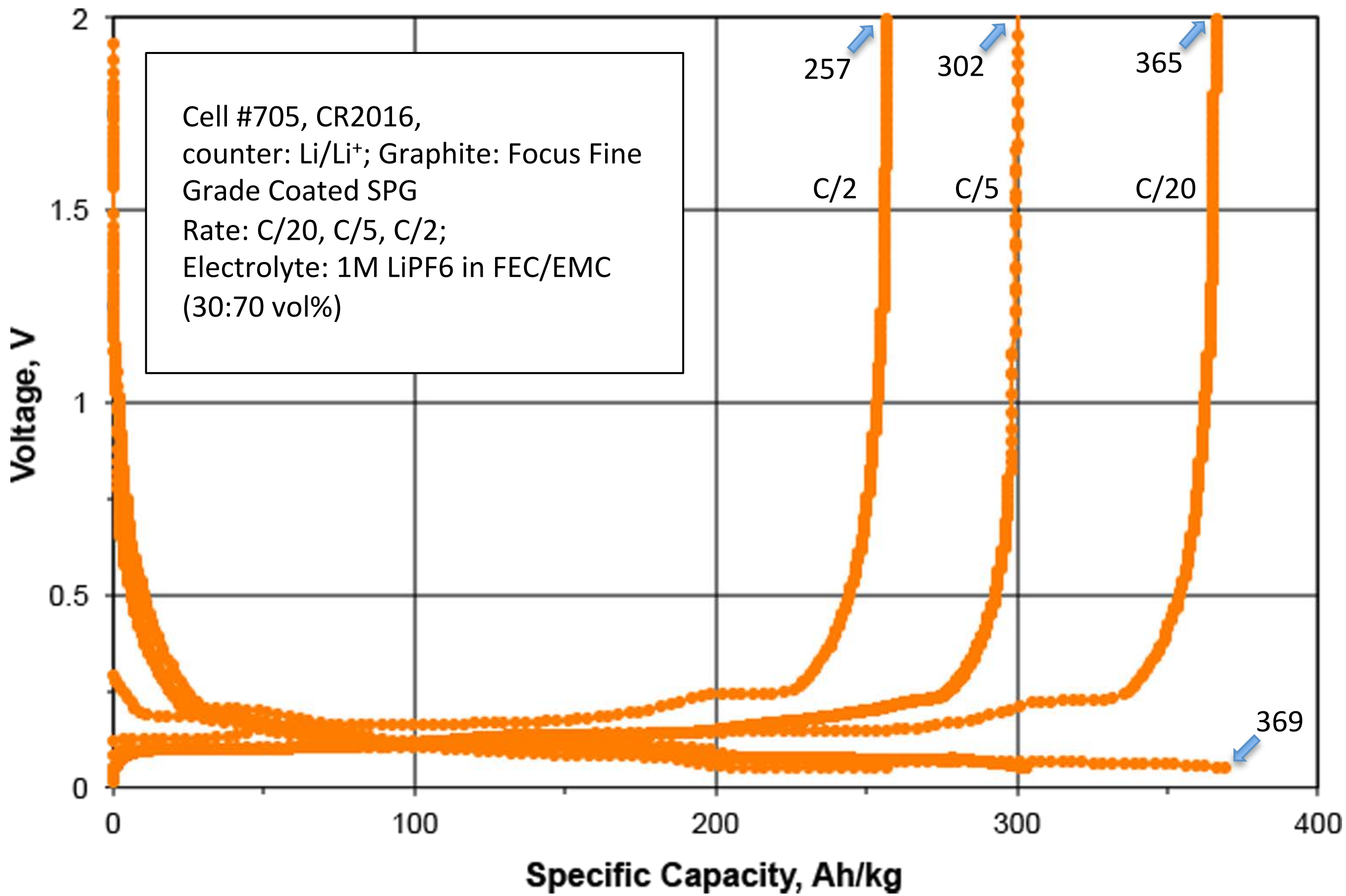
INITIAL CHARGE-DISCHARGE CURVES FOR LAC KNIFE FLAKE GRAPHITE COMPARED WITH SYNTHETIC GRAPHITE



FOCUS GRAPHITE

Fig.7

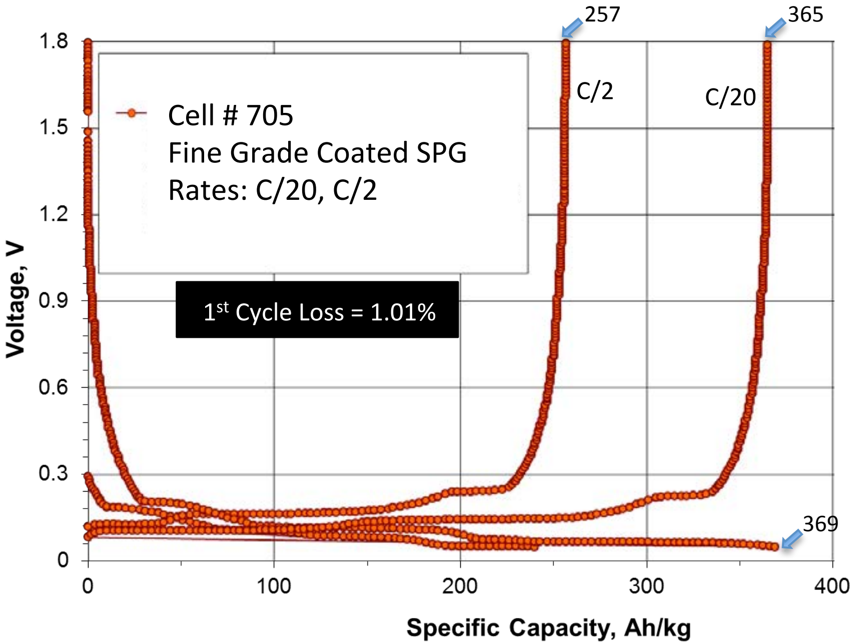
GALVANOSTATIC CHARGE-DISCHARGE CURVES FOR FINE GRADE OF CARBON COATED SPG AT C/20, C/5 AND C/2 RATES IN CR2016 HALF CELLS

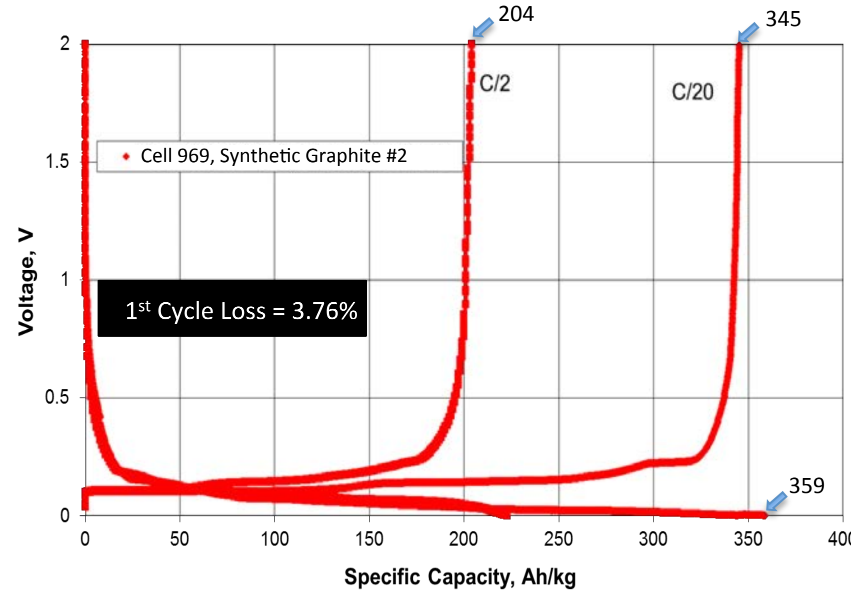


Cycling Protocol:
3 cycles at C/20
2 cycles at C/10
1 cycle at C/5
20 cycles at C/2

FOCUS GRAPHITE

Fig. 8 CHARGE-DISCHARGE CURVES FOR CARBON COATED SPG & SYNTHETIC GRAPHITE at C/20 and C/2 RATES IN CR2016 HALF CELLS

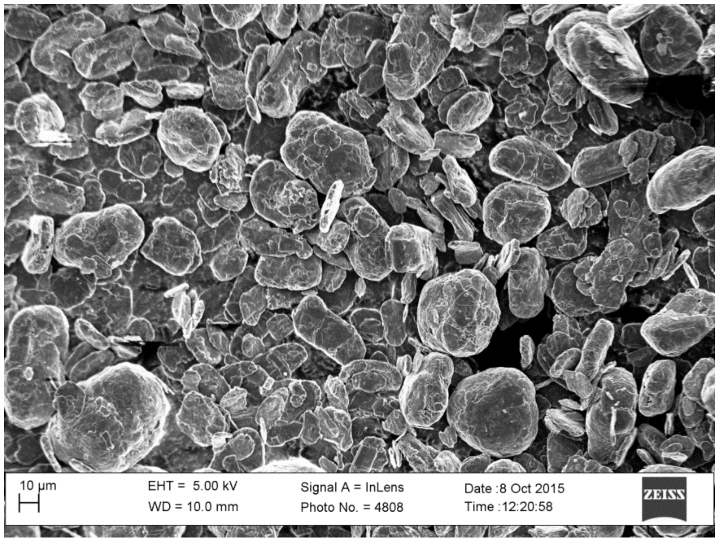




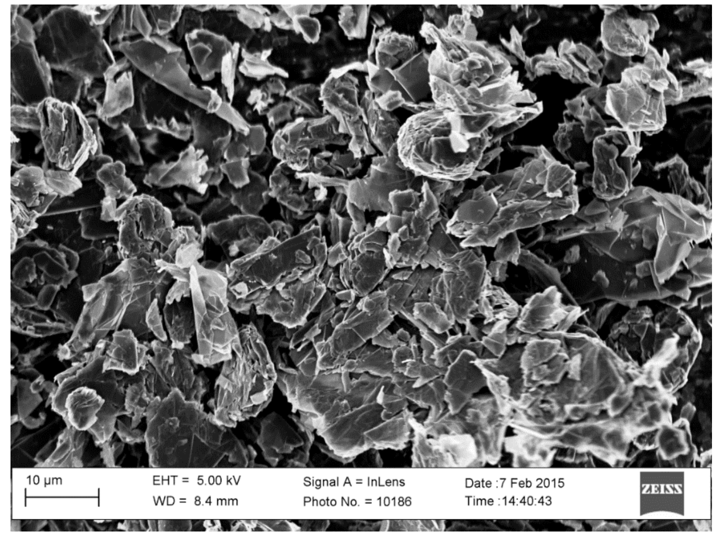
- The reduced C/2 Rate values are due to design limitations of the cells and not due to the graphite .
- The Lac Knife cell does show a higher specific capacity (256 Ah/kg) at the C/2 Rate than the synthetic cell (204 Ah/kg) at the same rate.

FOCUS GRAPHITE

Fig.9 PERFORMANCE OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN Li ION COIN CELLS



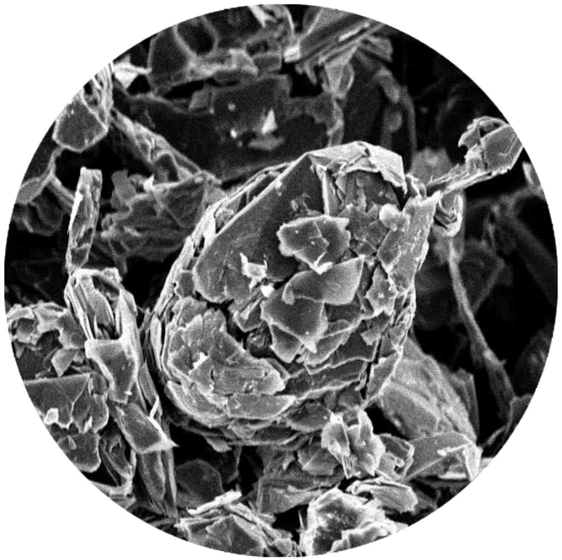
Coated Lac Knife Spherical Graphite



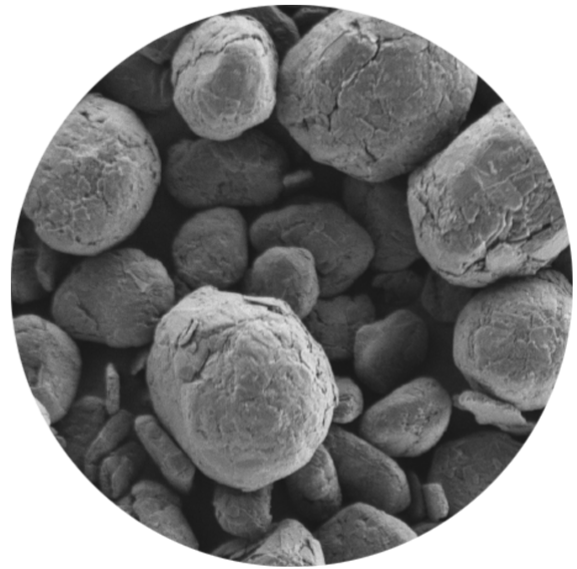
Commercial Grade of Synthetic Graphite

FOCUS GRAPHITE

LONG TERM CYCLING PERFORMANCE OF LAC KNIFE GRAPHITE



Formation of a Graphite Sphere



Spherical Graphite

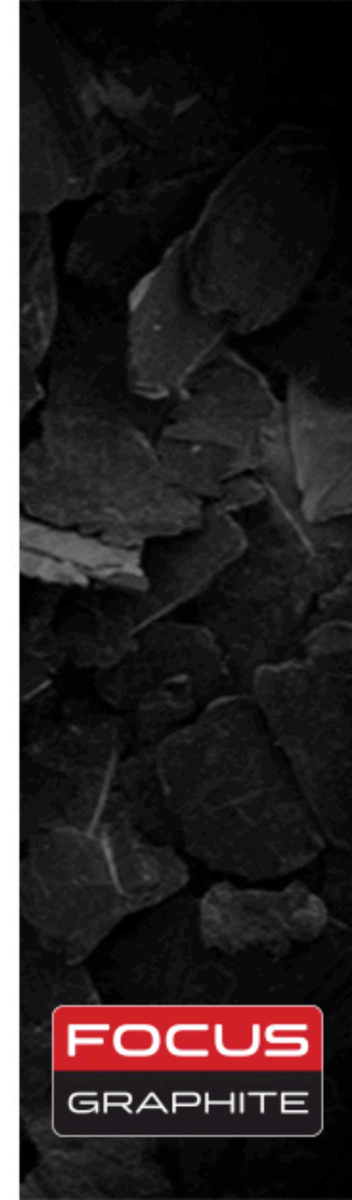
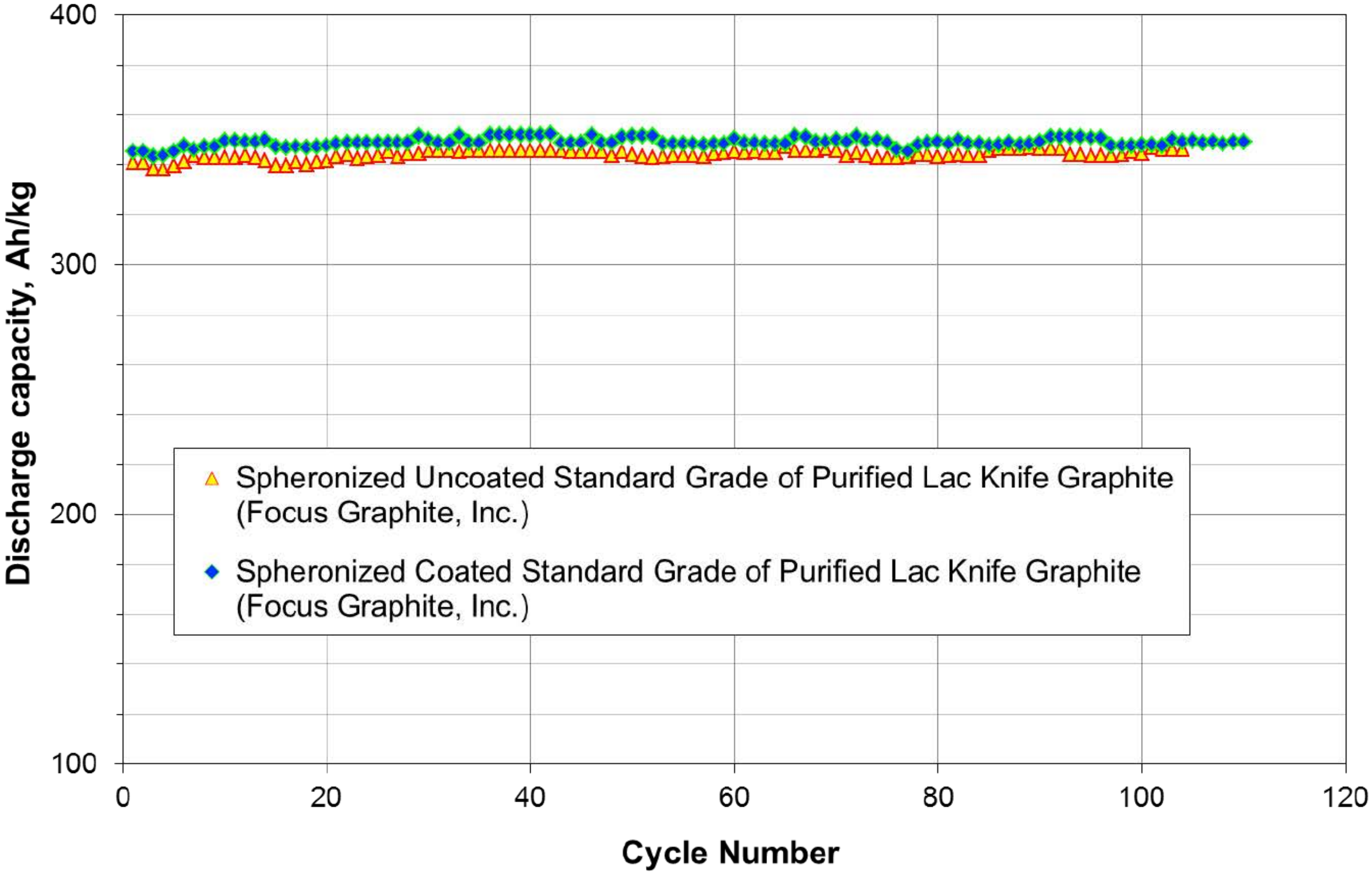


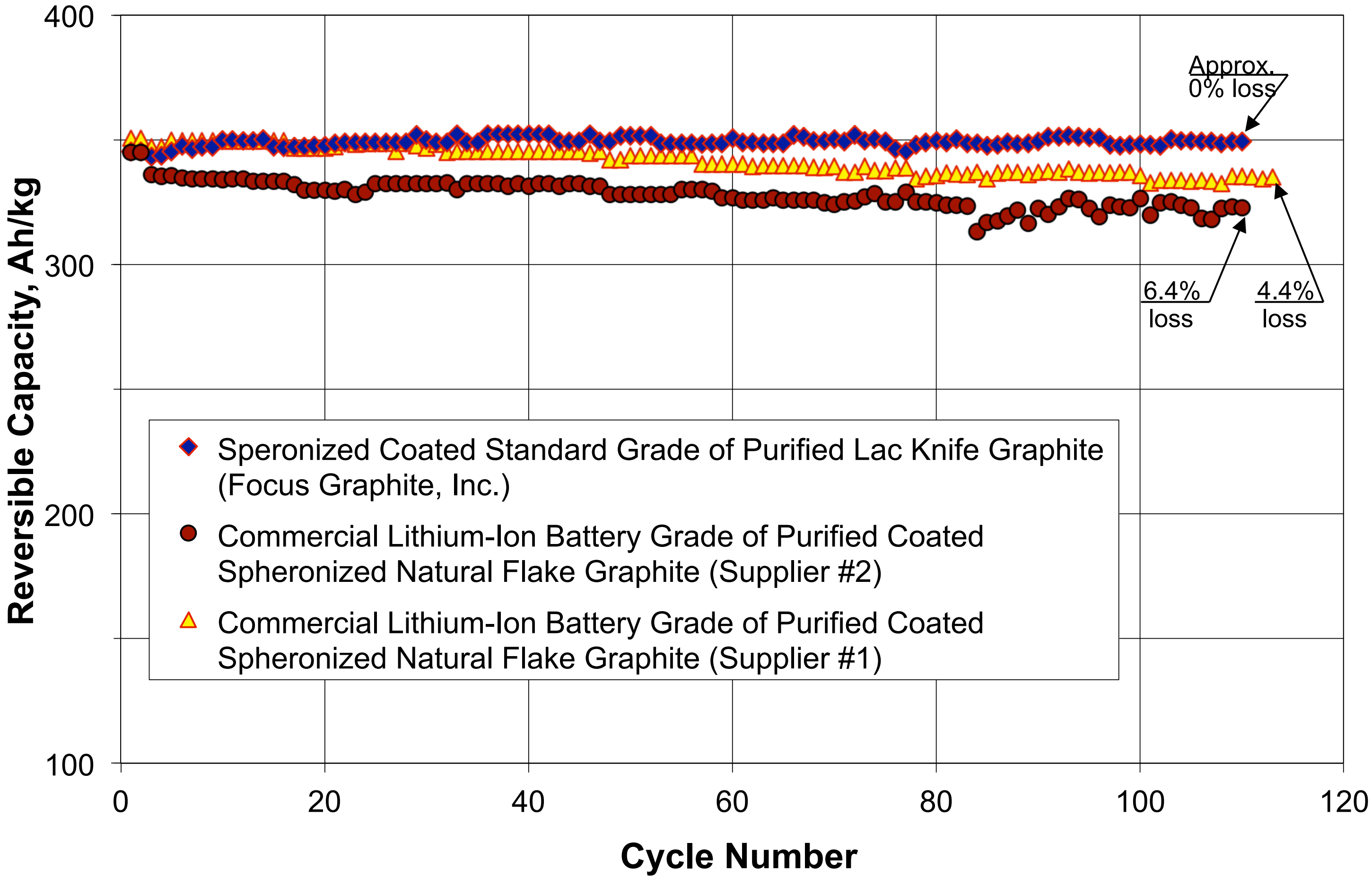
Fig.10 LONG TERM CYCLING PERFORMANCE OF UNCOATED AND CARBON COATED LAC KNIFE SPHERICAL GRAPHITE



Anodes consisted of graphite, binder and carbon black with a 20μ Cu foil current collector

FOCUS GRAPHITE

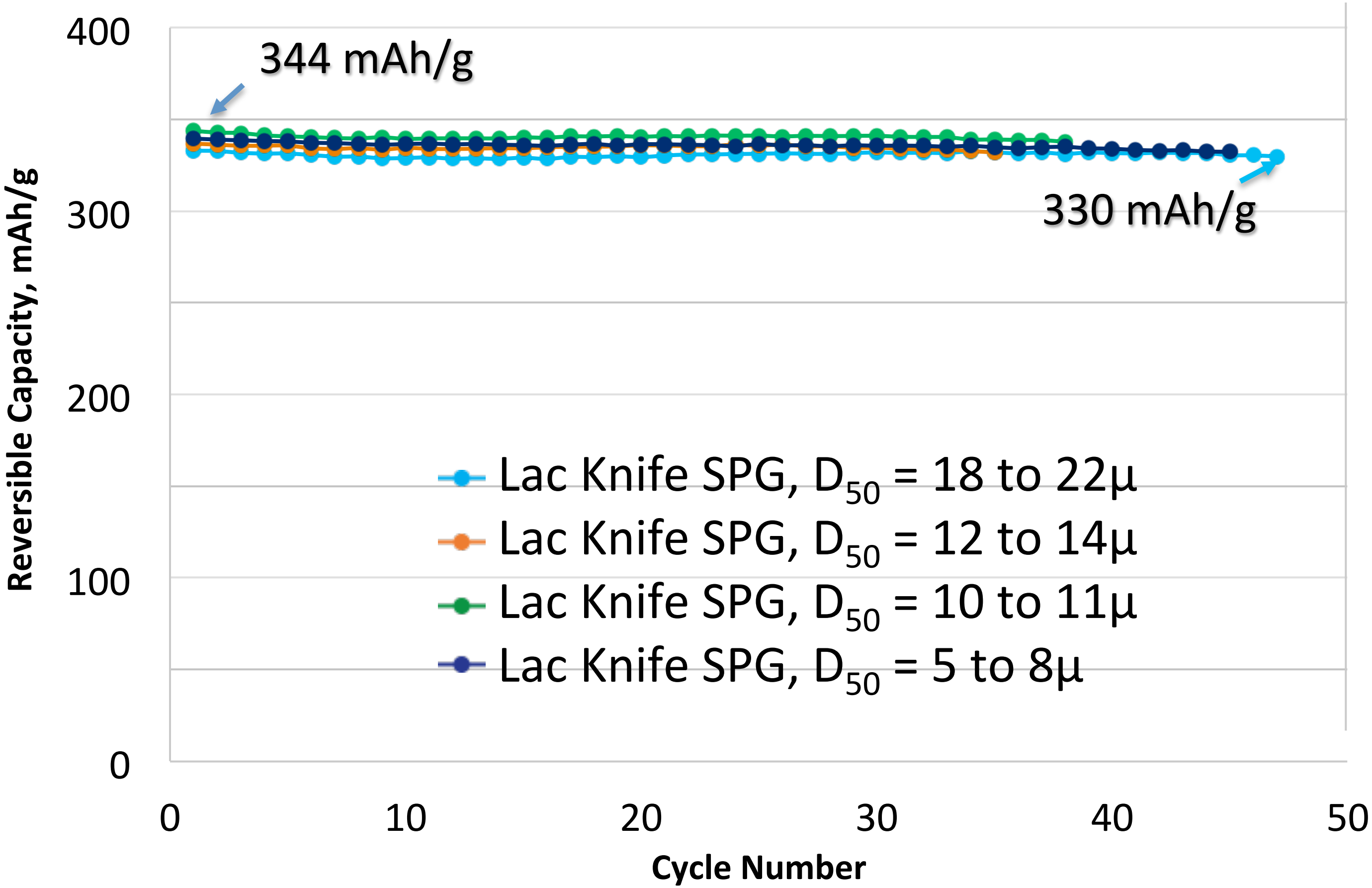
Fig. 11 LONG TERM CYCLING PERFORMANCE OF LAC KNIFE GRAPHITE COMPARED WITH TWO COMMERCIAL Li ION GRADES OF FLAKE GRAPHITE



Anodes were tested in CR2016 coin cells prepared with 1M LiPF6/EC/DMC electrolyte and Li foil reference/counter electrodes.

FOCUS GRAPHITE

Fig.12 LONG TERM CYCLING PERFORMANCE OF ULTRA FINE GRADES OF UNCOATED LAC KNIFE GRAPHITE



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

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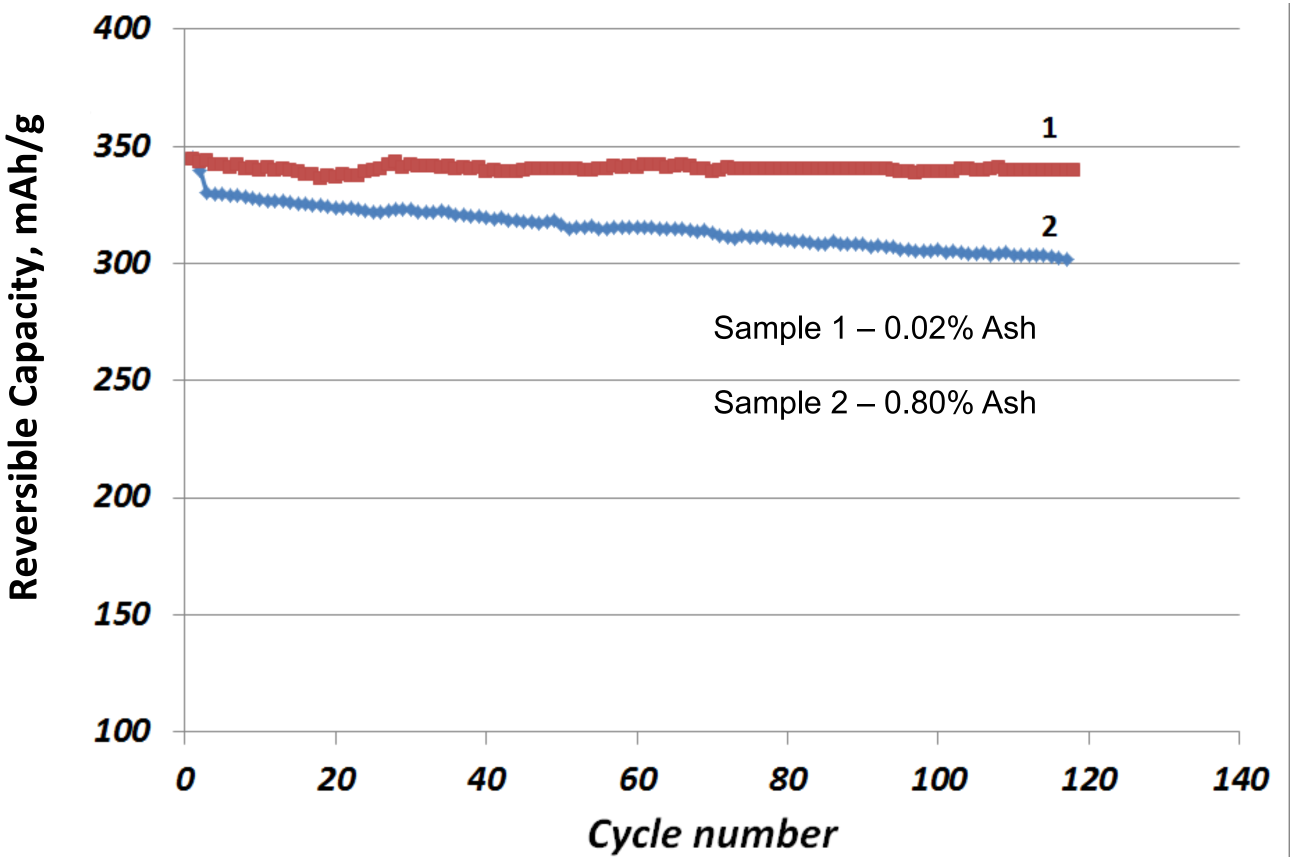
Fig. 13 LONG TERM CYCLING PERFORMANCE OF UNCOATED NATURAL FLAKE GRAPHITE PURIFIED TO DIFFERENT ASH LEVELS



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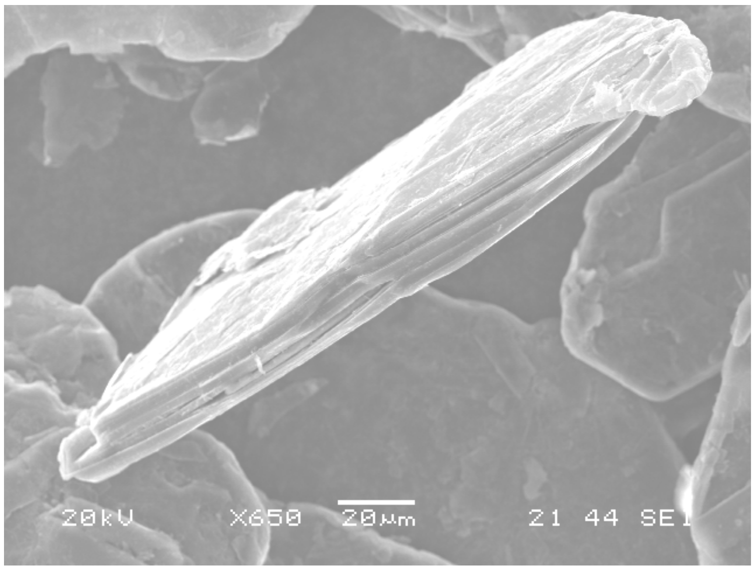
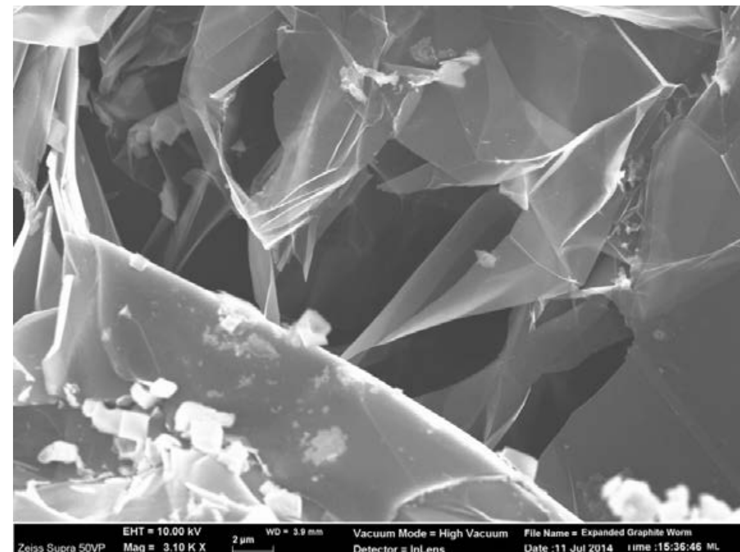
PRODUCTION OF EXPANDED LAC KNIFE GRAPHITE

FOCUS GRAPHITE

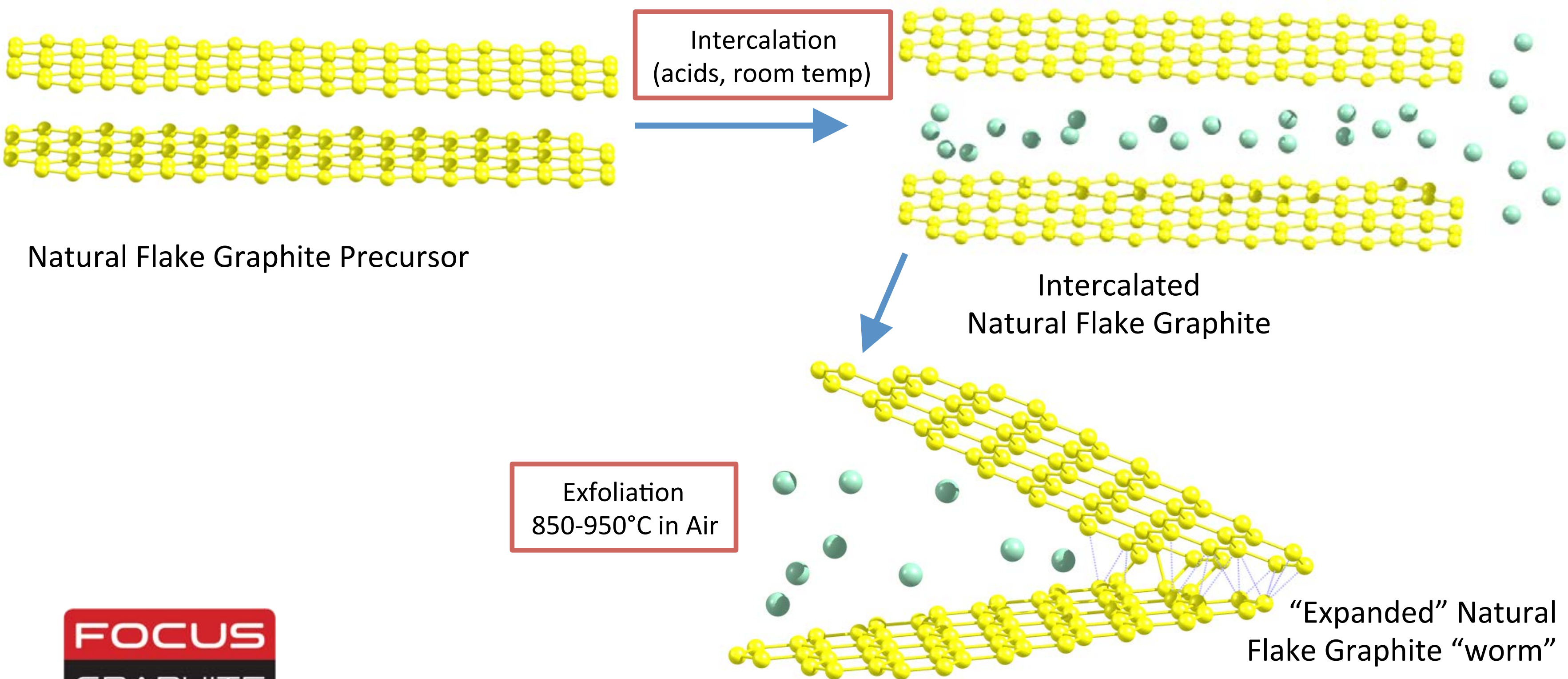


Purified Graphite



Expanded Graphite

Fig.14 PRODUCTION OF EXPANDED LAC KNIFE GRAPHITE



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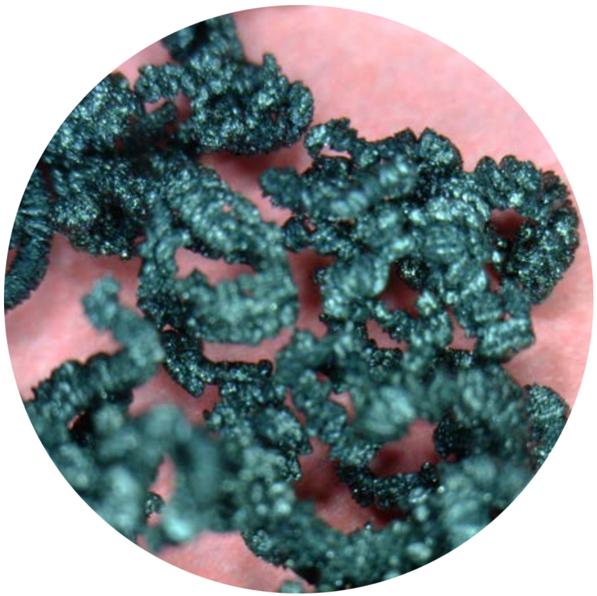
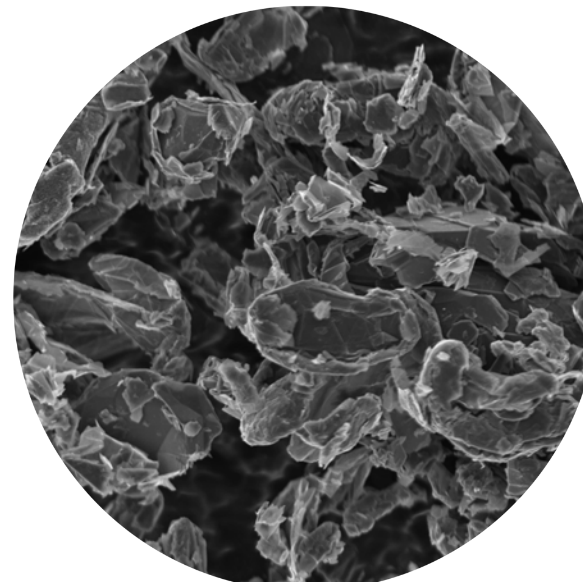
RESISTIVITY OF LAC KNIFE FLAKE GRAPHITE AND SYNTHETIC GRAPHITE IN CATHODE MATRIXES OF Li ION BATTERIES



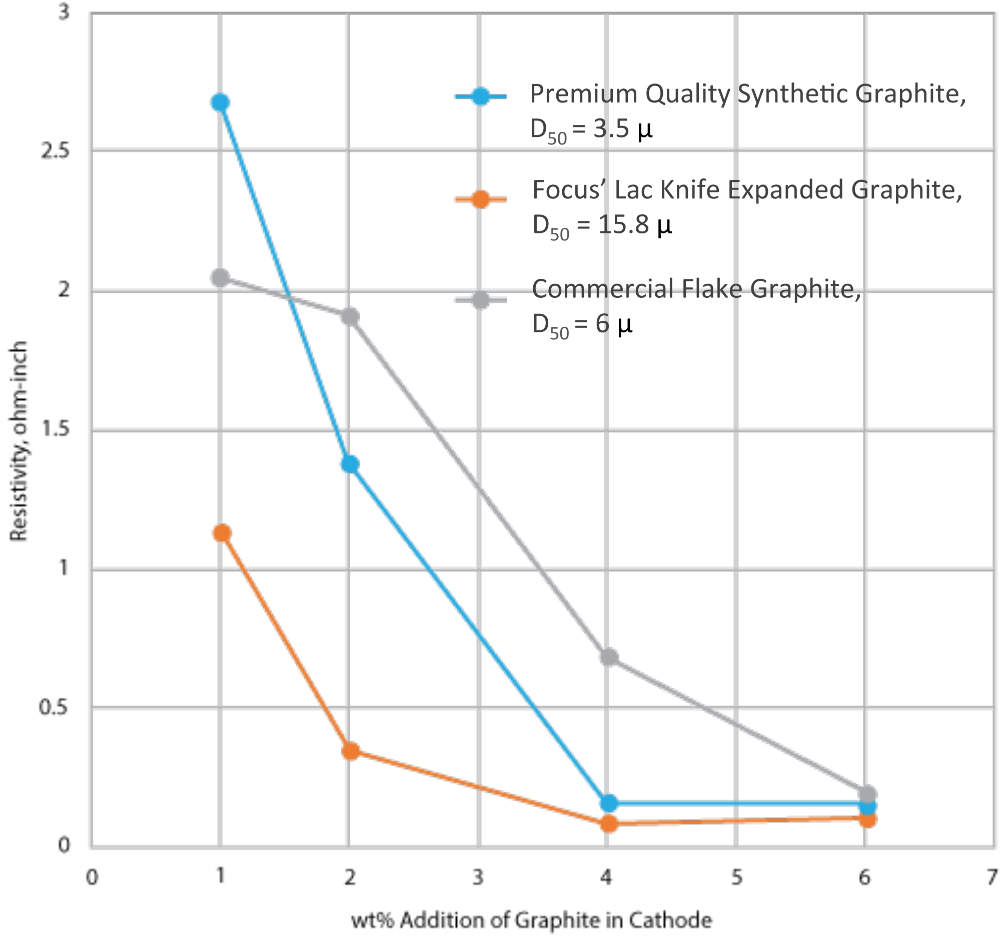
Expanded Graphite



Delaminated Graphite

Fig. 15 RESISTIVITIES IN Li ION CATHODE MATRIX:

$LiNiMnCoO_2$



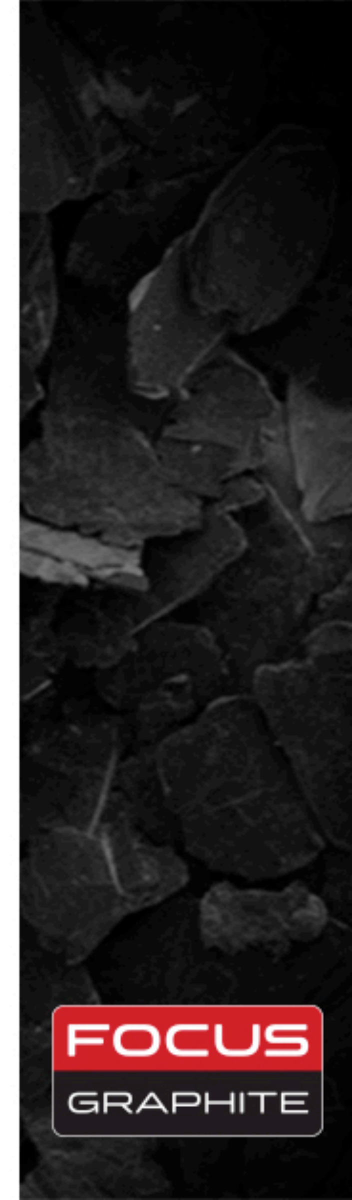
ADVANTAGES OF USING LAC KNIFE GRAPHITE IN BATTERIES

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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