Phase II Project Summary

PSI-6219

Firm: Physical Sciences Inc.
Contract Number: NNX10CA51C
Project Title: Silicon Whisker and Carbon Nanofiber Composite Anode

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)
Physical Sciences Inc. has successfully developed a novel high capacity anode material for lithium ion batteries. The innovation in this program is a nano-composite silicon anode with a unique architecture to stabilize silicon upon cycling. As a result of this unique "whisker-on-fiber" architecture, the composite anode has been demonstrated to possess a specific capacity of greater than 1100mAh/g, rate capability of 1C, 80+% first cycle reversibility, and superior cycle life of over 200 cycles. In this program PSI demonstrated the scalability and full cell performance of this composite anode material for next generation high energy density lithium-ion batteries by constructing and testing of cells up to 2500mAh. The anode material was demonstrated to be able to deliver >1000mAh/g at rates up to C/2 and loadings that allow for the construction of batteries offering >220Wh/kg. PSI demonstrated a path to high volume production of the composite material and continuous production of the electrode.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

Objective 1. Demonstrate 50-gram per batch production of silicon whisker on carbon nanofiber composites with 1:1 weight ratio.

Objective 2. For an anode with >20 mAh/in^2 loading in full cells, demonstrate a capacity of greater than 1000 mAh/g based a C/10 charge/discharge rate and 0^{o}C.

Objective 3. Demonstrate a full cell cycle life of over 300 cycles (20% capacity fade).

Objective 4. Demonstrate an operating temperature of -30^{o}C to 30^{o}C.

Objective 5. Demonstrate a rate capability of C/5 or higher.

Objective 6. Deliver to NASA three 2.5 Ah pouch cells with energy density of greater than 220Wh/kg.

Objective 7. Demonstrate the safety features of the anode and full cells.

Objective 8. Design a 1 kWh prismatic battery pack.

Tasks: Project management and reporting, electrode and cell fabrication optimization, design/build a 50-gram per batch reactor, fabricate anodes with a greater than 20 mAh/in^2 loading, full cell fabrication (pouch cells), anode evaluation in full cells, operating temperature and rate capability evaluation, design and fabricate 2.5 Ah pouch cells, safety test and evaluation on silicon whisker lithium ion cells, and design of a 1 kWh prismatic pack.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)
During this PSI II program PSI:

- Developed a silicon whisker and carbon nanofiber composite material capable of reversibly delivering >1000mAh/g at up to 1C rates.
- Demonstrated > 80% capacity retention over 200 cycles.
- Successfully scaled production of the composite anode material to the 50 gram scale with a clear path to the production of 250-500 gram batches.
- Refined the electrode formulation to produce electrodes delivering 1000mAh/g at loadings > 20 mAh/in^2.
- Demonstrated continuous production of the anode electrode.
- Demonstrated equivalent pouch cell and coin cell performance.
- Demonstrated greater than 90% capacity retention at 0°C.
- Built and delivered three 2.5Ah pouch cells to NASA.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)
Energy storage with reduced weight and volume is required for various orbital and planetary surface NASA applications. This lithium-ion battery system has the capability to provide an energy density of greater than 300 Wh/kg with a 5-year calendar year service life. The battery system contains no toxic materials and lends itself to being human rated for Exploration missions. These mission applications include portable power for landers, rovers, and astronaut equipment; storage systems for crew exploration vehicles and spacecraft; and stationary energy storage applications such as base power or peaking power applications.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)
Rechargeable lithium ion batteries have rapidly become the primary choice to power the next generation hybrid electric vehicles. These battery packs require large volumes of low cost anode materials that provide higher charge and rate capability than graphite anodes. The developed carbon nanofiber stabilized silicon nanowhisker material

provides high discharge capacity and good cycling performance. Further, during this program PSI has demonstrated the ability to readily incorporate the anode material into the construction of high energy lithium ion batteries. The scalable synthesis process and electrode fabrication techniques developed allows anode electrodes to be produced at a sufficiently low cost to allow incorporation in the targeted electric vehicle and bulk energy storage markets.

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