Development of Low Cost, Thin Flexible Graphite Bipolar Plates for Heavy Duty Fuel Cell Applications

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AMR Project ID: FC347

Project Goal

- The goal is to reduce bipolar plate assembly (BPA) graphite costs for next-generation heavy duty fuel cell applications by approximately 90% through the development of thin and durable flexible graphite.
- This represents a critical advancement in BPA technology and substantial progress towards meeting 2030 system level heavy-duty truck targets of $80/kW system cost and 25,000-hour durability.
- The success of this project depends on our ability to produce low basis weight, thin flexible graphite with very low content of naturally occurring or process-related impurities that may cause leakage in the finished BPAs.

Overview

- **Timeline and Budget**
  - Project Start Date: TBD
  - Project End Date: TBD
  - Total Project Budget: $2,053,946
    - DOE Share: $1,643,157
    - Cost Share: $410,789
    - DOE Funds Spent*: $0
    - Cost Share Funds Spent*: $0

  * As of 04/25/22

- **Partners**
  - Project Lead: NeoGraf Solutions, LLC
  - Ballard Power Systems
  - Strategic Analysis, Inc.
  - Norley Carbon & Graphite Consultants, LLC

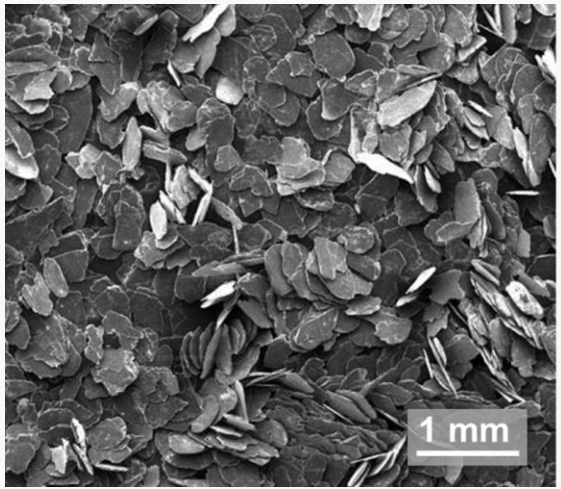
Relevance / Potential Impact

- Flexible graphite BPAs meet current requirements for durability, corrosion resistance, and other critical attributes demanded for heavy-duty fuel cell applications.
- To meet DOE cost targets, the amount of graphite, and therefore BPA thickness, must be reduced. This is challenging because the thickness of the plates already approaches that of minor mineral inclusions (i.e., ‘ash’ impurities) in the flexible graphite sheets.
- These impurities may cause pinhole defects and leaks in the finished BPAs. As BPA thickness decreases, leakage failure due to inclusions becomes more frequent.
- In this project, the flexible graphite costs for BPAs will be drastically reduced through the development of low basis weight, thin flexible graphite with very low content of leak-inducing impurities.

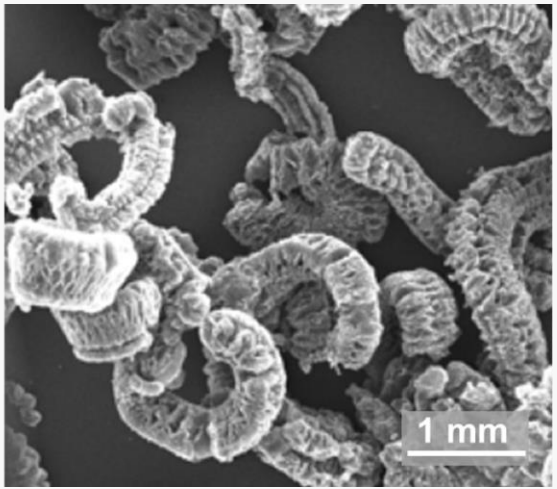
DOE 2030 Goal: Heavy-duty truck targets of $80/kW system cost and 25,000-hour durability.

Relevance / Potential Impact

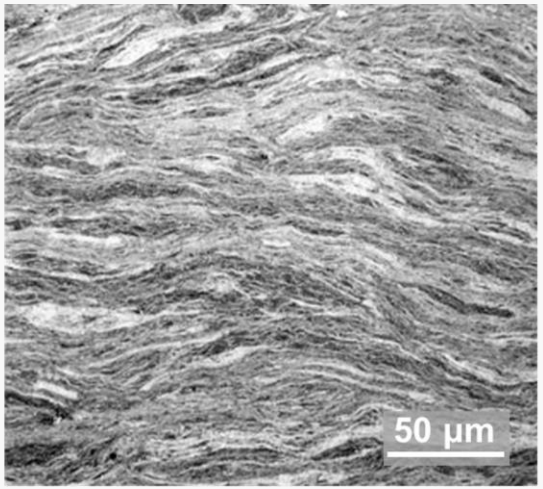
Natural Graphite Flake



Exfoliated Graphite 'Worms'

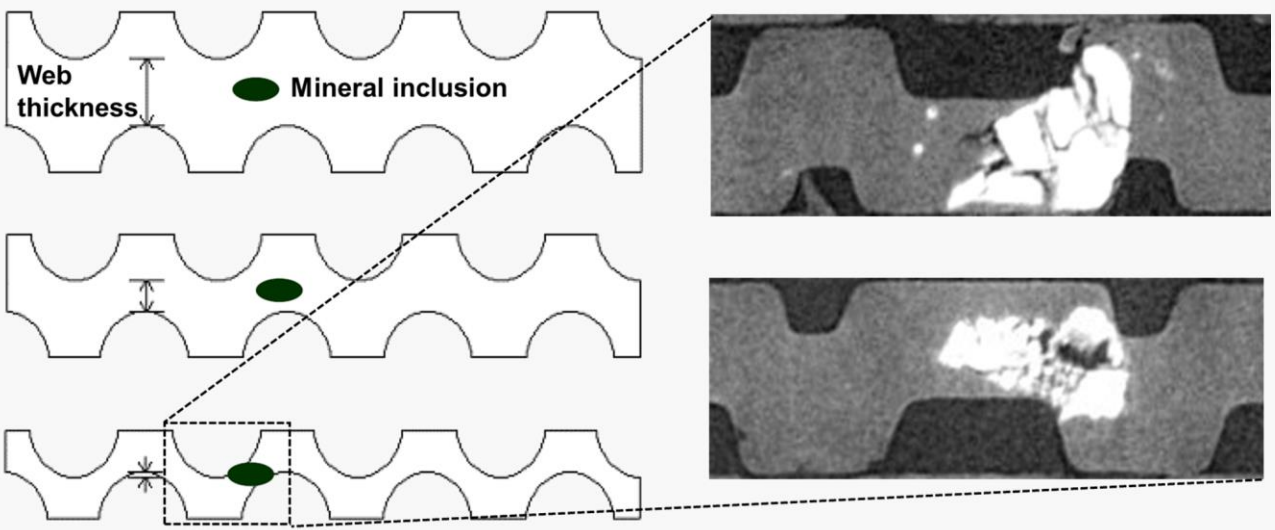


Cross-section of compressed flexible graphite sheet



Natural graphite flake (left) is treated with a combination of chemicals, exfoliated in a high temperature furnace to produce vermicular expanded graphite or "worms" (middle), and densified to produce flexible graphite sheet (right)

Relevance / Potential Impact



Schematic of mineral inclusions (i.e., ash) in flexible graphite bipolar plates (left) and X-ray computed tomography (XCT) images showing large particles causing leak failures (right) in processed plates. As BPA thickness decreases, leakage failure due to inclusions becomes more frequent.

Approach

- **Technical approach:**
  - Develop and evaluate technologies to eliminate leak-inducing impurity particles in the flexible graphite introduced from two main sources, raw material impurities and process contamination.
- **Key Objectives:**
  - Reduce BPA thickness from ~1.7 mm to less than 1.4 mm by decreasing the graphite basis weight from the current state of 600 g/m^2 to ~300 g/m^2.
  - Eliminate impurities in the graphite BPAs to maintain a leakage failure rate of less than 5% as thickness is reduced.
  - Demonstrate stable performance in durable BPAs through short stack testing at heavy duty conditions and accelerated materials testing.
  - Provide detailed and transparent cost estimates of the proposed BPA concept through a manufacturing cost analysis.

Approach

- **Go/No-Go Decision Point – End of Budget Period 1 (18 months)**
  - Show capability to produce thin (<1.4 mm), low basis weight (~300 g/m^2) BPAs which have a leak failure rate of <5%.
- **End of Project Goals:**
  - Demonstrate a leak failure rate of <5% for a statistically relevant sample set (~11,000) of BPAs made from thin, low basis weight flexible graphite.
  - Report the outcome of durability and performance tests in a fuel cell stack under heavy-duty operating conditions.
  - Deliver six or more BPAs (active area ≥ 25 cm^2) for independent testing and evaluation by the M2FCT.
  - Provide detailed and transparent cost estimates of the proposed BPA concept.

Accomplishments and Progress

- This is a new award, and the project has not started as of 04/25/22.

Response to Reviewer Comments

- This project was not reviewed last year.

Collaboration and Coordination

Partner	Type	Project Role
NeoGraf Solutions, LLC	Industry, Prime	Lead the development and manufacturing of next-generation flexible graphite
Ballard Power Systems	Industry, Sub	Lead BPA and short stack production, as well as leakage rate and performance evaluations
Strategic Analysis, Inc.	Industry, Sub	Conduct manufacturing cost analysis of the proposed BPA concept
Norley Carbon & Graphite Consultants, LLC	Industry, Sub	Provide technical guidance to NeoGraf Solutions for their development tasks
Million Mile Fuel Cell Truck (M2FCT) Consortium	National Laboratory	Test and utilize appropriate accelerated stress tests, use system-modeling efforts to assess the proposed technology's impact on heavy-duty fuel cell cost and performance

Remaining Challenges and Barriers

- This program has a high probability of technical success, due in part to the demonstrated performance to date of flexible graphite BPAs. In addition, the strong collaborative team possesses the required expertise in the core technical areas of graphite and BPA design to accomplish the work plan.
- However, the project is not without technical risks including the following:
  - Risk 1: Alternative raw graphite flake materials may not have sufficient expansion properties to form thin and strong flexible graphite. Contingency: Reformulate graphite intercalation process to enhance expansion properties.
  - Risk 2: The pilot scale graphite expansion furnace may not achieve sufficient graphite exfoliation to form flexible graphite with suitable properties. Contingency: Additional design work will be done before the new expansion process is implemented at full scale.
  - Risk 3: Expected BPA quality from the manufacturing process may not be met (e.g., permeability too high, dimensions out of specification). Contingency: Adjust process parameters to optimize for new incoming graphite material properties.
- The contingencies can be pursued without impacting the timeline of the project.

Proposed Future Work – FY 2022

- Award kick-off meeting with DOE program managers and team will be held.
- Tasks include developing and evaluating thin, low basis weight BPAs, exploring alternative graphite flake feedstocks, and conducting preliminary BPA manufacturing cost analysis.
- Key milestones:
  - Produce flexible graphite sheets at ~300 g/m^2 basis weight while meeting target area-weight uniformity.
  - Produce flexible graphite in a continuous roll of 1000’ length while meeting the target area-weight uniformity.
  - Identify two or more raw material candidates with lower impurity content and/or smaller particle size distribution compared to the current flake source and sufficient treated flake properties, particularly expansion volume.
  - Complete preliminary BPA manufacturing cost analysis and report on findings.

Any proposed future work is subject to change based on funding levels.

Proposed Future Work – FY 2023

- Tasks include continuing to explore alternative graphite flake feedstocks, optimizing graphite expansion process and material handling equipment to reduce ash/impurities, and developing a new graphite exfoliation process featuring clean furnace lining materials
- Key milestones:
  - Complete baseline leak rate dataset for low basis weight material.
  - Produce flexible graphite from alternative flake feedstocks.
  - Implement a new ash separation process and report on its efficacy.
  - Report results of parametric studies on the degree of ash carryover into the graphite sheet products and make recommendation for future furnace operating conditions.
  - Select and deploy at least one new furnace sealing material and evaluate degree of material loss and its potential to contaminate the expanded graphite stream compared to the conventional seal.
  - Complete leak rate datasets for BPAs produced from low-ash flexible graphite material.
  - Deliver the final design for a clean pilot scale expansion furnace based around a quartz glass tube furnace chamber

Any proposed future work is subject to change based on funding levels.

Summary

- The project is expected to begin later in 2022.
- The effort to develop low cost, thin flexible graphite bipolar plates for heavy duty fuel cell applications is led by NeoGraf Solutions, alongside partners Ballard Power Systems, Strategic Analysis Inc., and Norley Carbon & Graphite Consultants.
- The expected outcome is a bipolar plate assembly featuring thin flexible graphite that advances the state-of-the-art towards meeting the performance, durability, and cost targets set by the DOE.
- Technical development will be integrated with detailed cost and manufacturability analysis to ensure economic viability of the flexible graphite bipolar plates.
- This work will secure a US supply chain of the critical materials required to produce flexible graphite bipolar plates for heavy duty fuel cell vehicles.

Technology Transfer Activities

- This is a new award and there are no technology transfer activities to report as of 04/25/22.