Project ID#: mat211

Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer Composites (*S⁴CFRP*) for Next-Generation Vehicles

Masato Mizuta (PI)

Newport Sensors, Inc.

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Overview

Timeline

- Start Date: 6/29/20
- End Date: 3/28/21
- Project Complete: 100%

Budget

- DOE SBIR FY2020: $200K

Barriers Addressed

- High fiber cost and difficulty in damage inspection hinder wide deployment of lightweight CFRP composites for reducing vehicle GHG emission

Light-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials Workshop Report, February 2013

Partners

- N/A

Relevance

Impact

- Transformation of the structural materials (the carbon fiber and the polymer matrix) into a piezoelectric sensor and an energy harvester, achieving a new self-powered self-sensing/SHM multifunctional CFRP composite for vehicle application

Objectives

- To design and fabricate the multifunctional CFRP composites including circuitry hardware and software.
- To demonstrate the feasibility of self-sensing and detection of impact and damage.
- To demonstrate the feasibility of harvesting vibration energy sufficient to power the self-sensing/SHM system.

Milestones

- By the end of Month 4, the first prototype system including circuitry is completed.
- By the end of Month 8, the feasibility of self-sensing is demonstrated.
- By the end of Month 9, the feasibility of integrated sensing and energy harvesting is demonstrated.

Months

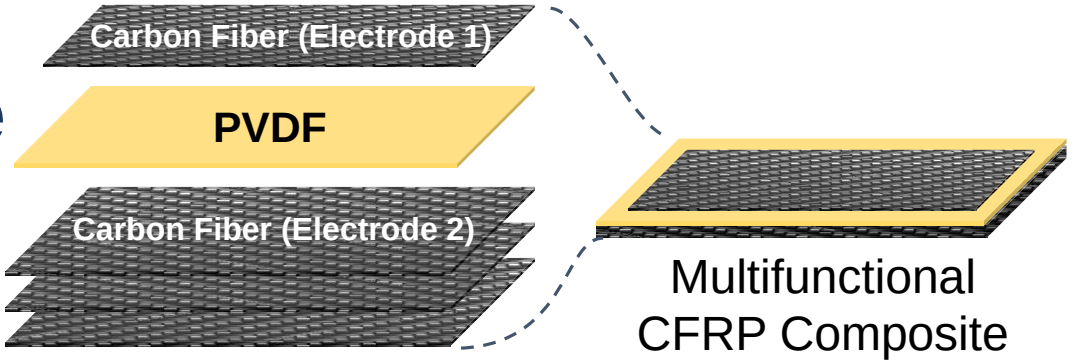
TASKS	1	2	3	4	5	6	7	8	9
1: Design of Simultaneous Sensing and Energy Harvesting Circuitry									
2: Prototyping of SLIC Specimens and System				▲					
3: Feasibility of Impact/Damage Detection								▲	
4: Feasibility of Energy Harvesting									▲

▲ Milestones

Approach

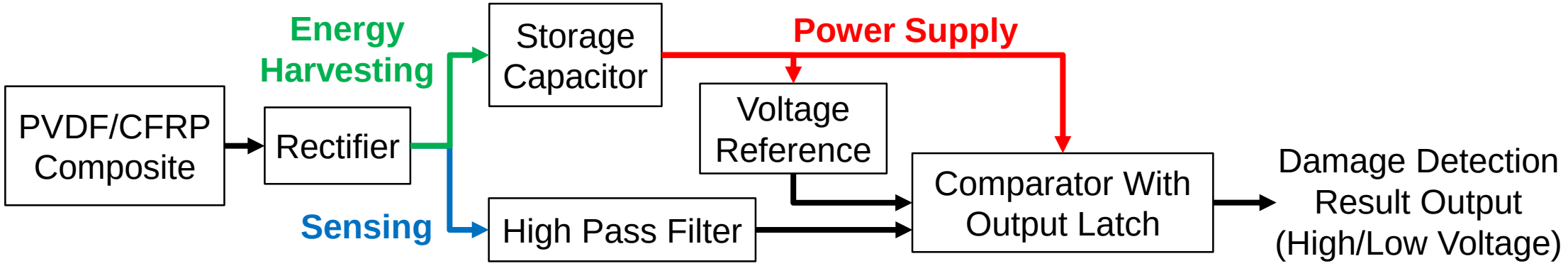
Multifunctional CFRP Composite

- Integrate Piezoelectric polymer as sensor
- Use carbon fiber layers as electrodes



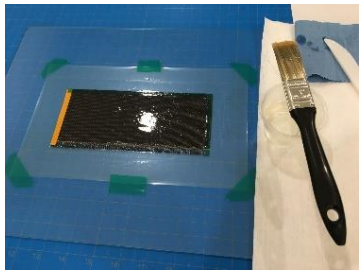
Simultaneous Sensing & Energy Harvesting Circuit

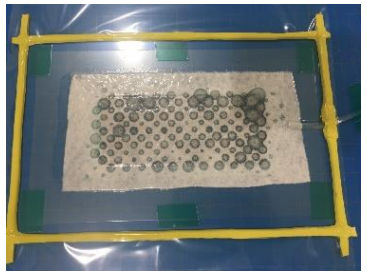
- Self-powered damage detection sensor circuit
- Harvest energy from vehicle vibration to power the sensor system
- Extract high-frequency impact/damage signal and compare with the threshold



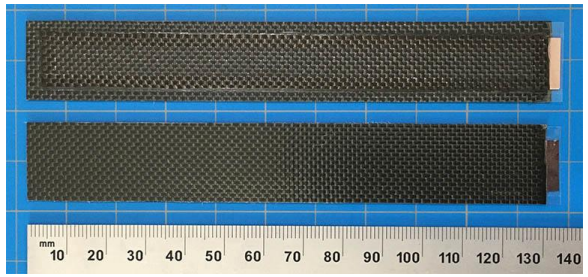
Accomplishments: Multifunctional CFRP Composite

- Fabricated the specimen by the hand layup and vacuum bagging method
- Specimen generated electric charge by vibration and impact shock
- Vibration and impact signals show different frequency characteristics

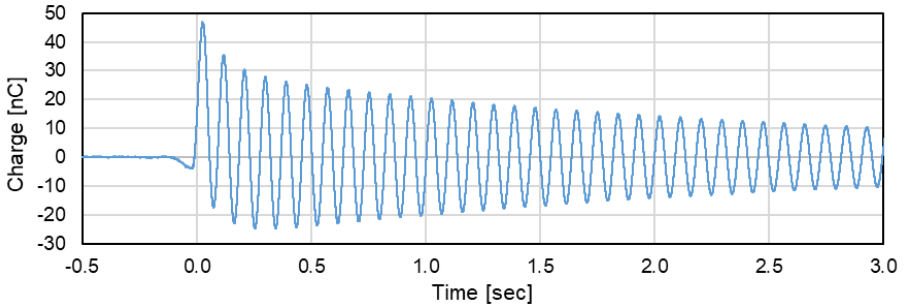




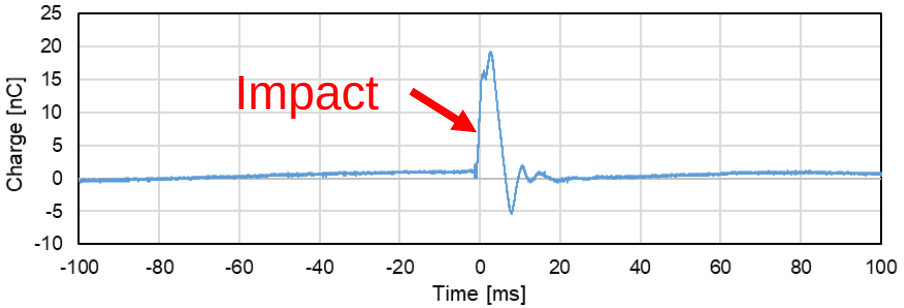
Fabrication Process



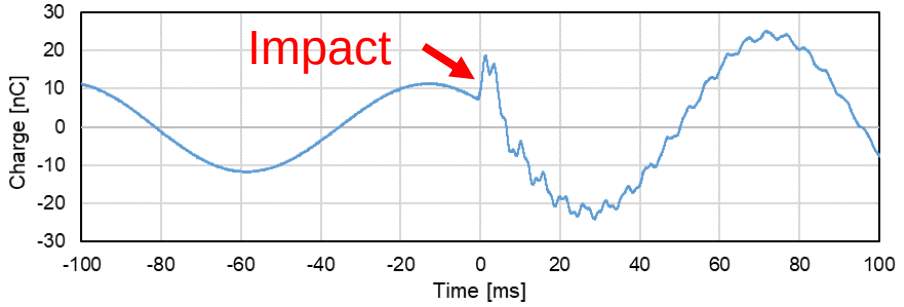
Fabricated Specimen



Vibration for Energy Harvest



Impact Shock for Damage Sensing

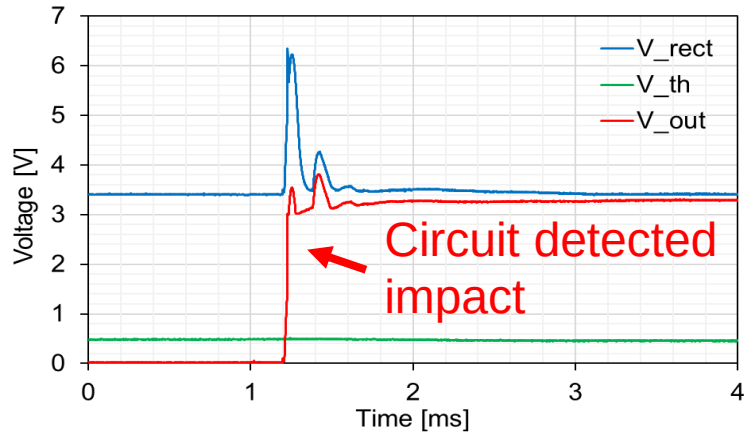


Vibration + Impact Shock

Accomplishments: Simultaneous Sensing & Energy Harvesting

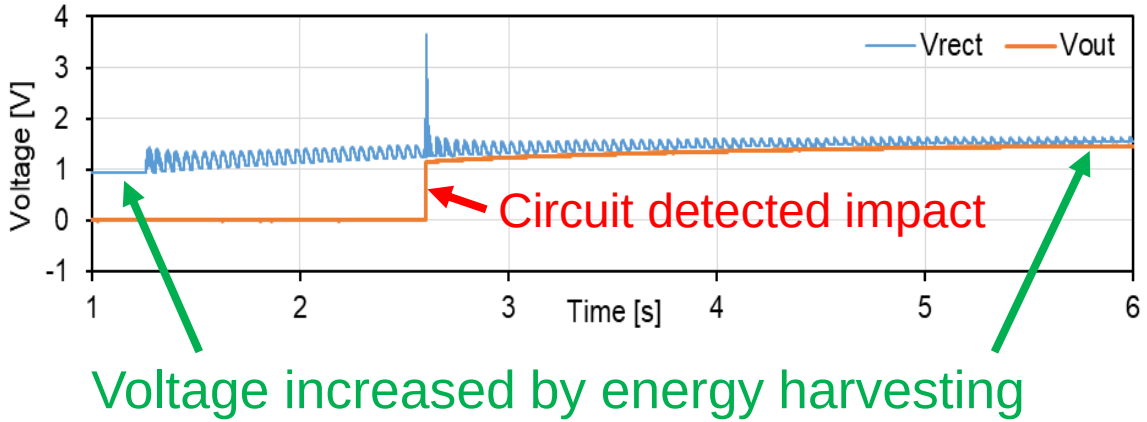
Damage Test

- Created damage with sharp object and hammer on specimen
- Developed circuit successfully detected the damage



Damage Detection during Energy Harvesting

- Vibration charged power storage and voltage was increased but does not trigger damage detection circuit
- Damage detection circuit only catches damage event



Responses to Previous Year Reviewers' Comments

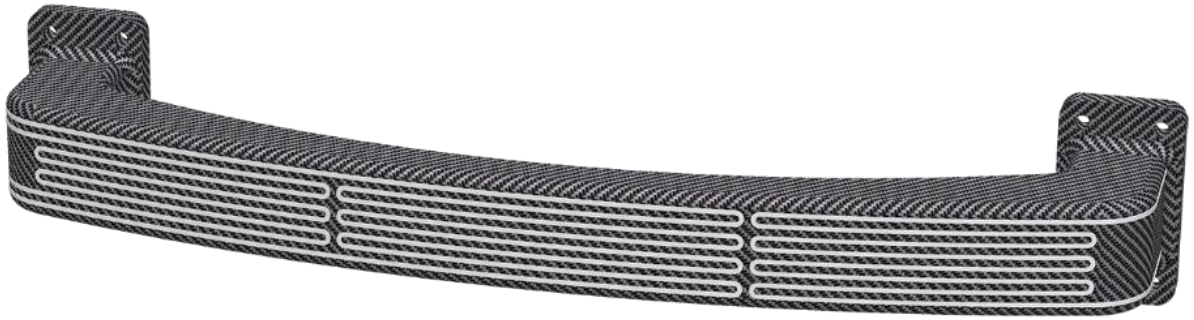
- This is a new start project and was not previously reviewed

Collaboration

- During Phase I, the team reached to automotive OEMs, tier-one suppliers, and researchers, and many of them have expressed an interest in collaboration.
- For future research, the team plans to engage
  - GM,
  - Continental Structural Plastics,
  - University of North Texas,
  - Kengrow Corporation.

Proposed Future Research

- Further expand the material's functionalities by adding a novel complementary piezo-resistive sensor to enhance the reliability of in-situ damage detection and enable damage location.
- Incorporate natural fiber to not only reduce cost, but also improve crashworthiness - the most critical and unique requirement for automotive vehicle structural materials.



Sustainable Lightweight Intelligent Composites (SLIC) Bumper Beam

Natural Fiber (Kenaf) Preform

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

Summary

- Successfully created an innovative multifunctional CFRP composite as a vehicle structural material that can be doubled as a distributed piezoelectric sensor and a vibration energy harvester.
- Developed a novel circuit for simultaneous detection of impact loads and structural damage and harvesting of vehicle vibration energy.
- Experimentally evaluation of the multifunctional CFRP specimens, through vibration and damage tests, demonstrated that
  - damage signal can be distinguished from the simultaneously measured ambient vibration signal, and
  - the ambient vibration signal can be harvested to sufficiently power the circuit.