Scalable and Passive Carbon Nanotube Thin-film Sensor for Detecting Micro-strains and Potential Impact Damage in Fiber-Reinforced Composite Materials

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Background

•Fiber-reinforced polymer composites (FRPCs) have become integral materials in the aerospace, civil, automotive, and marine industries of the global infrastructure.
•**Hypothesis**: Carbon nanotube buckypaper (CNT-BP) thin-films can serve as effective sensors for detecting micro-strains, low-force impacts, and potential property degradation in fiber-reinforced composites.
•The **purpose** of this research is to investigate the sensing performance of CNT-BP thin-films on stressed fiber-reinforced composites.

Figure 1: Example of Structural Health Monitoring

Experimental Methods

1. Multi-wall Carbon Nanotube Buckypaper Fabrication
2. Inkjet Printed Sensor Design
3. Manufacturing Carbon Fiber Reinforced Plastic Coupons for Flexural Testing
4. Manufacturing Glass Fiber Reinforced Plastic Panels for Impact Testing
5. Characterization of Buckypaper Sensors
6. Retrofitting for Pre-existing Damage Detection
7. Assessing Impact Severity and Damage Progression

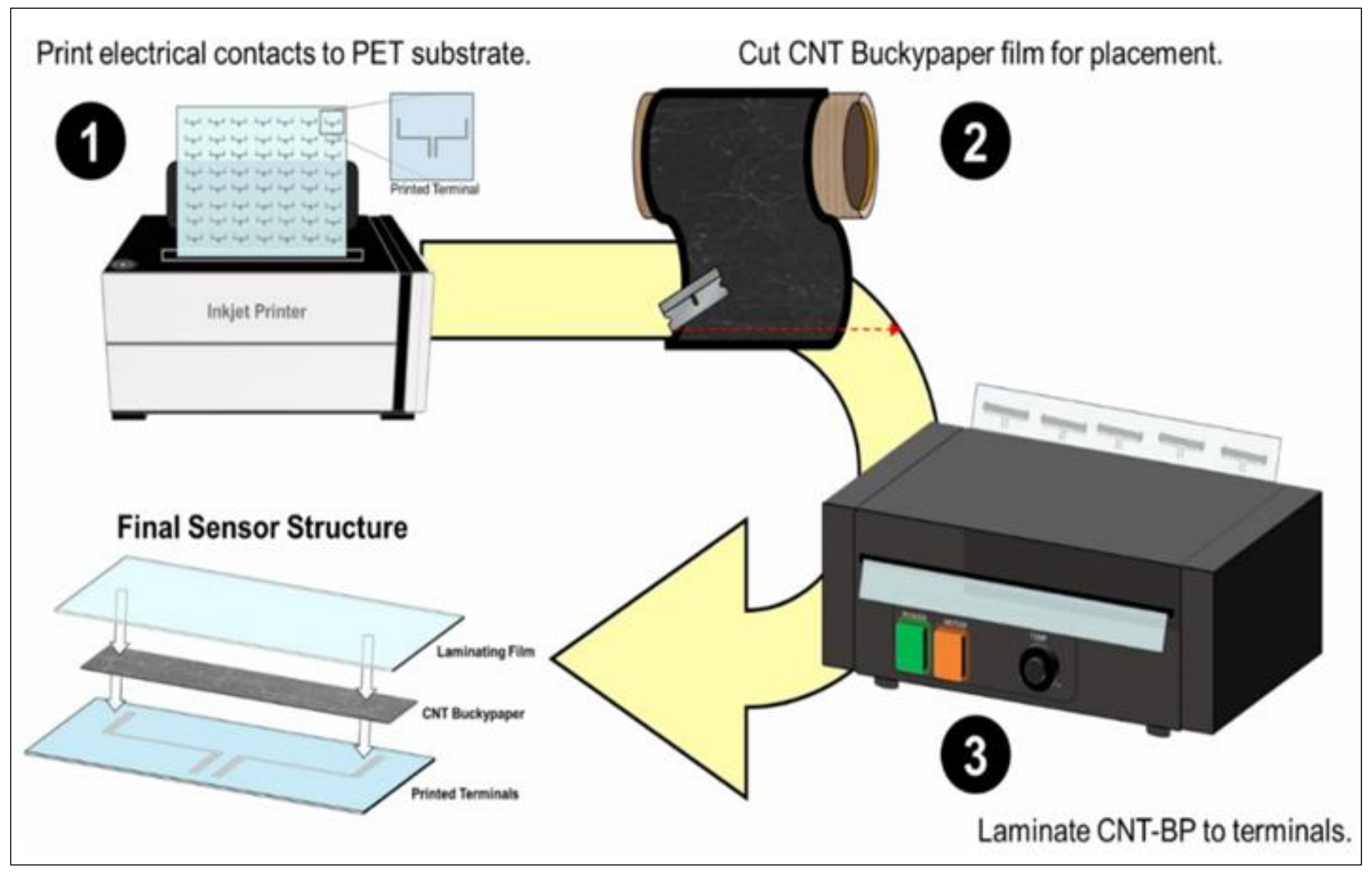

Figure 2: Sensor Manufacturing Process Flow

Results

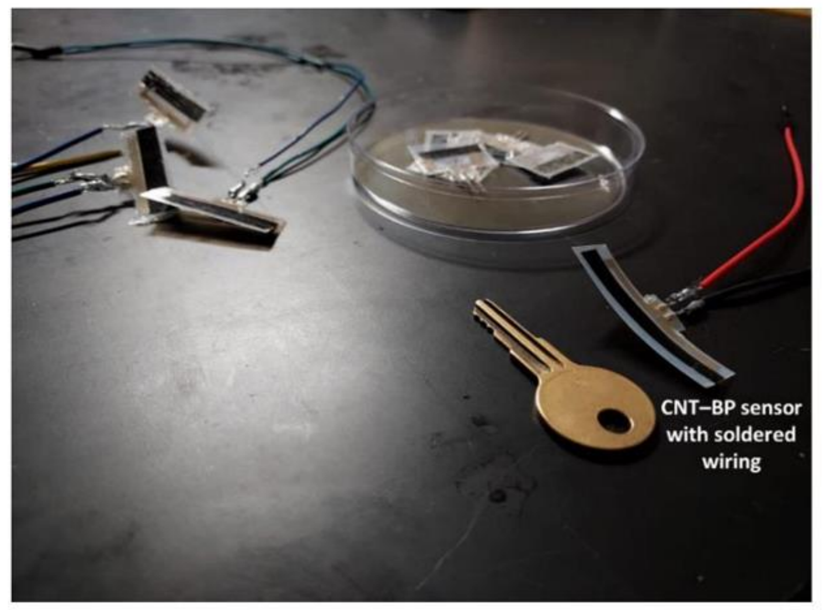

Figure 3: Final Low-Profile Sensor

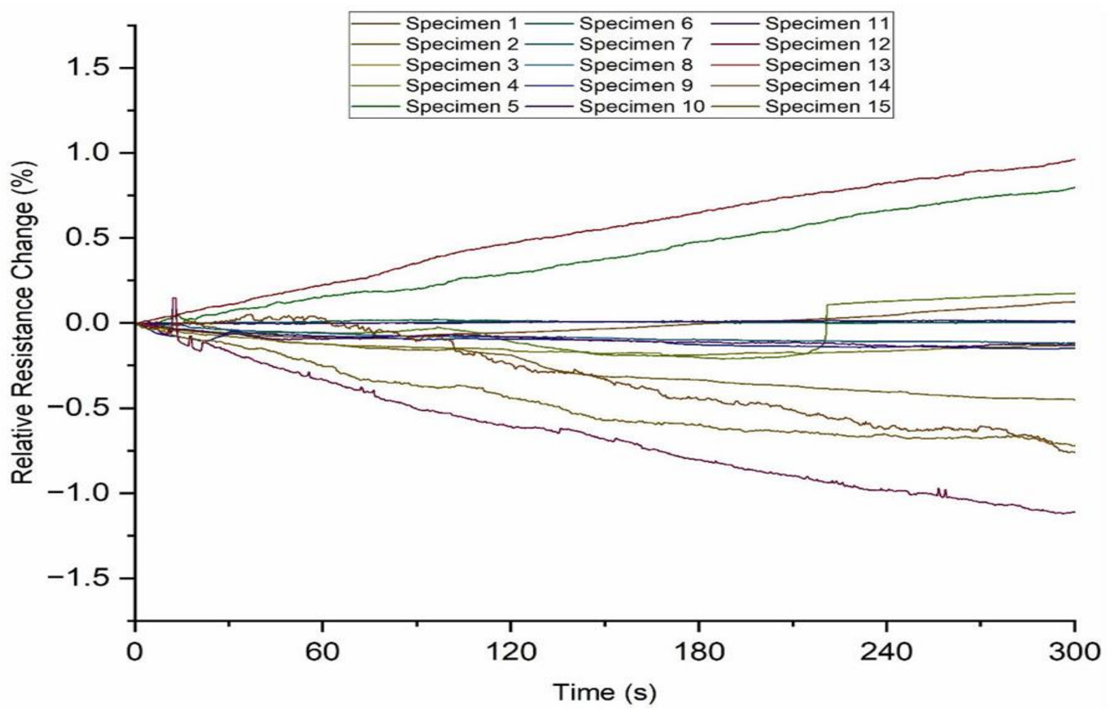

Figure 4: Resting Response of Sensors when No Event Has Occurred (Limits "False Positives")

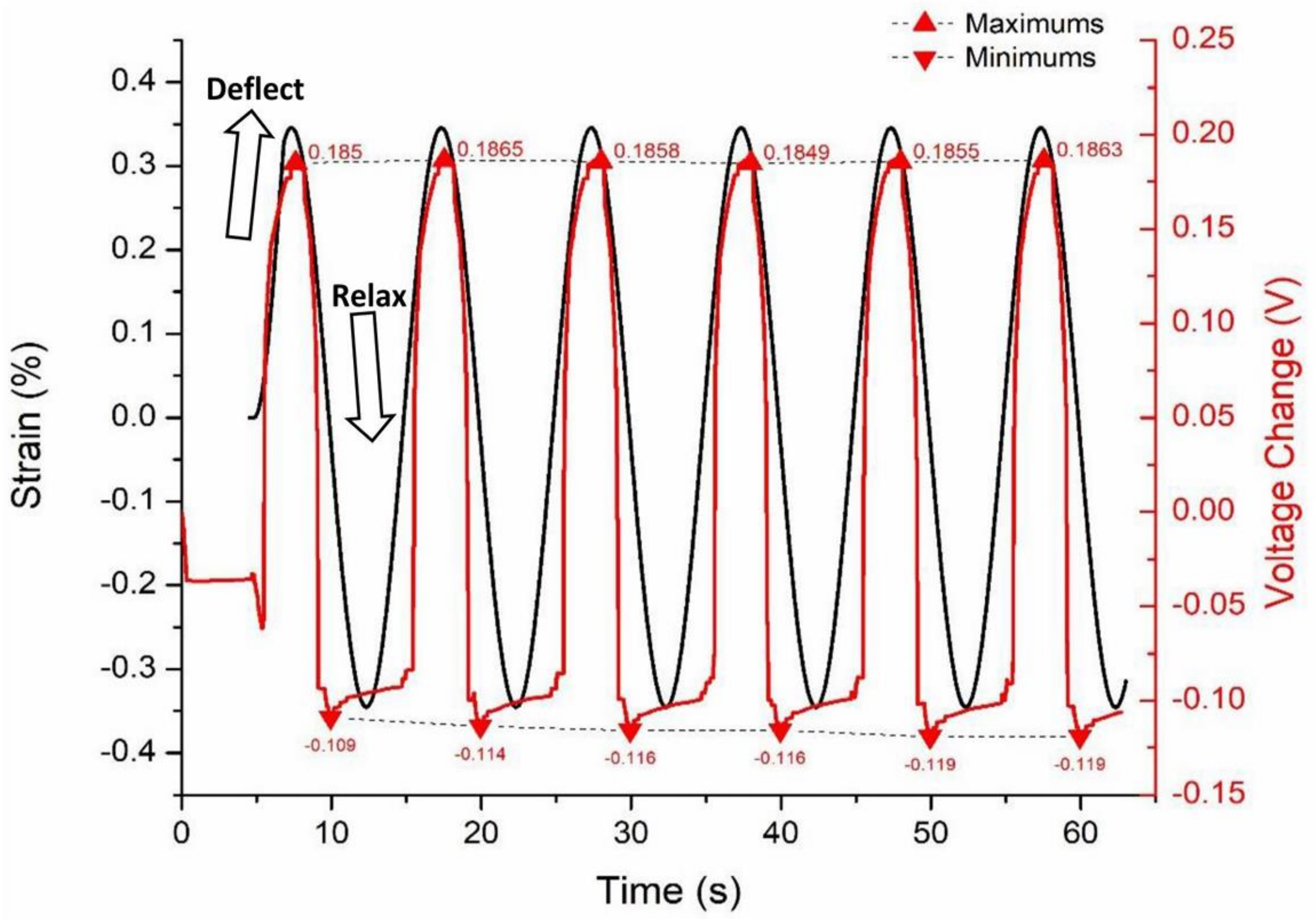

Figure 5: The Sensors Produce Interpretable Sensing Responses

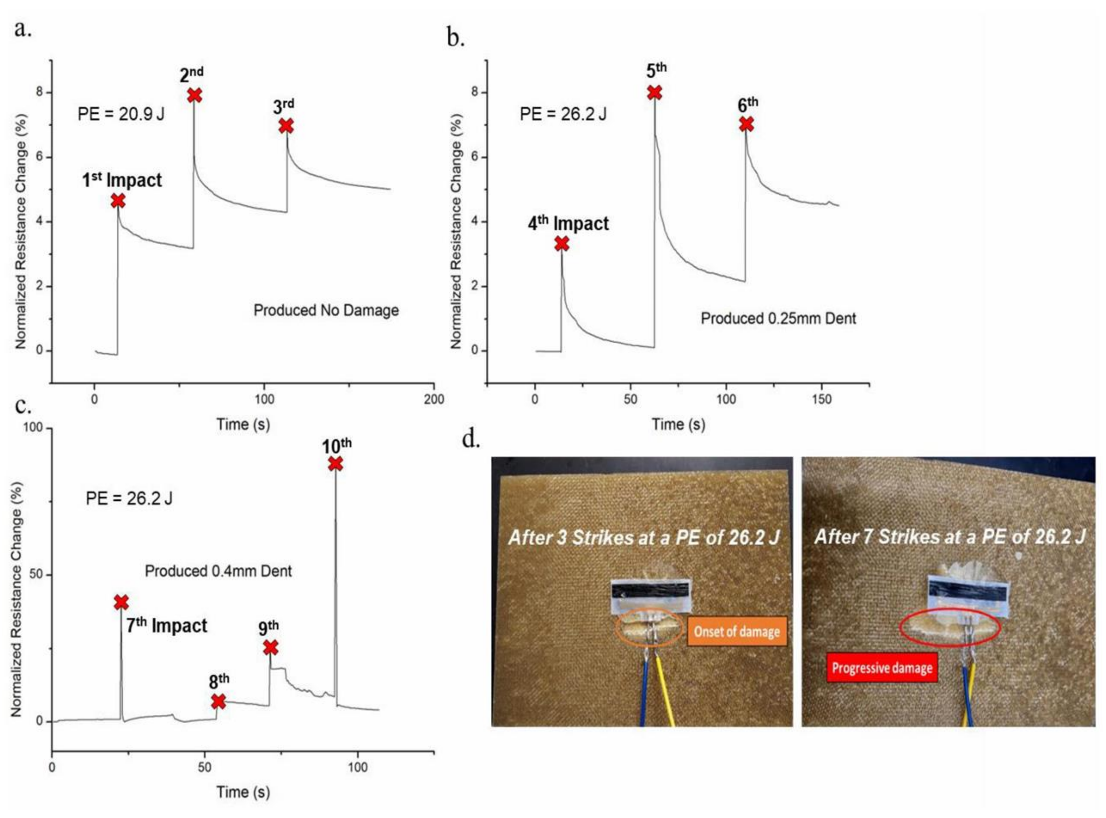

Figure 6: Impact and Damage Detection Results in Fiber-reinforced Composites

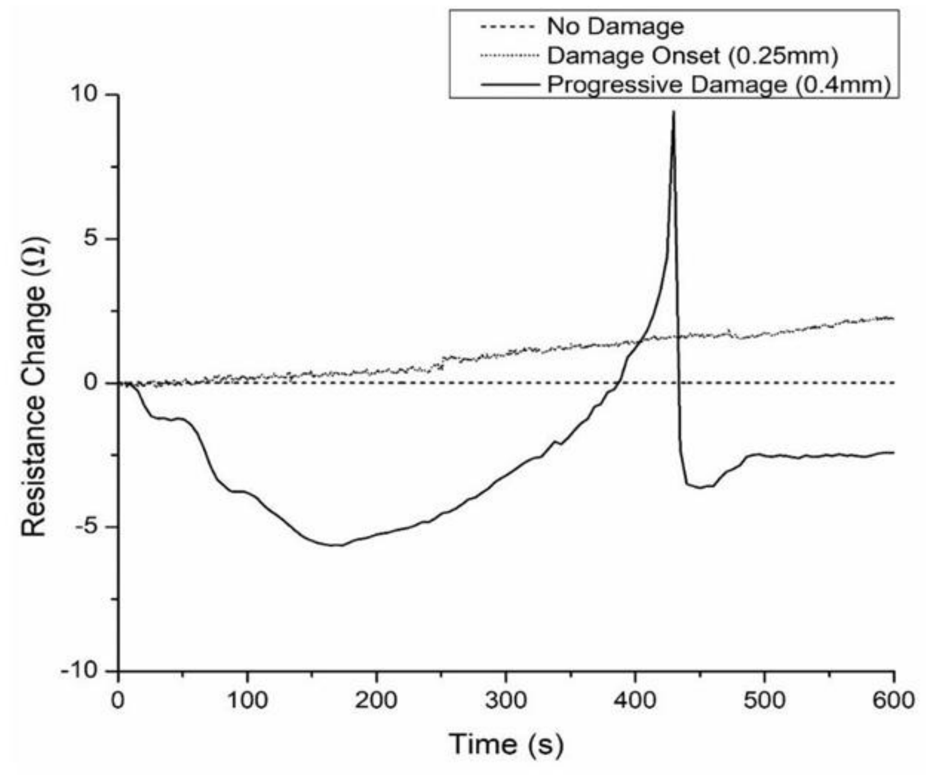

Figure 7: Resting Resistance of Sensors after Many Events Have Occurred (Damage Causes Signal Disturbance)

Potential Impacts

- The sensors can detect the smallest strains, and gives off stable signal with little background noise, ensuring reliable and precise measurements.
- Sensors were successful in detecting and assessing the severity of damage in brittle materials, such as glass fiber-reinforced plastic (GFRP) panels.
- The sensitivity of the sensor has led to passive sensing, which does not require voltage to operate
- The scalability and low-cost manufacturing of CNT-BP sensors make them attractive for widespread usage in different industries that require structural health monitoring.
- Overall, the study showed the versatility, sensitivity, and practicality of CNT-BP sensors in detecting and monitoring mechanical changes in structural materials, contributing to the development of smarter and safer infrastructure.

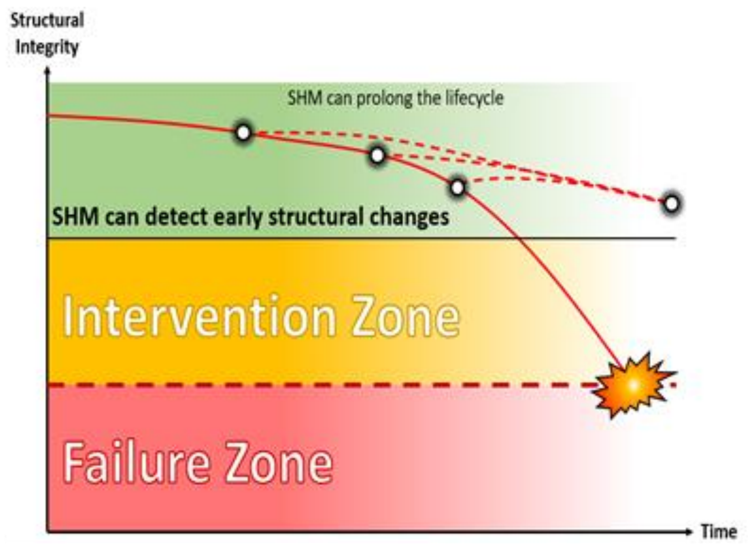

Figure 8: The Life Cycle of Structures can be Prolonged

Future Works

- Altering the structure of BP to change its properties and performance.
- Conduct durability experiments to assess the stability and reliability of CNT-BP sensors under different environmental and operational conditions.

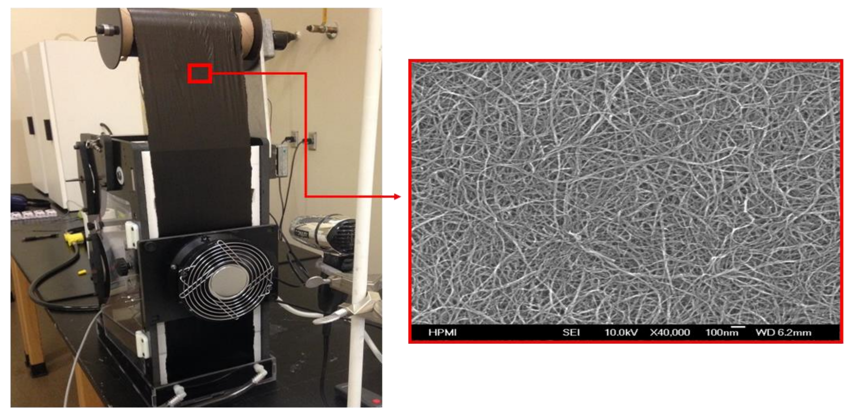

Figure 9: Carbon Nanotube Buckypaper

References

Joshua DeGraff, Anghea Dolisca & Richard Liang (2023) Scalable and passive carbon nanotube thin-film sensor for detecting micro-strains and potential impact damage in fiber-reinforced composite materials, Nanocomposites, 9:1, 215-230, DOI: 10.1080/20550324.2023.2291625

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