Polymer Reinforced Multifunctional Ultralight Carbon Nanotube Foams with Tunable Properties for Real-world Applications

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BRADFORD RESEARCH GROUP

Advancing Carbon Nanotube Textiles

Core Objectives

Transforming the unique, superior and diverse properties of ultralight aligned carbon nanotubes and integration of these novel properties with innovative design approach for developing smart multifunctional materials.

Significant Achievements

This work successfully developed a methodology for making stable, ultralight 3D CNT foams and demonstrated versatile applications, which can be easily extended to other nano-material systems, and opens up a broad way to prepare high-performance multifunctional materials.

WHY MULTIFUNCTIONAL?

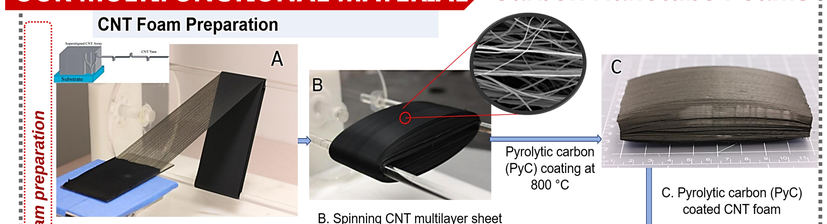
Multifunctionality = Material systems endowed with a superior set of properties + Ability to perform a variety of functions → Smart Nano-materials

- Eliminate the need of traditional bulky materials ⟷ Increase system-level efficiency
- Create the new era of wearable technology ⟷ Effective integration of superior properties

OUR MULTIFUNCTIONAL MATERIAL — Carbon Nanotube Foams

CNT-PDMS foam preparation

CNT Foam Preparation

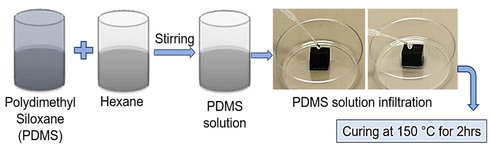


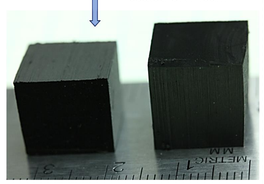
A. Spinning CNT multilayer sheet

B. Spinning CNT multilayer sheet

C. Pyrolytic carbon (PyC) coated CNT foam

PDMS Infiltration





Cut Foam samples

3 APPLICATIONS – 1 MATERIAL

Properties

- ▪Conductive ▪Piezoresistive response
- ▪Ultralight weight ▪Interconnected Network
- ▪Robust ▪Design Flexibility
- ▪Thermally Stable ▪Super porous
- ▪Selective Absorptivity ▪Wicking effect ▪Reusable

Real-world Applications

1 Human Motion Sensing

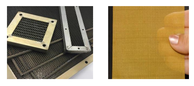
- Virtual reality technology
- Monitors health & therapeutics
- Captures performer's movements and transform into visual sensations

2 Electromagnetic Interference Shielding

- Interrupt & damage operation of nearby devices; as heart pacemaker.
- Affects bioelectrical signals of human body & cause brain tissue damages and health risk

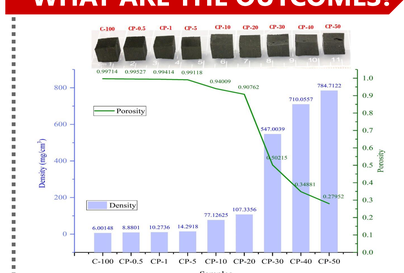
3 Oil Spill Clean-up

- Oil spills - extraction, transportation, transfer, and storage
- Causes long-term damage of ecological environment

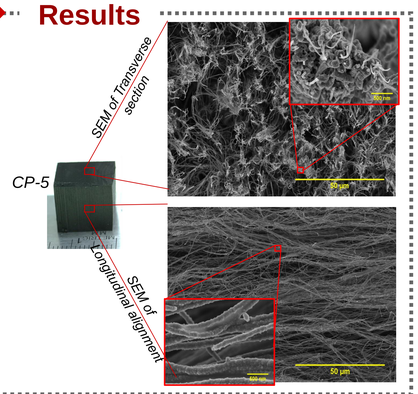
	1	2	3
Available Products			
Limitations	▪ Rigid, Multilayer, Complex design, Non-comfortable	▪ Metal based, High density, Poor flexibility, Corrosion	▪ Low absorption capacity, Non reusability, Stability
Desires	▪ Flexibility, Light-weight, Integrated with textile, Stability, Comfort	▪ Light-weight, Robust, Design flexibility, Thermal stability, Non-corrosive	▪ High absorptivity, Design flexibility, Light-weight, Robust, Re-usable

WHAT ARE THE OUTCOMES?

Results



- ✓ Ultralight, density ~ 10mg/cm³
- ✓ Super porous, porosity >99%



1 Human Motion Sensing

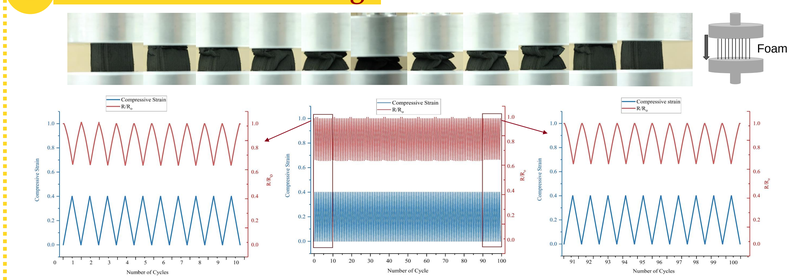


Figure: Piezoresistive response in cyclic compression of sample CP-5 (100 cycles shown)

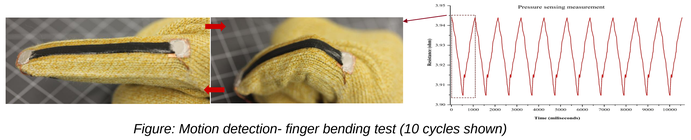


Figure: Motion detection- finger bending test (10 cycles shown)

- ✓Stable piezoresistive response in over 200 compression cycles
- ✓Successfully demonstrated human motion sensing in repeated movements.

2 EMI Shielding Effectiveness

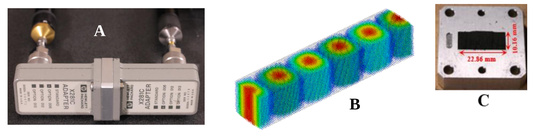


Figure: A) The sample holder and flanges of the Vector Network Analyzer waveguide, B) Illustration of how most of the E-field (magnitude) is centered at the middle of the waveguide. C) X- band flange filled with PDMS/CNT foam sample.

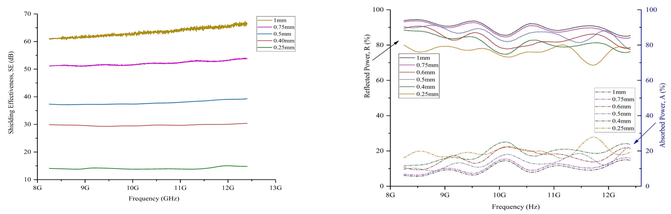


Figure: CNT-PDMS sample thickness vs EMI shielding effectiveness

- ✓CP-5 showed an EMI shielding effectiveness of around 64.78 dB
- ✓Only 1mm thickness foam showed >95% shielding effectiveness for RADAR band electro-magnetic wave

3 Oil Spill Clean-up

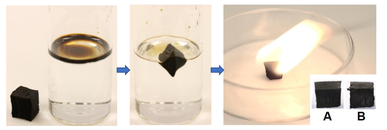


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Figure: 1) Crude oil removal from water and energy recovery by burning, A) after 1st burning & B) after 150 times burning

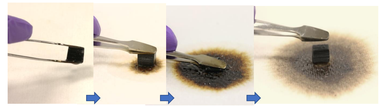

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Figure: 2) Crude oil recovery by squeezing sample & regaining the sample shape, ready to reuse

3

Figure: 3) Motor oil clean-up from water surface by burning off the oil

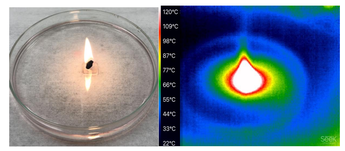

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Figure: 4) Thermal camera heat profile during oil burn-off

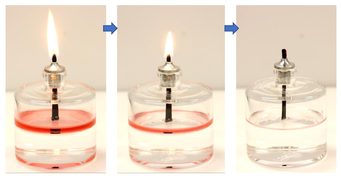

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Figure: 5) Wicking effect of CNT-PDMS foam; Selectively collecting the oil from water surface by capillary action due to the directional alignment of CNT within the foam structure

- ✓Selective absorption of oils from water
- ✓High oil absorptivity (~173 g/g CNT foam)
- ✓Superior reusability
- ✓Energy recovery by burning
- ✓Structural stability and absorption capability remain unchanged even after burning
- ✓Due to wicking effect no need to use huge amount of absorbent foam all over the spilled surface – oil can be collected from one spot

CONCLUSIONS

- ✓ Developed a processing technique to prepare the ultralight aligned CNT foam structure with PDMS coatings successfully
- ✓ Dynamically detected human motion in real time by the piezoresistive responses and easily formed into various shapes
- ✓ Showed shielding effectiveness above 95 % for RADAR band electromagnetic wave
- ✓ Selectively and efficiently clean-up oil from water with reusability and energy recovery capability

➢ Ongoing Research

- ➢ Integration of CNT in textiles for human motion sensing
- ➢ Analysis of the full range of EMI shielding effectiveness
- ➢ Detailed study on selective oil & organic liquid absorption and reusability.

THANKS TO

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AFOSR AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

AIF analytical instrumentation facility

Reference

Faraji, S., Stano, K.L., Yildiz, O., Li, A., Zhu, Y. and Bradford, P.D., 2015. Ultralight anisotropic foams from layered aligned carbon nanotube sheets. *Nanoscale*, *7*(40), pp.17038-17047.