Physics Investigations with Carbon Nanotube Materials

Terry Barchfeld
Timber Creek High School, Orlando, Florida

Summary

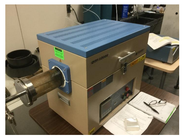
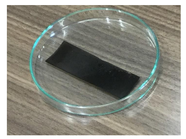
Carbon nanotubes (CNTs) in all of their configurations provide the backbone for a wide variety of innovative new materials. Conglomerates of CNTs on their own have resistive properties that make them ideal for strain sensors. There are multiple methods of creating CNTs and just as many methods of combining them. We modeled one method of creating CNT's from 2.5% toluene and 97.5% ferrocene in a tube furnace. We combined CNT's in multiple attempts to create buckypaper and crafted a 10 layer plate from carbon fiber sheets baked in an autoclave.

Exposure to CNTs and carbon fiber in the UCF labs have inspired high-school level investigations that revolve around those same materials. Electro-Yarn and Protech Composites have made it possible to put CNT yarn and carbon fiber panels in the hands of students for fundamental lab experiences. With guidance, once students have had the chance to investigate the behavior of CNT materials, they can investigate current uses for these materials and suggest new innovative applications.

Research Activities

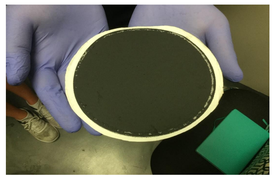
Making Carbon Nanotubes from Scratch



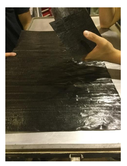



Buckypaper Fabrication from Worst to Best



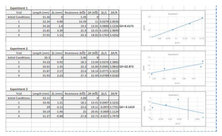


Carbon Fiber Plate Fabrication



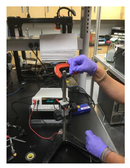

Testing Carbon Fiber Strain Sensor





This was a proof of concept activity to show that the resistance of a carbon nanotube sensor changes with strain

Strain Sensor Investigation with Electro-Yarn



Electro-Yarn is a literal yarn with carbon nanotubes woven into it.

As expected, the resistance changed as the yarn was stretched.

However is not very elastic and snapped from overuse

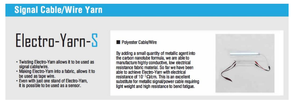
Lesson Plan

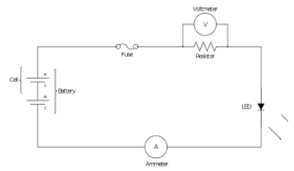
Day 1: Students will perform four short investigations in one day to build a common background of observed events. Each investigation will compare the behavior of carbon nanotube materials with other more common materials.

Day 2: Students will suggest uses for these materials without any research and then follow that up with research on actual uses. Finally they will propose a new carbon nanotube device that uses the unique properties of these materials for a novel use.

Day 3: Student groups each present an "elevator pitch" for their new device to the class.

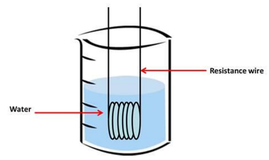
Electrical Resistivity





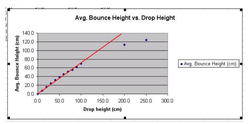
Students will compare this with typical wire materials and measure resistivity values.

Thermal Conductivity



Students will compare this with other conductors transferring heat to water.

Bounce Test



A standard test done for cell phone glass involves dropping a 128 gram steel marble from a height of 1 meter.

Students will record bounce heights for carbon fiber plates and other materials.

Sound-proofing

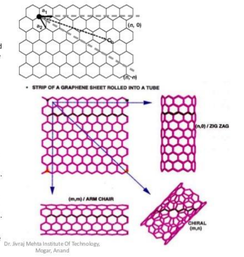
Carbon fiber materials are already being used for soundproofing materials.

Students will be able to measure decibel reductions for a variety of materials in between the speaker and the sensor

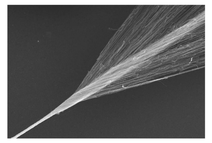
Lesson Learned Regarding Carbon Materials

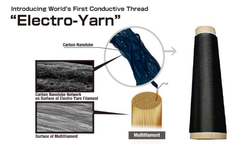
Carbon nanotubes can be conductors or semiconductors.

The armchair configuration makes a good conductor.



Carbon nanotube yarns can be exclusively CNTs or woven together with other materials .


Carbon nanotube threads woven into yarn



Carbon fiber cloth treated with epoxy, heat, and pressure turns into low mass high strength materials .


Carbon fiber flexible cloth


Carbon fiber holding 3 lbs. after treatment

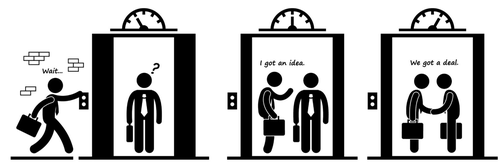
Implementation Strategy

When should this lesson be done?

The full lesson regarding carbon nanotube materials is intended for students of AP Physics Year 2 once students have covered both electricity and thermodynamics.

Any of the investigations can be used as stand alone labs for any class that studies the following topics: circuit electricity, thermodynamics, conservation of energy, and sound waves.

Predict
Observe
Explain



The student labs will start with Predict, Observe, Explain and finish with an elevator pitch for a gadget made from CNTs or carbon fiber

Acknowledgments

RET Site: COMET Program, College of Engineering and Computer Science, University of Central Florida. This content was developed under National Science Foundation grant EEC-1611019.

Materials and images from Electro-Yarn, Global Signature, 3003 North 1st Street, Suite 204, San Jose CA 95134. Contact person Sam Kim

Carbon fiber materials courtesy of Protech Composites, 11700 NE 60th Way, Suite 3B, Vancouver WA 98682. Contact person Michelle Fennimore

References

"Carbon Fiber 101" Whitepaper from Protech Composites, protechcomposities.com