Accelerometer and Gyroscope Designs Based on CNT Tape

Longer carbon nanotubes (CNTs) in tape form enable new sensor components

NASA Marshall Space Flight Center researchers have developed designs for two Micro-Electro-Mechanical Systems (MEMS) motion and position sensors: a single-axis accelerometer and a gyroscope. The designs leverage a new, highly aligned, multiwall carbon nanotube (MWCNT) tape with a P(VDF-TrFE) matrix that is mechanically robust and has excellent piezoelectric properties as the sensing and actuating element. The use of CNT tape in a gyroscope is made possible by recent improvements to CNT processing that yield longer CNTs that are more highly aligned. The use of CNT tape in a gyroscope is made possible by recent improvements to CNT processing that yield longer CNTs that are more highly aligned. The use of CNTs makes the accelerometer and gyroscopes stronger and more robust, without increasing their size or weight. The chief advantage, compared to silicone (Si) and quartz sensors, is easier manufacturing that requires no machining. NASA has worked to prove the concept and now seeks a licensee interested in developing these designs into products for consumer electronics or other applications.

BENEFITS

- Active damping: The CNT tapes both sense movement and actuate counter movement to damp vibrations.
- Longer life: Due to the extremely high strength and fatigue resistance of the CNT tape compared to quartz elements, this accelerometer design will have a longer life and improved resistance to external forces.
- Adjustable size: The CNT tape can be adjusted in size very easily, which means the overall size of the accelerometer can be adjusted as needed.
- Lower weight: CNT tapes potentially have lower weights than current gyros for satellites and electronics.
- Low cost: CNT tapes potentially have lower costs than Si- and quartz-based gyroscopes. Cost savings are a result of the simplified manufacturing.

APPLICATIONS

The technology has several potential applications:

- Consumer electronics: motion detection for smart phones, laptops, notebooks, and tablets
- Aerospace: aircraft control
- Gaming systems: video game controllers
THE TECHNOLOGY

NASA's accelerometer was designed to address the shortcomings of conventional piezoelectric-based accelerometers that are made from ceramic materials such as barium titanate (BaTiO3) or lead titanate (PZT). These materials are inherently brittle, have a tendency to be noisy, have difficulty sensing low frequencies, are subject to static charge build-up that affects polarization, and are relatively large and expensive. The unique feature of the NASA innovation is the use of carbon nanotube/P(VDF-TrFE) tape as the actuating and sensing element. As seen in the figure to the right, the new accelerometer acts as a spring-mass system. There is a moving mass (M) between fixed walls and attached to two CNT tapes on both sides. The mass will be displaced by u(t) along a single axis when an applied force, F(t), acts on the mass. This sensor uses one tape as an actuator to damp motion of the moving mass, while the other tape is used for sensing the mass displacement. The figure below left is a photo of the CNT tape being poled.

The single axis accelerometer can be used solo or as the basis for a novel two-axis gyroscope. The CNT tape is used as the vibrating element in the gyroscope. The NASA gyroscope design covers three configurations:
1. CNT tape wrapped around the conductive rotor of the gyroscope
2. The same CNT tape layered with piezo material to form a rotor shape
3. Piezo-sprayed CNT tape used as a rotor

The figure to the right is a stress vs. strain curve for the CNT tape that is used in the gyroscope and accelerometer.

PUBLICATIONS

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More Information

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