Cantilever bends repeatedly under light exposure for continuous energy generation

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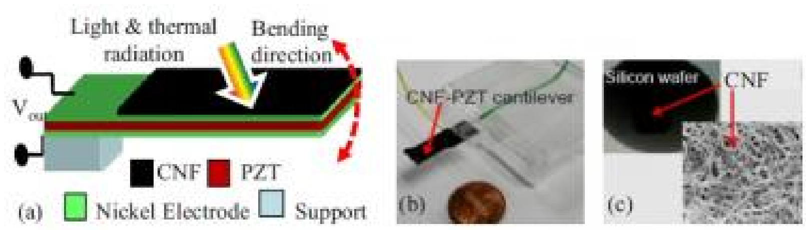

(a) An illustration of the energy-harvesting cantilever device. (b) A photo of the cantilever. (c) An optical micrograph and SEM image of the CNF material. Image credit: Venu Kotipalli, et al. ©2010 American Institute of Physics.

(PhysOrg.com) -- With the goal to enable small electronic devices to harvest their own energy, researchers have designed a device that can convert light and thermal energy into electricity. When exposed to visible light and/or heat (infrared) radiation, the 20-mm-long carbon-nanotube-film-based cantilever bends back and forth repeatedly, as long as the light and/or heat remains on. This is the first time that such cyclic bending behavior, which the scientists call "self-reciprocation," has been observed in this kind of system.

The researchers, led by Professor Long Que and including graduate students Venu Kotipalli, Zhongcheng Gong, and other students from Louisiana Tech University, have published a paper on the device in a recent issue of Applied Physics Letters. In their experiments, they demonstrated that the device could generate 2.1 microwatts of power at a light intensity of 0.13 W/cm^2, which is sufficient to operate some low-power microsensors and integrated sensors. The researchers predict that the power output could be significantly improved with further optimization.

"The greatest significance of this work is that it offers us a new option capable of continuously harvesting both solar and thermal energy on a single chip, given the self-reciprocating characteristic of the device upon exposure to light and/or thermal radiation," Que told *PhysOrg.com*.

The 20-mm-long energy-harvesting device consists of a layer of carbon nanotube film (CNF) placed on top of an electrode and a piezoelectric material called lead zirconate titanate (PZT). Since carbon nanotubes are excellent absorbers of photons, the CNF layer efficiently absorbs the radiation and causes the underlying PZT layer to bend. As a piezoelectric material (known for its ability to convert mechanical energy into electricity), the moving PZT layer generates power.

The impressive thing about the new device is that, once the cantilever reaches its maximum displacement under the radiation, the displacement decreases, then increases again, and continues this cycle as long as the radiation remains on. When the radiation is turned off, the displacement decreases to zero. As the scientists explain, the self-reciprocation is due to the cantilever continuously absorbing photons, as well as its high electrical conduction and rapid thermal dissipation into the environment. The self-reciprocation characteristic means that the energy-harvesting device has the ability to continuously generate energy without consuming other additional energy, such as for modulating the radiation.

"To the best of our knowledge, previous reported research mainly exploited and developed for DC displacement," Que said. "We observed this self-reciprocation phenomenon in my lab by accident for the first time, and thereafter we did a series of systematic experiments and confirmed that this phenomenon always occurs not only in the lab but also in the field under sunlight. In order to better understand this observation and optimize the performance of this technology, further fundamental investigations have been underway in our lab."

In the future, the scientists plan to investigate the contributions from the light and heat when the device is under illumination, although their observations so far indicate that the thermal portion is the major contributor. The scientists also anticipate that decreasing the device's internal resistance, and perhaps operating an array of devices, could improve the power output. The energy-harvesting device could potentially be used to power a wide variety of systems, from implanted biomedical devices to remotely located sensors and communication nodes.

"I also would like to mention that, given the nature of the cantilever-based device, actually this technology can harvest additional multiple types of energies such as all types of vibrational energies and wind energy as well, which we have already experimentally demonstrated but not reported in this article," Que said. "This technology is truly a hybrid energy-harvesting technology."

Additional coauthors of the paper are Pushparaj Pathak, Tianhua Zhang, Yuan He, and Shashi Yadav.

More information: Venu Kotipalli, et al. "Light and thermal energy cell based on carbon nanotube films." *Applied Physics Letters* 97, 124102 (2010). DOI:10.1063/1.3491843