This device harnesses the cold night sky to generate electricity in the dark

A prototype powered a small light-emitting diode in a trial run

By Maria Temming

SEPTEMBER 12, 2019 AT 11:00 AM

A new device is an anti-solar panel, harvesting energy from the cold night sky.

By harnessing the temperature difference between Earth and outer space, a prototype of the device produced enough electricity at night to power a small LED light. A bigger version of this nighttime generator could someday light rooms, charge phones or power other electronics in remote or low-resource areas that lack electricity at night when solar panels don't work, researchers report online September 12 in *Joule*.

The core of the new night-light is a thermoelectric generator, which produces electricity when one side of the generator is cooler than the other (*SN: 6/1/18*). The sky-facing side of the generator is attached to an aluminum plate sealed beneath a transparent cover and surrounded with insulation to keep heat out. This plate stays cooler than the ambient air by shedding any heat it absorbs as infrared radiation (*SN: 9/28/18*). That radiation can zip up through the transparent cover and the atmosphere toward the cold sink of outer space.

Meanwhile, the bottom of the generator is attached to an exposed aluminum plate that is continually warmed by ambient air. At night, when not baking under the sun, the top plate can get a couple of degrees Celsius cooler than the bottom of the generator.

Engineer Wei Li of Stanford University and colleagues tested a 20-centimeter prototype of the device on a clear December night in Stanford, Calif. The generator

produced up to about 25 milliwatts of power per square meter of device — enough to light a small light-emitting diode, or LED, bulb. The team estimates that further design improvements, like better insulation around the cool top plate, could boost production up to at least 0.5 watts per square meter.

A device that uses the night sky to generate electricity (pictured) powered a small LED bulb in one rooftop experiment.
WEI LI

“It’s a very clever idea,” says Yuan Yang, a materials scientist at Columbia University not involved in the work. “The power generation is much less than solar panels,” which generally produce at least 100 watts per square meter. But this nighttime generator may be useful for emergency backup power, or energy for people living off the grid, Yang says.

A typical lamp bulb might consume a few watts of electricity, says Shanhui Fan, an electrical engineer at Stanford University who worked on the device. So a device that took up a few square meters of roof space could light up a room with energy from the night sky.

Aaswath Raman, a materials scientist and engineer at UCLA, also envisions using their team's generator to help power remote weather stations or other environmental sensors. This may be especially useful in polar regions that don't see sunlight for months at a time, Raman says. "If you have some low-power load and you need to power it through three months of darkness, this might be a way."

Questions or comments on this article? E-mail us at feedback@sciencenews.org

New green technology generates electricity 'out of thin air'

Renewable device could help mitigate climate change, power medical devices

Date:

February 17, 2020

Source:

University of Massachusetts Amherst

Summary:

Electrical engineers and microbiologists have created a device they call an 'Air-gen.' or air-powered generator, with electrically conductive protein nanowires produced by the microbe Geobacter. The Air-gen connects electrodes to the protein nanowires in such a way that electrical current is generated from the water vapor naturally present in the atmosphere.

Share:

Scientists at the University of Massachusetts Amherst have developed a device that uses a natural protein to create electricity from moisture in the air, a new technology they say could have significant implications for the future of renewable energy, climate change and in the

As reported today in *Nature*, the laboratories of electrical engineer Jun Yao and microbiologist Derek Lovley at UMass Amherst have created a device they call an "Air-gen." or air-powered generator, with electrically conductive protein nanowires produced by the microbe Geobacter. The Air-gen connects electrodes to the protein nanowires in such a way that electrical current is generated from the water vapor naturally present in the atmosphere.

"We are literally making electricity out of thin air," says Yao. "The Air-gen generates clean energy 24/7." Lovely, who has advanced sustainable biology-based electronic materials over three decades, adds, "It's the most amazing and exciting application of protein nanowires yet."

The new technology developed in Yao's lab is non-polluting, renewable and low-cost. It can generate power even in areas with extremely low humidity such as the Sahara Desert. It has significant advantages over other forms of renewable energy including solar and wind, Lovley says, because unlike these other renewable energy sources, the Air-gen does not require sunlight or wind, and "it even works indoors."

The Air-gen device requires only a thin film of protein nanowires less than 10 microns thick, the researchers explain. The bottom of the film rests on an electrode, while a smaller electrode that covers only part of the nanowire film sits on top. The film adsorbs water vapor from the atmosphere. A combination of the electrical conductivity and surface chemistry of the protein nanowires, coupled with the fine pores between the nanowires within the film, establishes the conditions that generate an electrical current between the two electrodes.

The researchers say that the current generation of Air-gen devices are able to power small electronics, and they expect to bring the invention to commercial scale soon. Next steps they plan include developing a small Air-gen "patch" that can power electronic wearables such as health and fitness monitors and smart watches, which would eliminate the requirement for traditional batteries. They also hope to develop Air-gens to apply to cell phones to eliminate periodic charging.

Yao says, "The ultimate goal is to make large-scale systems. For example, the technology might be incorporated into wall paint that could help power your home. Or, we may develop stand-alone air-powered generators that supply electricity off the grid. Once we get to

an industrial scale for wire production, I fully expect that we can make large systems that will make a major contribution to sustainable energy production."

Continuing to advance the practical biological capabilities of Geobacter, Lovley's lab recently developed a new microbial strain to more rapidly and inexpensively mass produce protein nanowires. "We turned E. coli into a protein nanowire factory," he says. "With this new scalable process, protein nanowire supply will no longer be a bottleneck to developing these applications."

The Air-gen discovery reflects an unusual interdisciplinary collaboration, they say. Lovley discovered the Geobacter microbe in the mud of the Potomac River more than 30 years ago. His lab later discovered its ability to produce electrically conductive protein nanowires. Before coming to UMass Amherst, Yao had worked for years at Harvard University, where he engineered electronic devices with silicon nanowires. They joined forces to see if useful electronic devices could be made with the protein nanowires harvested from Geobacter.

Xiaomeng Liu, a Ph.D. student in Yao's lab, was developing sensor devices when he noticed something unexpected. He recalls, "I saw that when the nanowires were contacted with electrodes in a specific way the devices generated a current. I found that that exposure to atmospheric humidity was essential and that protein nanowires adsorbed water, producing a voltage gradient across the device."

In addition to the Air-gen, Yao's laboratory has developed several other applications with the protein nanowires. "This is just the beginning of new era of protein-based electronic devices" said Yao.

The research was supported in part from a seed fund through the Office of Technology Commercialization and Ventures at UMass Amherst and research development funds from the campus's College of Natural Sciences.

Journal Reference:

1. Xiaomeng Liu, Hongyan Gao, Joy E. Ward, Xiaorong Liu, Bing Yin, Tianda Fu, Jianhan Chen, Derek R. Lovley, Jun Yao. **Power generation from ambient humidity using protein nanowires**. *Nature*, 2020; DOI: 10.1038/s41586-020-2010-9

New droplet-based electricity generator:

A drop of water generates 140V power, lighting up 100 LED bulbs

Date:

February 5, 2020

Source:

City University of Hong Kong

Summary:

Generating electricity from raindrops efficiently has gone one step further. A research team has recently developed a droplet-based electricity generator (DEG), featured with a field-effect transistor (FET)-like structure that allows for high energy-conversion efficiency and instantaneous power density increased by thousands times compared to its counterparts without FET-like structure. This would help to advance scientific research of water energy generation and tackle the energy crisis.

Share:

The research was led together by Professor Wang Zuankai from CityU's Department of Mechanical Engineering, Professor Zeng Xiao Cheng from University of Nebraska-Lincoln, and Professor Wang Zhong Lin, Founding Director and Chief Scientist from Beijing Institute of Nanoenergy and Nanosystems of Chinese Academy of Sciences. Their findings were published in the latest issue of journal *Nature*.

Efficiency of electrical energy conversion greatly improved

Hydropower is nothing new. About 70% of the earth's surface is covered by water. Yet low-frequency kinetic energy contained in waves, tides, and even raindrops are not efficiently converted into electrical energy due to limitations in current technology. For example, a conventional droplet energy generator based on the triboelectric effect can generate electricity induced by contact electrification and electrostatic induction when a droplet hits a surface. However, the amount of charges generated on the surface is limited by the interfacial effect, and as a result, the energy conversion efficiency is quite low.

In order to improve the conversion efficiency, the research team has spent two years developing the DEG. Its instantaneous power density can reach up to 50.1 W/m2, thousands times higher than other similar devices without the use of FET-like design. And the energy conversion

efficiency is markedly higher.

Professor Wang from CityU pointed out that there are two crucial factors for the invention. First, the team found that the continuous droplets impinging on PTFE, an electret material with a quasi-permanent electric charge, provides a new route for the accumulation and storage of high-density surface charges. They found that when water droplets continuously hit the surface of PTFE, the surface charges generated will accumulate and gradually reach a saturation. This new discovery helped to overcome the bottleneck of low charge density encountered in previous work.

Unique field-effect transistor-like structure

Another key feature of their design is a unique set of structures similar to a FET, which is a Nobel Prize in Physics winning innovation in 1956 and has become the basic building block of modern electronic devices nowadays. The device consists of an aluminium electrode, and an indium tin oxide (ITO) electrode with a film of PTFE deposited on it. The PTFE/ITO electrode is responsible for the charge generation, storage, and induction. When a falling water droplet hits and spreads on the PTFE/ITO surface, it naturally "bridges" the aluminium electrode and the PTFE/ITO electrode, translating the original system into a closed-loop electric circuit.

With this special design, a high density of surface charges can be accumulated on the PTFE through continuous droplet impinging. Meanwhile, when the spreading water connects the two electrodes, all the stored charges on the PTFE can be fully released for the generation of electric current. As a result, both the instantaneous power density and energy conversion efficiency are much higher.

"Our research shows that a drop of 100 microlitres (1 microlitre = one-millionth litre) of water released from a height of 15 cm can generate a voltage of over 140V. And the power generated can light up 100 small LED light bulbs," said Professor Wang.

He added that the increase in instantaneous power density does not result from additional energy, but from the conversion of kinetic energy of water itself. "The kinetic energy entailed in falling water is due to gravity and can be regarded as free and renewable. It should be better utilized."

Their research also shows that the reduction in relative humidity does not affect the efficiency of power generation. Also, both rainwater and

seawater can be used to generate electricity.

Facilitates the sustainability of the world

Professor Wang hoped that the outcome of this research would help to harvest water energy to respond to the global problem of renewable energy shortage. "Generating power from raindrops instead of oil and nuclear energy can facilitate the sustainable development of the world," he added.

He believed that in the long run, the new design could be applied and installed on different surfaces, where liquid in contact with solid, to fully utilize the low-frequency kinetic energy in water. This can range from the hull surface of ferry, coastline, to the surface of umbrellas or even inside water bottles.

Journal Reference:

1. Wanghuai Xu, Huanxi Zheng, Yuan Liu, Xiaofeng Zhou, Chao Zhang, Yuxin Song, Xu Deng, Michael Leung, Zhengbao Yang, Ronald X. Xu, Zhong Lin Wang, Xiao Cheng Zeng, Zuankai Wang. **A droplet-based electricity generator with high instantaneous power density**. *Nature*, 2020; DOI: 10.1038/s41586-020-1985-6