ScienceDaily
Your source for the latest research news

Science News

from research organizations

Converting Wi-Fi signals to electricity with new 2D materials

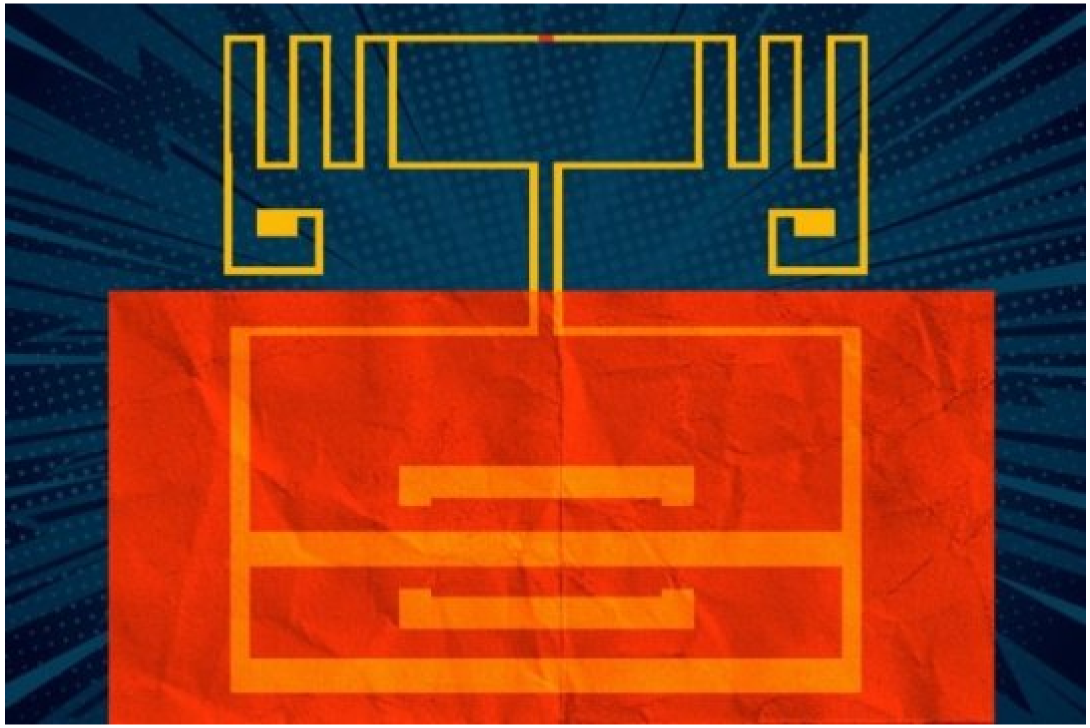
Device made from flexible, inexpensive materials could power large-area electronics, wearables, medical devices, and more

Date: January 28, 2019

Source: Massachusetts Institute of Technology

Summary: Imagine a world where smartphones, laptops, wearables, and other electronics are powered without batteries. Researchers have taken a step in that direction, with the first fully flexible device that can convert energy from Wi-Fi signals into electricity that could power electronics.

FULL STORY



Researchers from MIT and elsewhere have designed the first fully flexible, battery-free "rectenna" -- a device that converts energy from Wi-Fi signals into electricity -- that could be used to power flexible and wearable electronics, medical devices, and sensors for the "internet of things."

Credit: Christine Daniloff

Imagine a world where smartphones, laptops, wearables, and other electronics are powered without batteries. Researchers from MIT and elsewhere have taken a step in that direction, with the first fully flexible device that can convert energy from Wi-Fi signals into electricity that could power electronics.

Devices that convert AC electromagnetic waves into DC electricity are known as "rectennas." The researchers demonstrate a new kind of rectenna, described in a study appearing in *Nature*, that uses a flexible radio-frequency (RF) antenna that captures electromagnetic waves -- including those carrying Wi-Fi -- as AC waveforms.

The antenna is then connected to a novel device made out of a two-dimensional semiconductor just a few atoms thick. The AC signal travels into the semiconductor, which converts it into a DC voltage that could be used to power electronic circuits or recharge batteries.

In this way, the battery-free device passively captures and transforms ubiquitous Wi-Fi signals into useful DC power. Moreover, the device is flexible and can be fabricated in a roll-to-roll process to cover very large areas.

"What if we could develop electronic systems that we wrap around a bridge or cover an entire highway, or the walls of our office and bring electronic intelligence to everything around us? How do you provide energy for those electronics?" says paper co-author Tomás Palacios, a professor in the Department of Electrical Engineering and Computer Science and director of the MIT/MTL Center for Graphene Devices and 2D Systems in the Microsystems Technology Laboratories. "We have come up with a new way to power the electronics systems of the future -- by harvesting Wi-Fi energy in a way that's easily integrated in large areas -- to bring intelligence to every object around us."

Promising early applications for the proposed rectenna include powering flexible and wearable electronics, medical devices, and sensors for the "internet of things." Flexible smartphones, for instance, are a hot new market for major tech firms. In experiments, the researchers' device can produce about 40 microwatts of power when exposed to the typical power levels of Wi-Fi signals (around 150 microwatts). That's more than enough power to light up a simple mobile display or silicon chips.

Another possible application is powering the data communications of implantable medical devices, says co-author Jesús Grajal, a researcher at the Technical University of Madrid. For example, researchers are beginning to develop pills that can be swallowed by patients and stream health data back to a computer for diagnostics.

"Ideally you don't want to use batteries to power these systems, because if they leak lithium, the patient could die," Grajal says. "It is much better to harvest energy from the environment to power up these small labs inside the body and communicate data to external computers."

All rectennas rely on a component known as a "rectifier," which converts the AC input signal into DC power. Traditional rectennas use either silicon or gallium arsenide for the rectifier. These materials can cover the Wi-Fi band, but they are rigid. And, although using these materials to fabricate small devices is relatively inexpensive, using them to cover vast areas, such as the surfaces of buildings and walls, would be cost-prohibitive. Researchers have been trying to fix these problems for a long time. But the few flexible rectennas reported so far operate at low frequencies and can't capture and convert signals in gigahertz frequencies, where most of the relevant cell phone and Wi-Fi signals are.

To build their rectifier, the researchers used a novel 2-D material called molybdenum disulfide (MoS_2), which at three atoms thick is one of the thinnest semiconductors in the world. In doing so, the team leveraged a singular behavior of MoS_2: When exposed to certain chemicals, the material's atoms rearrange in a way that acts like a switch, forcing a phase transition from a semiconductor to a metallic material. This structure is known as a Schottky diode, which is the junction of a semiconductor with a metal.

"By engineering MoS_2 into a 2-D semiconducting-metallic phase junction, we built an atomically thin, ultrafast Schottky diode that simultaneously minimizes the series resistance and parasitic capacitance," says first author and EECS postdoc Xu Zhang, who will soon join Carnegie Mellon University as an assistant professor.

Parasitic capacitance is an unavoidable situation in electronics where certain materials store a little electrical charge, which slows down the circuit. Lower capacitance, therefore, means increased rectifier speeds and higher operating frequencies. The parasitic capacitance of the researchers' Schottky diode is an order of magnitude smaller than today's state-of-the-art flexible rectifiers, so it is much faster at signal conversion and allows it to capture and convert up to 10 gigahertz of wireless signals.

"Such a design has allowed a fully flexible device that is fast enough to cover most of the radio-frequency bands used by our daily electronics, including Wi-Fi, Bluetooth, cellular LTE, and many others," Zhang says.

The reported work provides blueprints for other flexible Wi-Fi-to-electricity devices with substantial output and efficiency. The maximum output efficiency for the current device stands at 40 percent, depending on the input power of the Wi-Fi input. At the typical Wi-Fi power level, the power efficiency of the MoS_2 rectifier is about 30 percent. For reference, today's best silicon and gallium arsenide rectennas made from rigid, more expensive silicon or gallium arsenide achieve around 50 to 60 percent.

There are 15 other paper co-authors from MIT, Technical University of Madrid, the Army Research Laboratory, Charles III University of Madrid, Boston University, and the University of Southern California.

The team is now planning to build more complex systems and improve efficiency. The work was made possible, in part, by a collaboration with the Technical University of Madrid through the MIT International Science and Technology Initiatives (MISTI). It was also partially supported by the Institute for Soldier Nanotechnologies, the Army Research Laboratory, the National Science Foundation's Center for Integrated Quantum Materials, and the Air Force Office of Scientific Research.

Story Source:

Materials provided by **Massachusetts Institute of Technology**. Original written by Rob Matheson. *Note: Content may be edited for style and length.*

Journal Reference:

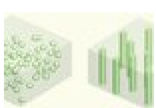
1. Xu Zhang, Jesús Grajal, Jose Luis Vazquez-Roy, Ujwal Radhakrishna, Xiaoxue Wang, Winston Chern, Lin Zhou, Yuxuan Lin, Pin-Chun Shen, Xiang Ji, Xi Ling, Ahmad Zubair, Yuhao Zhang, Han Wang, Madan Dubey, Jing Kong, Mildred Dresselhaus and Tomás Palacios. **Two-dimensional MoS_2-enabled flexible rectenna for Wi-Fi-band wireless energy harvesting.** *Nature*, 2019 DOI: 10.1038/s41586-019-0892-1

Cite This Page:

MLA APA Chicago

Massachusetts Institute of Technology. "Converting Wi-Fi signals to electricity with new 2D materials: Device made from flexible, inexpensive materials could power large-area electronics, wearables, medical devices, and more." ScienceDaily. ScienceDaily, 28 January 2019. <www.sciencedaily.com/releases/2019/01/190128111718.htm>.

RELATED STORIES



Freezing Lithium Batteries May Make Them Safer, Bendable

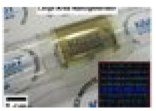
Apr. 24, 2017 — A new method that could lead to lithium batteries that are safer, have longer battery life, and are bendable has now been developed, providing new possibilities such as flexible smartphones. His new ... **read more** »

Diamonds Closer to Becoming Ideal Semiconductors

May 24, 2016 — The thirst for electronics is unlikely to cease and almost every appliance or device requires a suite of electronics that transfer, convert and control power. Now, researchers have taken an important ... **read more** »

From Trees to Power: Engineers Build Better Energy Storage Device

Oct. 6, 2015 — New work demonstrates an improved three-dimensional energy storage device constructed by trapping functional nanoparticles within the walls of a foam-like structure made of nanocellulose. The foam is ... **read more** »



Dramatic Improvements in Nanogenerator Power Efficiency for Wearable, Implantable Electronics

May 15, 2014 — The energy efficiency of a new piezoelectric nanogenerator has increased by almost 40 times, one step closer toward the commercial-ization of flexible energy harvesters that can supply power ... **read more** »

FROM AROUND THE WEB

Below are relevant articles that may interest you. ScienceDaily shares links with scholarly publications in the TrendMD network and earns revenue from third-party advertisers, where indicated.

Free Subscriptions

Get the latest science news with ScienceDaily's free email newsletters, updated daily and weekly. Or view hourly updated newsfeeds in your RSS reader:

- Email Newsletters
- RSS Feeds

Follow Us

Keep up to date with the latest news from ScienceDaily via social networks:

Facebook

Twitter

Google+

LinkedIn

Have Feedback?

Tell us what you think of ScienceDaily -- we welcome both positive and negative comments. Have any problems using the site? Questions?

Leave Feedback

Contact Us