Hybrid nanogenerator harvests hard-to-reach ocean energy

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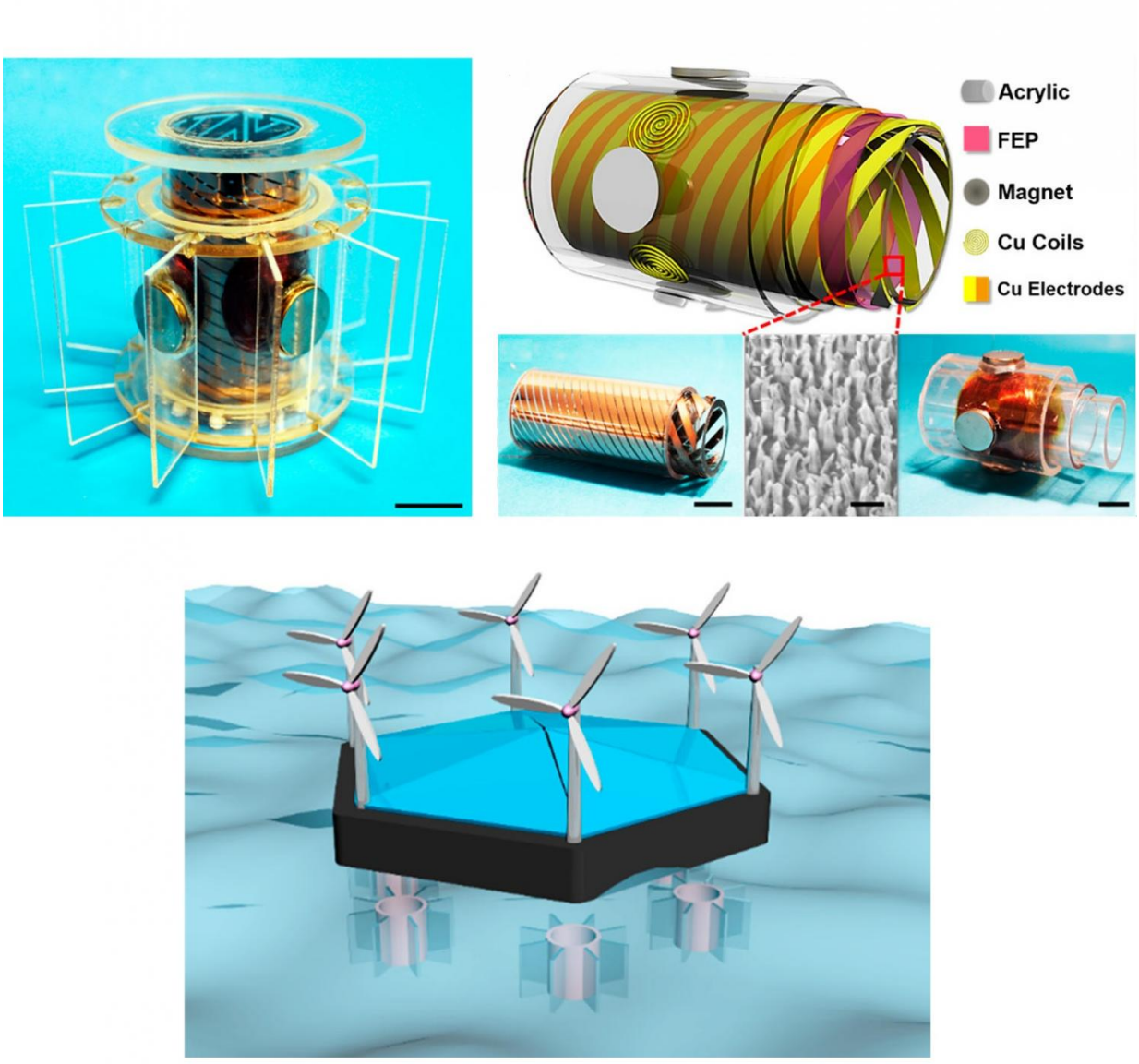

(Left) Photograph of the hybrid nanogenerator (scale bar: 2 cm). (Center)

Illustration of the hybrid nanogenerator structure, along with photographs of the TENG and EMG in the left and right lower panels, respectively. (Right) Illustration of the proposed energy harvesting panel floating on the ocean, which consists of wind-driven generators, solar cells, and hybrid nanogenerators. Credit: Wen et al. ©2016 American Chemical Society

(Phys.org)—Energy from the ocean, or "blue energy," is arguably the most underexploited power source, according to researchers in a new study. Although the oceans contain enough energy to meet all of the world's energy needs, currently there is no effective way to harvest it economically and with reasonable efficiency.

The main problem is that ocean waves are irregular and pass by at low frequencies, whereas most energy harvesters operate best with waves that have regular amplitudes and high frequencies. Unfortunately, the calming lull of slow, unpredictable waves beating against the shore that we tend to find so peaceful is not ideal for energy harvesting.

In a new study published in *ACS Nano*, a team of researchers led by Zhong Lin Wang at the Georgia Institute of Technology has developed a device that can harvest ocean waves in a very broad frequency range that encompasses almost all of the ocean wave energy spectrum, including the hard-to-reach low frequencies that are inaccessible to most harvesters.

The new device is a hybrid system that consists of two generators. An electromagnetic generator (EMG), which has traditionally been the main approach for harvesting ocean energy, is well-suited for harvesting waves at high frequencies and fast rotation speeds. A triboelectric nanogenerator (TENG), which has only recently been investigated for ocean energy applications, works better in the low-frequency range and

at slower rotation speeds.

"The TENG has the unique advantage of high output voltage, and its output power is linearly scaled with frequency, making it ideal for harvesting low-frequency energy," Wang told *Phys.org*. "On the other hand, the EMG's output power is proportional to the square of the frequency, so the EMG is ideally suited for harvesting high-frequency energy. At low frequency, (

When combined, the two types of generators operate in a broad frequency range and in two modes (fluctuation and rotation), allowing the hybrid device to collect a variety of types of ocean energies, including wave, current, and tidal. Each type of energy causes a different motion that requires a flexible harvesting capability.

The researchers demonstrated the device by using it to light up LEDs that form the words "BLUE ENERGY." The EMG is connected to the word "BLUE" and the TENG is connected to the word "ENERGY" so that the power output of each generator can be viewed individually.

The researchers envision the ocean wave energy harvester as one component of a larger energy harvesting panel floating on the ocean, which could simultaneously harvest wind, solar, and wave energy. They plan to further develop this concept in the future.

More information: Zhen Wen *et al.* "Harvesting Broad Frequency Band Blue Energy by a Triboelectric–Electromagnetic Hybrid Nanogenerator." *ACS Nano*. DOI: 10.1021/acsnano.6b03293