Digital Quantum Battery Could Boost Energy Density Tenfold

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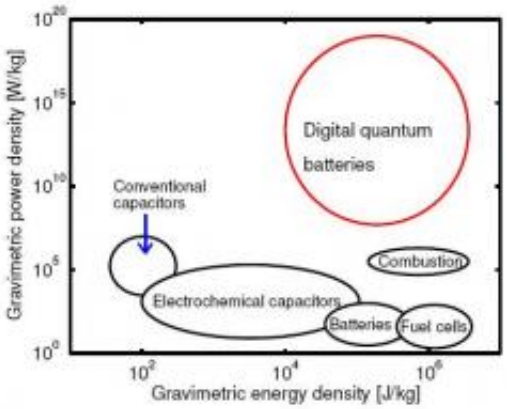

This figure shows the energy density and the power density of nano vacuum tubes in comparison to other energy storage devices. Credit: H?bler and Osuagwu.

(PhysOrg.com) -- Physicists theorize that quantum phenomena could provide a major boost to batteries, with the potential to increase energy density up to 10 times that of lithium ion batteries. According to a new proposal, billions of nanoscale capacitors could take advantage of quantum effects to overcome electric arcing, an electrical breakdown phenomenon which limits the amount of charge that conventional capacitors can store.

In their study, Alfred Hubler and Onyeama Osuagwu, both of the University of Illinois at Urbana-Champaign, have investigated energy storage capacity in arrays of nano vacuum tubes, which contain little or no gas. When the tubes' gap size - or the distance between electrodes - is about 10 nanometers wide, electric arcing is suppressed, preventing energy loss. Further, each tube can be addressed individually, making the technology digital and offering the possibility for data storage in conjunction with energy storage.

The physicists calculated that the large electric field exhibited under these conditions could lead to an energy density anywhere between two and 10 times greater than that of today's best battery technologies. The scientists also estimated that the power density (i.e., the charge-discharge rates) could be orders of magnitude greater than that of today's batteries. In addition, the nature of the charging and discharging avoids the leakage faced by conventional batteries, so that the nano vacuum batteries waste very little energy and have a virtually unlimited lifetime.

The scientists say that it may be possible to build a prototype of the battery in the next year. Since the energy density is independent from the materials used, the nano vacuum tubes could be built from inexpensive, non-toxic materials. The nano vacuum tubes could also be fabricated using existing photolithographic techniques, and could be easily combined with integrated circuits.

As for the possibility of data storage, the physicists explain that each nano vacuum tube can have two gates, an energy gate and an information gate. Each nano vacuum tube can also be charged and discharged individually, in any arbitrary order. By inserting a MOSFET (metal-oxide-semiconductor field-effect transistor) in the wall of a nano vacuum tube, the state of the tube can be determined without charging or discharging it.

"For example, to store the number 22, one would convert it to binary notation 22 = 10110," the scientists wrote in their paper. "Then use the energy gates to charge the first, third and fourth tube and leave the second and fifth tube uncharged. When the energy gate holds a charge, it induces an electric field in the MOSFET that partially cancels the electric field from the electrodes of the information gate, which modifies the threshold voltage of the MOSFET. During read-out, a voltage slightly above the regular threshold voltages is applied to the information gate, and the MOSFET channel will become conducting or remain insulating, depending on the voltage

threshold of the MOSFET, which depends on the charge on the energy gate. The current flow through the MOSFET channel is measured and provides a binary code, reproducing the stored data."

As Hubler explained in a recent article in MIT's Technology Review, the digital quantum battery concept can be viewed in different ways as a variation of several technologies.

"If you look at it from a digital electronics perspective, it's just a flash drive," Hubler said. "If you look at it from an electrical engineering perspective, you would say these are miniaturized vacuum tubes like in plasma TVs. If you talk to a physicist, this is a network of capacitors."

Hubler has applied for DARPA funding to develop a prototype of the digital quantum battery, and find out what will actually happen when loading the nano vacuum tubes with large amounts of energy.

More information: Alfred W. Hubler and Onyeama Osuagwu. "Digital quantum batteries: Energy and information storage in nano vacuum tube arrays." To be published in *Complexity*.

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