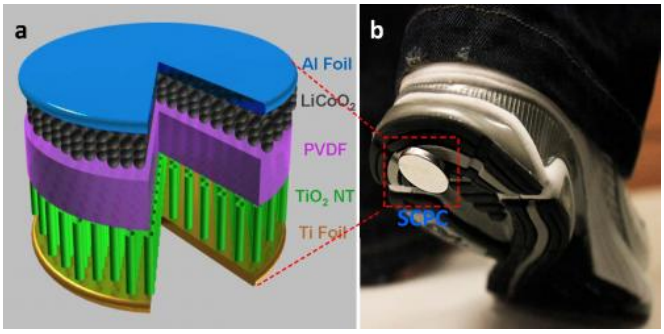
Self-charging battery both generates and stores energy

17 August 2012, by Lisa Zyga



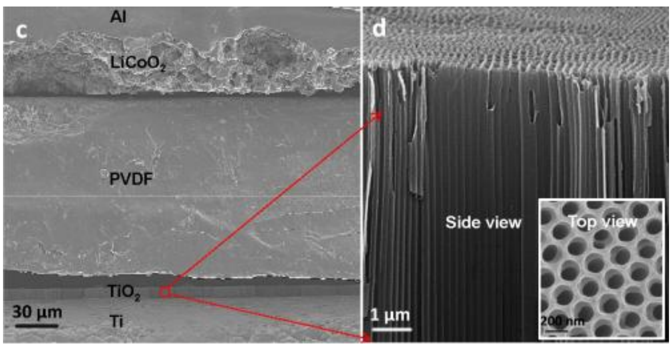
(a) In the self-charging power cell, the piezoelectric material PVDF replaces the conventional separator material and acts as a nanogenerator inside a Li-ion battery. (b) On the bottom of a shoe, the power cell converts the compressive energy generated by walking into chemical energy and stores it without converting it to electricity. Image credit: Xue, et al. ©2012 American Chemical Society

(Phys.org) -- Renewable energy technologies generally consist of two distinct processes: energy generation (using sources such as coal, solar, wind, etc.) and energy storage (such as batteries). These two processes are always accomplished through two separate units, with the first process converting the original form of energy to electricity, and the second process converting electricity to chemical energy. Now for the first time, engineers have demonstrated that energy can be generated and stored in a single device that converts mechanical energy directly to chemical energy, bypassing the intermediate step of electricity generation. The device basically acts as a hybrid generator-battery unit, or in other words, a self-charging power cell.

The researchers, Xinyu Xue, Sihong Wang, Wenxi Guo, Yan Zhang, and Zhong Lin Wang, from the Georgia Institute of Technology in Atlanta, Georgia, have published their study on combining energy generation and storage in a single unit in a recent issue of Nano Letters.

"This is a project that introduces a new approach in battery technology that is fundamentally new in science," Zhong Lin Wang told *Phys.org*. "This has a general and broad application because it is a unit that not only harvests energy but also stores it. It does not need a constant wall jet DC source to charge the battery. It is mostly to be used for driving small, portable electronics."

To fabricate the self-charging power cell, the researchers started with a coin-type Li-ion battery and replaced the polyethylene separator that normally separates the two electrodes with PVDF film. As a piezoelectric material, PVDF film generates a charge when under an applied stress. Because of its position between the battery electrodes, the PVDF film causes positive Li ions to migrate from the cathode to the anode in order to maintain a charge equilibrium across the battery. This ion migration process charges the battery without the need for any external voltage source; since the PVDF separator provides the voltage, or potential difference between electrodes, the battery is essentially self-charging.



A cross-sectional scanning electron microscope image of the self-charging power cell (left), and the enlarged TiO2 nanotube anode (right). Image credit: Xue, et al. ©2012 American Chemical Society

In order to apply a stress to the separator, the researchers attached the coin-sized battery to the bottom of a shoe, and found that walking could generate enough compressive energy to charge the battery. A compressive force with a frequency of 2.3 Hz could increase the voltage of the device from 327 to 395 mV in 4 minutes. This 65 mV increase is significantly higher than the 10 mV increase it took when the power cell was separated into a PVDF piezoelectric generator and Li-ion battery with the conventional polyethylene separator. The improvement shows that achieving a mechanical-to-chemical energy conversion in one step is much more efficient than the mechanical-to-electric and electric-to-chemical two-step process used for charging a traditional battery.

Once the new equilibrium between electrodes is reached, the self-charging process ceases. The cell can begin supplying power after the applied stress is released, since the piezoelectric field disappears and the Li ions can diffuse back from the anode to the cathode to reach a new equilibrium. As in a conventional Li-ion battery, ion diffusion involves electrochemical reduction-oxidation reactions, which here generate a current of about 1 ?A that can be used to power a small electronic device.

“The Li ions will not flow back immediately after the applied stress is removed because it forms a new compound with the anode material (LiTiO),” Zhong Lin Wang said. “The charges are preserved as in a conventional battery. They are released at a later time when power is required.”

Although these voltages and currents are low, the researchers showed that the power cell can also self-charge with higher voltages of around 1.5 V, which could make it useful for a broader range of applications. The researchers predict they can further improve the power cell’s performance by making several modifications, such as by using flexible casing to allow for greater deformation of the piezoelectric material.

More information: Xinyu Xue, et al. “Hybridizing Energy Conversion and Storage in a Mechanical-to-Electrochemical Process for Self-Charging Power Cell.” *Nano Letters*. DOI: 10.1021/nl302879t