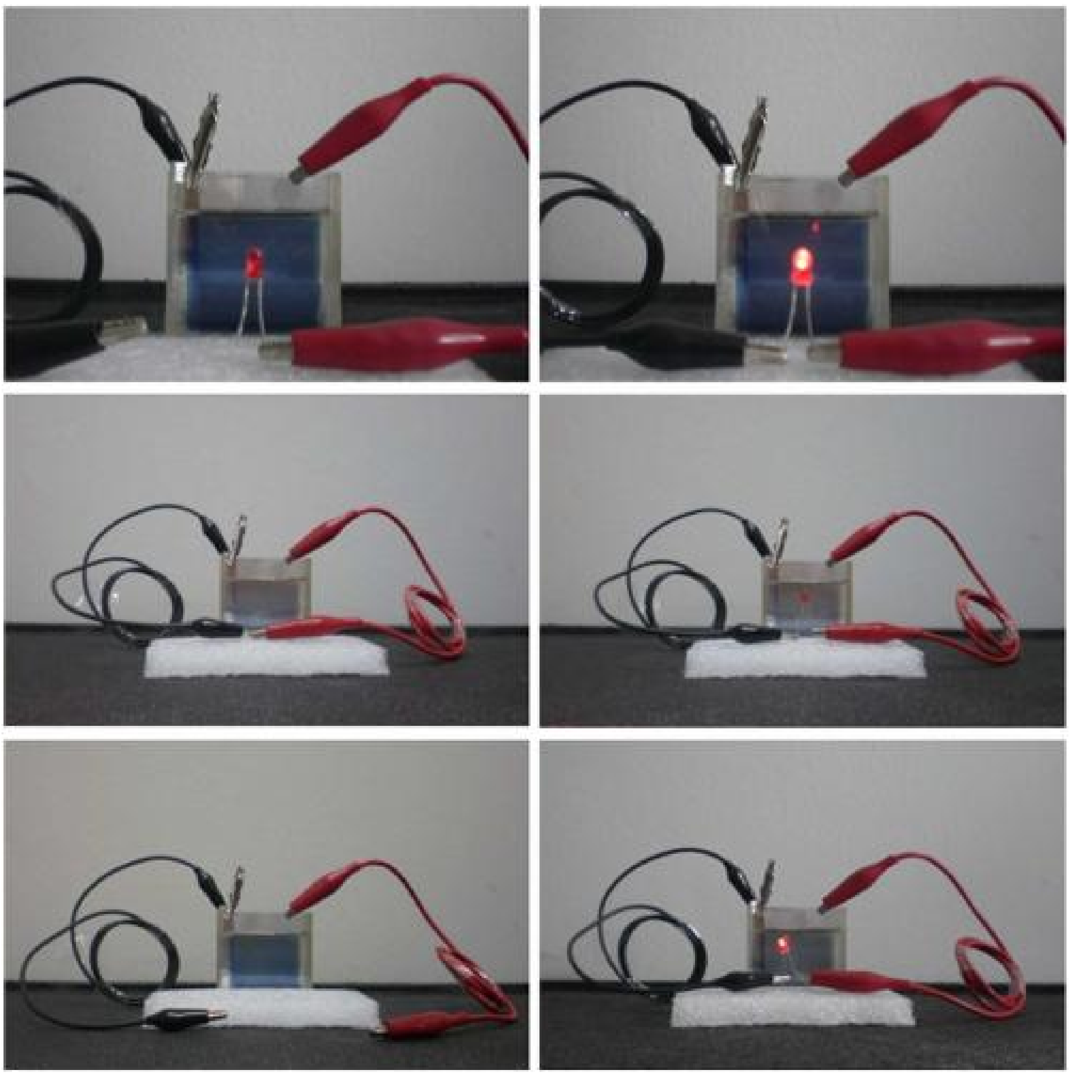
Self-powered smart window also functions as a self-rechargeable transparent battery

October 2 2014, by Lisa Zyga



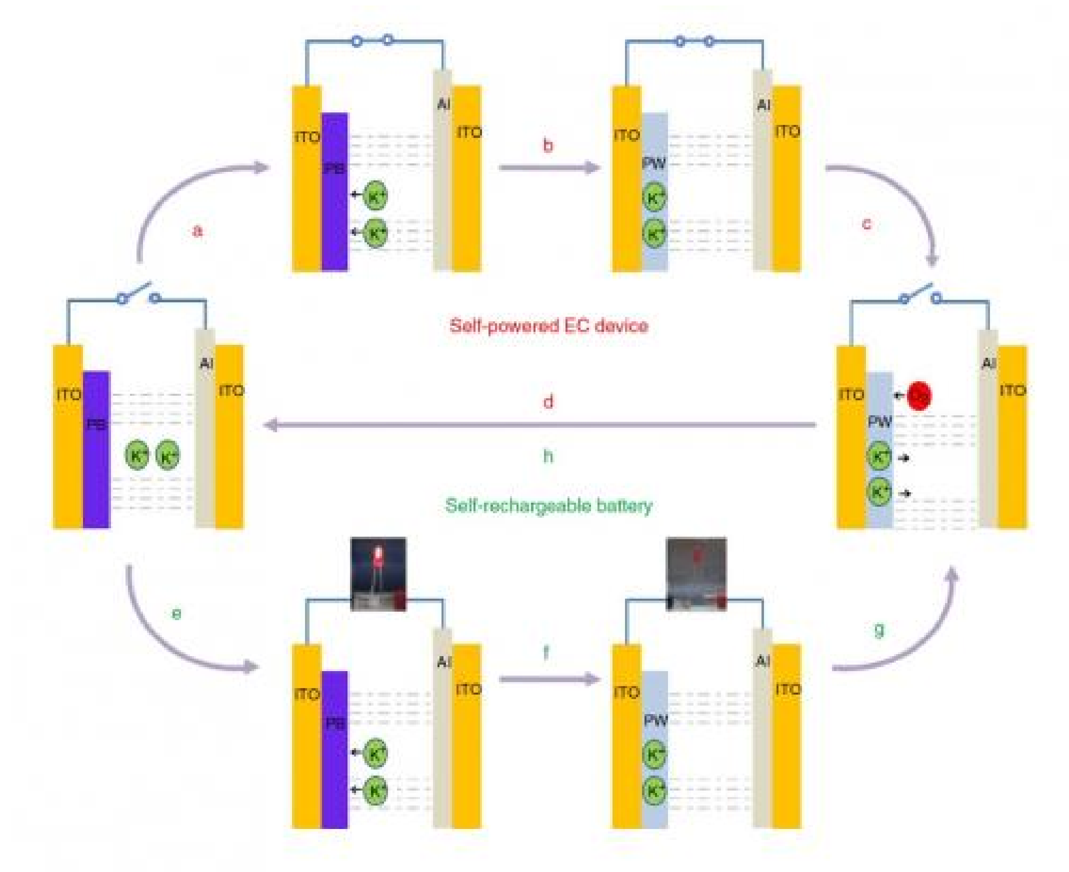
The PB/Al smart window/battery in different states. (a) With the electrodes disconnected, the glass is blue and (b) can power an LED. (c) With electrodes connected, the glass becomes transparent and (d) cannot light the LED. (e) Electrodes are disconnected for one hour to self-recharge the device, and (f) the device can power the LED again. Credit: Wang, et al. ©2014 Macmillan Publishers Limited

(Phys.org) —Smart windows have the ability to become darker or lighter in response to the brightness and heat of sunlight, offering the potential to greatly reduce heating and cooling costs, among other benefits. However, current smart windows require an external power supply to operate, causing an additional energy consumption that cuts into their overall cost savings.

Now in a new study published in *Nature Communications*, a group led by Professor Xiong Wen (David) Lou and Professor Xiao Wei Sun at Nanyang Technological University in Singapore have designed and fabricated a completely self-powered smart window. The window can change its color from transparent to blue depending on its exposure to air by using electrochromic materials, which are capable of storing and releasing ions and electrons, similar to a battery. These characteristics also enable the smart window to function as a self-rechargeable transparent battery to power other devices.

The key to the new smart window is the electrochromic (EC) material Prussian blue (PB). In the early 1980s, scientists discovered that PB can be transformed into colorless Prussian white (PW) by electrochemical reactions. Specifically, the color change occurs when the iron in the PB is reduced, so that it gains an electron from another material that can easily lose electrons. Here, the researchers used aluminum (Al) as the electron-donating anode, to complement the PB cathode.

When the PB and Al electrodes are connected to each other, the smart glass can be "bleached" to colorless PW in just 4 seconds. The researchers found that the smart window's transmittance changes by about 52% between the blue and colorless states. This bleaching process of the PB/Al smart window also corresponds to the discharging of the PB/Al cell. When the smart window becomes fully transparent, it can no longer light up an LED, indicating that it is fully discharged.



Functioning mechanisms of the bi-functional self-powered EC smart window and self-recharging battery: (a-d) shows the bleaching process of the device serving as a self-powered EC smart window, (e-h) shows the discharging and self-recharging processes of the device functioning as a self-rechargeable battery. Credit: Wang, et al. ©2014 Macmillan Publishers Limited

To recharge the smart window/battery, the researchers simply disconnected the PB and Al electrodes, exposing them to oxygen. The battery then spontaneously recharges itself by oxidizing the iron in the electrode, causing the smart window to slowly regain its blue color. After about an hour of the electrodes being disconnected, the battery can light up the LED again, indicating that it is partially recharged.

"We need to connect the electrodes to turn it from blue to transparent," Sun told *Phys.org*. "If we want it to become blue again, we need to disconnect the electrodes and expose the electrolyte to air. Oxygen here is used to react with PW to form PB. When PB is formed, the battery is recharged."

As Sun explained, the PB/Al cell's ability to recharge itself is due to the fact that PW spontaneously reverts to PB in the presence of oxygen. Interestingly, this property is generally regarded as a drawback in making a battery because it decreases the battery's voltage, so batteries are usually isolated from oxygen. However, here oxygen is critical for recharging the battery. The researchers note that the PB/Al cell is different than Al-air or Li-air batteries in which aluminum or lithium serves as the anode and oxygen as the cathode. In the PB/Al cell, PB is the cathode and oxygen is only involved in the self-recharging process.

The researchers also explain that, when Al is eventually used up, the battery will no longer function. In this sense, the battery is not truly self-rechargeable, and after all a truly self-rechargeable battery cannot exist due to the first law of thermodynamics. However, the battery contains enough Al to last for the reasonable lifetime of a normal rechargeable battery.

As a battery, the PB/Al cell shows fair performance. Although its specific capacity is relatively low compared to that of lithium batteries, it has a reasonably large total capacity considering its thin-layered structure. If an external power source is applied instead of self-charging in air, both the charge capacity and charge time can be significantly improved.

As a two-in-one device, functioning as both a self-powered smart window and self-rechargeable transparent battery, the new technology could have some novel dual applications. Its properties allow it to be simultaneously used for indoor light and heat management and as a power source for some low-power devices. In the future, the researchers plan to make further improvements.

"Future research is needed to expand the reliability, i.e., lifetime of the device," Sun said. "It is also needed to think of ways of exposing electrolyte to oxygen, for the device to breathe."

More information: Jinmin Wang, et al. "A bi-functional device for self-powered electrochromic window and self-rechargeable transparent battery applications." *Nature Communications*. DOI: 10.1038/ncomms5921