Time ripe to move energy storage idea off drawing board

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Need has caught up with Gerhard Welsch's ideas. Welsch, a professor of materials science and engineering at Case Western Reserve University, began patenting designs for a small, light, powerful and reliable capacitor in 2000.

Now it's just the kind of energy storage device makers of hybrid cars, computer power supplies, pacemakers and more are seeking to absorb and provide surges of electricity.

Funded with a recent $2.25 million stimulus grant from the U.S. Dept. of Energy's Advanced Research Projects Agency – Energy, or ARPA-E, Welsch will try to make a capacitor ready for market within three years.

Working with him are colleagues Chung-Chiun Liu, professor of chemical engineering, and Frank Merat, professor of computer science and electrical engineering.

ARPA-E is especially interested in the capacitor for hybrids and all-electric cars. A battery, which is a tortoise to this hare, can't supply or absorb energy nearly as fast as a capacitor. To accomplish this, capacitor-enabled power inverters convert the DC electricity from batteries, solar panels or fuel cells to high frequency AC power.

"Electric vehicles need power inverters to convert battery power into higher voltage AC power for their electric motors and to harvest braking power," Welsch said.

His capacitor would provide a 10-fold or higher increase in energy density over current models, yet would be a fraction of the size and weight. And, this model could greatly increase reliability because it can heal leaks of electrical current that plague models now in use.

The keys are the materials and design of the device.

Capacitors, like batteries, have two poles: an anode and a cathode. The anode of Welsch's capacitor is made of a titanium alloy so finely textured that it absorbs almost all the light falling on it. (It looks black.) A large surface area squeezed into a small volume enables high capacitance and a high energy density.

The fine porous structure is laid out on a spine with many branches, further increasing the surface area.

A layer of titanium oxide, made by coating the porous surface with metal oxide, creates a barrier called a dielectric. The dielectric separates positive and negative electrical charges with a certain voltage, which holds the energy. Next comes a layer of an ion-conducting electrolyte followed by a metallic layer, probably of carbon or titanium, which serves as the cathode.

"A capacitor is the equivalent of an electron pressure tank, and the trick is to make the dielectric film (or the wall of the pressure tank), impenetrable to electrons by making it strong and as perfect as possible," Welsch said. "Perfect is not possible, but we can make a material that's close."

Typically, defects in the dielectric allow electrons to leak between the anode and cathode, limiting the energy density or leading to failure of the device. A new synthesis process reduces the size and number of defects in the dielectric formed. When a defect does form, the same forces that store energy in the dielectric draw ions from titanium and the electrolyte, forming a new oxide in or near the defect, sealing the leak.

The spine and branches' design, high surface area, synergistic materials and the instant healing of the dielectric would provide unmatched efficiency and high energy in a small space, the researchers believe.

In addition to demonstrating the capacitor in power supplies for electric cars and LED lighting, Welsch's group aims to show how it can be used in a miniaturized implantable defibrillator. When a sensor detects uncontrolled contraction of heart muscle, a battery will send energy to the capacitor, which will in turn jolt the muscle with a pulse of electricity lasting a microsecond, restoring a normal beat.

Provided by Case Western Reserve University