The Evercell™ Power Cell

A Description of the Technology

The Evercell™ power cell (one of the Evergreen® technologies from The Face® Companies) is a passive structure that exploits known principles of quantum thermodynamics and applies them in a new and unexpected way. It has long been held that segregating, isolating and directing accumulation of electrons at the atomic level requires excitation by an infusion of energy – more energy than the resulting system would generate. The passive nature of the Evercell™ energy harvesting (EH) elements provides a structural capacity for the accumulation of electric potential with no energy expending budget to overcome. An Evercell™ demonstrator has been operating since October 2016, generating a continuous flow of electrical output with no reduction in performance over time, and materials analysis has shown that it cannot be operating as a battery.

All previous proposed methods to harvest thermal energy in a manner seemingly similar to Evercell™ were based on active techniques. Unfortunately, in those cases, the energy expended to segregate, isolate and direct accumulated electrons was greater than the energy generated. Evercell™ solves this problem with a semiconductor-based passive structure that requires no input of energy, except for ambient heat.

As described in Schrödinger's wave equation, electrons have certain inherent energy at the atomic level. Work function is the energy required, usually specified in electron volts (eV), for an electron to leave the surface of a material. In solid-state physics, the work function is the minimum thermodynamic work (i.e., energy) needed to remove an electron from a solid to a final electron position remote from the surface on the atomic scale. The work function is not a characteristic of a bulk material, but rather a property of the surface of the material. As temperature increases, electrons become more energetic and more easily leave the surface of the material.

When the temperature (and thus the corresponding energy) is below the energy required by the work function for electrons to leave the surface of the material, there is a small probability that the electrons will leave the surface. In other words, this is not an on-and-off function. Random electrons may leave the surface even when the temperature is below that which the work function indicates may allow the electrons to leave the surface. As a work function of a particular surface is decreased in a donor (or emitter) surface according to a number of different mechanisms, it becomes easier for larger numbers of electrons to leave the surface.

The donor surface is the surface with the lower work function and the receptor surface is the surface with the higher work function, because it is more difficult for electrons to leave the receptor surface with the higher work function.

When a particularly low work function (1.0eV or less) material, such as silver oxide cesium, is employed as the donor surface, a comparatively larger number of electrons leave the donor surface. When another surface with a higher work function of 5.0eV or more is employed, such as copper or gold, electrons do not leave the surface as freely. Thus, there is an accumulation of electrons at the higher work function surface. Put another way, the donor surface releases larger numbers of electrons than the receptor surface.

Tunneling effects are a necessary component of the Evercell's™ operation. The proximity of the donor and receptor surfaces, sandwiching a dielectric layer in a range of 100nm or less in thickness, supports a quantum tunneling effect. Quantum tunneling is the quantum mechanical phenomenon where a particle tunnels through a barrier that it classically could not surmount. This phenomenon is known to play an essential role in several conventional physical phenomena, with important applications to modern devices such as a tunnel diode, quantum computing, and scanning tunneling microscopes.

At rest, given the proper combination of materials, there will always be energy transfer from the donor surface to the receptor surface based on the designed difference in work function of the respective surfaces. In this manner, electron transfer is directed in a calculable and controllable way from a particular donor surface to a particular receptor surface by conditioning the respective surfaces and placing them in properly close proximity to each other. Evergreen®'s CTO and lead scientist determined, through extensive experimentation, a method of combining the respective surfaces in a manner that leads to measurable electrical power output.

The donor and receptor conductors are comprised of highly conductive materials for the purpose of completing the electrical path efficiently. To reduce the work function of the donor surface, a different material can be combined with the conductor by, for example, surface treating the conductor that conducts free electrons with an oxide, and potentially nitrogen, to turn the surface into a form of semiconductor, lowering the work function of the surface. Conductor materials themselves tend to exhibit fairly high work functions, absent a semiconductor or other surface treatment. As a result, any opposing conductor will have a surface with a comparatively high work function.

A dielectric layer in between the donor and receptor conductors could be in the form of a vacuum or an air gap. The difficulty is that, given the very small separation distances that must be maintained within the power cell's EH elements, it can be difficult to maintain those distances over a large area bounding an air gap. Some type of dielectric composition layer is therefore preferred in order to provide positive separation between the low work function surface of one conductor and the comparatively higher work function surface of the opposing conductor. Such a dielectric layer ensures (1) that the electrons transfer from the low work function surface to the comparatively higher work function surface and (2) that the two conductor surfaces do not internally short one another. The dielectric layer does not determine the direction of the flow of electrons. It provides the spacer for the flow of electrons from the lower work function surface to the higher work function surface. This ensures that the only path by which electrons can return to the low work function surface is through the load.

As indicated above, electrons will randomly leave the surfaces. In the structure described, comparatively few electrons will leave the high work function surface, while comparatively large numbers of electrons will migrate from the low work function surface and accumulate at the high work function surface. The flow of electrons accumulates in between the surfaces, and as the electrons repel each other, they cross the gap to the higher work function surface that accepts free electrons and holds them because of the high work function characteristic of the surface.

The tunneling effect essentially disappears at about 200nm separation between the electrodes. At around 20nm, however, the exponential function of the current increases significantly. A wave function begins to overlap the receptor conductor. Based on this overlap, the free electrons can be “sucked to” the high work function surface of the receptor conductor. The high work function surface maintains its high barrier. Thus, residual release of electrons, potentially for tunneling back in the other direction, is significantly limited.

The inventive nature of the Evercell lies in its structure, which enables these quantum effects that are not seen at a macro-level. It is a quantum tunneling effect that causes (or promotes) enough electron transfer to generate a measurable and usable current through the load.

The thickness of a layer is optimally in the tens of nanometers range. The dielectric layer would optimally be 20 to 60nm to as much as 100nm thick in order to increase the tunneling effect. Smaller is better to promote higher electron migration based on the quantum tunneling effects, better utilizing a tail of the wave function. In thicker dielectric layers (in a range of 200nm or more), the quantum tunneling effects are significantly reduced. In thinner dielectric layers (in a range of 0.2nm as a theoretical lowest-limit thickness) dielectric breakdown may occur.

When the surfaces are brought into close proximity with each other, separated by a dielectric layer in the manner described above, electron transfer occurs at a previously unanticipated rate. This electron transfer causes an electrical potential to accumulate in the layered structure. As with any other electrical power source, when a load is connected to the Evercell™, certain depletion of the electrical potential occurs. Consider that the electrons flow from the high work function surface conductor through the load to the low work function surface conductor. The established equilibrium between the low work function surface and the high work function surface is disturbed and electron transfer between those surfaces continues or resumes. Controlling the current flow through the load provides a capacity to power the load.

As indicated above, therefore, the physical configuration of the Evercell™ energy harvesting element, including the semiconductor nature of the low work function conditioning of the surface of one of the electrodes, is critical. Evergreen Technologies, LLC has produced a series of technology demonstrators since 2016, the latest of which is available for viewing.

A Description of the Patents

The Evercell™ technology is further explained in the Evercell™ patents. See, for example, U.S. Patent No. 9,793,317 directed to Devices and Systems Incorporating Energy Harvesting Components/Devices as Autonomous Energy Sources and as Energy Supplementation, and Methods for Producing Devices and Systems Incorporating Energy Harvesting Components/Devices.

The patents explain that the work function of free electrons on the surface of the donor conductor is lowered enough by surface conditioning or the presence of the low work function layer to cause the free electrons to leak into and through the very thin dielectric in a direction from the donor electrode to the receptor electrode via the mechanism of quantum tunneling. The patents acknowledge that a similar process is occurring in the opposite direction from the receptor conductor in the direction of the donor conductor, but at a rate that is orders of magnitude lower due to the comparatively high work function of the material of the facing surface of the receptor conductor.

It should be noted that differences in work function in the opposing conductor faces or surfaces of as little as 1.0eV may produce usable electrical output from the patent-disclosed structures. Quantum tunneling effects are a necessary component of the disclosed schemes and are implemented through the minimal proximities across the dielectric layer interposed between the facing surfaces of the conductors and the presence of the low work function conditioning, or low work function surface layer, on the surface of the donor conductor.

In the enabling disclosures provided in the patents, it is noted that, given the proper combination of materials, there will always be energy transfer from the donor conductor surface to the receptor conductor surface based on the above-described designed differences in work function of the respective surfaces. In this way, the transfer of electrons in a managed and predictable manner is directed from a particular donor conductor surface to a particular receptor conductor surface.

The unique design placement of the respective layers described above results in a previously unforeseen, and previously unachievable, measurable electrical power potential or output from the Evercell™ power cell.

For a particular surface area of the power cell EH element configurations disclosed in the patents, an element with a $10cm^2$ surface area (approximately 1.25 x 1.25 inches) can be expected to produce about 190nW. Ten square centimeters is a relatively large area compared to typical microelectronic devices and products of low power consumption. To scale down the packaged area, and/or to scale up the power, EH elements may be stacked in a manner described in further detail in the patents, with a practical limitation projected to be about 100 elements. For instance, a power cell with a stack of 50 EH elements of a $10cm^2$ surface area would produce approximately 5µW.

Conclusion

The above description explains the function of the Evercell™ power cell, a passive structure that operates according to known principles of physics exploited in a new and unique manner. The passive structure promotes the accumulation of electrons at the surface of one conductor of the Evercell™ power cell to generate an electric potential with no energy expending budget to overcome and no requirement for exposure to any disturbing or radiating power source. Evercell™ power cells function as energy collectors and accumulators in virtually any operating environment.

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