The Evercell™ Power Cell

Detailed Description of Technology

The Evercell™ power cell (one of the Evergreen® technologies from The Face® Companies) is a passive structure that operates according to known laws of physics captured and amplified in a previously unknown manner. It has long been held that segregating, isolating and directing accumulation of electrons at the atomic level required excitation by an infusion of energy – more energy than a resulting system would generate. The passive nature of the Evercell™ energy harvesting (EH) elements comprising the power cell provides a structural capacity for the accumulation of electric potential with no energy expending budget to overcome.

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 dilemma with the implementation of a semiconductor-based passive structure that requires no input of energy, except for ambient heat.

Electrons have certain inherent energy at the atomic level. That energy is described in Schrödinger's wave equation. Work function is the energy required, usually specified in electron volts (eV), for the electron to leave a 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 of the material. 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. 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, *e.g.*, silver oxide cesium, is employed as the donor surface, a comparatively larger number of electrons leave the donor surface at room temperature and below.

When another surface is employed, like copper or gold, which have a higher work function (5.0eV or more), electrons do not as freely leave the surface. As such, there is an accumulation of electrons at the higher work function surface. Put another way, at room temperature then, the donor surface releases larger numbers of electrons than the receptor surface.

Tunneling effects are a necessary component of the Evercell™ operating schemes. 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 materials, there is always going to be energy transfer from the donor surface to the receptor surface based on the design difference in work function of the respective surfaces. In this manner, electron transfer is essentially directed in a calculable and controllable manner from a particular donor surface to a particular receptor surface in a unique manner by conditioning the respective surfaces and placing them in properly close proximity to each other. Evergreen®'s Chief Technical Officer and Lead Scientist determined, through extensive experimentation, a method by which to properly combine the respective surfaces in a manner that leads to measurable electrical power output.

The donor and receptor conductors are comprised of good conductor materials in order to complete the electrical path by conducting electricity well.

To reduce a 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 a 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 a form of a vacuum or an air gap. The difficulty is that, given the small separation distances for the EH elements comprising the power cell to operate properly, it can be challenging to maintain the conductor layers nanometers apart 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 other 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 a direction of a flow of electrons. It, however, provides the spacer for the flow of electrons from the lower 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 above, 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 at about 200-nm separation between the electrodes essentially disappears. 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. As such, residual release of electrons, potentially for tunneling, back in the other direction is significantly limited.

A key to the inventive nature of the disclosed structure for the Evercell™ power cell lies in 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 an effective and measurable current through the load. The "layers" are 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 according to 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 the near contact with one another 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 power source, 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 structure (physical configuration) of the basic Evercell™ power cell energy harvesting (EH) element, including the semiconductor nature of the low work function conditioning of the surface of one of the electrodes, is critical. That said, Evergreen Technologies, LLC has produced a series of technology demonstrators over the last three years, the latest of which is available for display.

Patents Description

The Evercell™ technology is further explained in the Evercell™ patents. *See, e.g.*, 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 in the surface of the donor conductor is lowered enough by surface conditioning or the presence of the low work function layer such that the free electrons leak into and through the very thin dielectric in direction from the donor electrode to the receptor electrode via the mechanism of quantum tunneling at room temperatures. The Patents acknowledge that a similar process is occurring in the opposite direction from receptor conductor in a 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 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 is always going to 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 manner, 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 generally described above results in a previously unforeseen, and previously unachievable, measurable electrical power potential or output from the disclosed structures of the Evercell™ power cells.

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

Conclusion

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

