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Thermalvoltaic Cell and toalleviate Climate Change with reversible Emission

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Abstract

Climate change, food scarce and energy crisis are some major problems we human are facing today, the development of the industry emitted excessive CO_2 and it causes global warming effect since it is a gas with greenhouse effect. However, we need moderate CO_2 emission to meet our demand to the energy for all individual and society activities that maintain our lives and realize our dreams. In fact, CO_2 emission is reversible simply by afforesting and agricultural production, plant could just absorb CO_2 and water as raw material for photosynthesis using sunlight as energy resource to produce carbohydrate which is the food for any creature on the earth. By accident, it was also found that heat could directly be converted into electricity by a thermal voltaic effect which just altered the non-equilibrium injection in a solar cell from photoemission into thermionic emission, or their combination, it could directly generate electromotive purely by absorbing heat from the environment with material that has thermionic emission under this temperature connected into the p-n junction of a photovoltaic cell, and graphene is promising since it may provide thermionic emission under room temperature more easily since it is a 2-dimensional semi-metal which has many novel properties such as massless electron and relativistic effect at low velocity and probably has no depletion effect with silicon. The CO_2 emission could be reversed by more quality agricultural production and the excess heat in the environment could be directly absorbed to produce electricity by thermalvoltaic effect, in this way food scarce and energy crisis could resolve together with climate change, emission tax could be compensated by more production of vegetables and fruits or other vegetal growth.

Keywords: Climate change, Photovoltaic effect, Thermionic emission, Thermalvoltaic effect, Graphene

Thermalvoltaic Cell

The possibility to directly convert heat into useful work without any other change

In tradition, the perpetual engine is not legal by physical law,[1] in terms of the conservation of energy, momentum, and entropy, a machine that could absorb heat and produce energy thereby is forbidden because it would rebel the second law of thermodynamics. However, all these laws have no proof and quantum mechanics shows the energy and momentum could be probabilistically created or annihilated, by the uncertainty principle. And it could be proved that material could only be created by spirit and spirit could create material, as free mind could do what he purely likes which is not determined by anything existed, existence is the essence of material, to create new existence and this is a process of spirit creating material purely by labouring what he likes to do, and it changes the world.

Photovoltaic effect could convert the energy in light to be electricity, it is using the non-equilibrium carriers by light injection, in which process the electrons in depletion region of the p-n junction absorb photons with energy higher than their work functions to be excited as free electrons and holes and then drift immediately

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under the action of the built-in electric field in the depletion layer, to reverse the diffusion process in the p-n junction and create electromotive. The diffusion force, which acts on the carriers in p and n region to diffuse into the other region where the type of the impurity is opposite to the impurity that contributed them, created a potential, and the incident photons are constantly reversing this process; thereby, the diffusion potential energy was recovered but can't be released by the diffusion since the diffusion was consistently being reversed by the incident photons. As a result, the diffusion force produces an electromotive to try to release its energy in this way, and this is how photovoltaic cells produces electricity.

This effect could partly convert the heat from the sun into electricity to be energy source; furthermore, the non-equilibrium injection is from light, it could also be from heat since thermion is same electron as photoelectron, then the effect could be which directly converts heat into electricity to be energy source, heat could be directly converted into useful work without any other change. A thermal voltaic cell made by this effect rebels the second law of thermodynamics but verifies what Boltzmann interpreted about entropy, that the second law of thermodynamics is only valid for an isolated system and it should be probabilistic for a non-isolated system. It could be proved that the second law of thermodynamics is only valid when there is only material, while the real world is full of spirits and only spirit could create material, any macroscopic process has possibilities to go against the natural, entropy-increasing direction. This effect is just a case that totally reversed to the process described by the second law of thermodynamics.[2] To understand this effect, let's have a short review about p-n junction and the solar cell first.

P-n junction and solar cell

As Figure 1 shows, doping a semiconductor with donor (p) and acceptor (n) impurities with technologies such as diffusion and ion implantation,[3] a p-n junction can be constructed in the semiconductor where the p semiconductor was doped by n type impurity such as phosphorous that contributes holes as carriers, and the n semiconductor was doped by p type impurity such as boron that contributes electrons as carriers.[4] The gradient of the carrier density would generate a "diffusion force" which acts onto the carriers to diffuse into the other region where the type of doped impurity is opposite to the type of the impurity that contributed them, this diffusion combines the non-equilibrium electrons from n semiconductor with the acceptor atoms of the n-type impurity in p semiconductor forming negative ions and the non-equilibrium holes from p semiconductorwith the donor atoms of the$p$-type impurity in n semiconductor forming positive ions. As the diffusion continues, more and more non-equilibrium carriers were combined with the opposite type of impurity atoms forming negative ions in p region and positive ions in n region, and the region where these ions were would accumulate and expand to be adepletion region, as Figure 1 shows. There is no non-equilibrium carrier in the depletion region, non-equilibrium carriers originally were free and significantly denser than the inherent carriers of pure silicon. The positive ions in n region and negative ions in $p$region would also create an electric field, the force it exerts onto the carriers is exactly opposite to the direction of the diffusion force acted on them, this is called the built-in electric field and makes the carriers to drift. The diffusion would get equilibrium with the drift when the diffusion force balanced the force that the built-in electric field acted on the carriers, the depletion region is also called the space-charge region.

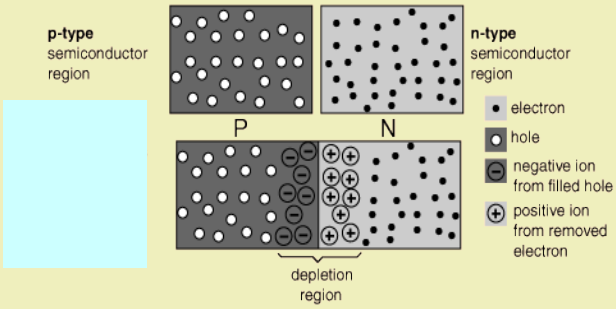

Figure 1: p-n junction.

When there is photon with energy quanta higher than the work function of the electron in the depletion region, as Figure 2 shows, the photon would excitethe combined electron-hole pairsfrom the depletion region apart; thereafter, the electrons and holes would drift back to the origin region where they diffused from under the force acted by the built-in electric field, this process exactly reversed the diffusion. And when there is constant light contains such photons luminating into the $p-n$ junction, the diffusion is constantly being reversed; thereby, the diffusion force would generate an electromotive and the energy from the photonscould produce electricity by the electromotive.

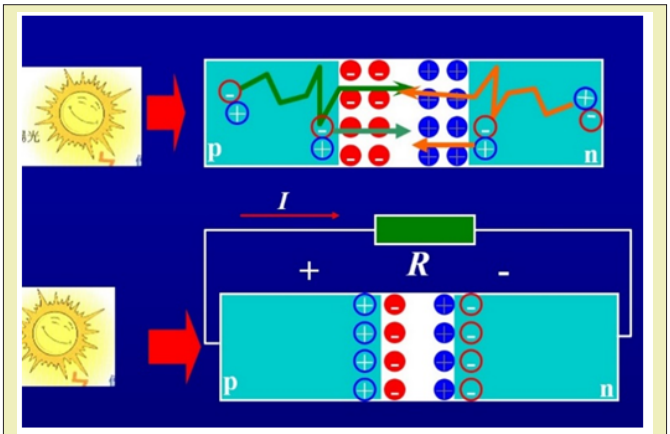

Figure 2: Solar cell.

Alteration from photovoltaic cell to thermalvoltaic cell

The essence of electricity generation of p-n junction solar cell is to use the diffusion force created by different kinds of impurity doping in p and$n$ region in one semiconductor material to convert the energy of photons from the sunlight into electricity when the photons was reversing the diffusion constantly.

The p region is doped with n-type impurity which is acceptor and contributes holes, the n region is doped with p-type impurity which is donor and contributes electrons, the contributed carriers are major carriers in region they came from. The p doping in n semiconductor makes the energy level of conduction band E_{Cp} further to the Fermi level E_{Fp}than the valence band E_{Vp} while the n doping in p semiconductor makes the energy level of conduction band E_{Cn} closer to the Fermi level E_{Fn}than the valence band E_{Vn}, and $E_{Cp} - E_{Fp} > E_{Cn} - E_{Fn}$, $E_{Fp} - E_{Vp} < E_{Fn} - E_{Vn}$.

The difference of the density of the carriers in two region creates a diffusion force because the Fermi levels of the two regions feel like to flatten, this force pushes the holes to diffuse from p semiconductor to n semiconductor where the energy level is lower while the electrons to diffuse to the opposite direction, as Figure 3(a) shows; consequently, the holes and electrons from p and n region would combine with the donor and acceptor impurity atoms in n and p region respectively, forming positive and negative ions and a built-in electric field that exerts force in opposite direction to the diffusion force onto the carriers, forcing the holes and electrons to drift in opposite direction to their diffusion, and the diffusion would stop at the equilibrium with the drift when the force of the built-in electric field balanced the diffusion force.

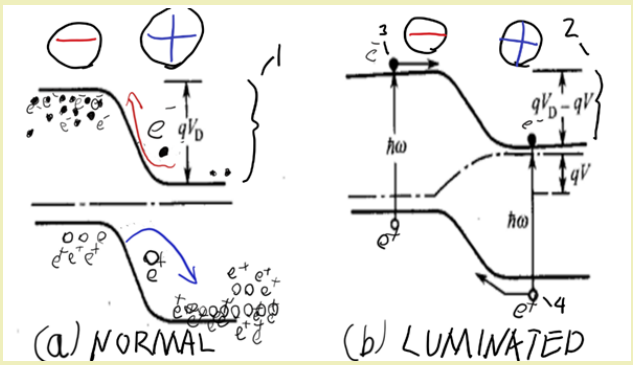

Figure 3: The energy band in solar cell p-n junction.

Once the sunlight with adequate frequency was luminating into the $p-n$ junction, the conjugated electron-hole pairs would be excited apart again by the photoemission and drift along the force that the built-in electric field acted onto them, reversing the diffusion and the diffusion force would break the balance with the built-in electric field force and could motivate the original diffusion again; furthermore, when the sunlight is stable and such excitation of electron-hole pairs by the photoemission was constant, the diffusion could not continue, the photoemission would consistently compensate the diffusion and deviate the equilibrium between the diffusion reversed to the diffusion, the diffusion force would be redirected to be the electromotive between the $p-n$ junction which could produce electricity, and the energy comes from the photoemission excited by the luminated sunlight, the photoemission from the incident light injects none quilibrium carriers into the $p-n$ junction and the diffusion process was reversed by the drift of the electron-hole pairs that were excited apart by the photoemission, between $p$region and $n$regionthe diffusion force larger than the built-in electric field force would create electromotive, and the combination energy of non equilibrium carriers are larger than the electric energy they needed to mate.[5,6]

Generally, any process that could inject non equilibrium carriers into the p-n junction, i.e., excite the conjugated electron-hole pairs inside the depletion region of p-n junction apart could same produce electricity. If the light injection in solar cell was altered to bethermal injection, i.e., the photoemission was altered to be thermionic emission to excite the electron-hole pairs apart, the apart electrons and holes would same drift reversed to the diffusion, the diffusion force would increase while the built-in electric field force would decrease, the balance between the diffusion force and built-in electric field force was broken, and the surplus diffusion force would create an electromotive which could persist as long as the injection was constant.

If connecting some material that is able to release thermions into the depletion region of the $p-n$ junction,the injected electrons and holes could still drift under the force of the built-in electric field, reversing the diffusion, then the diffusion force would increase while the built-in electric field force would decrease; thereafter, the diffusion force could create an electromotive which could persist as long as the injection by the thermions is constant into the depletion region of the $p-n$ junction, this electromotive can be used to produce electricity, and the total effect is just reversed to the process described by the second law of thermodynamics, heat was directly converted into useful work without any other change.

The temperature for thermionic emission is always very high for semiconductor and may destroy the semiconductor devices themselves, and the metal-semiconductor contact would also have junction effects, i.e., the electrons and holes in metal and semiconductor would severely diffuse into each other, it would form Schottky barrier when the semiconductor was doped with p-type impurity[7] and the thermionic emission would be harder for the metal since there are less free electrons inside. The depletion region of the Schottky contact may also intervene with that of the $p-n$ junction andthe temperature for thermionic emission of the metal is still not low. It

is hard to use traditional material to realize thermionic emission into $p-n$ junction under room temperature.

However, nano materials have novel properties different from the normal materials that consist of same element, especially graphene, it is a 2-dimentional material, has massless electrons and observable relativistic effect at velocity much slower than the speed of light;[8] hence, it could possibly have acceptable thermionic emission to produce electricity under room temperature. From the work by Yee Sin Ang[9] as Figure 4 from their study shows, graphene could emit$0.2\ A/cm^2$ at $300K$ in a graphene-Schottky contact, which has a low interface barrier of only $0.5\ eV$, this is exactly the case when the graphene was connected into the $p-n$ junction.

What's more, the semi-metal graphene has exactly same structure of the outer electrons shell with semiconductor silicon, they both have 4 electrons at the outmost electron shell; therefore, to connect graphene into the $p-n$ junction to provide thermionic emission as non-equilibrium injection would possibly have no depletion effect and therefore no influence to the depletion, built-in electric field, diffusion and drift of the carriers, and even photoemission which excites the electron-hole pairs apart so that they could drift under the action of the built-in electric field, reversing the diffusion process and create electromotive by constantly providing the photoemission, since the diffusion force is enhanced and the built-in electric field is weakened, there would be a surplus diffusion force between the $p-n$ junction motivating the carriers to diffuse, but the diffusion is prohibited by the constant photoemission therefore it could only become an electromotive between the $p-n$ junction.

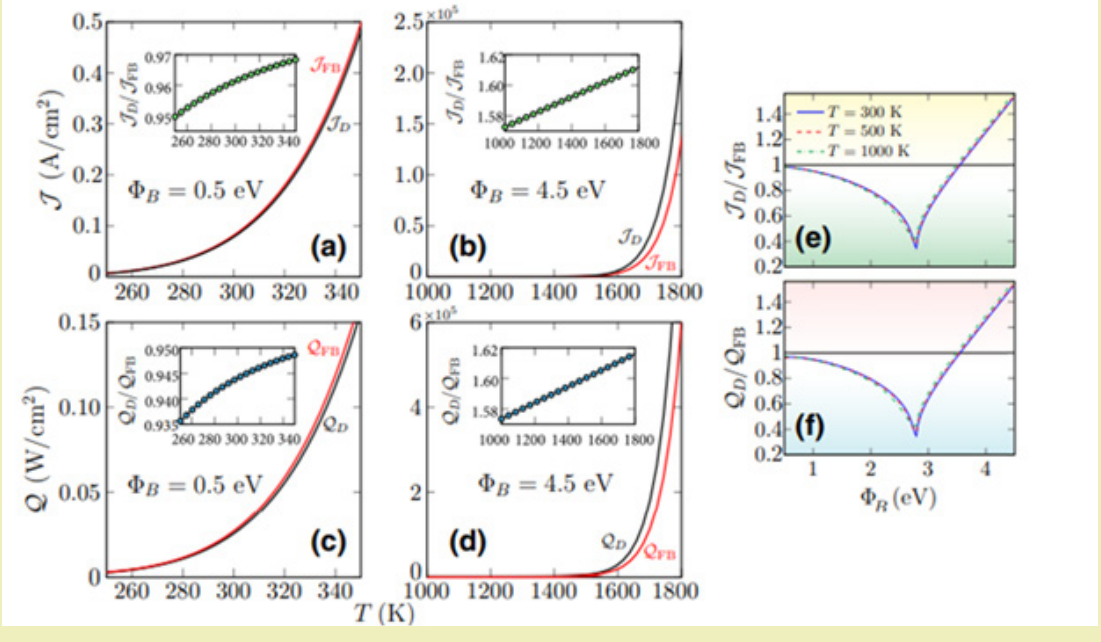

Figure 4: Thermionic emission of graphene Schottky contact.

Figure 5 shows how graphene should be connected into the $p-n$ junction to be combined with the photovoltaic cell to form our thermalvoltaic cell, the hexagons denote the graphene layers, a graphenelayer is 2-dimentional single layer of graphite with thickness of about only $0.335\ nm$.[9] The graphene could emit thermions when the electrons in the material could overcome the energy barrier by absorbing the heat from the environment to inject non-equilibrium carriers into the $p-n$ junction and the effect of such thermionic emission is exactly same to that of the photoemission when the light with adequate frequency for exciting the electron-hole pairs apart was luminated into the $p-n$ junction, the free electrons and holes injected would drift in direction reversed to the diffusion, the equilibrium between the diffusion and drift would deviate reversed to the diffusion; therefore, the diffusion force would be enhanced while the built-in electric field would be weakened and there would be a surplus diffusion force between the $p-n$ junction,this diffusion force could create an electromotive which could produce electricity, and the electromotive could persist as long as the thermionic emission injection was constant. Since the graphene-semiconductor contact has an interface barrier of only $0.5\ eV$, and could emit thermions with intensity of $0.2\ A/cm^2$ at $300K$, just the room temperature, the thermalvoltaic cell we constructed could directly absorb heat from the environment to provide non-equilibrium carriers injection into the $p-n$ junction by the thermionic emission of the graphene connected into the $p-n$ junction under room temperature and create electromotive that could produce electricity. The thermionic emission is constant at a given temperature therefore the electromotive could persist; thereafter, the heat could directly be converted into useful work without any other change by this device.

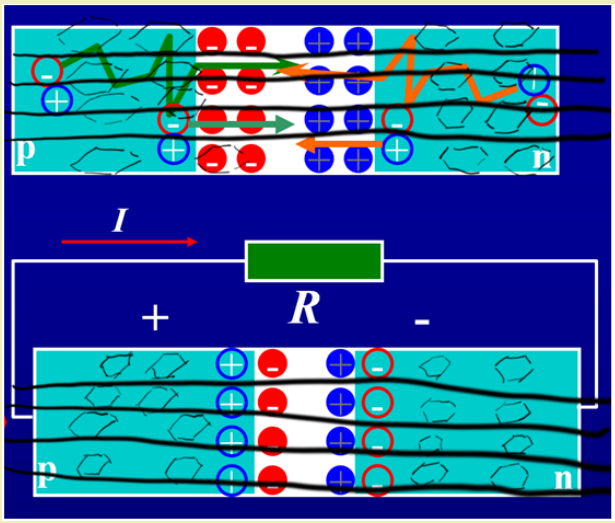

Figure 5: Graphene connected into p-n junction to form thermalvoltaic cell.

Any material that has such thermionic emission under low temperature is adaptable to the device, with consideration of the depletion effect when they contacted the semiconductor, a photovoltaic cell could be modified into a thermalvoltaic cell by combining thermion emission as the non-equilibrium carrier injection into the $p-n$ junction, and the device could directly produce electricity by absorbing heat from the environment.

Dealing Climate Change with Reversible Emission

Climate change is caused by the excessive greenhouse gas, carbon dioxide content exists in the atmosphere. Carbon dioxide CO_2 is a common product by cell respiration of both animal and plant, and is a raw material for the photosynthesis in plants that could absorb the energy from the sunlight to produce food[10] Plants could absorb the energy of the photons from the sunlight to synthesize starch using hydrogen and carbon dioxide, using a series of enzymes to catalyze the biochemical reactions, the total reaction is

$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$ (1), carbon dioxide is necessary for plant to produce food for human.

Carbon dioxide is also a kind of greenhouse gas that could preserve the heat of the atmosphere not to dissipate into the space, moderate CO_2 could keep our home warm but excessive CO_2 would arise global warming which is the problem of the climate change, our environment would not be habitable anymore if the average temperature rose several tenths of degrees, the sea level would be too high and the temperature of our cities would not be acceptable for human to live anymore, there would also be other catastrophic effect.

We have to emit CO_2 as long as we consumed energy, from respiration to driving car to work, the more active we were, the more CO_2 we need to emit, and excessive content of CO_2 causes the climate change. How to solve this problem? The UN assigned the goal for all countries to reduce their CO_2 emission, and the developed countries should even provide $100 billion a year to the developing countries to help them reduce the emission;[11] however, to reduce the emission is not good to the development of the economy. In fact, CO_2 emission is inevitable as long as we have activity, only using the energy stored in the carbohydrate could we live and do something we like, which is necessary for us to produce more food and living materials we would further need, and we need consume fossil fuels as energy resource for transportation, industry and any production activity of the society, we can absolutely never live without energy.

We rely on the energy stored by the carbon for all activities we want; therefore, we can absolutely not rely only on reducing the carbon dioxide emission to deal with the climate change, but have to think how to reverse those excess emissions to be available energy resources for us again and even directly produce energy using the excessive heat brought by the global warming. To produce energy directly by absorbing heat from the environment is possible by applying the thermalvoltaic cell we just constructed in the previous part of this paper, and the excess emission of $CO_2$is reversible, as we just know that plant could produce carbohydrate, which is the energy source of any creature on the earth, by absorbing the CO_2 in the atmosphere and the energy from the sunlight to use them as the raw material for photosynthesis. This is an easy and environment-friendly way to reverse the CO_2 emission, and the plants could also be agricultural productions which could alleviate the food crisis for the people all over the world as well, we need reverse our CO_2 emission as well as more food and energy.

CO_2emission could be reversed by cultivating more crops and other agricultural plants to produce more vegetables and fruits, this should be feasible to compensate their emission taxes for farmer. And this is currently the most easy, environmental friendly, and economical way to reverse the CO_2 emission, we could have more food and oxygen while the CO_2 content in the atmosphere was controlled, and the excess heat could also be directly absorbed to produce electricity by applying the thermalvoltaic cell we constructed, which introduced thermionic emission as non-equilibrium carriers injection into the $p-n$ junction of a photovoltaic cell. Both the climate change, food scarce and even energy crisis could resolve in this way.[12]

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Conflicts of Interest

Authors declare that there is no conflict of interest.

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