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Night-Time Power Generation by Night Howler Cells: A Review

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Abstract:
Everyday a large amount of solar radiation falls upon the Earth. Among a wide portion of frequencies radio waves, visible, infrared, ultraviolet and reach the Earth's surface in the decreasing order as mentioned. A portion of this incident radiation gets absorbed in the atmosphere while the other portion is reflected back into space. The portion absorbed by Earth and its atmosphere regulates the temperature of Earth when there is no sun overhead termed as Earth's albedo. Earth overthrows extra heat into atmosphere by radiative cooling phenomenon. This phenomenon takes place in long-wave infrared region of the electromagnetic spectrum. In order to generate power from this resource a number of infrared sensitive materials were studied on the basis of their radiation absorption and spectral properties. Amongst them most prominent results are given by Mercury-Cadmium-Telluride (HgCdTe). By doping different quantities of Mercury and Cadmium on Tellurium substrate a number of different bands of infrared absorbing materials could be generated. The HgCdTe PV cell was studied and the results were compared to that with the currently available PV cells. The results showed about one and a half times to two times more power generation in comparison.
Keywords: Radiative cooling, infrared radiation, Earth's albedo, infrared sensitive materials etc.

1. Introduction

An infrared detector is a device that has the ability to detect any kind of infrared radiation. It depends upon the purity and properties of the detector material that how small portion it is able to detect accurately. Infrared sensitive materials have a distinct property to get changed in some form or the other when a specific radiation is incident on them. Some of the insulator materials become conductor and some change in physical size or appearance. A similar infrared sensitive material is used in military for night vision. During the night time operations and attacks soldiers use night vision to see clearly in low or low lights. This night vision detects the heat radiations of enemy soldiers and their cavalry. This has been made possible by the use of a highly infrared sensitive material in specific combination of Mercury-Cadmium-Telluride. For different infrared bands different composition material is to be synthesized. When infrared radiations falls on the surface of HgCdTe material the band specific radiation gets trapped by it and there is release of electrons from the body of materials. As infrared radiation have the ability to break the bonds of this material. More the bonds are broken the more are charge carriers generation. This bond breaking process takes place up to a certain limit. After this limit there is no further more charge generation process and number of free charge carriers becomes constant throughout the body of material. If we require more free charge carriers we would have to focus on adjacent band of radiation and fabricate other material which would have the composition that could absorb the specific radiation.

In this research the focus is made upon the processes of generation of different HgCdTe material in different compositions. The fabrication of different composition of HgCdTe is studied under sunlight and its behaviour is matched with a photovoltaic. The material seems to perfectly behave as a photovoltaic. The results demonstrated that photovoltaic properties of HgCdTe are able to generate power from the sunlight. The results also demonstrated that power was continuously generated even in clouds and atmospheric disturbances. The most important result that came out from the study was night-time power generation. The night-time power generation was made possible by a certain phenomenon that cools down the Earth during night (i.e. Radiative cooling of Earth). The response of a particular composition of HgCdTe is specific for a particular band of infrared radiation. To work on entire infrared region a group of four different compositions were sandwiched one over another and response was studied. The fabricated material was found to be absorbing nearly all the infrared radiations during the night as well as day time. It means the material is able to generate power during the day as well as night time.

2. Literature review

Bin Zhao, Mingke Hu, XianzeAo, Gang Pei [1]
Building-integrated photovoltaic-thermal (BIPV-T) technology has been receiving considerable research attention because of its ability to generate electricity and thermal energy simultaneously. This study proposed a building-integrated photovoltaic -radiative cooling system (BIPV–RC) that can generate electricity via photovoltaic (PV) conversion during daytime and generate cooling energy via radiative cooling (RC) during night time to satisfy the demand in such areas. The total electricity production and cooling energy gain of this system are 96.96% higher than those of the BIPV system. Parametric studies show that the precipitable water vapour amount has remarkable effects on the nocturnal RC performance of the BIPV–RC system. A small precipitable water vapour amount corresponds to a high nocturnal RC power, thereby implying that a dry climate condition benefits the nocturnal RC of this system.

Jinchao Tong, Landobasa Y.M. Tobing, Peinan Ni, Dao Hua Zhang [2]

The effect of interface quality on the performance of InAsSb based hetero *n-i-p* middle wavelength infrared (MWIR) photodiodes. By adopting heavily dopingwide bandgap p- and n-type layers and inserting a thin layer between the two doped layers and the absorbing InAsSb region, the interface quality can be improved. Also employed proper fabrication processes in device fabrication to improve surface quality. It is found that the improved interface and surface quality can reduce the noise current and enhance generation performance. A detectivity of ~1.5×10^{9} cmHz$^{1/2}$W^{-1} can be achieved at room temperature, and it can be increased to ~4.0×10^{9} cmHz$^{1/2}$W^{-1} at 250 K. By inserting a thin quaternary layer between the doped layers and the active InAsSb region to improve interface quality and reducing electron flow due to the type II band edge lineup. The detectivity as high as ~1.5×10^{9} cmHz$^{1/2}$W^{-1} has been achieved at room temperature, which can be enhanced by ~2.6x (~4.0×10^{9}cmHz$^{1/2}$W^{-1}) when the temperature is slightly decreased to 250 K. This performance has potential for future room temperature imaging and applications.

Z.B. Tian, T. Schuler-Sandy, S. Krishna [3]

The quantum-engineered interband cascade (IC) photodetector is a new type of infrared detectors with many unique and highly desirable features. The multi-stage design allows much flexibility in device optimization for different application environment, such as operation temperature, irradiance level, and possibly high-speed and fast frame-rate application scenarios. Many other distinctive features, such as excellent photo-carrier extraction and photovoltaic (zero-bias) operations, are also very attractive for high performance infrared imaging applications. In this paper, we report our experimental investigation on the dark current mechanisms in mid-wave infrared (MWIR) InAs/GaSb type-II superlattices based IC photodetectors. The electrical performance of MWIR IC detectors with several different designs are presented in detail. The dark current density in the MWIR IC detectors is as low as 4.26 10 ^{8} A/cm^{2} (1.44 10 ^{3} A/cm^{2}) at 10 mV. Our results indicate that the dominating dark current in IC detectors is from tunneling components at lower temperatures, and changes to diffusion current at higher operating temperatures. Furthermore, our effort also shows that the dark current performance in IC devices can be improved substantially by refining the device design and implementations. Results suggest that the dark current in MWIR IC detectors at lower temperatures are dominated by tunneling processes. At higher temperatures, the dark current in IC detectors is dominated by diffusion process.

Jeff Gray, Xufeng Wang, Raghu Vamsi Krishna Chavali, Xingshu Sun, AbhiritKanti, John Robert Wilcox [4]

ADEPT/F tool solves Poisson's equation coupled with the continuity of hole and electron equations in one specific dimension in compositionally non-uniform semiconductors. It was originally written to model solar cells manufactured from a wide variety of materials, including amorphous silicon, copper indium diselenide, and cadmium telluride. However, since material parameters can be input by the user, devices fabricated from any material for which these parameters are known can be modeled. Dark I-V, light I-V, and spectral response of solar cells can be computed. Plots of many internal parameters, such as carrier density, recombination, electric field, etc., can be plotted at any operating point. The new Frozen Potential Approach is capable of simulating cases where the Principle of Superposition fails.

Richa Pandey et al [5]

This work was to examine the optical properties of tin naphthalocyanine dichloride ($SnNcCl_2$), and its response as an electron donor material in organic photovoltaic cells (OPVs). As an active material, $SnNcCl_2$ is good for its narrow energy gap which facilitates optical absorption greater than wavelength of k = 1100 nm. A power con-version efficiency of g_P = (1.2 ± 0.1)% under simulated AM1.5G solar illumination at 100 mW/cm^{2} using the electron acceptor to donor pairing of $SnNcCl_2$ and C_{60} in a bilayer device architecture was been demonstrated. While some phthalocyanines have been previously used to improve infrared absorption, this often realizes through the formation of molecular dimers. In $SnNcCl_2$, the infrared absorption is intrinsic to the molecule, arising as a result of the extended conjugation. It was expected that $SnNcCl_2$ could be utilized in bulk heterojunction OPVs without sacrificing infrared absorption.

A.Ferron, J.Rothman, O.Gravran [6]

The physical models implemented for HgCdTe infrared photodetectors are reviewed. In particular, generation–recombination models such as Shockley–Read–Hall through a trap level in a narrow bandgap and Auger recombination are included. These well-established models are described using widely published analytical expressions. This paper highlights both the unique set of trap parameters found to fit the dark current as a function of temperature and composition for mercury-vacancy *p*-type-doped photodiodes and their use in a finite-element code. An equivalent set of trap parameters is also proposed for indium *n*-type-doped material in a *p*-on-*n* photodiode simulated in three dimensions. Device simulations also include the impact ionization process to fine-tune the saturation dark current. Finally, excess dark current is also modelled with the help of nonlocal band-to-band tunnelling, which requires no fitting parameters.

Anne M. Itsuno[7]

A unipolar, barrier-integrated nBn detector structure is proposed to address the challenges associated with p-type doping in MBE grown HgCdTe. Numerically simulated performance characteristics of the HgCdTe nBn device predict values similar to comparable DLPH structures for a range of temperatures, motivating the experimental demonstration of mid- and long-wave IR HgCdTe nBn detectors. Fabricated nBn detectors successfully exhibit barrier-influenced current-voltage and photoresponse characteristics, but are limited by perimeter leakage currents which must be resolved in future work. Finally, this work culminates with the simulation study of the novel, hybrid NBvN structure which addresses both technology limitations by combining the advantages and designs of the Auger-suppressed HOT and unipolar nBn detectors in a single configuration.

Jeffrey Beck [8]

The operation of the mid-wave infrared (MWIR) HgCdTe cylindrical electron injection avalanche photodiode (e-APD) is described. The measured gain and excess noise factor are

related to the collection region fill factor. A two-dimensional diffusion model calculates the time-dependent response and steady-state pixel point spread function for cylindrical diodes, and predicts bandwidths near 1 GHz for small geometries. Bandwidth data are shown that indicate bandwidths in excess of 300 MHz for small unit cells geometries. Dark current data, at high gain levels, indicate an effective gain normalized dark density count as low as 1000 counts/ls/cm^2 at an APD gain of 444. A junction doping profile was determined from capacitance–voltage data.

Mark A. Goforth, George W. Gilchrist, Joseph D. Sirianni [9]

Ventilated façades systems are more and more used for thermal rehabilitation of existing buildings. Their energy performance depends on many situations, whose influence can be quantified by numerically. When designing ventilated façades, the cooling effect of the night sky cannot be neglected because of increased thermal losses through the exterior walls. In the current paper, the influence of wind velocity, ground and outer cladding emissivity is analysed numerically for an insulated brick wall with an exterior wood cladding. Heat gains and losses are compared to a reference value and some results are shown. The computation was based on the steady-state approach of the physical phenomena during the warm season.

P. Ballet et al [10]

The successive steps for realizing dual-band infrared detectors operating in the mid-wavelength infrared (MWIR) band were discussed. High crystalline quality HgCdTe multilayer stacks have grown by molecular beam epitaxy (MBE) on CdZnTe and CdTe/Ge substrates. Material characterization in the light of high resolution x-ray diffraction (HRXRD) results and dislocation density measurements were exposed in detail. These characterizations show some striking differences between structures grown on the two kinds of substrates. Device processing and readout circuit for 128x128 focal-plane array (FPA) fabrication were described. The electro-optical characteristics of the devices show that devices grown on Ge match those grown on CdZnTe substrates in terms of responsivity, noise measurements, and operability.

W. E. Tennant, S. Cabelli, K. Spariosu [11]

The property of having low fundamental dark current at any given wavelength and temperature makes Hg-Cd-Te attractive for high temperature applications. We are exploring detectors with cut off wavelengths from the near to middle infrared region (~1.5 to ~4 µm).It allows applications from low light level imaging in starlight and "nightglow" to thermal imaging theoretically, both with useful sensitivities at room temperature. The demonstrated possibility of reducing or eliminating traditional recombination processes furthermore increases the attractiveness of Hg-Cd-Te.The present day materials technology shows some relevances that these sensitivities can be attained. Current detector technology, being limited by SRH traps, appears to require modest cooling (to about 250K).

J.P.G. Price [12]

This paper describes the design, fabrication and performance of dual-band MW/LW infrared detectors made from HgCdTe (MCT) grown by Metal Organic Vapour Phase Epitaxy (MOVPE). In which the detectors are staring, focal plane arrays consisting of HgCdTe mesa-diode arrays bump bonded to silicon read-out circuits. Each mesa has one connection to the ROIC and the bands are selected by varying the applied bias. The development of the CONDOR II detector is showing very promising results with high pixel operability in both wavebands and excellent NETD performance.

3. Gaps in Literature

1. The photovoltaic system needs to be installed with batteries to store power. These batteries act as an alternative source of power when there is no sun overhead. The batteries require harmful chemicals to store power. The size and cost of these batteries depends upon the power required during night time. The more powerful a battery gets the more cost is increased in the installation of system.

Night time radiation power generation (Night howler cells) removes the batteries from flow chart or minimizes the use of them so as to make it simpler and dependable.

2. Research attempts have been made to collect this radiation with the use of concentrated collectors. However direct conversion of radiation into energy did not attracted much research because of lower amount of energy available. Though the energy available is small in amount but it is present in atmosphere. So it is possible to generate power from night howler cells.

With the advancements of science and technology it now seems feasible to take more steps towards night radiation power generation.

3. Research has been done for HgCdTe material only in the form of infrared detector as infrared imaging is related to military science. There are plenty of other applications that are waiting to be discovered. Since this material is a good infrared absorbing material then it can also be employed for power generation.

This infrared absorbing material should be tested further for more applications.

4. Problem Identification

1. Nearly all the photovoltaic technology especially focuses on visible light for generation of power. Solar panels are not being massively used due to lack of material and technology to lower the cost enough to be more affordable. Even with the present day advancements it is not possible to harness incident solar radiation fully. Geographical location influences the size of the solar panels for the same power generation. Cloudy days do not produce much energy to satisfy day to day demand.

2. Solar energy is unavailable at night. The most important problem is dependency on solar visible light is that makes photovoltaic dormant at night. The inactivity of solar photovoltaic during night makes them more costly and pay-back time is much longer.

3. The large battery bank increases cost of space and maintenance. Dependency upon battery for storing power uses toxic chemicals and hazardous substances. The inclusion of battery in flow chart also increases cost of installation further and maintenance cost at the same time.

4. The emphasis is on non-reliable visible band of solar spectrum and neglecting infrared radiation. This negligence is limiting our power generation to day time only.

5. Objective

1. To study solar radiation and its different radiation contents and to find out the percentage of visible and infrared radiation in it.
2. To investigate the materials those could generate power from visible-infrared region of solar spectrum as well as radiative cooling of Earth.
3. To investigate a material that could generate power from sunlight as well as radiative cooling of earth and be functional during day and night time as photovoltaic cell.
4. To study generation of power from HgCdTe under various conditions and circumstances.

6. Methodology

6.1 Full time power generation:

The present day solar photovoltaic could not generate full power because of the non-availability of ideal condition of incident solar radiation. Ideally the surface of photovoltaic device must capture the solar radiation in optimum amount so that could break a bond between materials so that there is a free electron and a free hole in the structure. This ideal situation could always not be met due to fluctuations in weather and climatic conditions. The most important factors that inhibits 24 hour power generation are:

A. Clouds: The clouds trap and reflect the sunlight incident on earth and inhibits a solar photovoltaic to work efficiently. In case of night howler cells the case is reversed. When there are clouds overhead the clouds capture infrared radiations from incident solar radiations and due to greenhouse effect the infrared radiation in bounced between earth and clouds. Hence night howler cells are able to generate power even under clouds.

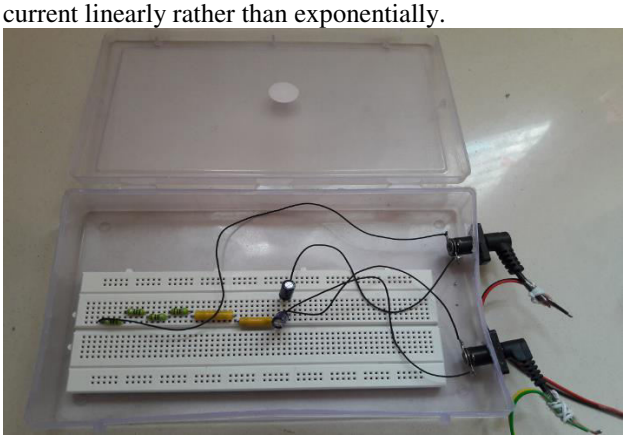
B. Non-availability of solar radiation during night: During night time no photovoltaic generate power as there is no source that could provide sufficient energy to generate power. In case of night howler cells as the basic manufacturing material is mercury cadmium telluride that is predominantly used in night vision for infrared imaging would be able to sense infrared energy during night. During night the phenomenon of radiative cooling of earth and heated structures [40] could supply enough energy to night howler cells that could generate power.

The night howler cells are fabricated from multiple concentrations of mercury and cadmium ($Hg_{0.8}Cd_{0.2}Te$, $Hg_{0.7}Cd_{0.3}Te$ and $Hg_{0.6}Cd_{0.4}Te$). The different concentrations of these materials allow different wavelengths of radiations (mainly infrared and partly visible) to enter the cells and generate power in wide variety of situations and conditions even during cloudy weather and low sunlight.
The experimental setup contains a few materials and components that are necessary to make this setup work.
The setup contains following components and materials:

- An array of cells
- A surge protector circuit
- A near infrared radiation generator circuit
- A mid infrared radiation generator equipment.

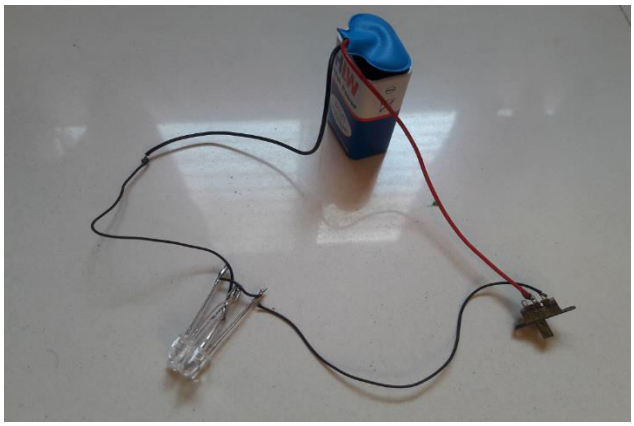
6.2 Description of components and materials

The basic building block of an infrared detection device is a minute cell that is composed of MCT. Multiple generations of infrared night vision devices used the same basic material for infrared detection.
To generate optimum voltage and current cells are arranged in combination of series and parallel. The more cells in series generate more voltage at the same time more cells in parallel generate more current. Four each parallel and eight in same series arrangement has been chosen for observation.
There is sudden fluctuation in the circuit when a load is connected or disconnected from the circuit. To avoid this voltage surge a surge control circuit is employed. It contains a series connection of 4 in number; 1-microHenry coils and two capacitors each if rating 16 volt; 22-microFarad that are connected in parallel. Thus creating a resonating circuit. These component handle the surge and increase the voltage and current linearly rather than exponentially.



A small surge protecting circuit

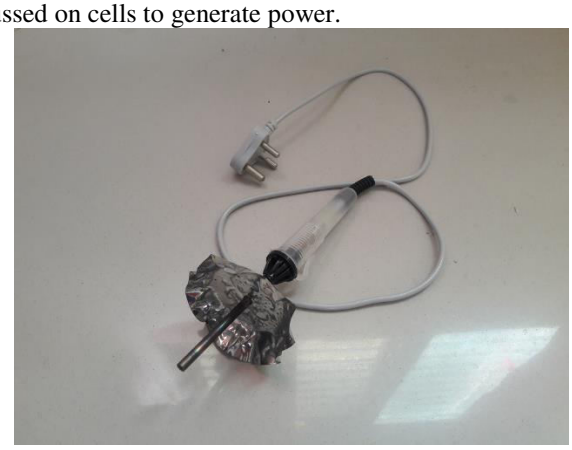
To study the behaviour of MCT cells in infrared illumination 4 in-parallel infrared LEDs have been used. The light of these LEDs is not visible to human eye but these supply sufficient energy to generate power in the circuit.



Four in parallel infrared LED that is used for night time illumination

The behaviour of circuit near heated object has to be studied. As the hated object produce infrared radiation to make equilibrium with the surroundings. These infrared radiations are captured by MCT cells to generate power.

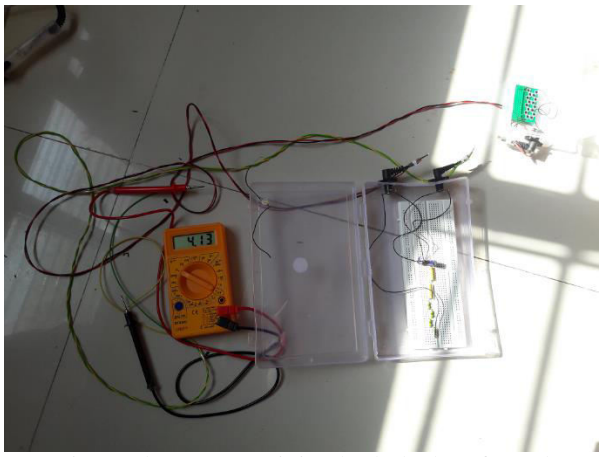
To analyse the situation a soldering iron has been connected to a dish type reflector. This device when become red hot produces huge heat and infrared radiation. The radiation is focussed on cells to generate power.



A typical device to generate infrared radiations

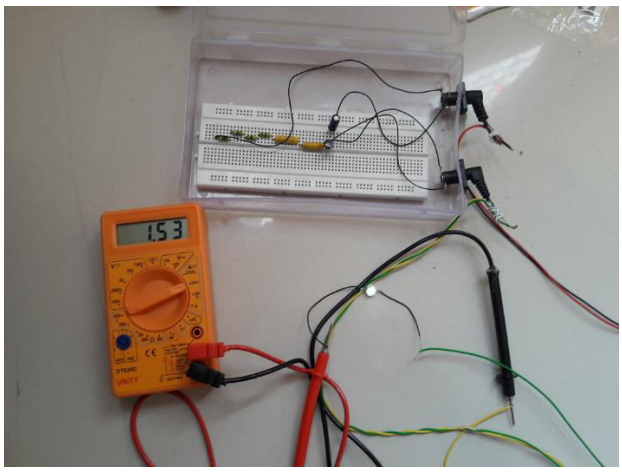
Procedure:

In total the experimental setup contains two box one having the MCT cells and the other box contains surge circuit. Following figure shows the experimental setup. While taking the voltage measurement the multimeter terminals are connected in end to end with the output terminals of the surge circuit.



Experimental setup containing both the box for voltage measurement

In attempt to take current measurement a load is connected in the circuit (e.g an LED). The circuit is completed by means of multimeter's leads. Then the reading is taken when LED glows. Following circuit demonstrate the reading taken for current measurement.



Circuit arrangement for current measurement (Load connected and glowing)

8. Result and Discussion

Even present day, modern and advanced materials are not able to harness solar radiation beyond a certain limit of day time. The scope of limited power generation has to be expanded by switching into some alternative materials which have ability to push the limits of present day solar power generating materials.

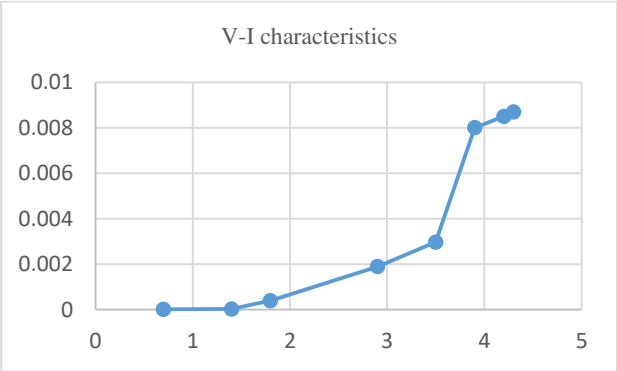
The results demonstrated by this basic wide band Night-howler cell has the power to change the current day solar technology fully.

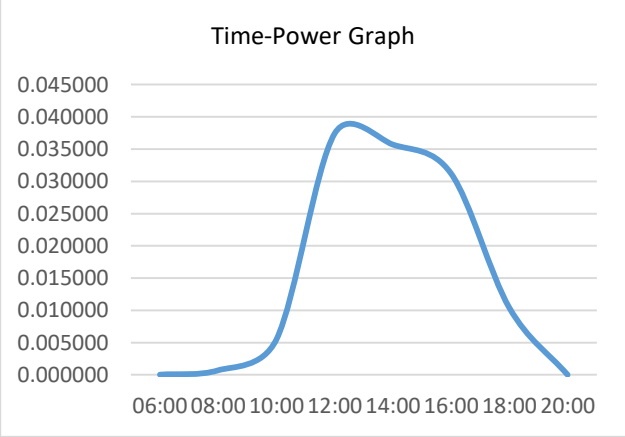
Condition/ Situation	Voltage (V)	Current (A)	Power (W)	Units needed to generate 1-Watt
Red Hot Soldering iron	1.72	11x10^-6	0.0000189 2	846023
Infrared	3.10	150x10^-6	0.000465	34409
Arc-welding	2.1	300x10^-6	0.00063	25396
Visible and sunlight	1.5 to 4.5	110x10^-6 to 1.9x10^-3	0.000165 to 0.00855	96970 to 1871

Moreover a graph plotted between time in Hours from morning to night and output power have following results:

		In open ground		
Time		Voltage	Current	Power
		in volts	in Ampear	in Watts
4:00		0	0	0

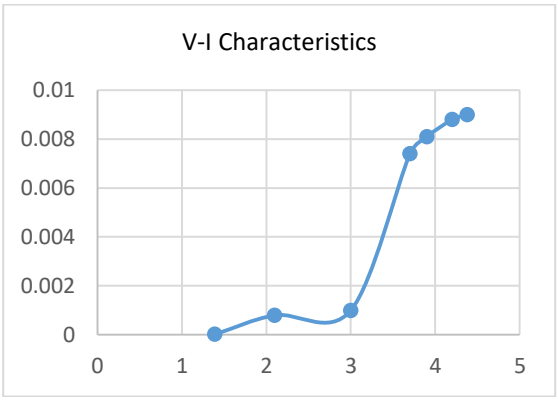
6:00	1.4	0.000022	0.0000308
8:00	1.8	0.00039	0.000702
10:00	2.9	0.00189	0.005481
12:00	4.3	0.0087	0.03741
14:00	4.2	0.0085	0.0357
16:00	3.9	0.008	0.0312
18:00	3.5	0.00297	0.003395
20:00	0.7	0.00001	0.000007
22:00	0	0	0

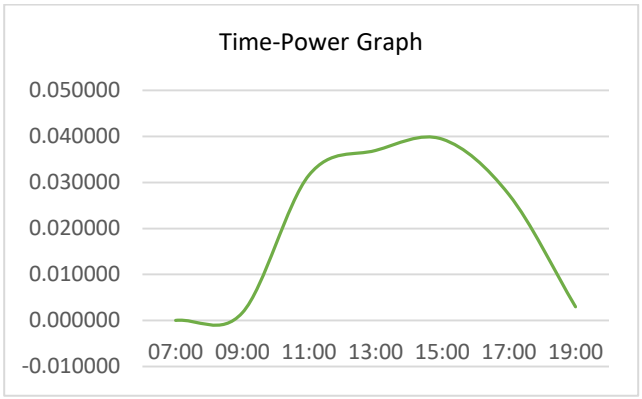




A graph plotted for power generation in watts against time in open ground

	Near civil structure		
Time	Voltage	Current	Power
	in volts	in Ampear	in Watts
5:00	0	0	0
7:00	1.39	0.000009	0.0000135
9:00	2.1	0.00079	0.001659
11:00	3.9	0.0081	0.01911
13:00	4.2	0.0088	0.03696
15:00	4.38	0.009	0.036792
17:00	3.7	0.0074	0.02738
19:00	3	0.00099	0.0015
21:00	0.0	0	0
23:00	0	0	0





A graph plotted for power generation in watts against time near a civil structure

The difference in time-power graph clearly shows there are two peaks in them. The graph of time-power near a civil structure shows first peak due to increase in temperature but the second peak is obtained because of heating of civil structure and the structure at the same time start to release the energyin the form of infrared radiation.

9. Conclusion and Future aspects

It is known fact that only sun is responsible for all life forms on Earth. The energy in one form or the other that every organism uses comes only from sun. In sunlight there are various other elements that balances Earth's atmosphere in more than one form.

The sun provides visible light that is responsible for vision in animal kingdom and at the same time for photosynthesis in the plant kingdom. Sunlight have ultraviolet rays that inhibits harmful bacteria to grow. The sunlight also have infrared radiations that helps our atmosphere to be in a temperature range that suits life on Earth. This infrared radiation has the property to heat up any object that absorbs it. Every object on Earth absorbs infrared radiations in different quantities according to their absorption properties. Even the Earth and its atmosphere absorb sunlight and infrared radiations. This absorption causes heating of Earth.

This absorption takes place during the day time. But during night time there is no sunlight that provide heat to Earth. During night time the atmosphere becomes cooler than Earth's

surface. According to black body radiation principle, a hot body transfer its heat to cooler body in order to create a thermal equilibrium. Hence, the Earth tries to make a thermal equilibrium with Earth's atmosphere. The equilibrium phenomenon takes place in infrared form only. In other words, the Earth tries to make thermal equilibrium with Earth's atmosphere by radiating infrared rays.

The outward radiation from the surface of the Earth not only releases heat from its surface but also tends to heat up the atmosphere. The hotness and coldness of a body from its surrounding could be found out by using a thermogram. Different materials absorb different amount of radiation in varying contents. Some materials could store energy to a small extent while some store to a large extent. All such materials are found on Earth. Therefore all the objects absorb energy (other than the Earth's surface) and tend to radiate it in different rates. There could be focus on Basaltic rocks, large skyscrapers, black soil area and a similar place where there is radiative cooling phenomenon is experienced to a large extent. We could use thermograms to study the site for night power generation.

Different materials could store energy to a small extent while some can store it to a large extent. As stated earlier, some materials have the property to absorb this infrared radiation to such an extent that it could generate a charge in material. For infrared applications a number of such materials are employed but the use of HgCdTe is inseparable from infrared sensitivity. Among all the infrared sensitive materials the sensitivity of (HgCdTe) MercuryCadmiumTelluride is found to have work function and radiation sensitivity equivalent to the incident solar radiation. The material is found to be an absorber of incident solar visible-infrared radiation and also the radiative cooling night radiations to generate power during the day time and night time respectively. It is the property of HgCdTe to absorb infrared radiations of all bands. Therefore the dependency on battery for power storage will be no more and the system will become cost effective to a much extent.

From the previous paragraphs, it is now clear that solar infrared radiation content is present in solar radiation spectrum. It means infrared is undoubtly present during day time. Solar infrared window of near-infrared, shortwave-infrared and midwave-infrared could be responsible for generation of power during the day time along with the visible light. And the most important point is that infrared is not associated with atmospheric disturbances. The cloudy day power generation and a sunny day will generate about same amount of power. During the night time infrared radiation is present in the form of long wave infrared radiation that is result of radiative cooling phenomenon. It means the power generation is possible even after sunset.

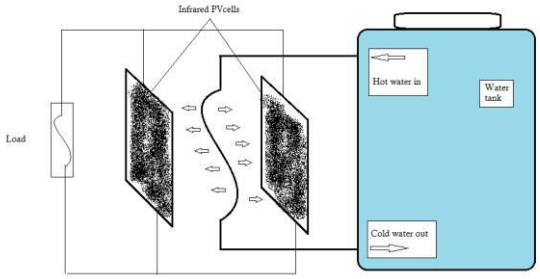
The dependency on infrared region of solar spectrum not only opened the lock of twenty-four hour power generation from solar energy but is also the solution of power generation from any heated body viz. fauna and human beings also radiative cooling of large buildings or the Earth. The investigation of power generation from HgCdTe paved the way of new variety of infrared power generating devices and instruments. The generation of power could be increased by further analysis, experiments and equipments.

The sunlight was found to have more infrared contents than visible light. It is infrared radiation only that is responsible for heating of the Earth's atmosphere and the Earth itself. The infrared radiation is far more responsible for the radiative cooling phenomenon. Hence depending upon infrared solar radiation is much more reliable and efficient as infrared could be a source of energy during night time. One of the important advantages of infrared radiations over other radiations is that it is not so easily disturbed by atmospheric elements viz. clouds, dust and smog. Hence it is far more reliable source of energy.

The material could not only generate power from solar and terrestrial activities but it could also harness power from biotic fauna thermal energy, within a room or animal husbandry farm.

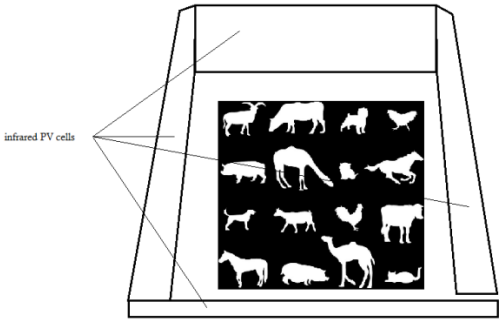
Future aspects:

1. 24 hour power generation by flowing liquid method where less radiative cooling takes place. A combination of solar water heater and photovoltaic. In this arrangement the hot water that absorbed solar radiation during day time is employed to generate power.

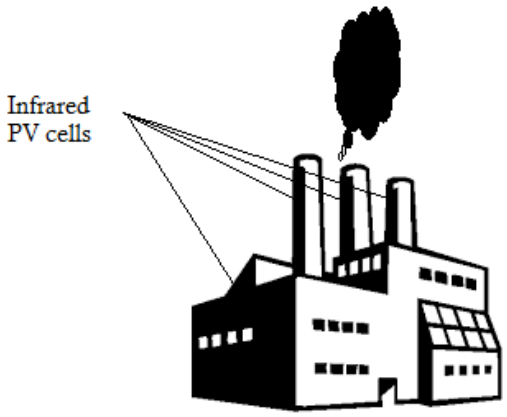


The heat from the water comes radially outward from pipes. Alongwith the pipes there are infrared PV cells arranged so as to catch the radiation from pipes. In this way water continuously cools down generation power.

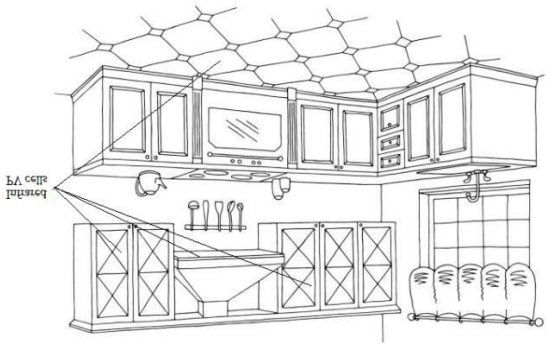
2. Night power generation in animal husbandry farm



3. Industrial heat waste system



4. Power generation in kitchen and fire places.



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