HOT SOLAR CELLS: A Review

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Abstract : A Hot Solar Cell will solve the basic problem with a single-layer silicon cell, which is the amount of solar energy lost by heat. Hot solar cells solve this problem by introducing an absorber-emitter on top of the cell. This device acts like a kind of funnel, which captures energy in sunlight and converts it into heat with nanophotonic crystals embedded in carbon nanotubes. Not only does this increase the efficiency and energy output of the system almost two-fold, but it also provides the possibility for continuous on-demand power. Also, because the system is able to convert heat to energy, the cells do not have to rely on a pure light source.

***IndexTerms* - words; Nanophotonic, MIT, Thermophotovoltaics (TPV) etc**

I. INTRODUCTION

Solar panels cover a growing number of rooftops, but even decades after they were first developed, the slabs of silicon remain bulky, expensive, and inefficient. There are several fundamental limitations which prevent the conventional photovoltaics from absorbing more than a fraction of the energy in sunlight. But a team of MIT scientists has built a different sort of solar energy device that uses inventive engineering and advances in materials science to capture far more of the sun's energy. The trick is to first turn sunlight into heat and then convert it back into light, but now focused within the spectrum that solar cells can use. While various researchers have been working for years on so-called solar thermophotovoltaics, the MIT device is the first one to absorb more energy than its photovoltaic cell alone, demonstrating that the approach could dramatically increase efficiency.

The technology is superior to standard solar cells on a very basic level. The semiconductor material of standard cells, which is almost always silicon, generally only captures light from the violet to red spectrum. This means that the rest of the sunlight spectrum is lost. Because of this fundamental problem, solar cells can only convert about a third of sunlight energy into electricity. Most PV cells are programmed to dissipate unusable heat in the system which can lead to the damaging of certain parts. However, the MIT students' system takes that extra heat and absorbs it, emitting a radiation in the form of wavelengths that can be captured by the solar cells. They've dubbed these light-capturing devices as Hot Solar Cells.

The pressing need for Hot solar cells stems from the fact that today's solar cells such as the conventional Photovoltaic cells are limited by the efficiency of electronic circuits. A typical solar cell can only convert a fraction of the sunlight acquired during daytime. One of the theoretical limits on how much efficiency a solar panel can provide. This is limited by the Shockley–Queisser limit. In physics, the Shockley–Queisser limit, also known as the detailed balance limit, Shockley Queisser Efficiency Limit or SQ Limit, refers to the maximum theoretical efficiency of a solar cell using a single p-n junction to collect power from the cell.

The basic principle of a Hot Solar Cell is that "By converting heat to focused beams of light, a new solar device could create cheap and continuous power".

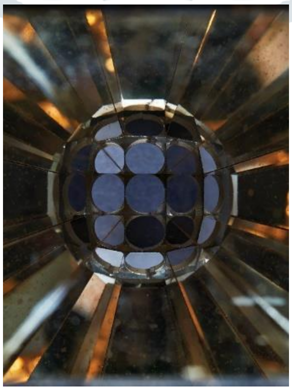

Fig. 1 – Inside a Hot Solar Cell

II Key Components

- **Absorber (Black Carbon Nanotubes) –** A Carbon Nanotube is a device which is used to absorb the heat from this system. It's known that for total heat radiation, the ratio of emissive power to absorptive ratio was the same for all bodies emitting and absorbing thermal radiation in thermodynamic equilibrium. This means that a good absorber is a good emitter. A black carbon nanotube is a perfect physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. It is an ideal emitter. At every frequency, it emits as much or more thermal radiative energy as any other body at the same temperature.
  Black, as we know it, might not be the darkest shade. The British tech company Surrey nanosystems says that it developed the world's blackest material, which is made of carbon nanotubes. It can absorb 99.96 percent of light that hits it. The developers say that to the human eye, the material, called Vantablack, completely erases any features on a surface, becoming basically a void.

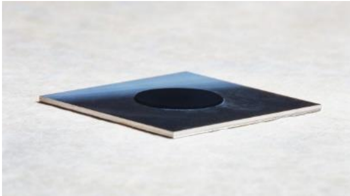

Fig. 2 – Black carbon Nanotube

- **Emitter (Photonic/Nano-Photonic Crystals) -** The emitter is made from a photonic crystal, which is a structure that can be fabricated at the nanoscale to manage which wavelengths of light flow through it. A highly specialized optical filter that transmits the converted light while reflecting most of the unusable photons back was added. This produces more heat, which generates more of the light that the solar cell can absorb, increasing the productivity of the system.
  Photonic crystals are intermittent nanostructures that are designed to affect the motion of photons by defining both acceptable and prohibited electronic energy bands. Generally, photonic crystals are composed of recurring dielectric, or metal-dielectric nanostructures, which have alternative lower and higher dielectric constant materials in one, two and three dimensions to influence the spread of electromagnetic waves inside the structure. As a result, the transmission of light is absolutely zero in certain frequency ranges which is known as Photonic Band Gap.

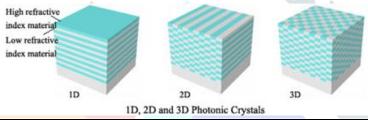

Fig. 3 – Photonic Crystals

III PRINCIPLE OF OPERATION

The basic problem with a single-layer silicon cell is the amount of solar energy lost by heat. Hot solar cells solve this problem by introducing an absorber-emitter on top of the cell. This device acts like a kind of funnel, which captures energy in sunlight and converts it into heat with nanophotonic crystals embedded in carbon nanotubes. Once the trapped heat reaches a temperature of 1,000 degrees Celsius, the nanophotonic crystals emit the heat back out as light. This light is focused in particular wavelength bands that the photovoltaic cells can absorb at their maximum efficiency.

Here's the best part – any unusable photons that don't get absorbed by the photovoltaic cell are then reflected back by an optical filter. This filter sends the light back through the absorber-emitter process, which effectively recycles unused photons to produce more heat. Thanks to the nanophotonic properties of the absorber–emitter surface, efficiencies of 3.2% can be achieved. The device integrates a multiwalled carbon nanotube absorber and a one-dimensional Si/SiO_2 photonic-crystal emitter on the same substrate, with the absorber–emitter areas optimized to tune the energy balance of the device. The device is flat and compact and could become a viable option for high-performance solar thermophotovoltaic energy conversion.

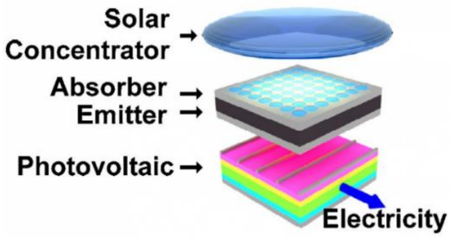

Fig. 4 – Methodology used in Hot Solar Cell

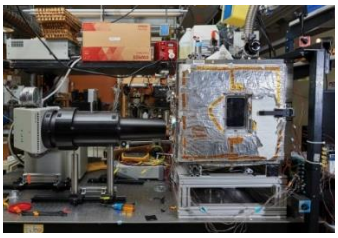

Fig. 5 – Experimental Setup for Hot Solar Cell

ADVANTAGES

As a Hot Solar Cell absorbs the light it receives and then transduces this into heat energy, this heat energy can be fed to Photonic devices to transmit the precise wavelength which is suitable for a PV cell, so it can easily provide higher efficiency as it can utilize the spectrum of light quite easily.

Not only does this increase the efficiency and energy output of the system almost two-fold, but it also provides the possibility for continuous on-demand power. Also, because the system is able to convert heat to energy, the cells do not have to rely on a pure light source.

DISADVANTAGES

The drawback for efficient collection of sunlight in the absorber and spectral control in the emitter is predominantly challenging at high operating temperatures. Limited experimental demonstrations of this approach to conversion efficiencies are around or below 1%.

FUTURE PURPOSE

To date, this technology is still in the prototyping stage and operates at only 6.8 percent efficiency. However, MIT researchers are confident that some enhancements will make it twice as efficient as traditional photovoltaic cells. While the research team continues to expand efficiency, they're also looking at ways to add in a thermal storage system. This would allow any excess heat generated by the hot solar cell device to be fed into the storage system. This stored heat would then act as a kind of battery, allowing electricity to be produced even when sunlight isn't available. If this is successful, we might be seeing always-on solar that works in any climate environment. The team has already proved that this storage system concept works under a trial test. They ran the system under direct sunlight and then blocked the sun, so only emissions from the nanophotonic crystal were being used. In both instances, performance matched the expected behavior and provided continuous electricity generation.

CONCLUSION

Thermophotovoltaics (TPV) is a method of converting heat to electricity using infrared light as an intermediary. Combustion heats an emitter to incandescence and the resulting thermal radiation is converted to electricity by a photovoltaic cell. The difference between a solar photovoltaic system and a TPV system is that a TPV system produces its own light. TPV offers some advantages over other microgenerator technologies. A static conversion process allows favorable scaling down to the millimeter scale, the high-power density of combustion and thermal radiation results in a compact microgenerator.

The researchers are also exploring ways to take advantage of another strength of solar thermophotovoltaics. Because heat is easier to store than electricity, it should be possible to divert excess amounts generated by the device to a thermal storage system, which could then be used to produce electricity even when the sun isn't shining. If the researchers can incorporate a storage device and ratchet up efficiency levels, the system could one day deliver clean, cheap and continuous solar power.

REFERENCES

[1] Mikhailova I. A. Introduction to nanoenergy: tutorial. – M: Moscow Power Engineering Institute "MPEI". Publishing house MPEI, 2011. – 317.1

[2] Keeling C D and Tans P. In: Houghton J, editor, Global Warming: the complbriefing. Cambridge, UK: Cambridge University Press, 1997.

[3] Meadows D H, Meadows D I, Randers J, and Behrens III WW. The limits to growth. New York: Universe Books, 1972.

[4] Peet J. Energy and the ecological economics of sustainability, Washington, D.C: Island Press, 1992 1

[5] Minger T. Greenhouse glasnost: the crisis of global warming. New York: Institute of Resource Management, 1990.

[6] Epstein P R, Haines A, McMichael A J. Canadian Medical Assn Journal 2000, 163(6): 729-734.

[7] World's Commission on Environment and Development, Our common future (The Bruntland Report). New York: Oxford University Press, 1987.

[8] French H. Vanishing borders: protecting the planet in the age of globalization. New York: W.W. Norton & Company Inc., 2000