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Solar Energy With Nano – Technology

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Abstract: The world is facing the threat of depleting fossil fuel (petroleum) resources. This could case a major setback to the world. Researches show that the fossil fuels will get depleted completely in about 15-20 years. The world needs an alternative source of fuels that could keep the world running on its wheels. Alternatives in the form of solar energy, wind en-ergy, bio-fuels, hydrogen fuels etc.. have been found, but they need more study and ex-perimentation before they could be launched commercially. The energy that reaches earth from sunlight in one hour is more than that used by all hu-man activities in one year. The dream of generating electricity from sunlight in large scale at low cost may not be that far from reality in this century. Rapidly emerging solar energy technology using low cost dye sensitized photovoltaic cells on plastics would be a real boost for the third world coun-tries. This paper discusses the conversion of sunlight into electricity by using nanotechnology. Though the conventional silicon solar cells are efficient in converting solar energy into electricity until now, the non conventional solar cells based on molecular photosensitiza-tion by colored materials in wide band gap semiconductors is a fast growing field of basic scientific and industrial research. Present state-of-the-art cells using molecular dyes shows energy conversion efficiencies of 10-11%. Generating electricity from sunlight by highly efficient sensitization of titanium dioxide (TiO2) is new revolutionary technology, that using nanotechnology to develop a better solar cell is to convert as much sunlight to elec-tricity as possible. TiO2 is the best suited semiconductor for chemisorbing the dyes for efficient light harvesting and energy conversion. This approach of generating electricity from sunlight has many advantages over silicon solar cell technology. This paper consists of process that formation of nano-crystalline TiO2 based solar cell.

Keywords: *World, Energy, Solar, Nano-Technology, TiO2*

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Introduction

Energy from the sun does not depend upon uncertain supplies and potential price rises in nonrenewable sources of energy such as petroleum or natural gas. There has been a grow-ing worldwide movement to reduce fossil fuel consumption. An alternative power solution must be developed that would be affordable, sustainable, efficient, clean and renewable.1 Solar power has been one of the most commercially available and renewable energy solu-tions. Today's solar cells are simply not efficient enough and are currently too expensive to manufac-ture for large-scale electricity generation.

Conventional solar cells are called photovoltaic cells. These cells are made out of semi-conducting material, usually sili-con. When light hits the cells, they absorb energy though pho-tons. This absorbed energy knocks out electrons in the silicon, allowing them to flow. By adding different impurities to the silicon such as phosphorus or boron, an electric field can be established. This electric field acts as a diode, because it only allows electrons to flow in one direction.2 Consequently, the end result is a current of electrons, better known to us as elec-tricity.

Conventional solar cells have two main drawbacks: they can only achieve efficiencies around 10% and they are expensive to manufacture. The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat.

In recent, nano-sized TiO2 powders are used as a working electrode for dye-sensitized solar cell (DSSC) due to its highest efficiency than any other metal oxide semiconductors. How-ever, as reported, the best efficiency of TiO2 solar cell could seldomly reached more than 10%. It seems that one of possible way to fabricate more efficient cell is enhancement in charge transfer in TiO2 and the doping would be the most promising solution for that.3

Dye sensitized solar cell, light is absorbed by an organic dye sensitizer (rather than by a semiconductor, as in a traditional solar cell), and the photogenerated charge transports out of the device through a nanostructured percolating TiO2 net-work.

However, potential advancements in nanotechnology may open the door to the production of cheaper and slightly more efficient solar cells. Nanotechnology might be able to in-crease the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost. The maximum efficiency achieved today is only around 25%.4

Working Principle

Dye-Sensitized nanocrystaline TiO2 Solar Cells (nc-DSC) are based on a wide bandgap semiconductor, usually TiO2, which is sensitized for visible light by a monolayer of ad-sorbed dye. The photoelectrode in such a device consists of a nanoporous TiO2 film (approx. 10µm thick) deposited on a layer of trans-parant conducting oxide (TCO, usually SnO2:F) on glass (Fig-ure.1). The counter electrode also consists of TCO coated glass on which a small amount of platinum catalyst is deposited. In a complete cell, photo- and counter electrode are clamped to-

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gether and the space between the electrodes and the voids between the TiO2 particles are filled with an electrolyte. This electrolyte consists of an organic solvent containing a redox couple, usually iodide/triiodide (I-/I3-).

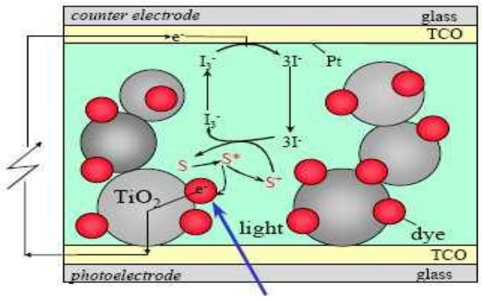

Figure 1: Working principle of a nc-DSC.5

A dye monolayer on a flat surface absorbs less than 1 % of the incoming light (one sun conditions). To obtain reasonable efficiencies comparable to established solar cell technologies, in the nc-DSC the surface area is enlarged by a factor of 1000, by using nanopar-ticles of TiO2 with a diameter of approximately 10-20 nm. The working principle of the nc-DSC is based on excitation of the dye followed by fast electron injection into the con-duction band of the TiO2, leaving an oxidized dye molecule on the TiO2 surface. Injected electrons percolate through the TiO2 and are fed into the external circuit. At the counter electrode, triiodide is reduced to iodide by metallic platinum under uptake of electrons from the external circuit:

I3- +2e --- -->3I

Iodide is transported through the electrolyte towards the photoelectrode, where it reduces the oxidized dye. The dye molecule is then ready for the next excitation/oxidation/ reduction cycle.

Design

Solar cells are devices that convert light into electricity, but they do not store electric power. In addition, since the actual amount of power produced varies depending on factors such as the installation conditions and location, as well as the weather, there are a few re-quirements which must be borne in mind when designing a system. Power supply systems employing solar cells generally fall into one of the following three categories.

(1) Direct connection to load

(2) Paired with storage battery

(3) Paired with commercial power supply

PV System Design : Four factors significantly affect solar array performance (efficiency)

- Operating temperature
- Solar intensity
- Sun angle
- I-V operating point (load matching for maximum power)

When designing a PV system, the four factors discussed are considered at different points in the design process. Solar intensity depends upon the site location – its prevalent weather, pollution, latitude, and percent shade. Operating temperature depends on the site location as well, but a cooling system using chill water piping will mitigate the effects of heat on cell efficiency. Finally, the mechanical and electrical controllers affect the site's operating performance. The mechanical controller tracks sun position and cants the PV cells to minimize the sun's incident angle, and the electrical controller loads the cell ap-propriately to maximize its efficiency.

Simulation

Photovoltaic cells play a key role in the home energy market which, according to a recent report, could provide 30 to 40% of the India's energy supply by 2020.6 Today's photo-voltaic panels convert about 15% of the energy they capture from the sun into electricity, leaving 85% to be dissipated as heat. This creates a major thermal design challenge since every degree of temperature rise in the photovoltaic panels reduces the power produced by 0.5%.

The power generated by panels decreases as their temperature increases at a rate of about 0.5% per degree Centigrade at a temperature above 25oC7. Adding forced air cooling adds to cost and maintenance requirements and consumes a significant amount of energy gener-ated by the cell so nearly all photovoltaic panels are cooled solely by natural convection. The modules are constructed so that air can flow under the panels in order to maximize convective cooling. The geometry and construction of the solar energy system can have a major impact on how effectively the panels are cooled. Engineers in the solar energy busi-ness typically use engineering calculations, experience and intuition to design panels to maximize cooling effectiveness. They build each design and then test it under various am-bient conditions to determine temperatures at various locations. The problem with this ap-proach is that the constraints of the design process usually only make it possible to investi-gate a small number of configurations from a thermal standpoint. The result is that the design is far from optimized from a thermal standpoint.

Global Solar Energy Technical Potential

Table.1 gives an estimate of the global solar energy potential for electricity generation based on the annual average irradiance and sky clearance in 11 different geographical re- gions worldwide.8 In this calculation we assumed that 1% to 10% of the unused land sur-face could be available to solar energy, that 1m2 of flat-plate PV collector module requires typically 2m2 of available land, and we used a conversion efficiency of 10%.

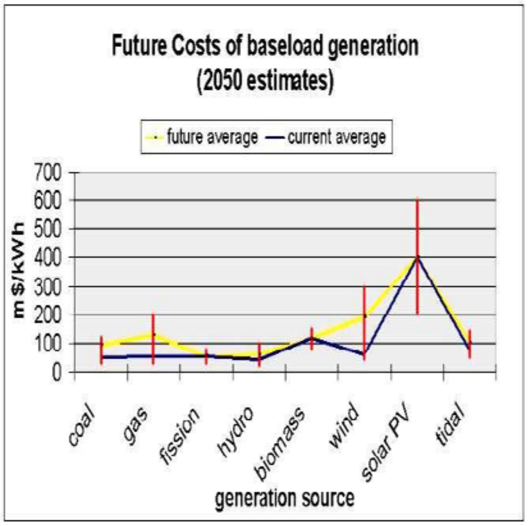

Figure 2: Future Costs of baseload generation

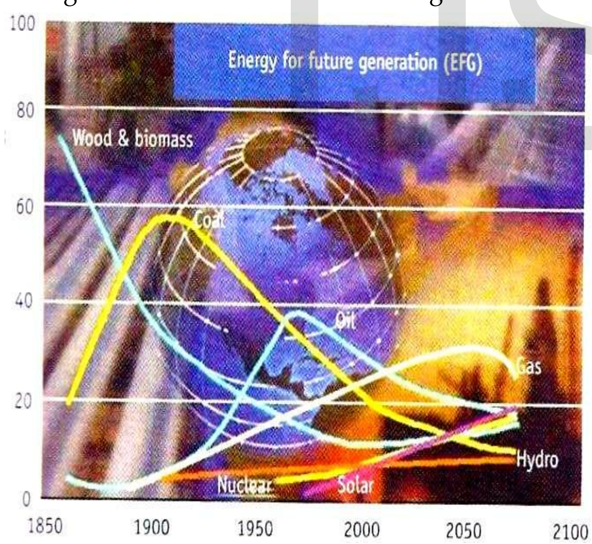

Figure 3: Pattern of Global Energy dependence.

The global solar energy potential ranges from 2.5 to 80TW. The lowest estimate represents ~18% of the total current primary energy consumption (13.7TW10), and exceeds 10% of the estimated primary energy demand by 2030 (21.84TW10). The highest estimate of the potential for solar energy exceeds 5 fold the current global energy consumption.

Region	Irradiance[(a)] (kW/m^2)		Sky clear-ance[(b)] (%)		Un-used land[(c)] (Mha)	Solar energy technical potential[(d)] (TW)	
	Min	Max	Min	Max		Min	Max
North America	0.22	0.45	0.44	0.88	594	0.29	11.76
Latin America and the carib-ben	0.29	0.46	0.48	0.91	256.7	0.18	5.37
Sub-Saharan Africa	0.31	0.48	0.55	0.91	692.5	0.59	15.12
Middle East and North Africa	0.29	0.47	0.55	0.91	820.9	0.65	17.55
Western Wurope	0.21	0.42	0.44	0.8	86.4	0.04	1.45
Central and Eastern Europe	0.23	0.43	0.44	0.8	14.2	0.01	0.24
New states from formar soviet Union	0.18	0.43	0.44	0.8	798.7	0.32	13.74
Pacific OECD States	0.28	0.46	0.48	0.91	171.6	0.12	3.59
Other Pacific Asia	0.32	0.48	0.55	0.89	73.9	0.07	1.58
Centrally planeed Asia and China	0.26	0.45	0.44	0.91	320.6	0.18	6.56
South Asia	0.27	0.45	0.44	0.91	103.8	0.06	2.13
Total					**3933.1**	**2.50**	**79.11**
Ratio to the current annual primary energy consumption (13.7TW)						0.18	5.77
Ratio to the annual primary energy consumption projected for 2030 (21.84TW)						0.11	3.62

(a) Assumed annual average clear sky irradiance
(b) Assumed annual average
(c) 1% - 10% of unused land surface were assumed available for solar energy
(d) Assumed 10% conversion efficiency and $2m^2$ of available land used for $1m^2$ of solar panels

Table 1. Global solar energy technical potential.8

Conclusions

The deployment of solar technologies for energy production at a large scale requires the involvement of both political and economical players, but also further improvements in the con-version efficiency and reduction of manufacturing cost. A large ongoing research effort aims to find innovative solutions to overcome these barriers. In the last decade, photo-voltaic technologies have experienced an astonishing evolution that led to the increase of the efficiency of crystal-silicon solar cells up to 25% and of thin-film devices up to 19%. Recently, nano-technology, innovative deposition and growth techniques, and novel mate-rials (TiO2 and Carbon Nanotubes) opened routes for reaching higher performances (mul-tijunction devices and other 3rd generation photovoltaics) and for developing very

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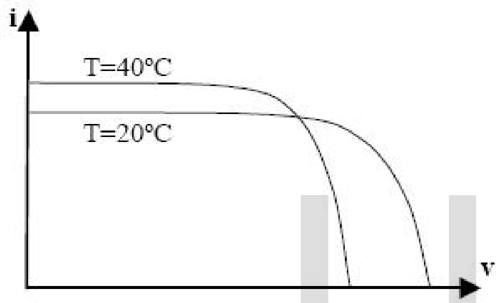
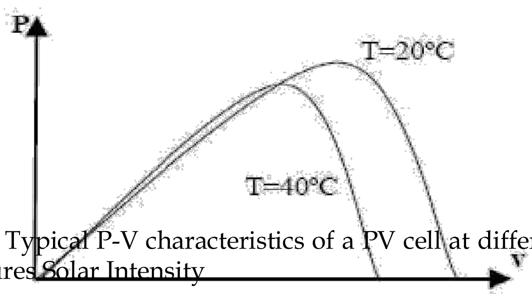
low-cost devices such as organic-based PVs. All these technologies face comparable funda-mental issues related to the steps involved in the conversion of photon energy into electric-ity: photon absorption, charge carrier generation, charge separation, and charge transport. Both fundamental research and technical development are critical requirements for these technologies to become more efficient, stable, and reliable. Direct production of chemicals fuels, and particularly hydrogen, from solar energy is a promising alternative to using fos-sil fuels for the development of a sustainable carbon-free fuel economy. Solar energy has a large potential to be a major fraction of a future carbon-free energy portfolio, but techno-logical advances and breakthroughs are necessary to overcome low conversion efficiency and high cost of presently available systems.

Appendix

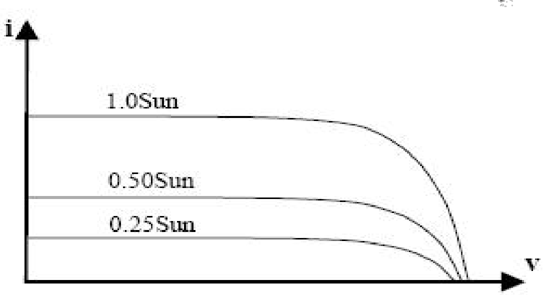
Operating Temperature



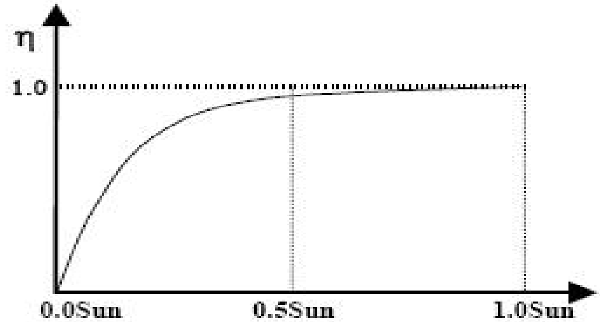
Typical I-V characteristics of a PV cell at different temperatures



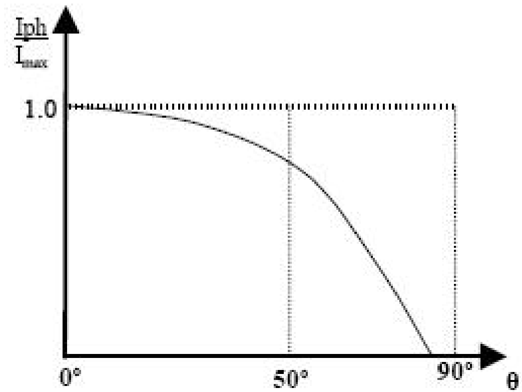
(b) Typical P-V characteristics of a PV cell at different temperatures Solar Intensity



I-V characteristics at varied solar intensities



PV cell efficiency (η) over the normalized range of insolation Sun Angle



(a) Relative photocurrent verses incident angle

References

[1]. Brian O'Regan and Michael Grätzel", A low-cost, hig h-efficiency solar cell based ondye-sensitized colloidal TiO2 films", Letters to Nature, vol. 353, pp. 737-740, October 1991.

[2]. Aldous, Scott. "How Solar Cells Work". How Stuff Wo rks. 22 May 2005.

[3]. "Increase the efficiency of dye- sensitized TiO 2 solar cell (DSSC) by doping on TiO2 semiconductor", Young Cheol Lee et al

[4]. Paul Preuss. "An unexpected discovery could yield a full spectrum solar cell".

[5]. Flexible Dye-Sensitized Nanocrystalline TiO2 Solar Cells" PM Sommeling

[6]. India 2020" – APJ Abdul Kalam

[7]. Flow Simulation Improves Photovoltaic Solar Panel Performance

[8]. R. Sims, "The renewable energy response to climate change", Advances in Solar Energy, 15, American Solar Energy Society Inc., Boulder (CO), 2003

[9]. Envisioning an Empowered Nation – APJ Abdul Kalam w ith A Sivathanu Pillai.

[10]. IEA, "World Energy Outlook 2004", International Ene rgy Agency, Paris, IEA/OECD, 2004