

Use of Solar Cell for Solar Energy Conversion in Electrical

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Abstract

It is expected that in the year 2050, all together the consumption of the energy is going to rise up to 22Gtoe every year from 10Gtoe every year which is energy consumption of the present time. Nearly 70% of this total energy is contributed by the fossil fuels that include coal and oil each of 26% and also the natural gas which contributes about 18% and the non fossil sources (equally divided between renewable and nuclear energy) contributes 30% of this total energy that is consumed every year at present. In the developing regions of the globe, the demand of the energy is growing rapidly where the basic requirement of the energy is not fulfilled satisfactorily. After the year 2010, in the developing countries the energy consumption will go beyond that of the developed world and 2/3 of total world in the year 2050. In India, the issue of the securities of energy is as same as of oil securities for the country. In India, when the geo-political implication of the increased requirement for “hydrocarbons” and the dependency of the country on its oil resources are important, the matter of the security of the energy should be kept at priority for “energy supplies,” “commercial,” and “non commercial” and it should not be stopped by just thinking about the availability of the hydrocarbon only. The requirement of our energy is increasing by 5.4 billion kW every year and the non commercial energy as “biomass,” “fuel wood,” and “animal waste” that is nearly 1/4th of the total requirement of the primary energy. There are some technologies that can be renewed are becoming viable for the commercial purposes and it is found that renewable can play a key part to provide electricity in the rural areas and if grab these opportunities the technology will be harnessed. The need of technological power covers the complete range of renewable forms of energy like “solar photovoltaic, solar thermal, solar hydro, bio-energy, ocean energy, etc.” The conservation of the energy is other crucial matter and number of ways is used for so many years for this, especially in respect of oils but it was not successful. Therefore, so as to meet up the “energy security” and the concerns of “climate change,” it is very important to address the issues like “rational energy pricing, energy efficiency, and new technology trusts.”

KEYWORDS: *Photo potential, photo current, Fill Factor, Conversion Efficiency, and storage capacity*

INTRODUCTION

Types of Cells: There are so many devices that are there and under the research for the “solar energy” conservation into “electrical energy.”

a) Conductor- insulator-semiconductor organic solar cells, b) Fuel cells, c) Photoelectric cells, d) Electrolytic cell, e) Electrochemical cell, f) Photovoltaic cells, g) Photo galvanic cells.

Conductor- insulator-semiconductor organic solar cells: By this method “solar energy” can be converted to “electrical energy” and this involves the semiconductors as the unit to harvest the light.

A new kind of CIS (conductor- insulator-semiconductor) organic “solar cells” are developed with the main feature like having a transparent, conductive electrode in the front and a thin layer that works as an insulator. The “CIS organic cells” can be divided into 3 categories on the basis of the front electrode that is used: 1) **a metal** – the front electrode is made up of metal in this “insulator-semiconductor cell.” 2) **A semiconductor-insulator-semiconductor** – consist of a “degenerate semiconductor electrode,” and 3) **an electrolyte-** in this insulator- semiconductor cell; an “electrolytic contact” is present. The functioning of the electrode (transparent and conductive) determines the barrier formation at the base of the organic semi-conductor cells. For the present study X-phase (mixture of metal-free phthalocyanine- polymer binder) is the material which is used to make the semi-conducting layer at the base of the cell that will deposit onto the substrate by the process of “solution casting.”

Fuel Cells: it is a device that converts the electro chemical energy into electrical energy and produces the electricity with the help of the “fuel” which is supplied externally on the anode side and the “oxidant” on the cathode side and the reaction takes place in the presence of an electrolyte. Generally it is seen that the flow of the reactants is always inwards and the flow of the products of the reactants is in outward direction and the electrolyte stays there in the cell only. The fuel cell can be operated in virtual and continuous manner until the required flows are maintained. The fuel cell is not like the battery that consumes reactant that need to replenish and they also stores the electrical energy by chemical process in a close system. Moreover, in the battery the electrodes reacts and changes when the battery is charged or gets discharged but in the fuel cell the electrode is catalytic and is more stable and it is possible to combine the “fuel” and “oxidant” in many ways. Hydrogen is used as the fuel and the oxygen is used as the oxidant in the hydrogen cells.

Photoelectric Cells: one of the most interesting and successful experiments is the photo sensitized decomposition of Hydrogen (H_2) and Oxygen (O_2). H_2 is a fuel that does not make pollution and when it is burned in the air it produces water again and releases huge amount of heat. In a cell that can generate the fuel, Hydrogen and Oxygen can be made to combine again. 1.23eV is the thermodynamic break down energy for water. There is a requirement of 2 electrons in the successive steps of the electro chemical decomposition of H_2O and due to this 2 quantum photo chemical processes can be used for water decomposition where the input of at least 2.46eV per molecule is needed. The effective wavelength of light for one quantum process should be shorter than 500nm.

Fujishima and Honda are the first that had observed the photo electrolysis of water where they had used TiO_2 semiconductor (anode) and Pt (cathode) in 0.1N Sodium Hydroxide (NaOH) solution. Later on there are scientists that have studied how the H_2 (Hydrogen) is been produced by using band gap of semi conductor. At present, “inorganic complex” and “organic dyes” are used as the photo sensitizers for the production of Hydrogen from PEC cells (Photo Electric Cells). Some studies are discussed below. In the presence of solid catalyst (Pt, TiO_2 , ZnO), Hydrogen (H_2) is reduced to H_2O (Water) by the aqueous solution of the reduced form methyl viologen of proflavinmethyl viologen and Ascorbic Acid while illumination done by visible light. Irradiation of the system that contains acridine yellow (sensitizer), Ascorbic Acid or crystalline (electrode donor) and “methyl viologen, europium (III) salicylate, europium (III) Ascorbic Acid complex or vanadium (III) salicylate (electron acceptor) in the presence of catalyst (Ni, Pd, Pt(IV) oxide or colloidal [Pt]), the process of water reduction goes along with the Hydrogen evolution. In the photo galvanic cell at cathode the production of Hydrogen (H_2) is leaded by Pt/FMN-Ascorbic Acid (PH=7)//5N H_2SO_4 /Pt). After the irradiation of 25h the production of H_2 was 1.1 μ mol and 0.008 is the quantum yield production of Hydrogen and the Voc was 600mV. In the process of water photo electrolysis, under illumination, 50 ml h-1 hydrogen (H_2) is generated by CdS photo anode where Eosin dye is used as the photo sensitizer and in this photo

electric cell (PEC) 35 μ A current was obtained. At different pH levels and light intensities, the photo response of “chlorophyll / Ascorbic acid and chlorophyll / buffer acetate junction” has been studied. It is seen that the area where the pH level is 4-5, the value of photo voltage and photo current reaches to its maximum. In addition, the photo induced charge transfer at the “chlorophyll-electrolyte interface” is been supported by hydrogen gas evolution. The capability of encouraging hydrogen (H₂) evolution is shown by the photo sensitizers “proflavin, acridine yellow and tris (2, 2-bipyridyl) ruthenium in Ascorbic Acid of methyl viologen.” The amount of hydrogen obtained was less than ten times when the CdS was used as a sensitizer in Ascorbic Acid of dyes.

Electrolytic cell: it is a vessel used for electrolysis that contains electrolyte which is generally a water solution or sometime it can be some other solvent in which the ions can be dissolved and it also had a cathode and an anode. The electrolyte is inert but when an external voltage is provided it goes into a redox reaction with anode and cathode. In literal meaning, it is cell that helps the ions to split and get loosen. 2 kinds of electrodes that are made up of different elements are there in the electrolytic cell, electrodes, and their chambers combines to form a unit. One electrode works as anode and other as cathode. A battery of cells that has moderate power of required value can be made when a number of units are combined in series and parallel combination. The power which is generated by this set up depends on the “nature” and the “condition” of the leave size and the “nature of the electrolyte” and also how the type of the combinations that are made by the units. It is convenient to use so many plants but it depends on the content of the electrolyte. The current which is seen is considered as a “short circuit current” and practically it is proportional to the “EMF” and this in turn fluctuates as per the concentration of the electrolyte. Any circuit that consumes less power (transistor radio, a calculator, an electronic wall clock a light emitting diode, etc.) can be operated by this device.

Electro chemical cell: a device that is used to create voltage (electromotive force) and current by chemical reaction. When the reaction release and accept the electrons by the reaction, the current is produced at the ends of the conductors. Oxidation or Reduction undergoes in each half part of the cell and in a complete electro chemical cell, oxidation takes place at one side where it loses electrons and on the side reduction take place where it gains the electrons. When the electrodes made up of metals are place in the electrolyte it creates an electro chemical cell where the current is generated or it is used by chemical reactions. The cell that generates current is called voltaic or galvanic cell and the battery has such kind of cells. In some cells current is supplied from outside to start the reaction and this cannot be impulsive and these cells are “electrolytic cells.”

It is reported by **Karunakaran & Senthilvelan** that CdO is used in the semi conductor catalysis of solar photo oxidation of “aniline” to “azo benzene.” “Stuart Licht.Hodes, G. et al., Licht, S. et al., Muller, N. & Cahen, D. Giggenbach, W., Hamilton, I. C. & Woods, R, Lessner, P, Frese, K. W. Jr & Canfield, D. G., Smotkin, E. S. et. al., Bratin, P. & Tomkiewicz, M., Flaisher, H. & Tenne, R., Marcu, et al., Orazem, M. E. et al. and Benito, R. M. & Nozik, A. J” have studied the explanation of the conversion of the energy in the photo electro chemical solar cell to find a substitute of solid state of “solar cell.”

Photovoltaic Cell: it converts the sun light into electricity with the help of thermo dynamic cycle and mechanical generator. “P” is for photo which is light and “V” is for voltaic (electricity), where the photon of sun light frees the electron from the common “silicon.” Solar cell (photo voltaic cell) generates the electricity directly from the sun light by using the photo voltaic effects of semi conductor. Since the manufacturing cost of these cells is high there use has be limited. It is found that

till the end of the year 2005, the “peak power” of the photo voltaic cell is nearly 1700 MW and this only part that generated by the solar energy.

If the manufacturing cost is declined as it is from 3-5% every year, its cost effective application will expand. From the year 1990 to 2005 its retail cost is been decreased from \$7.50 to \$4 per watt and the increase in its production all over the world was by 32% in the year 2003. All over the world, there is an increase in capacity of solar energy by 60% between the year 2000 and 2004 and it was expected that in 2005 it will increase more but since there is shortage of refined silicon it hampers the production process from last of 2004 all over. It is predicted by the analyst that the year 2006 and 2007 will suffer with this supply problem.

The photo voltaic cell is expensive as silicon crystals are used in it, and since these crystals are assembled manually and it is wasted in the process of purification it costs high. Silicon is a semi conductor that absorbs photons that has high or equal energy as of band gap energy and at the same time it produces electric power. Inorganic salt is used as an electrolyte to generate the power by the commercial voltaic cells. All the plant has organic and inorganic electrolyte that absorbed by the roots or prepared by the metabolic process. It was examined by Prajjal that it is possible to use the plant material to make a cheap vegetative voltaic cell.

Photo galvanic cells: it is an electro chemical cell in which current and voltage are produced due to photo chemical changes in the reactant’s concentration in the solution phase “oxidation-reduction” couple. The cell is named after Luigi Galvani that has 2 different metals that are joined with a salt bridge or the disk which is porous present between the 2 half cells. Each of these half cells has an electrode as shown in the figure and is made of plates of Zn (Zinc) and Cu (Copper) and an electrolyte which is an aqueous solution of zinc sulphate ($ZnSO_4$) and copper sulphate ($CuSO_4$). The metal of the metallic electrodes goes into the solution and releases the metal ions that has positive charge and the electrons that has negative charge is retained on the electrode and due this each half cell has its own half reaction. When the electrodes are connected with an external power supply the electrons starts flowing from the negative electrode which is made of zinc to positive electrode which is made of copper and as there is a negative charge on the electron, current is produced by this flow which is opposite the flow of the electron and at the same time there is a flow of electric current through the electrolyte.

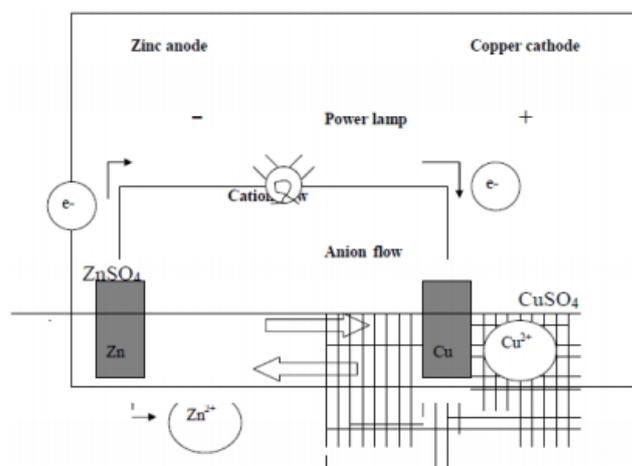


Fig. Schematic of Zn-Cu galvanic Cell.

Photo galvanic effects: when a dye is dissolved in a solution that contains a reducing agent and when the solution becomes photo chemically active it reduces the dye and it become colourless when

exposed to light. But the light source is removed the reaction start moving in opposite direction and goes back to the original form. The photo reduction of the dye occurs due to the change in the potential of the solution. In this photo galvanic cell, dye is used as photo sensitizer which is reduced as an electron source. The number of dyes electrodes and reductants that are used are same. Some interesting systems have reported by Gangotri et.

Fabrication: the photo galvanic cell is made up of a tube which is “H” shaped (H cell) made of hard glass and has electrodes that are made up of platinum and calomel. The diameter of the “H cell” is usually 1.4 cm and its height is 10 cm. A narrow junction tube is there that connects the two limbs of “H cell” and the length of this “junction tube” is called the diffusion length. In the present work the cell that is used has the diffusion length from 35mm to 55mm. the “H cell” is made dark from outer side by the help of black paper or black paint. The light is provided at the platinum electrode by the window which is made in the “H cell” by giving a cut at a place and the limb that has the “standard calomel electrode” is kept in the dark. Now a digital pH meter and an ammeter are connected with the “H cell” and with the help of water filter infra rays are cut off. There is an “inlet” and an “outlet” for water in the water filters.

Photo voltaic cells versus Photo galvanic cells: Both of these cells are photo electro chemical cells and both of these converts the “solar energy” into “electric energy” directly by using an electrolyte, dye solution, metal or semi conductor electrode. The concept of both the cells is totally different. On the photo voltaic cell the light is absorbed at the surface of the semi conductor electrode and the molecules also gets excited at the surface of the electrodes and this is the reaction by which light energy is converted into electrical energy and this also occurs on the surface of the electrode, therefore, it is a surface process. On the other side on the photo galvanic cell, the bulk of the solution converts the light energy into electrical energy. The dye of the “bulk solution” gets excited as the energy and when this starts getting back to the ground state it starts emitting energy which is trapped and converts into electrical energy or it can be said that the photo galvanic effect is a “bulk phenomenon.” In addition, the efficiency to convert is high in the photo voltaic cell but the storage capacity is lacking and in the photo galvanic cell both the storage capacity and the efficiency to convert is high.

Result:

Performance of the Cell: to study all the 3 systems a desired load is supplied externally to have the “potential” and “current” that corresponds to power point. When the light source is removed the time determined is $t_{1/2}$ and this is the time which is taken to reach half the value of “power.” The cell’s performance was analysed and the comparative values are shown below in table 1.

Table 1
Performance of the Photogalvanic Cells in Dark

System	Power (μ W)	$t_{1/2}$ (min)
Carbol Fuchsin & EDTA	64.0	90.0
Ponceau S and Mannitol	68.8	75.0

The above data shows that the “Ponceau S & Mannitol” is most efficient when it is seen from the electro chemical studies of photo sensitizers.

Conversion Efficiency of the Cell: the output at the “power point” and the “power of incident radiations” are used to calculate the conversion efficiency of these systems. At the optimum

conditions, the system is kept on the sun light. Table 2 reports the conversion efficiency and sun light conversion data for these three systems.

Table 2
Conversion Efficiency and Sunlight Conversion Data

System	Fill Factor (n)	Conversion Efficiency (%)	Sunlight Conversion Data	
			Photopotential (mV)	Photocurrent (μ A)
Carbol Fuchsin & EDTA	0.51	0.98	1239	180
Ponceau-S& Mannitol	0.56	1.24	1302	210

The observations show that the “Ponceau S & Mannitol system” has the highest conversion efficiency and this is followed by “Carbol Fuchsin & EDTA system.”

Conclusion: in alternate way, hydrogen (H₂) and oxygen (O₂) can be made to combine again in a cell that generates fuel. 1.23eV is the thermo dynamic break down energy for H₂O (water). In the successive steps of electro chemical decomposition of H₂O there is a need of 2 electrons. In a fuel electro chemical cell, at one side the electrons should be loosed to its electrode and on the side the electrons should be gained. When the electrodes made up of metals are place in the electrolyte it creates an electro chemical cell where the current is generated or it is used by chemical reactions. The electro chemical cells that generates electric current is known as voltaic cell or galvanic cell and a battery has one or more these kind of cells and it was studied by Benito, R. M. & Nozik, A. J that the energy conversion on the photo electro chemical solar cell needs to find an alternative of solid state “solar cell.”

“Solar cell” which is known as photo voltaic cell” uses photo voltaic effects of semi conductors for the generation of electricity from the sun light directly.

Acknowledgement

The authors are grateful to The Principal Deshbandhu College university of Delhi kalkaji New Delhi-110019 for providing the necessary laboratory facilities to conduct this research works.

References:

- [1] Becquerel E., 1839a C. R. Acad. Sci. Paris., **9**, 145–159.
- [2] Becquerel E., 1839b C. R. Acad. Sci. Paris, **9**, 561.
- [3] Surash J. J, and Hercules D. M., 1962 *J. Phys. Chem.* **66**, 1602-1606.
- [4] Alanso V.N., Belay M., P.Chartier, and Ern V., 1981 *Rev. Phys. Appl.* **16**, 5.
- [5] Jana A.K. and Bhowmik B.B., 1999 *J. Photochem. Photobiol.*, **122A** , 53.
- [6] Hara K., Kurashige M., Dan-oh Y., Kasada C., Shinpo A., Suga S., Sayama K. and Arakawa H., 2003 *New J. Chem.*, **27**, 783–785.
- [7] Ameta S. C., Ameta R., Seth S., and Dubey T.D., 1988 , *Afinidad*, **XLV**, 264–266.
- [8] Ameta S. C., Khamesare S., Ameta R. and Bala M., 1999 *Int. J. Energy Res.*, **14**, 163– 167.
- [9] Ameta S. C., Punjabi P. B., Vardia J., Madhwani S. and Chaudhary S., 2006 *J. Power Sources*, **159**, 747–751
- [10] Madhwani S., Ameta R., Vardia J., Punjabi P. B. and Sharma V. K., 2007 *Energy Sources.*, **29**, 721 — 729
- [11] Bohrmann-Linde C. and Tausch M. W., 2003 *J. Chem. Educ.*, **80** , 1471–1473.
- [12] Monat J. E. and McCusker J. K., 2000 *J. Amer. Chem. Soc.*, **122**, 4092–4097

- [13] Schwarzburg K. and Willig F., 1999 *J. Phys. Chem.* **103B**, 5743.
- [14] Tennakone K. and Kumara GRR.A., 1998 *J. Photochem. Photobiol.*, **117A**, 137.
- [15] Yadav Sushil , Yadav R. D. and Singh Gautam, 2008 *Int. J. Chem. Sci.*, **6(4)**, 1960-1966 [16] Singh Gautam, Yadav R. D., Yadav Sushil and Koushalya , 2009 *Int. J. Pure and App. Chem.*, **4(1)**,
- [17] Meena, R.C., Gautam Singh and K.M. Gangotri, 2003 *Afinidad* **59 (501)**, 253-256
- [18] Meena, R.C., and R.S. Sindal., 2004 *Int. J. Chem. Sci.*, **2(3)** , 321-330
- [19] Ameta, Suresh C., Sadhana Khamesra, Anil K., Chittoro and K.M. Gangotri., 1989. *Int. J. Energy Res.*, **13**, 643-647
- [20] Gangotri, K.M., R.C. Meena and Rajni Meena., 1999 *J. Photochem and photobiol. A: Chem*; **123**, 93-97
- [21] Gangotri, K.M. and Chhagan Lal., 2000. *Int. J. Energy Res.*, **24**, 365-371
- [22] Fisher, A.C., L.M. Peter, E.A., Ponomareve, A.B., Walker, and K.G.U. Wijayantha., 2000 *J. Phys. Chem. B.* **104(5)**, 949-958
- [23] Zhang, Zhi-Ying. and Chun-yanliu., 2000 *J. Photochem. and Photobio. A: Chemistry* **130**, 139-143
- [24] Gratzel, Michael., 2004 *J. Photochem. and Photobiol. A: Chemistry* **164**, 3-14
- [25] Hameed, A. and M.A., 2004 *J. Molecular Catalysis A: Chemical* **219**, 109-119
- [26] Coralie Houarner-Rassin, Errol Blart, Pierrick Buvat and Fabrice Odobel., 2007 *J. Photochem. and Photobiol A: Chemistry* **186** , 135-142
- [27] Bandara, J., U.W. Pradeep and R.G.S.J. Bandara., 2005 *solar cells.* **Vol. 170**, 273-278
- [28] Sindal, R.S., Gunsaria, R.K, Chandra Mahesh and Meena R.C., 2006. *The Arabian Journal for science and Engineering* **31(2A)**, 177-183
- [29] Minna Toivola, Lauripeltokorpi, Janne Halme, Peter Lund, 2007 *Solar energy materials and solar Cells.* **91**, 1733-1742
- [30] Kenisarin, mural. and Khamid Mahkamov, 2007 *Renewable and Sustainable energy reviews* **11**, 1913-1965
- [31] Sindal R S, Chandra Mahesh and Meena R C, 2008 *J. Ind. Council Chem* **25(2)**, 131-136.
- [32] Sirvi Sonal, Meena Vijay Kumar and Meena R C, 2008 *J. Indian Chem. Soc.* **85**, 825-829
- [33] Meena R C , 2008. *J. Indian Chem. Soc.* **85**, 280-285.
- [34] Sindal R S, Chandra M, Kumar V and Meena R C, 2009 *Energy Sources*, **31(16)**, 1-9
- [35] Kumari Manju, Pachwarya Ram Babu and Meena R C, 2009 *Int. J. Energy Sources* **31(11)**, 1- 8