ISSN 2250-3153

Solar Cell

Rashmi Swami

Lecturer, Department of Electronics, Govt.Girl's polytechnic Raipur, 492001, Chhattisgarh, India

Abstract- The world's fossil fuel resources are unable to sustain our current energy requirements beyond the next few decades and so the need for inexpensive alternatives is now urgent. Organic devices are well placed to meet the needs of both the electronics and energy industries because their manufacture does not require expensive processing steps and they can be adapted to a range of applications. Consequently there has been significant interest in this fiel d over recent years and there are now many research groups world-wide investigating the semiconducting properties of conjugated materials and their use in LEDs, photovoltaic and transistors. This activity of creating electricity through the use of organic solar cells is an example of one way scientists are trying to alleviate some of the dependence on non-renewable resources. It is the purpose of my research proposal to explore that with a little human ingenuity, other ways to create energy can be attained.

I. Introduction to Energy

Energy are broadly classifies into two main groups: Renewable and Non-renewable.

1.1 Non-Renewable Energy: Non-Renewable energy is energy which is taken from the sources that are available on the earth in limited quantity and will vanish fifty-sixty years from now. Non-renewable sources are not environmental friendly and can have serious affect on our health. They are called non-renewable because they cannot be re-generated within a short span of time. Non-renewable sources exist in the form of fossil fuels, natural gas, oil and coal.

According to recent predictions [1-2], the inevitable permanent de-cline in the global oil production rate is expected to start within the next 10-20 years. However, the combustion of fossil fuels in the past has *already* harmful effects on the delicate balance of nature on our planet. Today, about 20 X 10^{12} kg of carbon dioxide are put into the atmosphere every year, mainly by burning fossil fuel [3-5]. Today's plants are unable to absorb this huge amount of extra CO2. As a result the CO2 concentration in the atmosphere continues to mount adding considerably to the greenhouse effect which will increase the global mean surface temperature - depending on future emission scenarios and the actual climate sensitivity - by another 0.6-7.0^{o}C by the year 2100 [4].

Global mean surface temperature has increased by 0.3-0.6 $^{\circ}C$ since the late 19th century and the global sea level has risen by 10-25cm, most likely due to human activities [4].The consequences of this temperature change have already increased the frequency and severity of natural disasters [5] and are likely to have more devastating effects for humans and other life forms in all parts of Earth within the next decades.

1.2 Renewable Energy: Renewable energy is energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as and when required. They are available in plenty and by far most the cleanest sources of energy available on this planet. For eg: Energy that we receive from the sun can be used to generate electricity. Similarly, energy from wind, geothermal, biomass from plants, tides can be used this form of energy to another form. Worldwide, oil prices will then rise considerably favoring the introduction of various *renewable* energy sources such as the direct conversion of solar energy (solar cells), but also others like for example, hydroelectric- and wind-power systems. *Renewable* energy sources neither run out nor have any significant harmful effects on our environment.

II. What is Solar Cell?

Solar cells are devices which convert solar energy directly into electricity, either directly via the photovoltaic effect, or indirectly by first converting the solar energy to heat or chemical energy. Assemblies of cells used to make solar modules which are used to capture energy from sunlight, are known as solar panels. The energy generated from these solar modules, referred to as solar power. Cells are described as photovoltaic cells when the light source is not necessarily sunlight (lamplight, artificial light etc).The amount of power available from a PV device is determined by -the type and area of the material, the intensity of the sunlight , the wavelength of the sunlight.

III. The Need of Solar Cells

- the need for low maintenance, long lasting sources of electricity suitable for places remote from both the main electricity grid and from people; eg satellites, remote site water pumping, outback telecommunications stations and lighthouses;
- the need for cost effective power supplies for people remote from the main electricity grid; eg Aboriginal settlements, outback sheep and cattle stations, and some home sites in grid connected areas.
- the need for non polluting and silent sources of electricity; eg tourist sites, caravans and campers
- the need for a convenient and flexible source of small amounts of power; eg calculators, watches, light meters and cameras;
- the need for renewable and sustainable power, as a means of reducing global warming.

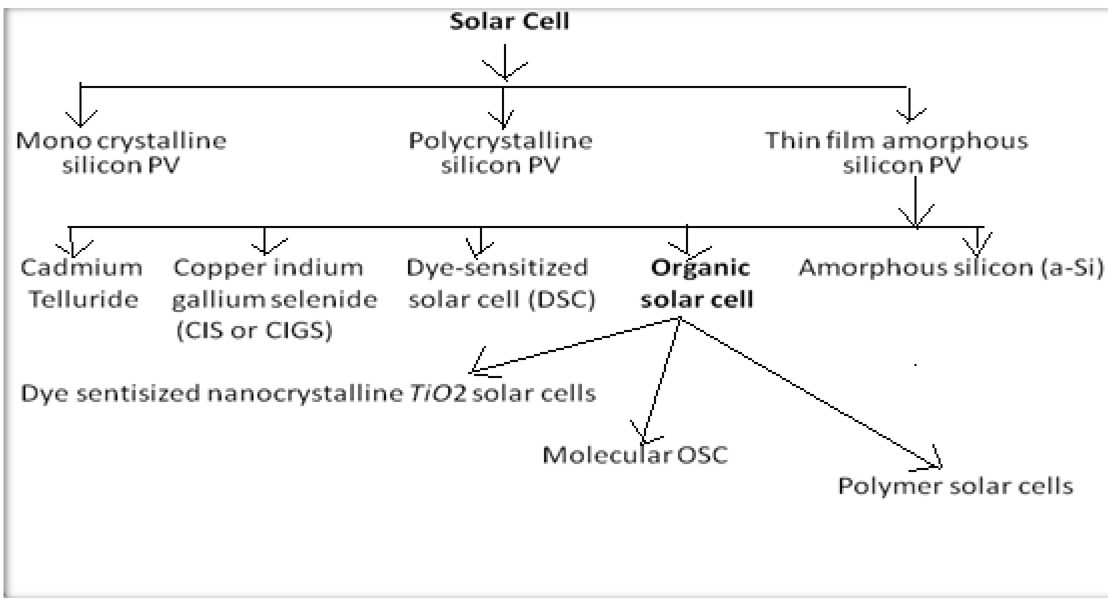
IV. Working of Solar Cell

The solar cell works in following steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Photons with energy equal to the band gap energy are absorbed to create free electrons. Photons with less energy than the band gap energy pass through the material.
2. Formation of electron-hole pair (exciton)
3. Exciton diffusion to Junction
4. Charge separation- Electrons (negatively charged) are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material to cancel the potential and this electricity is captured i.e. Electrons that are created on the n-type side may travel through the wire, power the load, and continue through the wire until they reach the p-type semiconductor-metal contact. Here, they recombine with a hole that was either created as an electron-hole pair on the p-type side of the solar cell. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
5. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

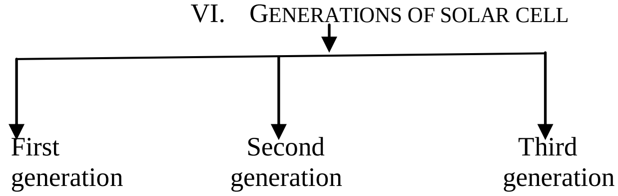
V. Types of Solar Cell

Based on the material used different types of solar cell are-



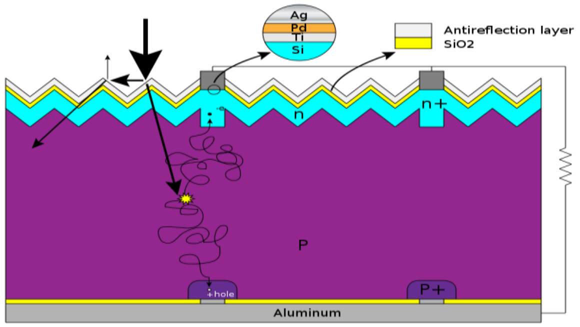
Materials presently used for photovoltaic solar cells include monocrystalline silicon[6], polycrystalline silicon[6], amorphous silicon[6], cadmium telluride[6,7], and copper indium gallium selenide [6,7]. Many currently available solar cells are made from bulk materials that are cut into wafers between 180 to 240 micrometers thick that are then processed like other semiconductors. Other materials are made as thin-films layers, organic dyes, and organic polymers[8] that are deposited on supporting substrates. A third group are made from nanocrystals and used as quantum dots (electron-confined nanoparticles)[9]. Silicon remains the only material that is well-researched in both *bulk* and *thin-film* forms.

VI. Generations of Solar Cell



6.1 First generation: This term refers to the classics p-n junction photovoltaic. Typically, this is made from silicon (multicrystalline and single crystalline) doped with other elements to make them preferentially positive (p) or negative (n) with respect to electronic charge carriers as shown in fig(1). However in the past these devices were made from other materials like Germanium as well. First generation photovoltaic cells (also known as silicon wafer-based solar cells) are the dominant technology in the commercial production of solar cells, accounting for more than 86% of the solar cell market. They are dominant due to their high efficiency. This despite their high manufacturing costs, a problem that second generation cells hope to remedy.

Monocrystalline silicon (c-Si) often made using the Czochralski process. Single-crystal wafer cells tend to be expensive, and because they are cut from cylindrical ingots, do not completely cover a square solar cell module without a substantial waste of refined silicon. Hence most *c-Si* panels have uncovered gaps at the four corners of the cells. Monocrystalline solar cells can achieve 17% efficiency [10]. P*olycrystalline silicon*, or *multicrystalline silicon*, (poly-Si or mc-Si) made from cast square ingots—large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient. Polycrystalline are only capable of achieving around 10% efficiency.



Fig(1): Silicon_Solar_cell_structure

6.2 Second generation: Thin films of photon-absorbers and layered stacks of thin films. It can combine multiple light absorbing materials in a "stack" of films, with each absorbing a slightly different range of light wavelengths than the one below it. The advantage of using a thin-film of material was reducing the mass of material required for cell design. Typically, the efficiencies of thin-film solar cells are lower compared with silicon (wafer-based) solar cells, but manufacturing costs are also lower. The most successful second generation materials have been cadmium telluride (CdTe), copper indium gallium selenide, amorphous silicon and micromorphous silicon.

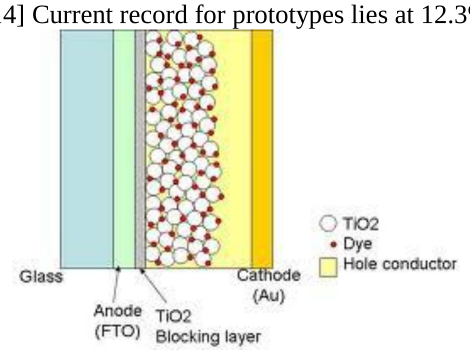
A cadmium telluride solar cell uses a cadmium telluride (CdTe) thin film, a semiconductor layer to absorb and convert sunlight into electricity. The cadmium present in the cells would be toxic if released. CdTe technology costs about 30% less than CIGS technology and 40% less than A-Si technology.

Copper indium gallium selenide (CIGS) is a direct band gap material. It has the highest efficiency (~20%) among thin film materials (see CIGS solar cell).

An amorphous silicon (a-Si) solar cell is made of amorphous or microcrystalline silicon and its basic electronic structure is the p-i-n junction. a-Si is attractive as a solar cell material because it is abundant and non-toxic (unlike its CdTe counterpart) and requires a low processing temperature, enabling production of devices to occur on flexible and low-cost substrates. As the amorphous structure has a higher absorption rate of light than crystalline cells, the complete light spectrum can be absorbed with a very thin layer of photo-electrically active material. However, because it is amorphous, it has high inherent disorder and dangling bonds, making it a bad conductor for charge carriers. Amorphous silicon has a higher bandgap (1.7 eV) than crystalline silicon (c-Si) (1.1 eV), which means it absorbs the visible part of the solar spectrum more strongly than the infrared portion of the spectrum.

6.3 Third generation: Third generation technologies aim to enhance poor electrical performance of second generation (thin-film technologies) while maintaining very low production costs. Generally, third generation cells include solar cells that do not need the p-n junction necessary in traditional semiconductor, silicon-based cells. Third generation contains a wide range of potential solar innovations including polymer solar cells, nanocrystalline cells, and dye-sensitized solar cells.

A dye-sensitized solar cell (DSSC, DSC or DYSC [11]) is a low-cost solar cell belonging to the group of thin film solar cells[12]. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a *photoelectrochemical* system. A modern DSSC shown in fig(2) is composed of a porous layer of titanium dioxide nanoparticles, covered with a molecular dye that absorbs sunlight. The titanium dioxide is immersed under an electrolyte solution, above which is a platinum-based catalyst. As in a conventional alkaline battery, an anode (the titanium dioxide) and a cathode (the platinum) are placed on either side of a liquid conductor (the electrolyte). Sunlight passes through the transparent electrode into the dye layer where it can excite electrons that then flow into the titanium dioxide. The electrons flow toward the transparent electrode where they are collected for powering a load. After flowing through the external circuit, they are re-introduced into the cell on a metal electrode on the back, flowing into the electrolyte. The electrolyte then transports the electrons back to the dye molecules. In the DSSC, the bulk of the semiconductor is used solely for charge transport, the photoelectrons are provided from a separate photosensitive dye. Charge separation occurs at the surfaces between the dye, semiconductor and electrolyte. The dye molecules are quite small (nanometer sized), so in order to capture a reasonable amount of the incoming light the layer of dye molecules needs to be made fairly thick, much thicker than the molecules themselves. To address this problem, a nanomaterial is used as a scaffold to hold large numbers of the dye molecules in a 3-D matrix, increasing the number of molecules for any given surface area of cell. Overall peak power conversion efficiency for current DSSCs is about 11%[13][14] Current record for prototypes lies at 12.3%[15].



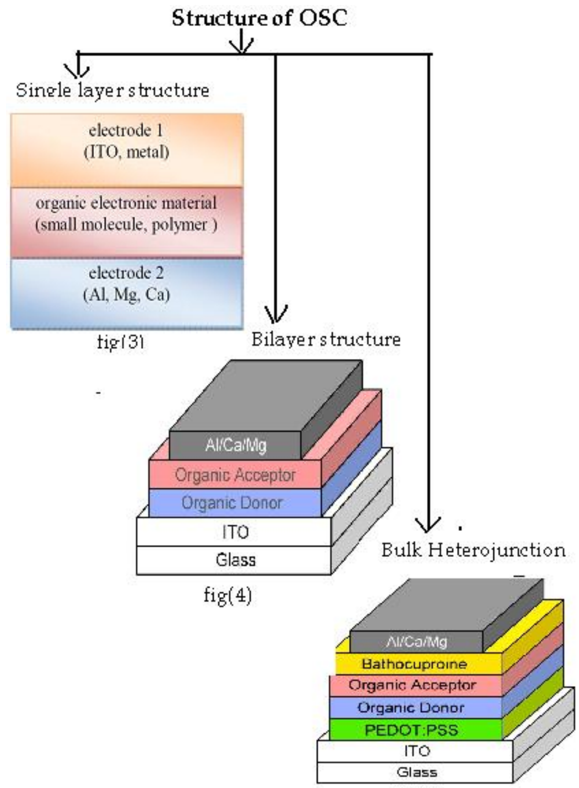
Fig(2): dye-sensitized solar cell

Quantum dot solar cells (QDSCs) are based off of the Gratzel cell, or dye-sensitized solar cell, architecture but employ low band gap semiconductor nanoparticles, also called quantum dots (such as CdS, CdSe, Sb_2S_3, PbS, etc.), instead of organic or organometallic dyes as light absorbers.

(**nc-Si)** has about the same bandgap as c-Si, the nc-Si and a-Si can advantageously be combined in thin layers, creating a layered cell called a tandem cell. The top cell in a-Si absorbs the visible light and leaves the infrared part of the spectrum for the bottom cell in nc-Si.

Organic solar cells and polymer solar cells are built from thin films (typically 100 nm) of organic semiconductors including polymers, such as polyphenylene vinylene and small-molecule compounds like copper phthalocyanine (a blue or green organic pigment) and carbon fullerenes and fullerene derivatives such as PCBM. Energy conversion efficiencies achieved to date using conductive polymers are low compared to inorganic materials. However, it has improved quickly in the last few years and the highest NREL (National Renewable Energy Laboratory) certified efficiency has reached 8.3% for the Konarka Power Plastic[16]. In addition, these cells could be beneficial for some applications where mechanical flexibility and disposability are important.

These devices differ from inorganic semiconductor solar cells in that they do not rely on the large built-in electric field of a PN junction to separate the electrons and holes created when photons are absorbed. The active region of an organic device consists of two materials, one which acts as an electron donor and the other as an acceptor. When a photon is converted into an electron hole pair, typically in the donor material, the charges tend to remain bound in the form of an exciton, and are separated when the exciton diffuses to the donor-acceptor interface. excitons are broken up into free electrons-hole pairs by effective fields. The effective field are set up by creating a heterojunction between two dissimilar materials. Effective fields break up excitons by causing the electron to fall from the conduction band of the absorber to the conduction band of the acceptor molecule. It is necessary that the acceptor material has a conduction band edge that is lower than that of the absorber material[17][18][19][20]. The short exciton diffusion lengths of most polymer systems tend to limit the efficiency of such devices. Nanostructured interfaces, sometimes in the form of bulk heterojunctions, can improve performance[21].



fig(3)
fig(4)
fig(5)

As shown in fig (3) single layer structure of OSC[20] consists of - Organic material is sandwiched between two electrodes, One electrode is transparent, Organic material absorbs/emitts light (OPV/OLED). As shown in fig (4) bilayer OSC structure[22] consists of - Two different organic materials, Exciton dissociation at the interface, Power conversion efficiency > 1% is possible.

Structure of bulk heterojunction OSC[22] shown in fig (5) consists of -

Bathocuproine:

- Exciton blocking layer
- Hole blocking layer
- Prevents metal diffusion into acceptor

PEDOT:PSS:

- Smoothes rough ITO surface
- Exciton blocking layer

OSC Advantages

– Low temperature, low energy processing
– Low material requirement
– Relatively cheap in production and purification.
– Can be used on flexible substrate.
–Materials can be tailored for the demand
–Can be shaped or tinted to suit architectural applications.
- Low manufacturing cost
-Utilization of eco friendly materials
-Scalable manufacturing processes for large area Organic solar cells (OSC) are flexible, semi-transparent and relatively inexpensive to produce.

OSC Disadvantages

– Low efficiency
– Unproven technology
– Limited lifetime/ stability issue

VII. Conclusion

In the past year the price of fossil fuels has increased more than anytime in recent memory. Because of this fact, the race for alternate energy sources to replace or lessen the use of fossil fuels has risen. This activity of creating electricity through the use of organic solar cells is an example of one way scientists are trying to alleviate some of the dependence on non-renewable resources. It is the purpose of my research proposal to explore that with a little human ingenuity, other ways to create energy can be attained. It is therefore plan to develop a simulator for Organic Solar Cell which can reproduce the behaviour of a real device as close as possible

At present, solar cells comprising an inorganic semi-conductor such as mono- and multi-crystalline silicon have found markets for small scale devices such as solar panels on roofs, pocket calculators and water pumps. These conventional solar cells can harvest up to as much as 24% [23] of the incoming solar energy which is already close to the theoretically predicted upper limit of 30% [24] . This illustrates that technologies which allow low fabrication costs - rather than somewhat higher conversion efficiencies - are now desired. One approach here would be to reduce the amount of silicon by using thinner films on (cheap) glass substrates. Today, the production of these solar cells still requires many energy intensive processes at high temperatures (400-1400^{o}C) and high vacuum conditions with numerous lithographic steps leading to relatively high manufacturing costs [25].

Considerably less effort and production energy is necessary if organic semiconductors are used because of simpler processing at much lower temperatures (20-200 °C) than the above mentioned inorganic cells. For example, electro-chemical solar cells using titanium dioxide in conjunction with an organic *dye* and a liquid electrolyte [26] already exceeded 6% power conversion efficiencies [23] and are about to enter the commercial market thanks to their relatively low production costs. Possible applications may range from small disposable solar cells to power smart plastic (credit, debit, phone or other) cards which can display for example, the remaining amount, to photo-detectors in large area scanners or medical imaging and solar power applications on uneven surfaces.

References

[1] C. J. Campbell and J. H. Laherrere "The end of cheap oil." *Scientific American March, 60 (2011)*

[2] C. B. Hatfield "Oil back on the global agenda. Perma-nent decline in global oil is virtually certain to begin within 20 years. " *Nature 387, 121 (2009)*

[3] P. Benett, "Earth: The Incredible Recycling Machine", *Wayland (Publishers) Ltd, East Sussex (1993)*

[4] Intergovernmental Panel on Climate Change (IPCC) "Second Assessment Report - Climate Change 1995", (1995) Web site: www.meto.gov.uk

[5] United Nations Environment Programme (UNEP) "Global Environment Outlook (GEO)-2000", *Earth- scan Publications Ltd., London (2000).* Web site: www.unep.org

[6] A. Shah et al. "The case for thin films", *Science, 285:692, 1999.*

[7] T.J. Anderson, S.S. Li, O.D. Crisalle, and V. Craciun, "Fundamental materials research and advanced process development for thin-films cis-based photovoltaics", *Technical Report NREL/SR-420-40568, National Renewable Energy Laboratory, 2006.*

[8] W. U. Huynh et al, " Hybrid nanorod-polymer solar cells" *Science, 295:2425, 2002*.

[9] Robert Service, " Can the upstarts top silicon" *Science, 319:718, 2008.*

[10] A.D. Upadhyaya ; Yelundur, Vijay ; Rohatgi, Ajeet, "High Efficiency Mono-Crystalline Solar Cells with Simple Manufacturable Technology", *Georgia Tech, SmartTech Search, 2006*

[11] Wan Haiying "Dye Sensitized Solar Cells", *University of Alabama Department of Chemistry, p. 3*

[12] "Dye-Sensitized vs. Thin Film Solar Cells", *European Institute for Energy Research, 30 June 2006*

[13] American Chemical Society, "Ultrathin, Dye-sensitized Solar Cells Called Most Efficient To Date",*ScienceDaily, 20 September 2006*

[14] F. Gao; Y.Wang; J. Zhang; D. Shi; M. Wang; R. Humphry-Baker; P.Wang; Sm. Zakeeruddin; M.Grätzel , "A new heteroleptic ruthenium sensitizer enhances the absorptivity of mesoporous titania film for a high efficiency dye-sensitized solar cell". *Chemical communications (23): 2635–7.doi:10.1039/b802909a. PMID 18535691(2008).*

[15] Yella, A; Lee, HW; Tsao, HN; Yi, C; Chandiran, AK; Nazeeruddin, MK; Diau, EW-D; Yeh, C-Y; Zakeeruddin, SM; Grätzel, M (2011). "Porphyrin-Sensitized Solar Cells with Cobalt (II/III)–Based Redox Electrolyte Exceed 12 Percent Efficiency". *Science* (6056): 629–634. Bibcode 2011Sci...334..629Y.doi:10.1126/science.1209688.

[16] Konarka Power Plastic reaches 8.3% efficiency. *pv-tech.org. Retrieved on 2011-05-07.*

[17] D.G. McGehee, M.A. Topinka , *Nature Mater. 5, 675-676 (2006)*

[18] J. Nelson , Current Opinion in Solid State and Materials Science 6, 87-95 (2002)

[19] J.J.M. Halls, R.H. Friend, M.D. Archer , R.D. Hill , editors, Clean electricity from photovoltaics, *London: Imperial College Press, 377-445 (2001)*

[20] H. Hoppe and N. S. Sariciftci, *J. Mater. Res. 19, 1924-1945 (2004)*

[21] A. Mayer et al. ,"Polymer-based solar cells". *Materials Today **10** (11): 28.doi:10.1016/S1369-7021(07)70276-6 (2007).*

[22] Serap Gunes, Niyazi Serdar Sariciftci, "An overview of organic solar cells ",*Sigma Vol./Cilt 25 Issue/Sayı 1(2007).*

[23] Solar Cell Efficiency Tables (Version12), *Progress in Photovoltaics: Research and Applications* 7 (1998). Website (University of New South Wales): www.pv.unsw.edu.au/eff/

[24] W. Shockley and H. J. Queisser "Detailed balance limit of efficiency of PN junction solar cells " *J.Appl.Phys.* 32, 510 (1961)

[25] C. F. van Nostrum "Self assembled wires and channels." *Adv.Mat.* 8, 1027-1030 (1996)

[26] B. O'Regan and M. Graetzel "A low cost, high efficiency solar cell based on dye-sensitized colloidal TiO2 films." *Nature* 353, 737 (1991)

Authors

First Author- Rashmi Swami
B.E.(Electronics), M.Tech.(Comp.Tech.)
Lecturer, Department of Electronics
Govt. Girl's Polytechnic Raipur - 492001(C.G.),India
E.mail- rashmi.swami3@gmail.com