

SOLAR ENERGY-CLEAN AND SILENT

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Abstract

In looking for the solution to the perennial problem of electric power supply in Nigeria, this paper analyses the solar energy conversion system; looks at the developments in photovoltaic cell fabrication so far and suggests its use by private individuals, corporate bodies and the national electric power industry (PHCN). Photovoltaic cell is very expensive but it is hoped that the price will come down since serious research work is still going on in that field.

Key words:- Solar, radiation, photovoltaic cell, radiated energy, efficiency.

1.0 Introduction

Solar cells absorb light energy and convert it to electric energy. They consume no fuel, make no noise, pose no health hazard and produce no waste products. Light is an electromagnetic radiation having the wavelength between 0.4mm to 4mm but 0.4mm is violet while 4mm is in infra red region[1]. We know that only the wavelength between 0.4mm to 0.8mm is visible light. Solar energy conversion involves directing the photon energy from the sun to move electrons in the irradiated material. The Radiated energy,

$$E_r = hf = h^C/\lambda \quad (1)$$

Where h is the plank's constant, 6.626×10^{-34} J-s, C is the velocity of light (3×10^8 m/s) and λ , the wavelength of the electromagnetic radiation.

However, this radiated energy, E_r , is depleted as it travels; so that at any distance, d , from the stricken point,

$$E_r = E_o + E_L \quad (2)$$

Where E_L is the energy lost in moving the electron while E_o is the energy at the distance, d .

In other words,

$$Nd = N_o e^{-\alpha d} \quad (3)$$

Where Nd is the photon at a distance, d , from the stricken point, α is the radiation coefficient and N_o is the applied photon. If α is meant to be $1/d$, eqn (3) becomes; $Nd = 1/3 N_o$. Indicating that about $2/3 N_o$ is lost in the process [2]. This is why it has been difficult to achieve more than 30% efficiency in photovoltaic energy conversion. The physical parameters of some materials are given in table 1.

Table 1: Parameters of some photo cell materials.

Material	Radiated energy, E_r		Intrinsic concentration	Mobility $m^2 v^{-1} s^{-1}$		Diffusion Constant $m^2 S^{-1}$	
	EV	Joules	Ni (m^{-3})	μ_n	μ_p	D_n	D_p
Silicon	1.12	1.79×10^{-19}	10^{16}	0.15	0.045	0.0039	0.0012
Germanium	0.67	1.07×10^{-19}	10^{19}	0.39	0.19	0.010	0.0049
Gallium Arsenide	1.42	2.27×10^{-19}	10^{12}	0.85	0.04	0.022	0.0010
Indium Phosphide	1.35	2.16×10^{-19}	10^{14}	0.46	0.015	0.012	0.00039

2.0 Trapping of Solar Radiation

Solar energy can be trapped in the following ways:

- By direct collection using solar panels made of semiconductor materials. This

arrangement is called photovoltaic cell (PVC) system.

- Other methods involve using special collectors: Some have a collecting center fed from heliostats or mirrors, some use microwave and dishes[1].

The heat generated from these processes can be used to heat water, the steam of which can be used to drive steam turbine.

2.1 The Photo Voltaic Cell

One form of the earliest photovoltaic cells was made of selenium as shown in fig1.

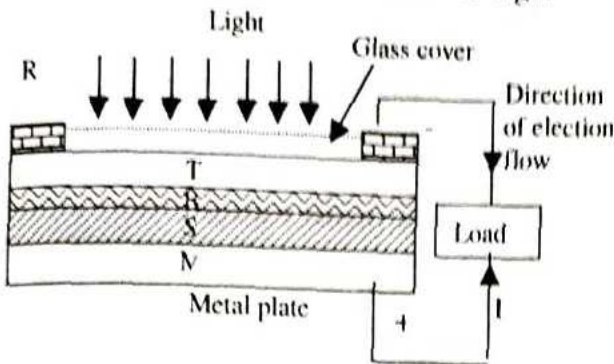


Fig1: Selenium photovoltaic cell

Light falling on the cell, through the glass cover, penetrates to the selenium film, S, deposited on a flat metal plate, M, causes electron to be released from the selenium, S. This electron passes through the copper oxide barrier layer, B, to the transparent metal film, T, from where it is picked up by the connecting ring, R, and to the load. The efficiency of this cell is less than 10% and today more research is still going on in order to improve on the solar conversion efficiency. So many arrangements have been tried but unfortunately the efficiency of 22% achieved by Gallium Arsenide has not been exceeded[3]. Homo-junction Silicon achieved an efficiency of about 18%. Table 2 shows the data for recently developed photovoltaic cells.

Table2: Recently manufactured Photovoltaic cell types and their efficiencies.

Types of cell	Semiconductor composition	Efficiency percent
Homo-junction	Silicon	18
Homo-junction	Gallium	22

Homo-junction	arsenide Indium phosphide	6
Homo-junction	$Al_xGa_{1-x}As$	18
Hetero-structure	PtU_2S/nSi	5
Hetero-junction	$PInP/nCdS$	14
Metal-insulator-semiconductor-cell (MIS)	Silicon	12
MIS	Gallium Arsenide	15
Semiconductor insulator-semiconductor-cell (SIS)	Indium tin Oxides /Silicon	12
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MIS	Gallium Arsenide	15
Semiconductor insulator-semiconductor-cell (SIS)	Indium tin Oxides /Silicon	12
SIS	Tin oxide/silicon	12
Heterojunction	$PCdTe/nCdS$	8
Schottky barrier	wSe_2	5
Polycrystalline	Silicon	8
Thin film/thin film	$PCu_xS/nCdS$	9
Thin film heterojunction	$PCu_2Te/nCdS$	6
Thin film amorphous semiconductor, schottky Barrier	Silicon	6

2.2 Photovoltaic Energy.

The light energy is converted to d.c. voltage in a unit cell. Cells can be combined to form a module, and modules can be arranged into photovoltaic panel. Panels can also be arranged to form solar panel arrays for the purpose of building up the photovoltaic energy, Ep.

The basic arrangement of photovoltaic array to produce electricity is shown in fig 2.

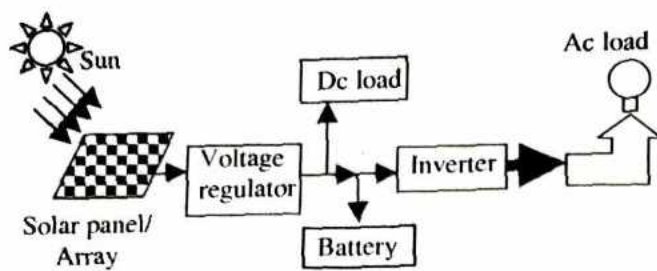


Fig 2: Photovoltaic energy conversion system

If E_s is the solar radiation and the conversion efficiency = 0.3

Then maximum photovoltaic energy,

$$E_p = 0.3E_s \quad (4)$$

If E_d = maximum demand from the PVC

$$E_d = \sum_{t=0}^T P_t \cdot t \quad (5)$$

Where P_t is the power consumed at time, t , and T = no of hours in use.

The maximum load, E_m , that can be connected to the PVC can be given as

$$E_m \leq 0.3E_s/T \quad (6)$$

Also

$$E_m \cdot T = P_t \cdot T \cdot K_1 \cdot K_2 \cdot \eta_{ef} \quad (7)$$

Where;

T = no of hours in use

K_1 = Radiation constant depending on the radiation intensity period of the day.

K_2 = Radiation constant depending on the season of the year and

η_{ef} = the overall efficiency of the system.

Since the charging rate of the battery is related to the capacitance, C_B , of the battery;

$$C_B = \frac{P_t \cdot T \cdot C_1 \cdot C_2}{V_{pv}^2} \quad (8)$$

Where: C_B = capacitance of the battery,

V_{pv} = the terminal voltage of the PVC

C_1 = loss factor during charge and discharge and

C_2 = over-charge factor (about 1.05)

Photovoltaic cells are very expensive and cannot be afforded by the poor. The average cost of installation is about ₦2,000/watt. That is to say that it will cost about ₦200,000 to install a 100watts of PVC system. However it is hoped that with time the price will go down since more research work is going on in that field.

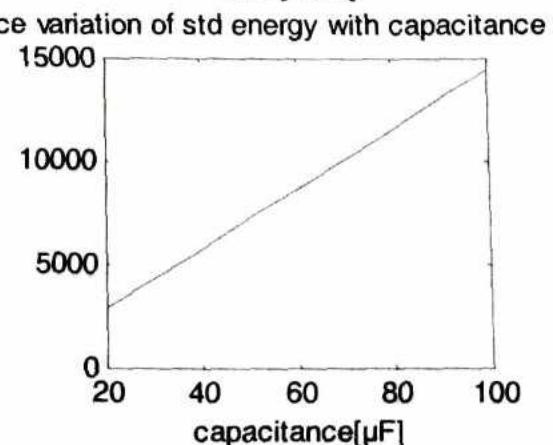
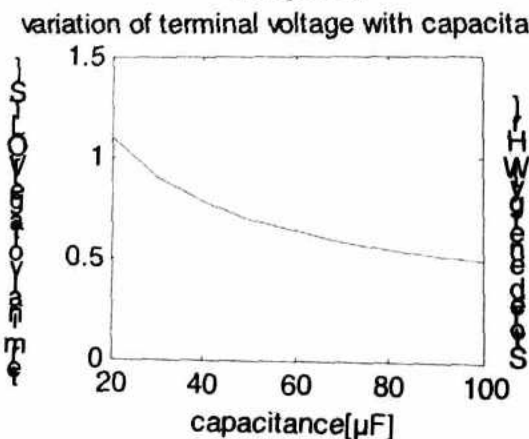
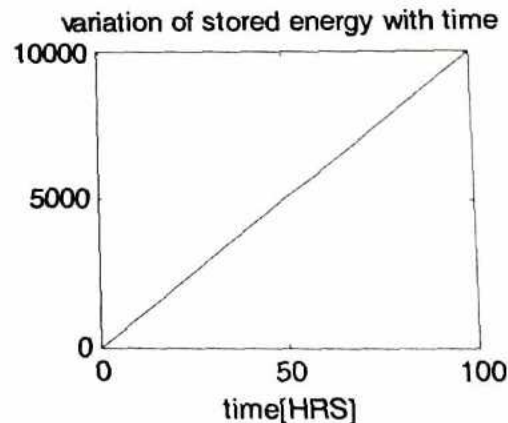
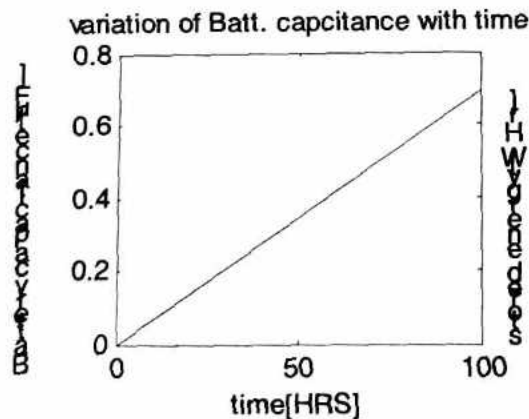


Fig.3 Effect of variation of parameters in PVC system

3.0 Recent Advances in Photovoltaic Cell Manufacturing

Promising advances have been made in PVC fabrication processes. Different ways of producing thin sheets of monocrystal silicon may replace the older methods of chemical processing, zone refining and down through slicing and polishing of the ingots.

The new method of film depositing of semiconductor compounds seem to be offering greater efficiency and low cost: For example amorphous silicon instead of monocrystal silicon products[5].

We may study variety of solar-cell types which could be developed for possible use as large-scale electric power supplies.

Silicon photovoltaic cells are the first cells developed in bell laboratories in 1954. But now many types have emerged and more are still under research. Table 2 shows some of the developed solar cells with their efficiencies.

Now the target is to produce single crystal sheets by methods different from the conventional slicing of large monocrystal ingots produced or grown by the Czochralski process. Mobile Tyco coy produced silicon ribbon by pulling from molten ingot through a narrow slit crucible. WestingHouse formed a ribbon through by pulling a web of silicon out of container of molten silicon. Cells made by the web - dendrite process have efficiencies comparable to those made from Czochralski process. The sheet-growth methods promise better efficiencies and low cost when they are perfected.

Solarex (USA) and AEG-Telefunken (Germany) are making cells from polycrystalline silicon sheet with grain dimensions in millimeter range. The production of 'poly' materials does not require a big degree of process control as does in monocrystal materials. Another advantage of producing sheet material is that any shape, other than circular shape, can be produced from it because

Czochralski process produces only circular shape ingots.

Fabrication costs can be reduced also by improving methods of forming semiconductor junction; for example, through ion implantation, followed by laser or electron-beam annealing/molecular beam epitaxy, instead of the conventional diffusion process.

There are two types of two layered cells;

- (i) Semiconductor - Insulator - semiconductor (SIS) and
- (ii) Metal - Insulator - semiconductor (MIS). They can be achieved by simple and in-expensive deposition processes.

Amorphous silicon could be doped by adding phosphine (PH_3) to produce n-type material and diborane (B_2H_6) to produce p-type material. A thin layer about 50nm of n-type hydrogenated amorphous Silicon (a-si:H) from a gas mixture of PH_3 and SiH_4 into a still substrate. The ratio of PH_3 and SiH_4 in the mixture is about 1:100.

Next step is the application of a layer of about 0.3 to 1.0 μm of undoped (a-Si. H). Anti reflection coating is formed by depositing 45nm of ZrO_2 in a p-i-n cell [5].

1. GALLIUM ARSENIDE SINGLE - CRYSTAL CELLS: One version of this type of cell consist of a heterostructure of Aluminum-gallium arsenide over a gallium arsenide pn junction.

Another type consists of a very thin film of n-type GaAs of about 10 μm on a P-type GaAs substrate the efficiency is about 22%

2. ELECTROCHEMICAL SOLAR CELLS: A semiconductor/liquid-junction cell. This type of cell was developed in Bell laboratories (USA). It consists of a single-crystal of gallium arsenide, in a solution of selenium compounds. Ruthenium is first used to treat the surface of the crystal to increase the efficiency and then etched

to increase light absorption area. The efficiency of this cell is about 12%. A silicon Pn junction wafer immersed in an acid solution is another type of solar cell developed by Texas instrument. Light impinging on the wafer sets up current that decomposes the acid and generating hydrogen gas which can be stored as fuel

3. **AMORPHOUS SILICON CELLS:** This is another promising cell – very simple to fabricate. It consists of non-crystalline glass-like silicon. The cells can be simply produced by passing Silane (SiH_4) over a substrate in a radio frequency discharge. Although the efficiency is about or little above 5.5% this type of cell attracts further research due to the simple way it can be produced. See fig. 4 for the RCA version of the amorphous silicon cell.

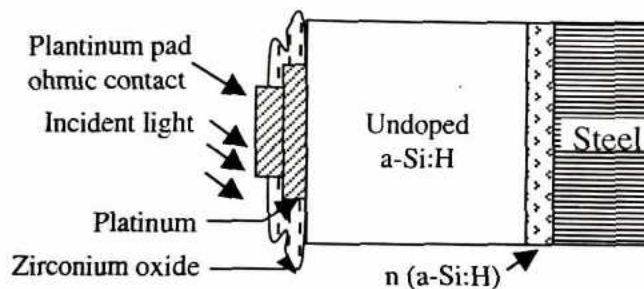


Fig4: One Form of Amorphous Cell (Schottky barrier [a-Si:H] cell)

4. **THIN-FILM COPPER-SULPHIDE/CADMIUM – SULPHIDE CELLS.** This consists of polycrystalline cadmium sulphide layer deposited on a glass or metal substrate, a copper sulphide on the cadmium sulphide. The interface between the copper sulphide and the cadmium sulphide is a heterojunction Pn diode since it is between two layers of dissimilar semiconductors. See fig. 5. The efficiency is about 9%.
5. **POLYCRYSTALLINE GAAS CELLS:** These cells are based on GaAs polycrystal. The thin film poly GaAs is about or over 6.5% while poly

GaAs with MIS cells claims about or over 5% efficiency. (poly GaAs as the semiconductor layer).

6. **COMPOUND CELLS:** These cells are new and are based on materials such as indium phosphide/copper indium selenide, cadmium telluride. Much attention has not been given to this type of cell but the efficiency is well above 5%.

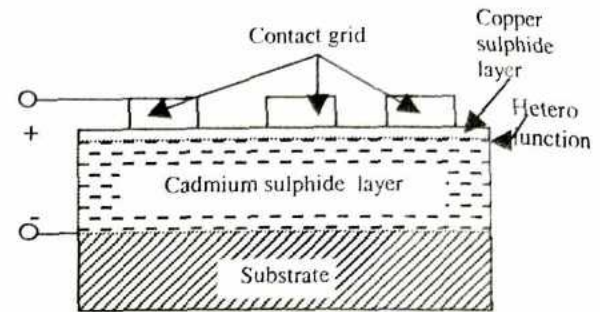


Fig 5: copper sulphide/ cadmium sulphide solar cell.

4.0 Adoption of PVC to Nigeria's Power System

The photovoltaic cell can be used by individuals or corporate bodies for domestic, commercial and industrial purposes. It can also be used by the PHCN to power isolated loads or synchronized to the national grid to support the available power since there is general demand for more electricity power to meet the energy requirement of the Nigerian populace. Again the experience of the Niger-Delta militants (who vandalized gas pipelines) has affirmed the need to diversify our energy sources [4]. The energy production in this country from 2000 to 2008 is shown in the table 3 and plotted in fig 6. It is very obvious that the energy demand of Nigerian electricity power consumers is very far not met.

Table 3: Actual Power Generated Capacity in Nigeria (2000-2008)

Year	Actual Generated Capacity (MW)	Max. Demand (MW)

2000	1175	3000
2001	2200	4000
2002	2700	4300
2003	2800	4800
2004	3000	6900
2005	3020	7100
2006	2850	7200
2007	2900	9250
2008	2650	10200

actual gen Power/max demand 2000-2008

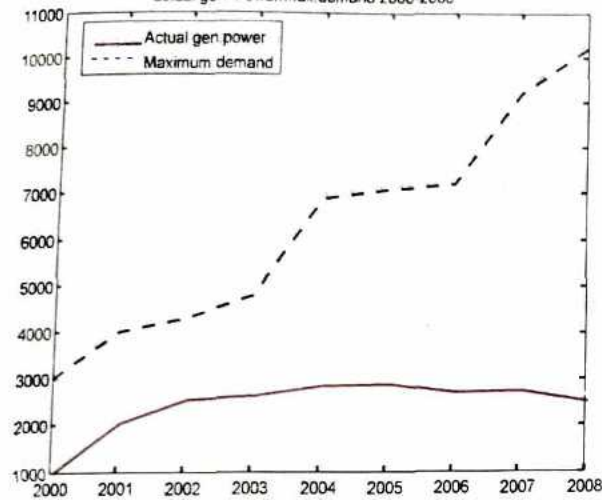


Fig 6: Actual Power Generated Capacity in Nigeria (2000-2008) plotted from table 3

5.0 Conclusion

Solar cells absorb light energy and convert it to electric energy. They consume no fuel, make no noise, pose no health hazard and have no waste products. Although it

produces clean energy, the conversion efficiency is still too low and yet it is still expensive, but there is hope that the price will come down since aggressive research is still continuous in that field.

If properly located, the PVC can be used by an individual or group of individuals forming cooperative society in homes, commercial centers and/or industries.

The national electric power industry, PHCN, can use the PV cells to feed Isolated loads or can synchronized it into the grid system to boost energy supply.

References

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