

THE ROLE OF PHOTOVOLTAIC IN THE REDUCTION OF GREENHOUSE GASES

D. G. Diso^{1,2} and A. I. Abubakar²

¹Electronic Materials & Sensors Group, Materials and Engineering Research Institute, Sheffield Hallam University, Sheffield, S1 1WB, United Kingdom.

²Department of Physics, Kano University of Science & Technology, Wudil, PMB 3244, Kano-Nigeria.
E-mail: dgdiso@yahoo.co.uk

ABSTRACT

The use of solid, liquid and gaseous fuels continuously pumps large quantities of oxides of sulphur, nitrogen and carbon into the atmosphere contributing to the pollution of the environment causing health problems, global warming, climate instability and acid rain. Forests are cut down to produce wood as the major fuel, creating problems of soil erosion, increased risk of floods and in some areas desertification. Photovoltaic (PV) is the direct conversion of sunlight into electricity by solar cells. It is a renewable, versatile technology that can be used for almost anything that requires electricity, from small, remote applications to large, central power stations. PV energy not only can help meet the growing worldwide demand for electricity, but it can do so without incurring the high environmental costs of burning fossil fuels. The system size varies from 50 W to 1 kW for standalone system with batteries storage, from 500 W to 5 kW for top grid connected ground based systems and larger building integrated systems.

KEYWORDS: Photovoltaic, Fossil fuels, Greenhouse gases, Environment

INTRODUCTION

The photovoltaic effect was first observed by a French experimental Physicist Edmund Becquerel in 1839 [1] while experimenting with an electrolytic cell, made up of two electrodes placed in an electricity-conducting solution. He observed that current increased when the electrolytic cell was exposed to light [2]. Adams and Day in 1876 [3] observed a similar effect in a selenium diode. PV devices based on Se and CuO were developed in 1930s [4-7] and found application as cheap, simple to operate devices for measuring light intensity, but their efficiency is <1%. Crystalline silicon was used to produce a solar cell with an efficiency of 6% by F. M. Chapin et al. [8] and this solar cell was considered for generating power. The energy bandgap (E_g) is equal to 1.1 eV which is not the best material for solar cell conversion, and therefore a strong research interest has been in progress, for PV applications, of other semiconductor materials such as GaAs [9] and CdTe [10, 11] which have energy bandgaps close to the optimum value of $E_g = 1.5$ [12]. This is the minimum value of the visible region in the solar spectrum. CdS/Cu₂S thin film solar cell [13, 14] is another device of early interest but its energy bandgap is 1.2 eV which is lower than the optimum value of 1.5 eV, but these devices were found to degrade with times after substantial research efforts and its stability problem has not been overcome [15]. It also showed degradation in the short-circuit current (J_{sc}) and fill factor (FF) under illumination due to the electrochemical decomposition of Cu₂S at operating voltages of higher than 0.33 V and the rapid diffusion of Cu through the junction structure.

Today, solar cells and modules can be divided into two main categories: wafer type and

thin film. Wafer-type cells are made from silicon wafers cut from a rod or ingot, or from a silicon ribbons. Thin film cells are deposited directly onto a substrate, usually glass, stainless steel, or plastic. Currently, CuInSe₂ and CdTe are the key candidates (materials) used for thin film solar cells worldwide [16, 17]. In 1969, E. I. Adirovich et al. [18] fabricated first thin film solar cell based on CdS/CdTe with an efficiency of 1%. A CdTe thin film was evaporated onto a glass/SnO₂/CdS substrate. At the Battle Institute in Frankfurt, Bonnet et al. in 1972 [19] produced another devices with an efficiencies in the range 5 - 6 % using close space sublimation (CSS) to deposits CdTe on a CdS substrate. In 1982 [20], Tyan and Perez had produced 10% efficiency cell, and Wu et al. [21] in 2001 reported the highest world record CdTe solar cell conversion efficiency of 16.5% under air-mass 1.5 (AM1.5) illumination, with $V_{oc} \sim 845$ mV, $J_{sc} \sim 25.88$ mA/cm² and FF \sim 75%. PV technology is a uniquely attractive source of electricity. The technology is already cost-competitive with traditional alternatives such as kerosene lamps and small diesel generators compared to the energy from fossil fuels, solar energy system are flexible, low maintenance, pollution free and environmentally benign.

TYPES OF SOLAR ENERGY TECHNOLOGIES

Solar energy is a renewable resource that is inexhaustible and readily available, unlike fossil fuels. It is a clean energy sources that can be used pollution-free and allows for local energy dependence. This energy can be tapped indirectly as wind, biomass and hydroelectric power, and directly as solar energy (thermal and photovoltaic). The renewable resources are free and the cost to use them is lower than non renewable.

There is a strong need to develop renewable energy sources, nearly 80% of all energy used worldwide originate from fossil fuels. This massive exploitation of fossil fuels improves a major threat to the environment in terms of emission of greenhouse gases and acid rain [22]. Solar energy can be utilized in three ways.

Passive solar system

The sun's energy is converted directly into heat for use for at the site where it is collected. Light energy is transformed to heat energy where it is absorbed by a surface. Some of the earliest uses of this system were to dry food and clothes and to evaporate sea water to produce salt. Since there are no moving parts a passive solar system is maintenance free. None of energy is used to transfer heat within the system, and there are no operating costs.

Active solar system

In an active solar system, the sun's energy is converted into heat, but the heat must be transferred from the collection area to the place of use. It requires a pump and a system of pipes to transfer the heat from the site of its production to the area to be heated. It requires a specially designed collector, consisting of a series of liquid-filled tubes; a pump and a pipes to transfer the warm liquid from the collector to the space to be heated.

A device called flat plate collector is used for these purposes. It consists of glass cover plate over a black background where water is circulated through tubes. Short-wave solar radiation enters the glass and is absorbed by the black background. Longer wave radiation is emitted from the black material, but it cannot escape through the glass, so it heats the water in

circulating tubes to 38°C to 93°C. An active solar system has no moving parts; it also has operation and maintenance costs like any other heating or cooling system.

Photovoltaic

A solar cell or photovoltaic cell is a device that converts light energy into electrical energy. All solar cells require a light absorbing material contained within the cell structure to absorb photons and generate electrons via the photovoltaic effect. The solar cell is the basic building block of solar PV modules and panels. The cell can be considered as a two terminal device which conducts like a diode in the dark and generates a photo voltage when charged by the sun. The cells are connected together in series and in capsulated into MODULES. A module typically contains 28 to 36 cells in series to generate a d.c output voltage of 12 V in standard illumination conditions (i.e. AM 1.5). The 12 V modules can be used singly or connected in parallel and series into an array with a larger current and voltage output, according to the power demanded by the application. When a solar cell is exposed to the solar spectrum, a photon that has energy greater than the bandgap, makes no contribution to the cell output i.e. does not generate any electron-hole pairs. A photon that has energy greater than the bandgap contributes to the cell output by creating an electron-hole pair.

Figure 1 show the equivalent circuit of a solar cell consisting of a current generator in parallel with a resistor-diode network. The photo-induced current I_{ph} is proportional to the intensity of solar radiation S (in kWm^{-2}) expressed as [23].

$$I_{ph} = \left[I_{scr} + C_i \frac{T - T_r}{1000} \right] S \tag{1}$$

where, T is the cell temperature, T_r is reference temperature, I_{scr} is short circuit current under the reference operating conditions (i.e. $1 kWm^{-2}$, AM 1.5, 298 K), C_i is the temperature coefficient of short circuit current.

The forward dark current relationship of a solar cell can be expressed as;

$$I_D = I_o \left[\exp\left(\frac{eV}{nkT}\right) - 1 \right] \tag{2}$$

or
$$I = SAT^2 \exp\left(\frac{-e\phi_b}{kT}\right) \left[\exp\left(\frac{eV}{nkT}\right) - 1 \right] \tag{3}$$

where, I is the external current flow, e is the electronic charge = $1.602 \times 10^{-19}C$, ϕ_b is the potential barrier height, k is the Boltzmann constant = $1.38 \times 10^{-23}JK^{-1}$, T is the absolute temperature, S is the area of the contact, A is the effective Richardson constant = $12 \times 10^4 AKm^{-2}$ and n is the diode quality factor, which depends on the dominating transport mechanism and usually varies from 1 to 2. For pure thermionic emission, $n = 1$ and for pure recombination and generation, $n = 2$.

For applied voltages, $V > 0.075 V$; $\exp\left(\frac{eV}{nkT}\right) \gg 1$ and therefore equation 2 reduces to

$$I_D = I_o \exp\left(\frac{eV}{nkT}\right) \quad 4$$

The saturated current I_o can be expressed for Schottky or p-n junction;

For a Schottky junction; $I_o = SAT^2 \exp\left(\frac{-e\phi_b}{kT}\right) \quad 5$

For a p-n junction; $I_o = Aq\left(\frac{D_p P_{no}}{L_p} + \frac{D_n n_{po}}{L_n}\right) \quad 6$

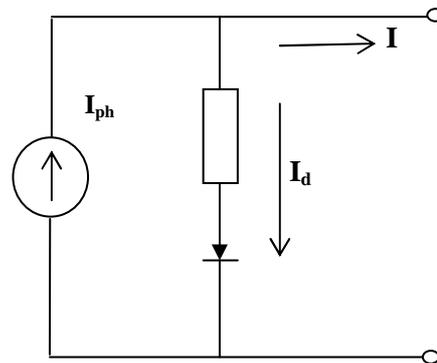


Figure 1: Equivalent circuit of solar cells.

In PV solar cell devices, three main functions should occur in order to achieve higher conversion efficiencies. These are, namely:

1. Absorption of the major parts of the solar spectrum,
2. Effective creation of electron-hole pairs within the devices, and
3. Separation of charge carriers before their recombination and passage of these through the external circuit to create useful power.

THE USE OF FOSSIL FUELS AND THE ENVIRONMENT

The fossil fuels are all forms of stored solar energy and they are found within the top layer of the earth's crust. They range from very volatile materials with low carbon: hydrogen ratios like methane, to liquid petroleum to non volatile materials composed of almost pure carbon, like anthracite coal. It is generally accepted that they formed from the fossilized remains of dead plants and animals by exposure to heat and pressure in the earth's crust over hundreds of millions of years [24, 25]. The use of solid, liquid and gaseous fuels continuously pumps large quantities of oxides of carbon, sulphur and nitrogen into the atmosphere, polluting the global environment, causing health problems, global warming, climate instability and acid rain. Fossil fuels and nuclear energy provides 80% of the energy required today, with more than 70% of the energy being consumed by developed countries [26].

Carbon dioxides (CO_2) is produced when oil, coal and gas combust into power station, heating system and car engines. CO_2 in the atmosphere acts as a transparent blanket that contributes to

the global warming of the earth or greenhouse effect. It is possible that this warming trend could significantly alter our weather. Possible impacts include a threat to human health, environmental impacts such as rising sea levels that can damage coastal areas. Sulphur dioxide (SO_2) is also emitted into the air when coal is burnt; it reacts with water and oxygen in the clouds to form precipitation known as acid rain which kill fish and trees. Monuments and sculptures made from marble and limestone are particularly vulnerable, as the acids dissolve calcium carbonate.

Fossil fuels also contain radioactive materials, mainly uranium and thorium, which are released into the atmosphere. In 2000, about 12,000 metric tons of thorium and 5,000 metric tons of uranium were released worldwide from burning coal [27]. It is estimate that during 1982, US coal burning released 155 times as much as radioactivity into the atmosphere as the Three Mile Island incident [28]. In both fossil fuels and nuclear power plant, generating steam to produce electricity results in a great deal of waste heat. In a nuclear power plant, only one-third ($\frac{1}{3}$) of the heat generates electricity, and two-third ($\frac{2}{3}$) is waste heat [29]. The addition of this waste heat to the environment is known as Thermal pollution, and this is particularly a problem in aquatic environment, since many aquatic organisms are sensitive to changes in the temperature. Primary air pollutants are emitted directly into the air when fossil fuels are burned. They include particulates, SO_2 , CO, NO and hydrocarbons. The reaction between primary pollutants and normal atmospheric compounds yields secondary pollutants, e.g. ozone.

ENVIRONMENTAL ISSUES RELATED TO PV

Since PVs does not generate emissions during operations, the environmental impacts are mainly associated with emissions related to production of modules and their disposal at the end of their service life. All PV system rely on metals to a large extent, both in semiconductor compounds and its contacts, as well as for modules fumes, connectors and supporting structures. As PVs is increasing its small but steadily growing fraction of the global power production, the demand for metals will increase. In particular, mass production of the emerging thin films technologies would to accelerated many of the elements Cd, Te, In, Ga and Ru, which could SO₂ emissions and metal leakage from waste dumps, and cause large-scale land transformations [30].

PV modules will have to be decommissioned at the end of their useful life, 20 to 30 years after their first installation. In decommissioning these devices, the principal concern will be associated with the presence of these elements. If these solar based modules end in municipal waste incineration (MWI), the heavy metals will gasify and a fraction of those will be released in the atmosphere. If the MWI is equipped, this fraction can be small as 0.5% with the balance of the heavy metals remaining in the ash. The ash itself will have to be disposed of in controlled landfills. A valid assumption is that, the modules will be either recycling or disposed off at the end of their useful life, therefore atmospheric emissions during and after decommissioning will be zero. Even if pieces of modules inadvertently make

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it to MWI, the element(s) will dissolve in the molten glass and would become part of the solid waste.

CONCLUSION

Solar energy is a renewable resource that is inexhaustible and readily available, unlike fossil fuels. It is a clean energy sources that can be used pollution-free and allows for local energy independence. The renewable resources are free and the cost to use them is lower than non-renewable. Solar cells, which are semiconductors diodes, convert sunlight directly to electricity without any noise or pollution through the photovoltaic effect. The use of fossil fuels continuously pumps large quantities of oxides of carbon, sulphur and nitrogen into the atmosphere, polluting the global environment, causing health problems, global warming, climate instability and acid rain. PV uses in generating electricity is free from any hazards than coal-fired power plants is erroneous: the former are impossible during normal use, whereas the later happen routinely during normal operation. During a useful life of 20 to 30 years, the solar modules containing these elements do not produce any pollutants or noise, and furthermore, by displacing fossil fuels, they offer great environmental benefits.

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