

Hybrid Solar Cells Based on Organic Inorganic Materials Photovoltaic Applications: A Review

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Abstract

Hybrid solar cells based on organic/inorganic materials would be fabricated from conjugated polymers and inorganic oxide materials. Nanostructured dye sensitized solar cells would be designed and efficiencies will be evaluated from semiconducting oxides and mixed oxides semiconductors. New strategies would be followed for extending the electrolyte absorption range as well as co-sensitization would be incorporated in the system. This review enumerates the results of researchers about different types of organic and inorganic solar cells and its parameters.

Keywords: Solar cells; Photovoltaic; Organic/inorganic materials; Efficiency

Introduction

The photovoltaic effect was discovered in 1939 by French experimental physicist, Edmund Becquerel, while experimenting with an electrolytic cell made up of two metal electrodes. It was not until 1950s that a major breakthrough was made in terms of development of p-n junction based PV cells. In 1954 Bell Labs reported the development of silicon solar cells with an efficiency of 4.5% that was raised to 6% within a few months. These solar cells were primarily driven by the power requirements for space programs and satellites.

Efficiency of Hybrid Solar Cells

Hoffman Electronics made crucial advancements in the technology lowering the production cost and increasing the efficiency to 14% by 1959, also contributing to solar-powering the first satellite Vanguard 1 that was launched in 1958. This solar cell technology could produce reliable electricity for long periods, especially with no maintenance. Solar cells have dropped significantly, leading to inexpensive mobile devices such as solar powered calculators and cell phone chargers. For large scale power generation, the cost for every watt of electricity produced from photovoltaic remains higher than alternatives such as energy from coal or nuclear power. The overall trend for decreasing costs for solar cells is likely to continue into the foreseeable future. Photovoltaic cells hold great promise in future applications the smallest practical electric motor for a car requires about 40 kW of energy, at 40% efficiency. The limited energy in sunlight restricts the performance of any vehicle that relies on photovoltaic cells [1].

According to Shockley and Queisser, the thermodynamic efficiency for an ideal single junction cell is around 31% [2]. This is because the efficiency of a single-junction device is limited by transmission losses of photons with energies below the band gap and thermal relaxation of carriers created by photons with energies above the band gap [3]. Higher efficiencies can be obtained from solar cells by better capitalization of the solar spectrum. One way of doing this is through multi-junction cells that combine two or more cells with different band gaps. Tandem cells made from different materials with different band gaps can significantly increase the efficiency. Over 41% efficiency has already

been achieved from multi-junction cells that are presently being used mainly in space applications [4]. A solar cell, or photovoltaic cell (PV), is a device that converts light into direct current using the photoelectric effect, and the prototype selenium cells converted less than 1% of incident light into electricity, both Ernst Werner von Siemens and James Clerk Maxwell recognized the importance of this discovery [4]. To avoid the use of noble metals (i.e., platinum), subsequently used their one-step hydrothermal route to synthesize novel cadmium zinc sulfide/TNT (i.e., $Cd_{0.5}Zn_{0.5}S/TNT$) nano composites with low-cost metallic elements. This architecture led to the high level of dispersion of the $Cd_{0.5}Zn_{0.5}S$ nanoparticles, and to the intimate multipoint contacts between the $Cd_{0.5}Zn_{0.5}S$ and the TNTs. Under visible light irradiation, the $Cd_{0.5}Zn_{0.5}S/TNTs$ exhibited improved activities for hydrogen evolution compared with a single $Cd_{0.5}Zn_{0.5}S$ particle. They also examined the effect of sacrificial reagents on the photo catalytic activity of $Cd_{0.5}Zn_{0.5}S/TNTs$. They obtained a highest apparent quantum yield of 38.1% at 420 nm. Moreover, the $Cd_{0.5}Zn_{0.5}S/TNTs$ displayed good stability for hydrogen production and the (toxic) cadmium content was as low as 4 wt% in the Nano composites. All of these factors are important and beneficial for the application of $Cd_{0.5}Zn_{0.5}S/TNT$ Nano composites in the field of solar energy conversion (Figure 1) [5].

There has been a growing amount of attention to 2D met surfaces since their introduction for manipulating the propagation of electromagnetic waves. Indeed, many researchers have explored various designs for the deflection of an impinging beam into anomalous refraction channels. These specific characteristics of the NiS_x/CdS

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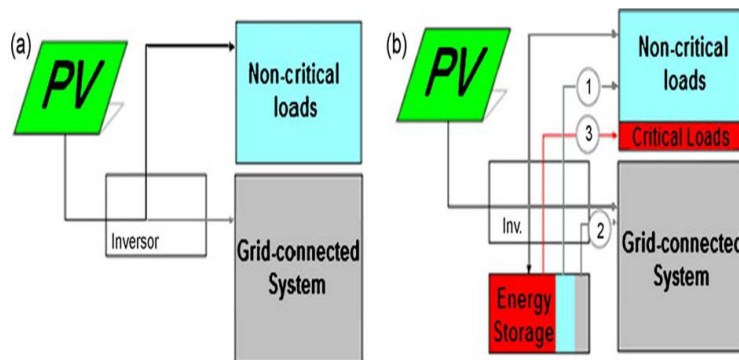


Figure 1: Photovoltaic systems interconnected to the grid. (a) Without energy storage; (b) Utilizing energy storage with the following options: (1) Local load management; (2) Load management for the utility; (3) Considering critical emergency loads.

resulted in efficient charge separation and rapid surface reaction. These, in turn, gave rise to significantly improved photo catalytic activity, with an apparent quantum efficiency as high as 60.4% at 420 nm [6].

GA As and its ternary alloys hydrogenated amorphous Si copper Indium dieseline, CdTe solar cell was reported by Si (16%) solar cell was analyzed by Bailey and Flood [7], Si (18%) solar cell was reported by Jaganathan and Anderson [8]. A-Si:H/c-Si heterostructured solar cell was reported by Wronski [9]. Polycrystalline Si:H (3.15%) solar cell was reported by Diehl et al. [10]. C-Si:H window layer or intrinsic layers in Solar cells was reported by Fujiwara et al. [11]. The photovoltaic effect is one of the possible forms of solar energy conversion into electricity which occurs in devices known as photovoltaic cells. Solar energy conversion occurring in these photovoltaic cells consists of two essential stages [12]. The photovoltaic system with a NaS battery storage system is an efficient method to add value and make its connection to the energy grid economically viable.

For a solar cells,

Open circuit voltage (V_{oc}):

$$V_{oc} = \left[\frac{I_{sc}}{I_o} \right] \ln \left[\frac{I_{sc}}{I_o} \right] + 1$$

Power Output of a solar cell:

$$P = IV = I_o V \left[\exp \frac{qV}{nKT} - 1 \right] - I_{sc} V$$

The condition for maximum power can be obtained by setting $\frac{\partial P}{\partial V} = 0$ hence,

$$I_m = (I_{sc} + I_o) \frac{qV_m / nKT}{1 + qV_m / nKT}$$

as the current output is at maximum power and

$$\exp \left(\frac{qV_m}{nKT} \right) \left[1 + \left(\frac{qV_m}{nKT} \right) \right] = \left[\frac{I_{sc}}{I_o} \right] + 1$$

$$= \exp \frac{qV_{oc}}{nKT}$$

It allows the voltage at the maximum power point, V_m is to be calculated. The maximum output power is given by

$$P_m = I_m V_m$$

Fill Factor (FF) of a solar cell:

$$FF = V_m \left[\frac{I - (I / I_{sc}) [\exp(qV_m / nKT) - 1]}{(nKT / q) \ln[(I_{sc} / I_s) + 1]} \right]$$

$$= \frac{V_m}{V_{oc}} \left[1 - \frac{\exp(qV / nKT) - 1}{\exp(qV_{oc} / nKT) - 1} \right]$$

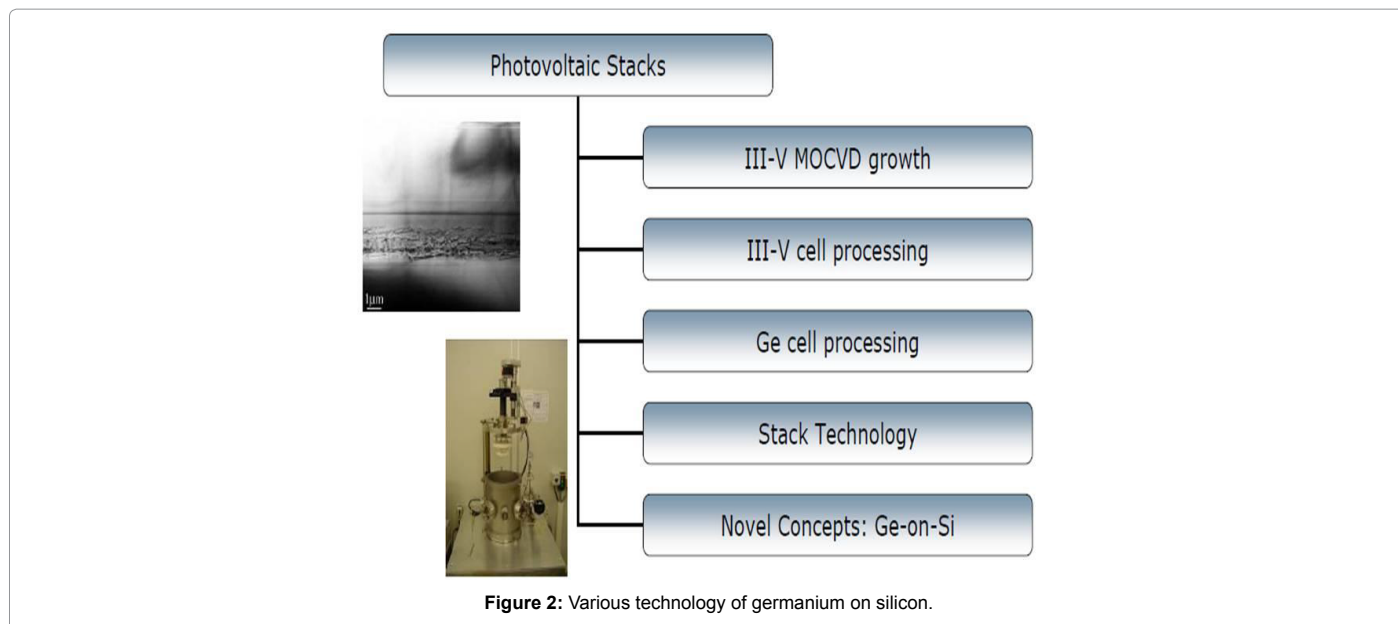
Conversion efficiency (η) of a solar cell:

$$\eta = \frac{V_m I_m}{P_m}$$

In future the investigation and exploitation of the effects of doping using organic semiconductors or gases like oxygen as dopants will most likely allow further enhancements of efficiencies; the photovoltaic effect was discovered in 1939 by French experimental physicist, Edmund Becquerel, while experimenting with an electrolytic cell made up of two metal electrodes. It was not until 1950s that a major breakthrough was made in terms of development of p-n junction based PV cells [13].

These solar cells were primarily driven by the power requirements for space programs and satellites. Hoffman Electronics made crucial advancements in the technology lowering the production cost and increasing the efficiency to 14% by 1959, also contributing to solar-powering the first satellite Vanguard 1 that was launched in 1958. Solar cells based on compound semiconductors (III-V and II-VI) were first investigated in the 1960s. At the same time, polycrystalline Si (pc-Si) and thin-film solar cell technologies were developed to provide high production capacity at reduced material consumption and energy input in the fabrication process, and integration in the structure of modules by the deposition process and consequently cost reduction for large-scale terrestrial applications [1]. According to Shockley and Queisser, the thermodynamic efficiency for an ideal single junction cell is around 31% [2,3]. This is because the efficiency of a single-junction device is limited by transmission losses of photons with energies below the band gap and thermal relaxation of carriers created by photons with energies above the band gap [14].

Higher efficiencies can be obtained from solar cells by better capitalization of the solar spectrum. One way of doing this is through multi-junction cells that combine two or more cells with different band gaps. Tandem cells made from different materials with different band gaps can significantly increase the efficiency. Over 41% efficiency has already been achieved from multi-junction cells that are presently being used mainly in space applications (Figure 2) [15].



In terms of composition, PV cells have seen a wide range of diversity; the mono- and poly-crystalline silicon PV cells are now being commercially accompanied by PV cells made of materials like gallium-arsenide, gallium-antimony, Copper-indium-diselenide and Cadmium-telluride. While the plastic and organic PV cells are largely in the research and development (R&D) phase, multi-junction tandem PV cells with efficiency of over 40% are already in market.

In 954 Bell Labs reported the development of silicon solar cells with an efficiency of 4.5% that was raised to 6% within a few months. All carriers that pass over the built-in potential with the probability $\exp(-qbi/kT)$ recombine with the velocity at the interface while all carriers that pass over the complete barrier recombine with the surface. Stangl reported that extracted from capacitance measurements, PEDOT:PSS introduces a ψ_{bi} of 690 meV in c-Si, a conduction band offset ΔE_c of 0.45 eV to c-Si, and selectivity comparably to p-doped a-Si:H with a valence band offset of 0.44 eV [16]. Accounting for the lower V_{OC} of the hybrid PEDOT:PSS/c-Si/a-Si solar cells, and c-Si surface in the PEDOT:PSS/c-Si junction cannot be as well passivated as in the conventional c-Si/a-Si junction by the thin a-Si:H(i) interlayer.

Graphene is deposited on top of a self-assembled CCNT monolayer which creates parallel conducting paths on the graphene surface. In order to understand the results, they developed a 2D resistance network model in which we couple the CCNT layer to the graphene sheet and demonstrate the model accounts quantitatively for the resistance decrease. They showed that a graphene-CCNT hybrid system has high potential for use as a transparent electrode in photovoltaic applications [17].

Discussion

A recent study published in Nature reveals development of low cost newly developed photovoltaic at the Princeton University which is made from organic materials, which consist of small carbon-containing molecules, as opposed to the conventional inorganic, silicon-based materials. These PV cells consist of materials that are ultra-thin and flexible and could be applied to large surfaces. The cells also could be made in different colors, making them attractive architectural elements. These cells are not only economical but have also achieved a significant

jump in efficiency - from the first organic solar cell, developed in 1986, with 1 percent efficient these newly developed cells have recorded an efficiency close to 5%. With further developments, the research is targeting to improve the efficiency of these cells to 10% (REW, 2013). Industry-academic research partnership in Germany have reportedly developed organic cells with 12% efficiency Heliatek achieves 12% organic solar cell efficiency [18,19].

Conclusion

The optically transparent and thermo chromic and smart film was prepared successfully via different technique. The PMMA-Nano composite showed the incorporation of Nano composites. The solar modulation ability is 6.88% with luminous transmittance of 21%. Incorporation of Hybrid solar cells achieved an efficiency of above 20% by the researcher. The efficiency enhancement is based on concurrent improvement in optical and electrical properties by the photon down conversion process and the improved conductivity of QDs. The short circuit current and the fill factor of Hybrid solar are increased from 30-40 mA/cm² and 62-64% respectively. The organic and inorganic hybrid solar cell obtained herein holds the promise developing photon managing, low cost and highly efficient photovoltaic devices.

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