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Solar Photovoltaic Paint for Future: A Technical Review

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Abstract. An extraordinary methodology is needed to satisfy the need of financially suitable solar cell technology. By utilizing ongoing advances in semiconductor nanocrystal research, we have now invented a one-coat solar paint for planning quantum dot solar cell. The conversion behavior of this semiconductor film electrode was assessed in a photo electrochemical cell comprising of graphene–Cu2S counter electrode and sulfide/polysulfide redox couple. The efficiency of Power conversion exceeding 1% has been observed for solar cells developed utilizing the straightforward traditional paint brush approach under ambient conditions. Though further upgrades are important to develop procedures for huge region, all solid state devices, this primary effort to make solar paint offers the benefits of simple design and financially suitable for next generation solar cells. The solar paint has shown the extensive possibility because of its flexibility, tunable size characteristics, and economically profitable nature in manufacturing. However, there is as yet a requirement for the improvement in the power transformation efficiencies of these paints, which elaborates further research to make the optimum materials for the paint. The point of this study is to discover the materials for the paint, which would have high electrical, thermal conductivities and higher efficiencies.

Keywords. Solar; Photovoltaic; Fill factor; Quantum dot

1. Introduction

This is the thought behind photovoltaic paint, a revolutionary new application for solar cells that is not difficult to apply, can be introduced anyplace, and is financially profitable. Sounds like something in the far off future, isn't that so? Not exactly. Various universities and researchers have been dealing with solar paint throughout the most recent 5 years, one in any event, going the extent that publicly supporting for business creation. Conventional solar cells use wafers made of light-sensitive silicon, a plentiful component tracked down all around the earth.[1] Unfortunately, refining of pure silicon from raw material is costly, laborious , and uses and creates various hazardous substances.

Eventually, however, this cycle is awesome, in light of the fact that silicon solar panel are genuinely efficient. The normal solar panel can change over about 18% of all the sunlight into usable electricity.[2]Right now, solar paint isn't pretty much as efficient as silicon-based solar cell and this is the single significant obstacle analysts should conquer before sun based paint is financially practical. Solar paint is generally stuck in the single digits – somewhere in the range of 3% and 11% depending upon its technology. When scientists figure out the economic way how to increase efficiency however, Solar paints going to popular with respect to silicon-based solar panels. Solar paint is needed to lower price and require specialized instruments and no hazardous chemicals, so there are too much barriers to entry for potential solar paint manufacturers. In 2014, researchers at the University of Toronto explored with a solar paint known as colloidal quantum dots. These dots are made of semiconductor and are utilized in solar cells just as LEDs and PCs. While others have recently utilized these light sensitive dots for solar, the university tracked down another approach to apply the dots that is quicker and less expensive than the customary mechanical production system framework. The dots are basically sprayed, layer by layer (the thickness of each molecule in turn), onto a backing. When dry, this backing can be transported, and applied to any surface actually like wallpaper.[3] As of 2014, the solar cells were just about 8% efficiency, not awful thinking about how from the get-go in the advancement interaction it is, however many concur that solar paint should arrive at 10% efficiency before it's monetarily feasible. 10% isn't close to as efficient as solar cell, but since solar paint is a lot less expensive to create even at this lower effectiveness level it's actually cost-effective [4].Dr. Torben Daeneke, from RMIT University in Melbourne, Australia, discovered that the compound in with titanium oxide particles prompts a solar paint that produces hydrogen fuel from sunlight and moist air. In 2016, researchers at John Hopkins University are exploring with colloidal quantum dots, exploring different layers in a different manner to make the things more efficient [5].As of 2013, the University of Buffalo in New York is likewise chipping away at solar powered natural photovoltaics, a plastic-like substance dependent on chains of hydrocarbon atoms. The solar cells can be suspended in a paint-like substance and splashed. The following Figure 1depicts the schematic diagram of thin film photovoltaic paint.

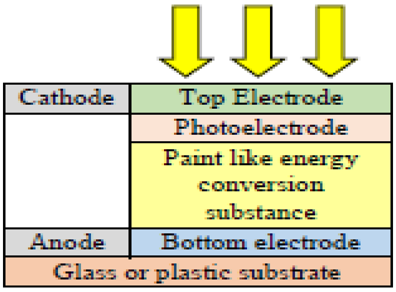

Figure 1. Schematic Diagram of Thin Film Photovoltaic Paint.

Likewise with the dots, the primary advantage of organic PV it is very lower cost to produce. In any case, though efficiency is lower than silicon-based PV module and below the 10% threshold.

2. Principle of Operation

The basic principle of photovoltaic paint with a thin film architecture can be defined as when sunbeam strikes the light absorbing substances (photo electrode), electrons of photo electrode gains energy and the drifted electron with high-energy into a layer of paint like substance, leaving behind an electron vacancy. Then the electrode collected the electron and power is produced using the energy from the electron. This drift of electron completes the circuit by combining with an electron vacancy as illustrated in Figure 1. The solar paint additionally can join the sensitizer and large band gap semiconductor in a single layer.

The power conversion of solar cells depends on the principle of photovoltaic impact. Photons of energies more than the band gap energy (Eg) are absorbed and accordingly, an electron energizes from the valence band to conduction band. Solar cells have inherent asymmetry which makes the electrons reach towards outside circuit utilizing an electrical potential. For getting better efficiency, we need stability on Open circuit voltage (Voc), Short circuit current density (Isc) and fill factor (FF). These parameters are directly related to improvement of efficiency.

$$PCE = I_{sc} V_{oc} FF / P_{in}$$

Where, V_{OC} : Open circuit voltage,

I_{SC}: Short circuit (photo) current,

FF: Fill factor (It is a ratio of actual maximum obtainable power to the product of the open circuit voltage and short circuit current.

$$P_{\max} = I_{\max} V_{\max}$$

and is defined as the product of I_{SC} and V_{OC} and is also a measure of the squareness of I vs V profile). Efficiently extraction of electrons and holes is the most important key parameter for highly efficient solar cells. Solar cell performance is determined by the measurement of current density as the voltage across the photovoltaic device is biased with the variable load during the insulation of device. Figure 2 depicts the plotting of energy versus temperature.

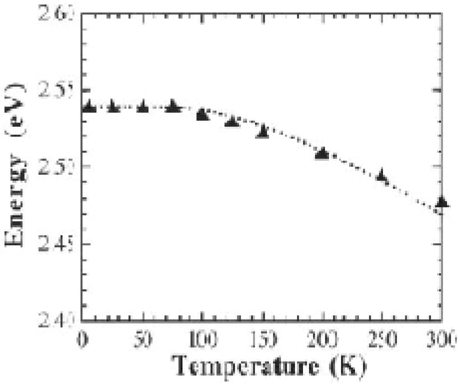

Figure 2. Plotting of Energy vs Temperature.

As the energy of photon is inversely proportional to the wavelength 1240/λ[nm]); Therefore, the value of short circuit current (ISC) depends on the value of band gap energy Eg . If the value of E is greater than the value of Eg and the solar spectrum is over the visible and infra-red regions, then generally the ISC factor increases with the increasing λ . Even though power conversion efficiency (PCE) increases with ISC, there is also an existence of optimum value of Eg for attaining significant PCE because of the trade-off associated with VOC. The band gap energy (Eg) required achieving optimum power conversion efficiency ranges from 1.0 to 1.6 eV for the crystalline silicon solar cell. However, photovoltaic paint requires band gap energy (Eg) ranging from 0.6 to 1.1 eV to achieve optimum power conversion efficiency through utilizing multiple excitation generation. With the increase of thickness of the film there is an exponential decrease in the absorption of light intensity. Therefore, thickness of the photoactive layer is a important parameter dominating the PCE for a solar cell as compared to the absorption length (1/α), where "α" is the absorption coefficient in cm-1 and it is the distance over which 63% of the non-reflected light is absorbed. Monocrystalline or Polycrystaline solar cells have relatively low values of α, which results in the need of thicker photoactive layers of hundreds of millimetres and micrometers and this significantly causes an increase in the production cost of crystalline solar cells. Alternately, photovoltaic paints need thinner photoactive layers, which in turns bring about the decrease of material cost and production cost. The following Figure 3(a) and 3(b) are representing the plot of current density versus voltage of a solar cell and the plot of photon flux density and maximum attainable short-circuit current density.

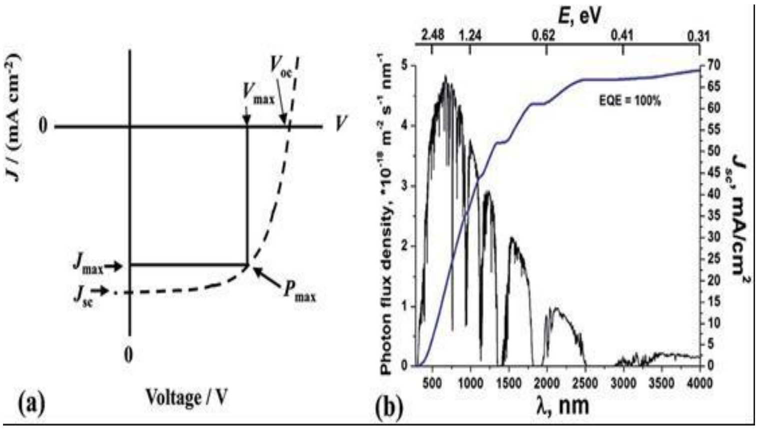

Figure 3(a). Current density vs voltage of a solar cell. **(b)** Photon flux density and maximum attainable short-circuit current density.

3. Results

Table 1. Best Research Cell Efficiencies of Different Generation Solar Cell

Generation	Solar Cell	Efficiency (%)	Reference
First	Crystalline Silicon	26.7±0.5	[14]
First	Multi Crystalline Silicon	22.3±0.4	[15]
Second	Amorphous Silicon	14.0±0.4	[16]
Second	Micro Crystalline Silicon	11.9±0.3	[17]
Second	CIGS (cell)	23.3±1.2	[18]
Second	CdTe (thin film)	22.1±0.5	[19]
Third	Dye sensitized (cell)	11.9±0.4	[20]
Third	Organic (thin film)	11.2±0.3	[21]
Third	Perovskite (thin film)	22.7±0.8	[22]
Third	Quantum dot sensitized	9.56±0.12	[23]

The level of efficiency of the third generation solar cells is lagging to achieve comparable with other generations (Table 1). Therefore, the materials which will be used for photovoltaic paint is a critical factor towards the enhancement of efficiency. Each material has its own attractive features. However, the selection of each material associates with the availability of raw materials and adequate manufacturing process. Most of the second and third generation materials are use to making photovoltaic paint.

Among the various models of materials, Tandem Solar cell consolidated with Quantum dot solar cell (QDSSC) has band-gap with tuning facility, which differs by changing their size. Then again, the decision of material makes the band gap fixed in mass materials (CIGS or CdTe). Additionally, QDSSC has higher absorption coefficient, tuneable band gap, capacity to create multiple electron-hole pair just after striking with one photon, huge size confinement, and higher doping abilities and have unique method without the necessity of high temperature and vacuum. These properties give QDSSC edge over dye-sensitized solar cell and make it a potential candidate for the efficiency enhancement of thin film photovoltaic paint.

A combination of quantum dot with perovskite likewise upgrades the charge carrier extraction in collecting layer of Quantum dot solar powered cell. Solar cell additionally give the adaptability of conveying high accuse transporters of the capacity to permit electrons to travel all the more longer distance absent a lot of loss of energy. A gathering of Organic solar cell likewise offers a lot less expensive and less complex photovoltaic with an impulse of activity solidness in high temperature climate. What's more, a material comprised of Copper zinc tin sulphide (CZTS) likewise satisfies the material prerequisite for arrangement processable photovoltaic paints yet it utilizes Selenium, being a moderately uncommon component, which is not used properly. In any case, it can possibly give another leap forward in the productivity of slim film paints by conquering the restriction. The materials for photovoltaic paint could be QDSSC and perovskite, which offers special properties in comparison with different materials, and are appropriate to be researched to build the technology of increase of efficiency of solar paints.

Table 2. Material Requirement for the thin film photovoltaic paint

Material Requirement	**Materials satisfying the requirement**
Abundant material	CZTS, Perovskite.
Low-toxic material	CZTS, Quantum dot, Dye sensitized.
High temperature material	CIGS, CdTe, Quantum dot, Dye sensitized, Perovskite.
Solution processable	Organics, Perovskite, CIGS, CdTe, Quantum dots, Dye sensitized, CZTS
Suitable bandgap	CdTe, CIGS, CZTS, Dye sensitized, Perovskite.
Bulk heterojunction	Organics
Low-Cost synthesis	CdTe, CIGS, Perovskite, CZTS, Quantum dot, Dye sensitized.
Roll to roll	Organics, Perovskite, Dye sensitized, CIGS, CdTe, Quantum dot.
Mechanical Stability	Perovskite, Organic.

Thin film gives an approach to synthesize solution based photovoltaic paints. This innovation has been received because of its qualities highlights for example utilization of least material with promising efficiency. The point of thin film incorporation in solar oriented innovation is to satisfy the light weight, minimal expense and mass region processing.

Another significant parameter is drying rate of ink (preferably having more limited drying steps). Then again, substrates of high uniformity and favourable surface properties are additionally required. Every arrangement processable technique has its own appealing highlights. A few techniques give high efficiency of power conversion lack of manufacturability. Other gives bulk volume production but low in power conversion efficiencies. Various benefits of solar paint are recorded underneath.

- Photovoltaic paint is pollution free and makes no ozone depleting substances be radiated after utilized. The organic cells are coated from water onto recyclable plastic sheets, for example, PET and along these are totally harmless to the ecosystem. Non conventional clean power is available each day of the year.
- Organic solar cells will use the same standard inverter technology used by conventional solar cells to connect the electricity grid network. Also have ability to live grid free if all power generated provides enough for the home / building
- Can be painted virtually anywhere; so chances of generating power are too high.
- Efficiency will be high with improving of technology, so the same material that is available today

will become more efficient tomorrow

- Aesthetics are further developing making the solar paint more adaptable contrasted with more established and so forth.
- It can be printed at high speeds across enormous regions utilizing roll-to-roll processing strategies thus creating the tantalizing vision of coating every roof and other suitable building surface with photovoltaic materials at a very low cost.
- These solar paints will initially be put onto plastic sheets that can be replaced on the roof of a house. In the longer term, it may be possible to directly paint a roof or surface of the building.
- It consists of a newly developed compound that works as like silica gel, which is used in sachets to absorb moisture and keep food, medicines and electronics fresh and dry.

4. Conclusion

Thin film has given an approach to change over the idea of solar paint technology into the real world. In this paper, a brief study report on different advantages and disadvantages with respect to efficiency is discussed. The choice of material and deposition technique plays a important role in the development of efficient photovoltaic paint. Quantum dots and Pervoskite based thin film solar paints can provide a way to improve the efficiency. The new advancement of water-based NPOPV (nanoparticulate natural photovoltaic) coatings addresses a change in perspective in the improvement of minimal expense OPV (organic photovoltaic) devices. The future viewpoint for these materials is incredibly promising, with device efficiencies having increased from 0.004% to 4% in less than five years Similarly, spin coating deposition technique seems to be more suitable for future studies for increasing performance efficiency.

References

[1] Stigka EK, Paravantis JA, Mihalakakou GK (2014). Social acceptance of renewable energy sources: A review of contingent valuation applications. *Renewable and Sustainable Energy Reviews*, *32*, pp. 100-106

[2] Ellabban O, Abu-Rub H, Blaabjerg F (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, *39*, pp. 748-764

[3] Eslamian M (2014). Spray-on thin film PV solar cells: advances, potentials and challenges. Coatings, *4(1)*, pp. 60-84

[4] Javier A, Foos E. E. (2009). Nanocrystal photovoltaic paint sprayed with a handheld airbrush. *IEEE Transactions on Nanotechnology*, *8(5)*, pp. 569-573.

[5] Genovese, M. P., Kamat, P. V (2011). Sun-believable solar paint. A transformative one-step approach for designing nanocrystalline solar cells. *ACS nano*, *6(1)*, pp. 865-872.

[6] Hoth, C. N., Schilinsky P, Choulis SA, Balasubramanian S & Brabec,C. J. (2013). Solution-processed organic photovoltaics. In Applications of Organic and Printed Electronics pp. (27-56).

[7] Krebs, F. C., (2009). Fabrication and processing of polymer solar cells: a review of printing and coating techniques. *Solar energy materials and solar cells*. *93(4)*, pp. 394-412.