Article

An overview of 3D printing technology effect on improving solar photovoltaic systems efficiency of renewable energy

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Abstract

Energy is necessary to conserve it and improve our lifestyle. Today all major production from power is generated from fossil fuels; it is non-renewable and pollutes the environment significantly. Access to clean and renewable energy is crucial for assuring the development of countries. Most of countries economy is based on producing energy from fossil fuels and the change to sustainable ways of life. Photovoltaic energy has previously proven to be a valuable technology for sustainable development and renewable energy. This paper gives an overview of solar photovoltaic (PV) as renewable energy by using 3D printing which can create physical objects from a geometrical representation by successive addition of material. Moreover, this paper gives an overview of the 3D printing concept and its types. 3D printing technology for the production of PV solar systems is low cost than current manufacturing methods. Moreover, 3D printing technology is eco-friendly and higher efficacy than the ordinary PV solar system. The 3D printed panels need more research and development to make them capable to be adopted on a larger scale. 3D printing is seen as a way to not only clean up renewable energy supplies the chain but also to lower costs and enhance the development process, which helps to encourage that the renewable energy sector thrives so that it can capture fossil fuels.

Keywords renewable energy; solar photovoltaic; 3D printing; sustainable development.

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1 Introduction

The renewable energy is an influential element for palliating air pollution problems and promoting sustainable development (Nugent and Sovacool, 2014). The most prevalence and growing technology for renewable energy to generate electricity is the use of photovoltaic (PV) systems or the solar system that converts sunlight into applicable electrical energy (Parida et al., 2011; Kouro et al., 2015; Qi et al., 2020). The advantages of solar photovoltaic (PV) energy as type of renewable energy technology are Eco-friendly and and silent which is unlike customary energy sources, when PV solar panels generate electricity, it does not discharge harmful greenhouse gases, pollute groundwater or exhaust any natural resources. In addition, PV energy lowers operational cost, lowers maintenance and highest power density compared to the other renewable energy technologies (Bazilian et al., 2013; Richardson and Harvey, 2015). Regardless of the multiple advantages offered by the PV technology, This diversion system has intermittent problems, such as not bright at night but also during the day there may be cloudy or rainy weather, dust and surface working temperature which can adversely affect the efficiency of the conversion system (Raghunathan et al., 2005; Silva and Fernandes, 2010; Kim et al., 2013). Moreover, the initial cost of purchasing a PV system is comparatively high, there are also some toxic and hazardous materials used during the manufacturing process of PV units, which can indirectly affect the environment (Huesemann, 2001; Tsotsos et al., 2005; Fthenakis et al., 2008). However, PV energy pollutes much less than other alternative energy sources. Due to the mentioned shortcomings, researches are focused on introducing new, safe, non-toxic, environmentally benign materials, products and improving the PV solar system efficiency and performance. Efficiency in solar energy conversion systems must be improved for this technology to be renewable energy viable the solution. Recently, interest in 3D printing has increased to overcome these obstacles, defects and improve of performance and efficiency of PV cell. In this review article, the concept of the PV industry has evolved using an energy uprising 3D Printed Solar Panels.

2 Concept of Solar PV

PV cells are electronic devices that convert sunlight directly into electricity using photovoltaic effect. Photons, depending on their energy, produce electron hole pairs (i.e., charge carriers). PV cells have built-in P-N junctions for charge separation. When a PV cell is exposed to solar radiation, the P-N junction absorbs the photon, which creates a potential difference across the junction. The charge-carriers start to flow and the resulting photocurrent is denoted as diode current (I_d) the simple equivalent circuit model shown in Fig. 1 (Bana and Saini, 2016), which is paralleled by a P-N junction diode. In conventional solar cells, metal contacts are placed on the front and back sides, to remove those charges. Some highly developed device structures have metal contacts only on the back side (Siecker et al., 2017).

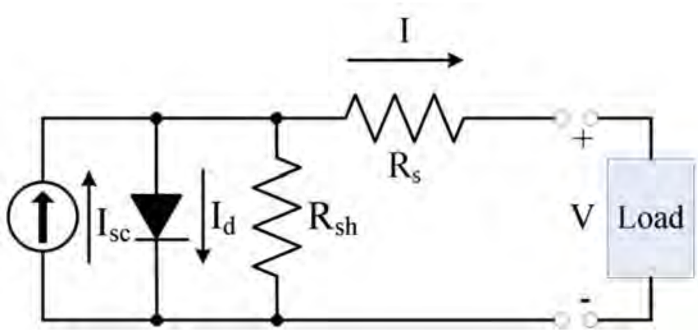

Fig. 1 PV cell simple equivalent circuit.

3 Basic Components of A Solar PV

3.1 Photovoltaic cell

PV cell are classified according the basic material used into three generations (Dolf, 2012).

3.1.1 First-generation: crystalline silicon

There are many semiconductor materials, including silicon, which have proven suitable for photovoltaic applications; silicon PV cells silicon recorded the maximum efficiency ranges from 14% to 20%. Wafer-based

C-Si PV photovoltaic cells dominating the current market, it is estimated that 80% of all solar panels sold worldwide are made of silicon (Kumar et al., 2014). Crystalline silicon cells are classified into three types as the following:

- Mono crystalline (Mono C-Si).
- multi crystalline (mC-Si), or Poly crystalline (Poly C-Si).
- Ribbon silicon

3.1.2 Second-generation: thin-film and amorphous silicon

Thin-film solar cells consist of successive thin layers, with a thickness of only 1 to 4 μm, of solar cells deposited in a large economical substrate such as polymer, glass or metal and cadmium. Thin-film solar cells require less semiconducting material to manufacture for absorbing the identical quantity of sunlight (up to 99% fewer material than crystalline solar cells).There are three types from thin-film solar cells: Copper-Indium-Selenide (CIS), Cadmium-Telluride (CdTe) and Copper-Indium-Gallium-Diselenide (CIGS). Amorphous silicon (A-Si and A-Si/μc-Si) can be deposited on small and very big substrates (up to 5.7 m^2 of glass) on the basis of continuous deposition techniques.

3.1.3 Third generation: concentrated photovoltaic (CPV) and organic material

PV module technologies introduces some new and exciting like Concentrating PV (CPV), Cooling of concentrating PV system, Copper zinc tin sulfide solar cell (CZTS), Dye-sensitized solar cell (DSSC), Organic solar cell, Polymer solar cell, Quantum dot solar cell etc (Sugathan et al., 2015).

3.2 Cables for connecting modules

For safe connections between the modules, excellent mechanical strength cables are needed for use in high mechanical tension conditions, in dry and wet conditions, high temperature conditions and high solar insolation, as well as in buildings with high explosion and fire hazards (Kumar and Sudhakar, 2015).

3.3 Solar charger controller

A solar charge controller manages the power that is inserted into the battery bank from the PV cell. It ensures that the deep cycle batteries are not overcharged during the day and that the power is not turned back on to the solar panels overnight and batteries are drained. Some charge controllers are available with additional capabilities, like lighting and load control, but power management is their primary function. A solar charge controller is accessible in two dissimilar technologies, Pulse Width Modulation (MPPT) and Pulse Width Modulation (PWM), and they perform in a system that is very different from each other (Kumar et al., 2018).

3.4 Batteries

Most of the batteries commonly used in PV solar applications are lithium batteries, lead batteries, lithium polymer batteries, nickel cadmium batteries. Batteries used in solar PV systems must adhere to the requirements of unsteady grid power, weighty cycling (discharging and charging) and irregular, full and recharging (Chaurey and Deambi, 2003). The PV panels receive a different irradiance during the day and as a result they will have a different I-V and P-V curves, and hence the voltage set by the inverter will result in huge conversion losses. To avoid this problem, a battery can be used for store energy and to provide constant power to the inverter.

3.5 Inverter

The goal of using the inverter is to convert the DC voltage generated by solar panels into AC voltage of grid frequency. Modern inverters can be operated with efficiency approximately 98% (Shukla et al., 2016) as the most important feature of an inverter is the conversion efficiency. The other important tasks of the inverter are maximize power point tracking (MPPT), monitoring the energy production from the PV station and securing the station in an case of faults by disconnecting it from the grid.

3.6 PV system metal structures

Module mounting structures are made of three types of materials as the following:

(1) Hot Dip Galvanized Iron. In galvanizing zinc coating is applied to iron or steel to prevent it from rusting.

(2) Aluminum. It is extremely resistant to corrosion and does not corrode simply. Compared to galvanized iron, this is light weight and cost-effective.

(3) Mild Steel (MS). Mild steel is not used very often in case of PV solar module mounting. It is regularly employed in case of not so strong roofs, when there is a need for very lite structures. Mild steel has extremely less carbon. It is very flexible and can be made in to several shapes as it is machinable.

4 Factors Affecting Solar Power Production Efficiency

The PV energy of a PV system is highly dependent on two variables: cell temperature and sunlight. This makes the solar panel efficiency can reach 30-40%.

4.1 Factors affecting efficiency

4.1.1 Cell temperature

PV cells generally work best at lower temperatures. High temperatures transform the properties of the semiconductors and as temperature increases the band gap of the intrinsic semiconductors shrinks, resulting in a slight increase in current, but a much greater decrease in the open circuit voltage (V_{oc}) also solar cells have a positive temperature coefficient equal to I_{sc} (α) when short circuit current (I_{sc}) increases for a given insolation, because a greater percentage of the incident rays have sufficient energy to raise charge carriers from the valence band to the conduction band. Therefore, PV solar cell shave a negative temperature coefficient of V_{oc} (β). Moreover, it produces less output power given same photocurrent because charging carriers have been released at a lower potential. A decrease in V_{oc} results in a smaller theoretical maximum power $P_{max} = V_{oc} \times I_{sc}$ given the same short circuit current (Cotfas et al., 2018). Generally, as the temperature decreases, the PV cells produce a higher voltage. Any calculation of the PV solar panel system must include a modification of this temperature effect (Suita and Tadakuma, 2006).

4.1.2 Reflection

Reducing the amount of incident light reflected away from the cell's surface led to increasing in the Energy Conversion Efficiency. There are two methods in order to reducing the incident light reflection by apply an antireflection coating, and the other is optical imprisonments of incident light with textured surfaces. Energy conversion efficiency remains low, this mean requiring large areas for adequate insulation and raises concern about the unfavorable ratios of energy required for cell production versus the collected energy (Queisser and Werner, 1995).

4.1.3 Wavelength

Sunlight incident the Earth’s surface has wavelengths from ultraviolet, across the visible range, to infrared. When light hits the surface of the solar cell, some photons are reflected, while others pass through them. Some absorbed photons convert energy into heat. The rest has the correct amount of energy to separate the electrons from their atomic bonds to produce charge and electric current carriers, this mean enhancing the spectral sensitivity of the silicon photodiode from the deep UV rays and across most of the visible region and increasing energy conversion efficiency (Goetzberger et al., 2003; Dinçer and Meral, 2010).

4.1.4 Photovoltaic systems maximum power point tracking

Maximum Power Point Tracking (MPPT) is used for get the maximum power from these systems, hence improve efficiency of PV cells.

4.2 Factors affecting performance

Performance of PV solar cell is assessed under Standard Test Conditions (STC) as the following (Gupta et al., 2014):

(1) Temperature: at 25^{o}C, this temperature of the PV solar cell itself, not the temperature of the surrounding.

(2) Solar Irradiance: 1000 W/m^2, this number submits to the quantity of light energy falling on a given area at a given time.

(3) Air mass spectrum (AM): 1.5, Air mass is the length of the optical path across the Earth's atmosphere to light from the empyreal source. 1.5, this number is somewhat misleading because it indicates how much light must pass through the Earth's atmosphere before it can hit the Earth's surface, and it mostly depends on the angle of the sun relative to a reference point on Earth. These correspond to the radiation and spectrum of a sunlight accident on a clear day on a sunny 37° surface with the sun at 41.81° above the horizon. 1.5, this number decreases When the sun is directly above it where the light must travel to the lowest straight distance down, and increases as the sun goes beyond from the reference point and must go at an angle to reach the same spot.

(4) Wind Speed, (W): 1 m/sec.

Therefore, it is important to accurately predict the power output of the PV unit in real conditions before installing the PV system in order to minimize factors that may affect PV system performance. Moreover, the two - dimensional panel poses definite boundaries such as unsatisfactory energy the conversion due to the relative imperfection in the direct incident light, particularly in high height above sea level regions. Light at irregular angles of incidence impacts the efficiency of the flat solar panel, and this is specially obvious not Only when looking at the movement of the sun during its daily cycle , but also the sun ' s movement during its yearly cycle. That is why many scientists are dedicated to finding and developing methods, materials and technologies to improve and develop the performance of the photovoltaic cell. One of the newer technologies that can be used in the manufacture of photovoltaics is 3D printing technology.

5 Concept of 3D Printing

There are many terminologies used to illustrate 3D printing like rapid prototyping and additive manufacturing. 3D printing is one of the developed techniques, where the pieces are artificial by dividing their 3D designs in to very small layers using software data treatment, and then they are manufactured using 3D printers by printing one layer upon the other until the final shape is formed (Bird, 2012; Lipson and Kurman, 2013; Mohsen, 2017; Tuan, 2018; Andrea et al., 2020). In another meaning, 3D printing is a procedure by which 3D solid objects of any form or geometry can be produced from a digital file. The formation is achieved by laying down successive thin layers of a specific material until the entire object is shaped. Each of these layers represents a thinly sliced horizontal cross-section (like to the yield of are regular printer, this is why it is called printing) of the final object (Ceccarelli et al., 2016).

Recently, 3D printing used for producing artificial 3D printed cornea (David, 2018), steel bridge in Amsterdam (Thomas, 2018), heart pump (Thomas, 2018) , PGA rocket engine (Wang et al., 2018), aerospace industry (Sreehitha, 2017), Automotive industry (Sreehitha, 2017; Petch, 2018) , Food industry (Liu et al., 2019), healthcare and medical industry (Esmaeil et al., 2018; Norman et al., 2018), Architecture, building, and construction industry (Knowlton et al., 2015; Liu et al., 2016; Alyson, 2016; Mori et al., 2018; Yan et al., 2018), fabric and fashion industry (Lee et al., 2017), electric and electronic industry (Bassett et al., 2015; Saengchairat et al., 2016; Chuan et al., 2018). Also, 3D printing has been used to successfully produce wind turbines (Gwamuri et al., 2016).

6 Concept of Solar PV 3D Printing

Since the past decade there has been a surge of significance to endorse and broaden awareness on renewable energies. Solar powered 3D printing is transferred 3D printing from an industry based technology to a technology that can be used in the developing world for sustainable development (Branke et al., 2011). The PV industry is presently undergo considerable structural modification as the costs of PV modules per watt has dropped 80% in the last 5 years, which resulted i) a clear decrease in the cost of solar electricity growing of demand (Barbose et al., 2012) and ii) the economic role of racking is gaining importance for the modules (Wittbrodt et al., 2015). One of fields where 3D printing can be used with PV is in custom module mounting. Using 3D printing: a great way to reduce costs that there are new developments in 3D printing that provide the possibility for individuals to manufacture PV racking to lower overall PV system prices, since the PV installation and racking now make up a large portion of the PV system costs (Wittbrodt and Joshua, 2017). Recently, it was found that the racking system can be printed effectively with Rep Rap 3D printers and cost saves between 85% and 92% from available commercially alternatives, this system has the potential to aid in hasten of solar proliferation in the developing world by providing a low cost solution PV racking (Gaget, 2018; James and Contractor, 2018).

3D Printing technology is structured to take its space to bestow distinctly in the making of solar cells which 3D printing is the greatest solution for producing solar panels. This technique is achievable by printing solar cells through manufacturing 3D printers and some perovskite materials (Dijk et al., 2015). This new technique of making 3D printer solar cells has the potential to dislocate the use of silicon-based panels, those are formed in chips. The technology can be used for directly depositing solar cell parts or to create external structures (i.e., light trapping structures) to be positioned on the active device. Third generation PV solar cells, that is copper zinc tin sulfide (CZTS), organic solar cells, quantum points, dye-sensitized solar cells (DSSC), and perovskite solar cells (PSC) were produced using 3D printing techniques (Conibeer, 2007; Morales et al., 2017; Saengchairat et al., 2017). The efficiency of PV systems can be superior with unique 3D solar cells that capture almost all of the light that strikes them while reducing their size, weight, and mechanical difficulty. The novel 3D solar cells capture photons from sunlight by use an array of minuscule structures that can be similar to high-rise buildings in a city street grid. The cells could find close to term applications to power spacecraft, and by facilitating efficiency enhancements in photovoltaic coating materials, could also amend the way solar cells are designed for a wide range of applications. The ability of the 3D cells to absorb nearly all of the light that beats them could also facilitate enhancements in the efficiency with which the cells convert the absorb photons into electricity. 3D printing has verified that it can be used to amplify the effectiveness of renewable energy, by creating solar panels that are more efficient. 3D printed panels need more research and enlargement to make them capable of be adopted on a larger scale. However, they have been confirmed to be 20% more effective than customary ones, and plus this, they cost less than half the price to build them. 3D printing works in a different way to create the solar panel. It prints semiconductor ink into every very thin layer of the panel’s surface, creating cells that are only 200 microns thick (Hiroyuki et al., 2019). Kyung-In Synthetic made, a 10×10 cm solar cell film is sufficient to generate up to 10-50 watts per square meter (Low et al., 2016). Due to the use of provoskite material, the approach is organic and the resulted strips require significantly less sunlight compared to their silicon-based counterparts.

7 Types of 3D Printing

7.1 Binder jetting

Binder jetting is a speedy prototyping and 3D printing process where a liquid joining agent is selectively deposited to join powder particles and uses jet chemical binder onto the spread powder to form the layer (Yee et al., 2017). Binder jetting can print a variety of materials including metals, polymers, hybrid and ceramics.

7.2 Materials extrusion

The first pattern of a material extrusion system is fused deposition modeling (FDM). FDM fabricates parts layer by layer from the undermost to the top by heating and extruding a thermoplastic filament the, where buffering needed 3D printer deposits a removable material that acts as scaffolding (Syed et al., 2017).

7.3 Directed energy deposition

Directed energy deposition techniques regularly used to repair or put in additional material to presented components (Zhang et al., 2018). The working principle of directed energy deposition is similar to the type of material extrusion type, but the nozzle is not fixed to annex act axis and can move in several directions.

7.4 Materials jetting

Material jetting is process in which construct material is selectively deposited drop by drop where the print head dispenses droplets of a photosensitive material that solidifies, creating a part layer by layer under ultraviolet (UV) light (Tiwari et al., 2015).

7.5 Powder bed fusion

The process of powder bed fusion technology includes the EBM (Electron Beam Melting), SLS (Selective Laser Sintering) and/or selective heat sintering (SHS) printing technique to melt or fuse the material powder together. SLS is fast speed, has high accuracy, and varies surface finish (Vikayavenkataraman et al., 2017).

7.6 Sheet lamination

Sheet lamination is procedure in which sheet of materials are joined together to produce a part of object (Tiwari et al., 2015). Sheet lamination is used in process that uses laminated object manufacturing (LOM) technology and ultrasound additive manufacturing (UAM) technology (Zhang et al., 2018). The advantage in LOM technology enables complex engineering parts to be manufactured with lower manufacturing cost and running time (Low et al., 2017). UAM technology is an innovative process that uses sound to merge layers of metal drawn from featureless foil stock.

7.7 Vat Photopolymerization

Vat Photopolymerization, which in includes the curing of photo reactive polymers resin by using a laser, light or ultraviolet (UV) are used to cure or harden the resin where required, while the platform moves the object being formed downwards after each new layer is cured (Quan et al., 2020). SL or SLA (Stereo Lithography) and DLP (Digital Light Processing) three dimensional printing technologies uses photopolymerization.

8 Recent State of Printing Technologies in Photovoltaic Applications

There are several types of printing technologies that have been used in diverse applications of photovoltaic. Under this topic we will provide a brief overview of the technology of printing and its implication for use in photovoltaic technologies.

8.1 Screen printing

Screen printing method is suitable for production with high rate plus that it is low cost and rapid. In this technology, a mesh with the printing design required for printing is used. In PV applications, it is the most popular method of depositing desired films due to its suitability roll to roll production on large scale. Some screen printing applications include the printing of silver contacts on the solar cells and deposition of the meso-porous layer TiO_2 into the sensitive dye solar cells (Wan et al., 2019).

8.2 Ink-jet printing

Ink-jet printing can be used to print any preferred model. The main advantage over screen printing is that waste of materials is reduced in ink-jet printing. Ink-jet printing is regularly used to print electrical connections in silicon solar cells (Tina and Xu, 2011). Ink-jet printing was used to produce complete CIGS solar cells (Lin et al., 2012; Jung et al., 2014) and organic solar cells (Eggenhuisen et al., 2015). It has also been used to deposit TiO_2 films of sensitive dye solar cells (Eggenhuisen et al., 2015).

8.3 Laser printing

The Laser printing was used to prove the high temperature stability of paper based PV (Poulain et al., 2011) and it also used to fabricate high efficiency solar cells (Gebhardt et al., 2013). Organic PV cells were fabricated using laser structuring (Li et al., 2012).

8.4 Thermal evaporation

Thermal evaporation is a valuable technique for depositing thin films. It is a widespread technique in organic solar cells to deposit organic molecules in high vacuum environment (Liu et al., 2013b). Thermal evaporation was utilized to manufacture the Al and Ca layers in organic solar cells which achieved 10% efficiency (Liu et al., 2013a). The perovskite absorber was deposited by use a thermal evaporation process (Roldán-Carmona et al., 2014). Thermal evaporation was used to deposit of gold as a cathode in perovskite solar cells (Ding et al., 2010). In dye sensitized solar cells, silver electrodes have been thermally evaporated (Mader et al., 2010). Thermal evaporation was used to deposit Al rear side contacts in silicon solar cells (Katkhouda et al., 2014). Moreover, Copper was deposited by use thermal evaporation in CIGS solar cells (Huang et al., 2018). ACdS buffer layer was deposited by use thermal evaporation, chemical bath deposition (CBD), sputtering, atomic layer deposition, and spray ion layer gas reaction in CIGS solar cells (Wolfram et al., 2014). CdTe solar cells were totally manufactured by use thermal evaporation (Tursun et al., 2020).

8.5 Sputtering

The solid target material atoms in sputtering method are expelled due to offensive by high energy particles. These expelled particles are deposited onto the substrate located under the target material (Compaan, 2004). There are numerous types of sputtering including RF sputtering, DC sputtering and magnetron sputtering to use for depositing thin films with thicknesses varying from a few nanometers up to tens of micrometers which it is extremely useful. Magnetron sputtering is used worldwide to it’s a high sputtering rate. More advantageous than sputtering onto an evaporation system is that superior adhesion of films to a substrate is obtained using the sputtering system. Sputtering has been extensively used to produce high efficiency CdTe solar cells (Gupta et al., 2004) and an efficiency of 14% was achieved by all sputtered CdS/CdTe solar cells (Gulkowski and Krawczak, 2020). An efficiency of about 9.65% was obtained for CIGS solar cells employing the sputtering process (Jiang et al., 2013). Sputtering of amorphous silicon onto crystalline silicon was reported to form hetero junction solar cells (Zhang et al., 2014). In dye-sensitized solar cells, platinum has been reported to be sputtering onto metal substrates made of stainless steel to stabilize the solar cells (Bae et al., 2014).

8.6 Spin coating

Spin coating use to deposit thin layers of uniform thickness on a flat substrate. The spin coating method was used to deposit the antireflection coating into CIGS solar cells (Bae et al., 2014). Nanocrystals of CdTe were deposited using the layer by layer spin coating technique; but, unfortunately the efficiency was imperfect to only 2% (Lee et al., 2012). The spin coated TiO_2 layers were deposited to enhance the stability of the solar cells, in dyes sensitized solar cells (Faller and Hurrle, 1999).

8.7 Chemical vapor deposition and electrochemical deposition

Chemical vapor deposition (CVD) is commonly preferred method in different industries to deposit thin layers. A silicon thin film (10-50 μm) was deposited using CVD at the high temperature of 1100^oC to achieve a 17.6%

efficient silicon thin film solar cell (Kalita et al., 2012). Large area CVD grown graphene were used as transparent electrode for effective organic solar cells (Romeo et al., 2004). The metal organic chemical vapor deposition (MOCVD) technique was used to manufacture CdTe and CIGS solar cells (Irvine et al., 2008). CVD cultured TiO_2 particles were employed for light scattering for improving the light absorption which enhanced the performance up to 22% (from 4.4% to 5.4% efficiency) of dye sensitized solar cells (Pazoki et al., 2012). Electrochemical deposition is an attractive low cost approach for the formation of thin layer coatings. Electrochemical deposition was employed for producing of different types of PV technologies like dye sensitized and CdTe solar cells (Valvoda et al., 2006; Echendu et al., 2016).

8.8 Photolithography and nano imprinting

Photolithography is used to pattern a thin layer of a substrate. Photolithography is a common method to form contacts in crystalline silicon solar cells as it is suitable for large scale mass production. The highest efficiency crystalline silicon solar cells have used this method for their fabrications as well (Saga, 2010).

Nano imprinting is low cost, high throughput and high resolution novel technique for formulating nanometer scale patterns. Nano imprinting offers a superior resolution than photolithography as it is not affected by beam scattering or light diffraction (Lan and Ding, 2010). Nano imprinting has been successfully employed in crystalline silicon, thin layer and third generation solar cells (Battaglia et al., 2011; Han et al., 2011; Mellor et al., 2013; Hubert et al., 2015).

8.9 Electrophotography

Electro photography is a printing that uses electricity to fabricate an image on a photoconductive surface (Johannes, 2014). Electro photography technique is seldom used in PV cell fabricating which some organic dyes were reported to both photovoltaic cells and photoconductive electrophotography systems (Bird et al., 2001).

8.10 Lamination technology

Lamination technology is a process of accumulating successive layers of a substance and bonding them together using adhesives. The main reason of using lamination technology is to protect print or layer. In general, PV modules are covered and shielded using a vacuum lamination machine and a roll lamination machine has been reported (Schmager et al., 2020). The roll lamination is extensively cheaper and faster than vacuum lamination. Roll lamination machine takes approximately 1 minute where vacuum lamination machine takes 8-20 minutes for glass/back sheet and 8-25 minutes for glass/glass modules to cover a PV module (Schmager et al., 2020).

8.11 Sheet-fed and web printing

Sheet-fed printing is done on continuous roll of paper, on individual sheets of papers unlike web presses. Both of these technologies have been used for producing of organic solar cells (Rardin and Xu, 2011; Søndergaard et al., 2012).

8.12 Gravure

Gravure is a printing technique that uses engraved cylinders or plates attached to a cylinder as image carrier. In this printing method an image is etched on the surface of a metal plate or cylinder. This printing method has been used in the manufacturing of organic solar cells and printing of packaging on a variety of non-paper substrates (Kopola et al., 2010).

9 3D Printing PV Solar Cell As Renewable

There are two main strategies to reduce the energy production cost of photovoltaic; one is to increase their efficiency and the other one is to reduce production costs of the starting materials. Lately, there are various printing processes throughout manufacturing stages to achieve efficiency and reduce costs. There are printing processes like screen printing, inkjet printing suitable for making different types of PV solar cells. For example 3D printing used to manufacture PV racking can reduce racking cost by more than 80% which greatly improves the economic condition of multi-unit PV systems in the developing world (Wittbrodt and Pearce, 2017). Moreover, in order to increase the efficiency and reduce the cost we can use both technologies 3D printing and 3D dimensional nature in manufacture PV solar system. In a renewable energy system, the incorporation of three-dimensional (3D) technology into solar power generation takes advantage of the 3D nature of the biosphere so that energy accumulation occurs in volume, unlike what is usually obtained in 2D planar structure PV. 3D PV technologies are able to generate more power from the same base area when compared to the 2D planar structure (Saha, 2016).

3D printing solar panel more eco- friendly than current solar panels the because the minerals currently used to create solar panels are highly toxic when mined, and it also poses a threat to the health of the soil and water in the surrounding area due to excavations. Current solar panels are produced by fusing polysilicon with boron to make a semiconductor. Wafers of silicon are added on top, and electrical contact is etched in to the surface. 3D printing creates solar panels by printing semiconducting ink into each very thin layer of the panel’s surface, resulting in cells only 200 microns thick. 3D printing has proven that it can be used to increase renewable energy efficiency. By creating more efficient solar panels, 3D printing in this sector will help encourage the global shift from fossil fuels to renewable energy sources by making them affordable for everyone. 3D printing is a method that is not only one of the cleanest in the renewable energy supply chain but also lowers costs and boosts development, helping to encourage the prosperity of the renewable energy sector in order to be able to reduce the use of fossil fuels.

10 Conclusion

In this Overview, there is rich background of 3D printing in manufacturing industry. This paper is to overview the types of 3D printing technologies, materials used for 3D printing technology in manufacturing industry and lastly, the applications of 3D printing technology in producing PV solar cells. This overview showed that the photovoltaic cells that will be produced by the 3D printing method will be more efficient and environmentally friendly than those currently produced by the regular methods. The reduction in the cost of producing PV solar cells by using 3D printing will have implications for the widespread adoption of renewable energy, as it opens the door to the use of renewable energy sources in developing countries where Governments have less money available to invest in these new technologies. 3D printed three - dimensional photovoltaic system was studied (Daniel and Orangevale, 2018) and our suggestion is to use both 3D printing and 3D configuration as two combined methods for producing photoelectric solar system to output a system that gives higher energy than its current counterpart.

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