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GENERATION OF ELECTRICITY FROM TRANSPARENT FLEXIBLE SOLAR CELL USING PHOTOVOLTAIC EFFECT

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Abstract: Energy is fundamental for financial turn of events and development. With the quick turn of events and development of the economy, society needs more power. Alongside the comprehension that unreasonable energy creation can destructively affect our current circumstance. Sun oriented energy is nature's most bountiful method for getting energy. Monetary impetuses to make sunlight- based cells more savvy and productive have persuaded the improvement of different dissipation techniques like drenching, plating, thick film testimony, and meager film statement. Ordinarily, for sun- oriented energy to work successfully and store energy in structures, a great deal of room as rooftops and ground is expected to introduce sun powered chargers These solar panels' need for space is a major hedge to their commercialisation. Transparent solar cells(TSC) have been used by experimenters as a result to this debit. By converting glass wastes into solar cells, it finds a result to this issue. These cells produce energy by collecting and using extraneous light from vehicles' windows and structures, making optimum use of available architectural space. About nine different transmission photovoltaic (TPV) technology types are presently being delved with the thing of achieving high translucency with electrical performance perfect for solar panels This review composition's main thing is to detail all of the most cutting- edge photovoltaic transmission styles with an average transmission of at least 20 published since 2007. Including demonstrating the procedures

Key-words:- Electricity generation. Photovoltaic effect, Energy conversion, Transparent conductive oxide, Efficiency, Durability, Nanotechnology, Thin-film solar cell, transparent flexible battery

Nomenclature
TPV
Thin-film Photovoltaic (TPV)
EPD
Electrophoretic deposition
ITO
Indium-doped tin oxide
PSC
Polymer Solar Cells
P-max
the panel's maximum power output (W) under usual test conditions
P
AC electricity at a moment's notice (W)
QD
Quantum dot
TFSC
Thin film solar cell
NT-TiO2
Titanium dioxide nanotubes
η
efficiency (%)
T
transparency (%)
TDSSC
Solar cell made on transparent dye -synthesis

I. INTRODUCTION

the ongoing expansion of the economy has led to a surge in clean renewable energy research, with solar energy emerging the most affordable and accessible energy source that meets society's needs [1-3]. Solar energy plays a crucial role in our daily lives, serving as a reliable source of energy for various applications, including water heating and electricity generation . Solar energy is now a significant component in supplying the growing energy needs of society as the world continues to place a high priority on sustainable development. Its versatility and reliability make it an essential source of power for multiple uses.

The photovoltaic phenomenon allows the conversion of sunlight into electricity, which is the fundamental principle behind solar energy. When photons from the sun interact with a conventional solar cell, they trigger the photovoltaic effect, resulting in the activation of electrons and the generation of an electric current. The emergence of transparent and flexible solar cells that utilize the photovoltaic effect holds tremendous potential for the advancement of renewable energy technology.

The development of transparent and flexible solar cells has opened up a world of possibilities for harnessing the power of the sun, with thin-film technology offering a promising avenue for achieving the delicate balance between transparency and efficiency, through a meticulous fabrication process that involves a range of intricate steps.

The development of transparent and flexible solar cells represents a significant step forward in the quest for sustainable energy solutions, with thin-film technology offering a promising approach to achieving the delicate balance between transparency and efficiency, With the possibility of a variety of uses With the possibility of a variety of uses, from wearable tech to smart cities, making it an exciting area of research with endless possibilities.

I. MANUFACTURING TECHNOLOGY OF PHOTOVOLTAIC CELL

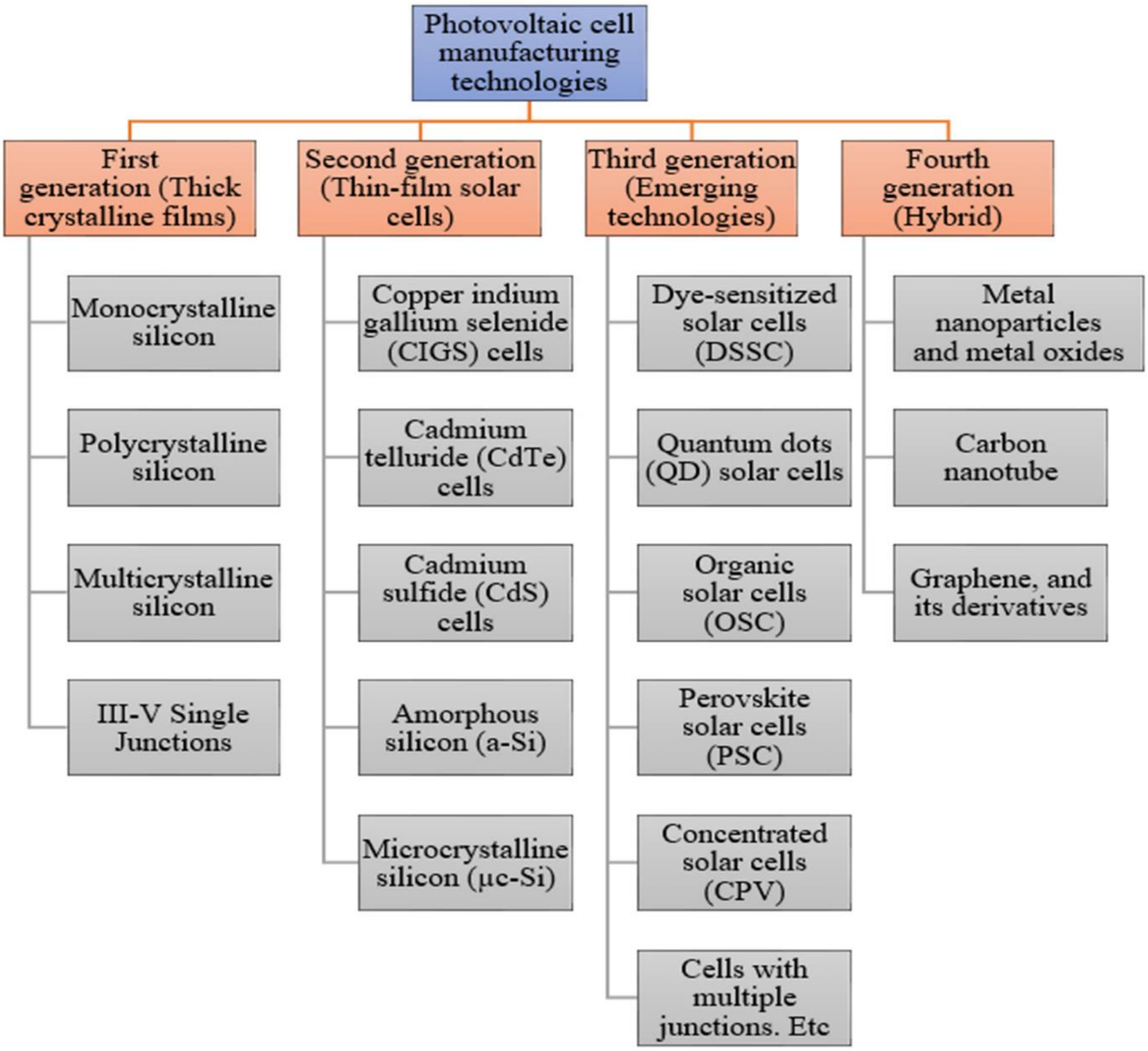

Figure 1: photovoltaic manufacturing technology

II. PHOTOVOLTAIC THEORY

A photovoltaic cell use semiconductors that converts sunlight into electricity. that acts as a solar-powered conductor. The semiconductor material absorbs photons from sunlight, which then generates a one-way flow of electrons that produces electricity. The cell's performance is optimized by the diffusion length and energy band gap, which work together to ensure maximum efficiency. In essence, a photovoltaic cell functions similarly to a semiconducting diode, with the ability to discharge electrons when sunlight is absorbed, and directing them in a specific direction to provide a current.[5], [20], [21].

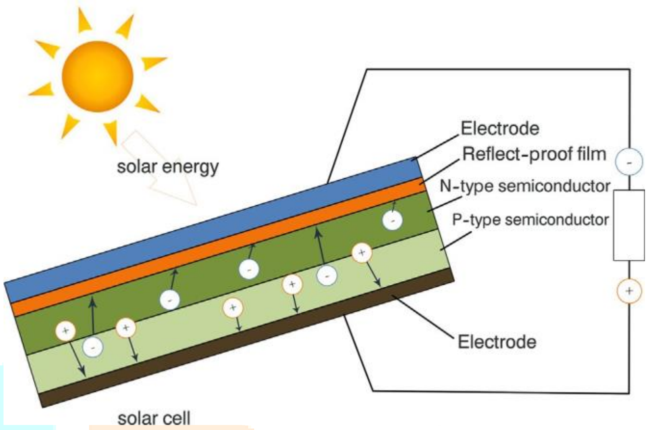

Figure 2 Si solar cell

III. MATERIALS AND METHODS:

Utilising the photovoltaic effect, the following components and methods are frequently employed in the generation of energy from transparent flexible solar cells:

a) Materials:

1. pliable materials, as metal foil or sheet plastic
2. 2. A kind of semiconductor material, such as silicon, amorphous or cadmium telluride.
3. Encapsulation's transparent protective layer
4. Conductive electrodes that are transparent, such as indium tin oxide (ITO)

b) Methods:

1. Deposition of semiconductor layers: A variety of methods, such chemical vapour deposition, sputtering, or physical vapour deposition, are utilised to deposit thin layers of semiconductor materials on the substrate.
2. Encapsulation: To protect the solar cells from damage from moisture and other impurities, a transparent protective film is used to encapsulate the cells.
3. The electrical properties of solar cells are characterized through various tests, including the measurement of current-voltage curves and the efficiency of power conversion. These tests provide valuable information about the effectiveness of solar cells and help to optimize their design and functionality.
4. Cleaning the substrate: The flexible substrate is cleaned to get rid of any dirt or foreign objects that may impede the deposition of semiconductor layers.
5. The addition of transparent conducting electrodes: Transparent conductive electrodes, such as ITO, are positioned on top and bottom of the semiconductor layers to permit the collection of electrical current generated by the photovoltaic effect.
6. Electrical characterization: The electrical characteristics of the solar cells are measured, such as their current-voltage curves and their power conversion efficiency.

The transparency and conductivity of the electrodes, the quantity and quality of the semiconductor layers, and the encapsulation method constitute a few of the factors that impact the effectiveness of solar cells are. The objective of ongoing research is to increase the efficiency of transparent and flexible solar cells while looking into novel applications for these.

IV. WORKING PRINCIPLE

The photovoltaic effect is used to produce electricity from transparent flexible solar cells by converting solar energy into electrical energy using the following process:

1. **Absorption of light: -** The photons in the light energy are absorbed when sunlight attains the semiconductor material in the solar cell. This excite the material's electrons and produces an electric current.

2. **Separation of charge :-**When the semiconductor material becomes active, electrons go from the valence band to the conduction band, producing an electron-hole pair. This process results in a separation of charges within the material due to the opposite charges of the electron and the hole.
3. **Collection of charge** :- Electrodes constructed from transparent conductive substances like indium tin oxide (ITO),that are attached to the top and bottom of the semiconductor layer serve to collect the separated charges. The electrodes enable current to depart the solar cell and enter a circuit far beyond it.
4. **Transfer of energy:-** Devices can be powered by the electric current produced by the solar cell, or it can be stored in a battery for later use.

Several applications are conceivable using transparent flexible solar cells., such as building-integrated photovoltaics, car windows, or wearable devices, where they can generate electricity from sunlight without compromising the transparency or flexibility of the substrate. Ongoing research is focused on improving the efficiency and durability of transparent flexible solar cells and exploring new applications for their use.

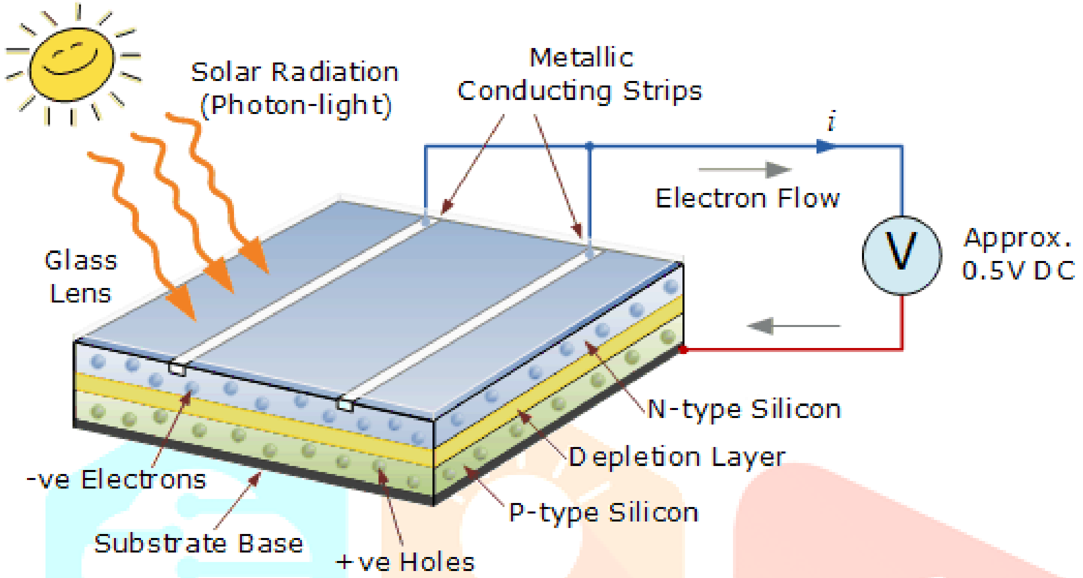

Figure 3: working principle in solar energy

V. The operational principles of DSSCs

O'Regan and Gratzel's development of dye-sensitized solar cells (DSSC) in 1991 was a crucial step in the development of energy-generating the latest technology.. DSSC is an affordable and efficient device, making it an attractive area of research for scientists and researchers. An ideal DSSC includes of a dye-sensitized transparent conducting substrate, a semiconductor layer, an electrolyte, and counter-electrode (CE), such as TiO2, ZnO, SnO2, and Nb2O5. The mesoporous oxide, which has a thickness of approximately ten metres and a diameter of between 10 and 30 nm, contains TiO2 nanoparticles and acts as a conduit for electrons to go from the cathode to the anode. On a glass substrate covered with TCO or FTO, which are common substrates, the TiO2 layer is deposited after being doped with a dye for absorbing photons. The dye is oxidised when photons from the conduction band undergo the removal from their electrons by the dye. The iodide/triiodide redox system, in which I- loses electrons to the dye and produces 3I3 triiodide, recovers the lost electrons from the electrolyte. By collecting electrons from the cathode, the triiodide turns back into iodide. It features a platinum catalyst protection, and electrons go from the semiconductor side to the counter electrode side to generate a current flow. Since DSSC has a high power-to-conversion efficiency, it offers a potential substitute for traditional silicon-based solar cells.

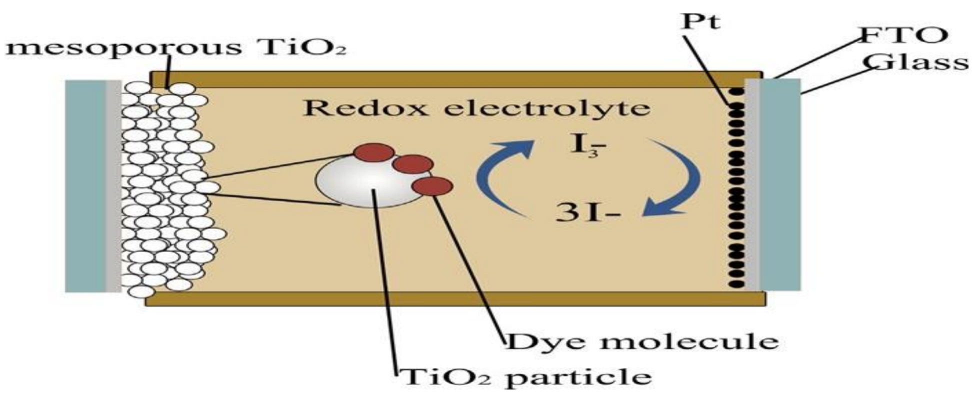

Figure 4: The operation of a hybrid solar cell

$$I^{-} + 2e^{-} = 3I^{-}$$

VI. The Semi-conductors

Components made of silicon are used in around 78% of the photovoltaic cells manufactured globally [34]. The markets are in favour of lowering the cost for resources and production. Therefore, choice, less expensive materials must be used. Wide band gap semiconductor metals are now an attractive substitute for traditional inorganic semiconductor-based In the presence of an organic dye, dye-sensitized solar cells (DSSC) are a specific kind of solar cell that can generate pairs of electrons and holes through photosynthesis. These solar cells are based on semiconductors that are ideal for solar energy applications, such as titanium dioxide (TiO_2), zinc oxide (ZnO), and tin dioxide (SnO_2). Unlike metals and insulators, semiconductors are crystalline solids. Dopants work at low temperatures and affect the characteristics of semiconductors.

1. Electrolyte

The electrolyte's main job in a solar cell is to use the iodide species I^- to replace the oxidised dye., which acts as the electron an electrolyte donor. In DSSCs (Dye-Sensitized Photovoltaic Cells), the electrolyte typically consists of I^-/I_3^- redox suspended inside a liquid organic mixture. When the dye is oxidized, I_3^- ions are produced. To regenerate I^-, I_3^- soaks up electrons from a source beyond the body [46], [47], [48].

VII. 1.3.2. Dye

One of the most desired characteristics of Dye-Sensitized Photovoltaic Cells (DSSC) is the widening of the semiconductor material's band gap, emphasising the dye's significance as a crucial component of DSSC. The method of dye synthesis increases the excitation process' effectiveness and widens the excitation wavelength range, enabling the absorption of solar photons and the production of electrons and holes in DSSC. The dye is chemically attached to the porous surface of the semiconductor, and the effectiveness of the DSSC is dependent on the characteristics of the dye material, such as its capacity to absorb light and convert photons into the finished device. But in order to be appropriate for DSSC usage, the dye must adhere to a set of requirements. For instance, the dye has to have anchoring groups to attach it to the semiconductor surface, and the absorption spectrum must span the full visible range, including the near-infrared (NIR) region. Furthermore, the photosensitizer must be in a more positively charged oxidised state than the redox potential of the electrolyte and possess a higher energy level in the excited state than the conduction band in the n-type semiconductor. For the DSSC to last a long time, the dye must also be stable. The difficulty of developing solar cells with high efficiency and transparency has a possible answer in this ground-breaking method, and further research is being done in this field.

VIII. The Counter-Electrode (CE)

Dye synthesis is a crucial process that enhances the efficiency of the excitation process and broadens the range of the excitation wavelength, enabling the absorption of sunlight photons and the generation of electrons and holes in dye-sensitized solar cells (DSSC). The dye is bonded chemically to the porous surface of the semiconductor, and the efficiency of the DSSC depends on the properties of the dye material, such as its ability to absorb light and transform photons into the final device.

IX. Utilising methods for transparent solar energy cells

Only solar farms and rooftop panels can now harness the power of the sun to produce energy, despite the fact that the sun is an infinite resource. Due to its potential for several uses, transparent solar cells have lately piqued the interest of scientists. When their efficiency improves in the not-too-distant future, several nations currently utilise transparent solar cells for these uses, and others plan to do the same. Transparent solar cells, which can presently only be employed as power consumers, have the potential to one day convert buildings in crowded cities into power plants. Building Integrated Photovoltaics (BIPV) is the newest and most important use of transparent solar cells. A intended use of TSC is the use of solar energy to power vehicles, such as cars, aircraft, trains, and boats, and the solar cells would be printed in clear on the exterior of any structure that is 90% glass. Transparent solar cells (TSC) may also be used in fuel-free or solar-powered electronics, provided that TSC are included into the glass surfaces of these goods. TSC has the potential to power all of the electronics we use on a daily basis, including computers, mobile phones, tablets, MP3 players, and readers. The issue of developing solar cells with high efficiency and transparency can be overcome with this novel technique, and more study in this area is now being conducted.

X. The Thin-film of solar collector

The technologies that obtained at least 1% efficiency and more than 20% transmittance are listed in chronological order under. Less than 80% openness is now the best that can be done. Certain substances, like titanium dioxide, can have their transparency enhanced by thinner the film Thin films are created through the combination of the material layers that typically are utilised for creating solar cells; such films are then utilised to create thin film solar cells (TFSC). The cost of the solar cell's components might be lowered by simply depositing the right quantity of material to ensure that the solar cell works according to schedule. [67–70] The how the cell performance of as a whole is gets affected by each of the layers since various substances possess distinct qualities. The interaction between these levels is significant because the crystal structures of these layers differ.

thin, transparent film The material employed, the film's thickness, and other factors have significant effects on solar cells creation process, and the deposition technique. It was said that the first translucent thin films were screen printed; corresponding components might have used distinct thin film deposition methods.

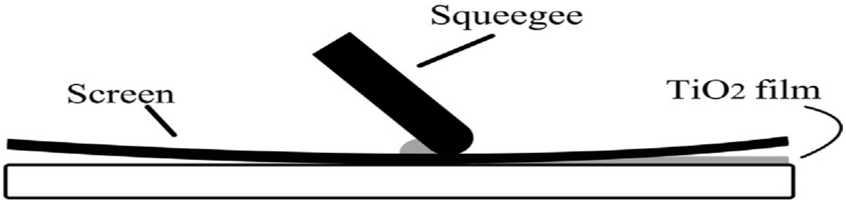

Figure 5: Polymer screen-printing film schematic diagrams

The mesh count, mesh aperture, thread diameter, open surface, and manufacturing thickness of the screen—which is created from a mesh stretched through a frame—determine the thickness and porosity of the film in transparent solar cells. The screen is made from a mesh stretched through a frame. Squeegee speed and pressure may also have an impact on transparency. Three commercially available TiO2 nanoparticle pastes with the designations P25, ST22 and ST21, and ST41 were examined by researchers in 2007, who found a transparent solar power cell. According to the results, ST41 was completely white and opaque, ST21 was hazy, and P25 was the most transparent of the pastes when imprinted on FTO glass with an 83 m thick fabric. The P25 TiO2 thin film's final thickness was also calculated after screen printing.

The screen's characteristics include its mesh count, mesh aperture, thread diameter, open surface, and production length. having an impact on the film's thickness and porosity when the method of screen printing is used to regulate transluscent. Transparency is additionally affected by the squeegee's motion's speed and pressure. A transparent solar cell became known in 2007 after researchers assessed three easily accessible TiO2 nanoparticle pastes, known as ST41, ST21, and P25. The outcomes of imprinting each paste onto FTO glass with an 83 m-thick cloth revealed that P25 was the ST41 was completely white and impenetrable, whereas ST21 was the most transparent.The total DSSC efficacy at the ends of the screen-printed P25 TiO2 thin film was 17 m, the resultant light transmission was 60%, and the DSSC at the ends of the DSSC construction technique was 9.2%.

Another study conducted in Korea and released in 2008 examined several TDSSC variations. One of the explored techniques used a bilayer TiO2 DSSC to increase the photocurrent density in the TSC. The material displayed a wide band gap and was nanocrystalline. This material enhanced DSSC performance by increasing the amount of dye per unit volume of the nanocrystalline layer. The film's surface area was widened by using small particles, which increased dye absorption. However, the smaller particles did not always translate into better performance because of the recombination of

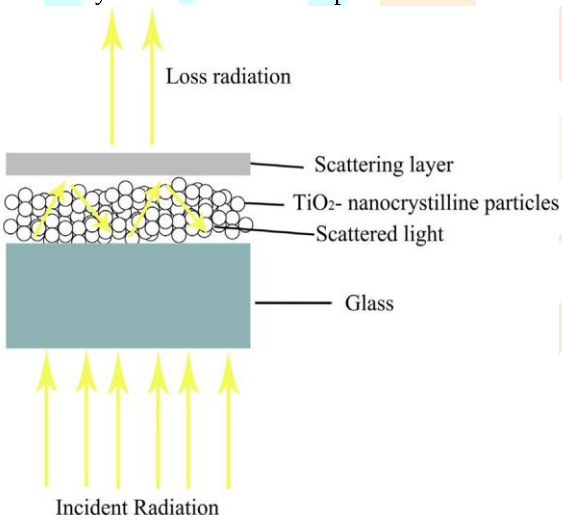

Figure 6: Diagram expresses several layers on top of nanocrystalline TiO2 and scatter light

XI. Transparent IR-transmitting photovoltaic cell

Research on photovoltaic cells has mostly focused on the challenge of incorporating transparency and photonic energy absorption in one material. Cells with an average transparency of less than 30% but sufficient efficiency have been produced as a result of intensive study into the creation of thin layers that are translucent to some extent but still absorb visible lightBut in 2011, Richard Lupnt's research group used a different strategy and modified the dye molecules to absorb UV and near-infrared (NIR) wavelengths (650-850 nm) in order to create a transparent solar cell. The research team developed a heterojunction organic PV (OPV) that is transparent to visible light with a transmission of more than 65% and absorbs in the near-infrared spectrum with an efficiency of 1.3 0.1%. Chloro-aluminum phthalocyanine (ClAlPc), a molecular organic donor, and C60, a molecular acceptor, are the two parts of the OPV [106]. The challenge of developing transparent solar cells with great efficiency has a potential remedy in this new method, and more research in this field is going on.

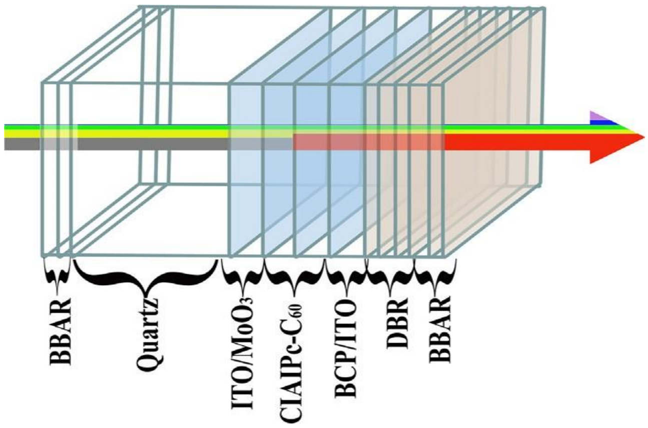

Figure 7:The transparency

XII. POLYMER SOLAR CELLS

The prospect of solution processing for the creation of transparent solar cells (TSC) was investigated by a research team from the University of California in 2012. The absorbing materials must completely soak up each of the light in the near-infrared (NIR) and ultraviolet (UV)) bands while still allowing visible light to pass through for them to achieve an adequate TPV. Numerous materials, including transparent conducting solids like graphene and carbon nanotubes, have these features. However, with only these components, a TPV can't be created. As an outcome, It is advised that a transparent polymer solar cell be used in conjunction with a transparent conducting material.In 2012, a research team from the University of California examined whether transparent solar cells (TSC) might be produced by solution processing. For an appropriate TPV, the absorbing materials must completely absorb each of Near-infrared (NIR) and ultraviolet (UV) light waves bands while still allowing visible light to pass through. These features are present in a wide range of materials, including transparent conducting solids like graphene and carbon nanotubes. A TPV cannot be created solely from them, though. This leads to the recommendation that you combine an opaque polymer solar cell with a transparent conducting substance.

Polymers are used in three TPV systems that appear to absorb in the NIR region. They vary in how they mix the parts. For instance, the first analysis proposed a TPV that combines an AgNW conductor with a polymer that is highly transparent to visible light and sensitive to NIR light.

Another TPV method known as visibly transparent polymer solar cells (PSCs) uses a polymer that is capable of absorbing near-infrared light while allowing visible light move across. Through a mild solution process, a silver nanowire metal oxide is coated to the visible electrode. At 550 nm, the transparency is 66% and the efficiency is 4%.

shows the architecture of the transparent PSC. A UV and NIR light-sensitive chemical separates the two transparent electrodes. PBDTT-DPP: PCBM is generated when the active substance and PCBM form a polymer heterojunction in which the active component acts as an electron acceptor and PCBM as a donor of electrons.

The photoactive material utilised in this study precisely reflects UV and NIR light while having an average visible transmittance (AVT) of 68%. ITO, which acts as the electrode anode substrate and has been modified with a PEDOT: PSS layer, is the primary component of the PV cell. Choosing the electrode that will be affixed to the top is crucial since organic materials are prone to failure and might not withstand the deposition process. The most effective method to deal with this issue is to use a spray deposition process to apply a covering of AgNW. The PV cell's quality and lifelong are ensured by this approach.

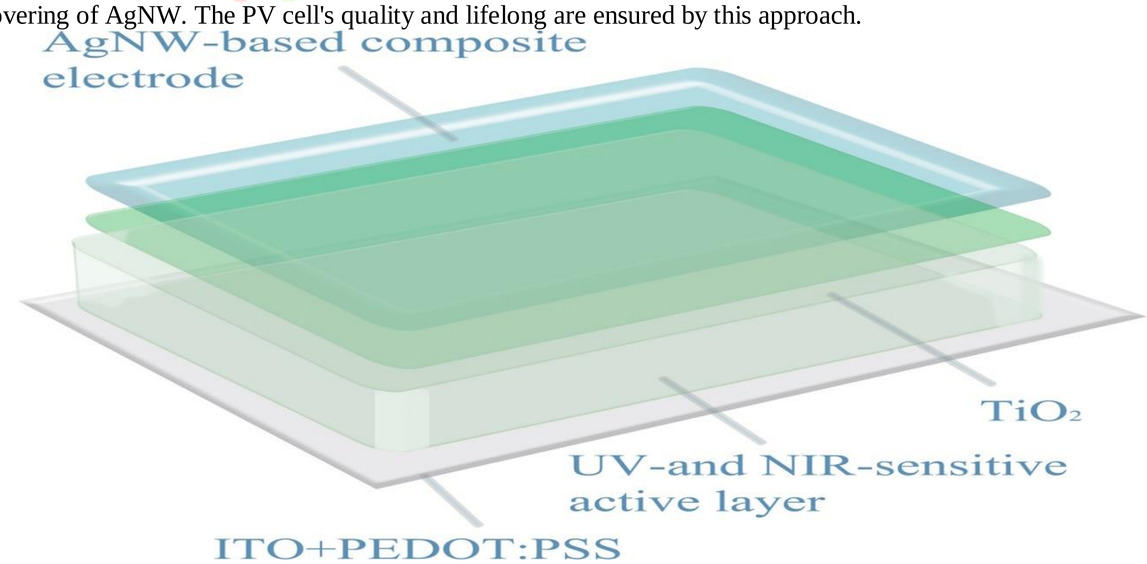

Figure 8: Transparent PSC.

Based on the study, a narrow band gap polymer (PBDTTT-C-T) in the TPV produced a gearbox efficiency of 7.56 % and an average of 25 %. The active component is PC71BM, and the polymer is built from alternating units of thieno [3,4-b] thiophene (TT) and benzo [1,2-b: 4,5-b'] thiophene (BDT). ITO glass was utilised as the substrate. A spin-coated ZnO sol-gel layer was then put on top, and then a self-assembled C60 monolayer was added. Heat-induced evaporation of MoO3 and Ag formed the anode. A possible polymer material with a high effectiveness of 7.6% in the visible light spectrum is the PBDTTT-C-T: PC71BM bulk-heterojunction (BHJ). The PTB7: PC71BM material was used in a different study, which recorded a transmittance of 30% and an efficiency of 5.6%. The solar cell construction consists of five layers.

Transparent solar windows

TLSC approach to solar cell design, invented at Michigan State University in 2014, utilises organic salts to construct a special framework that combines efficiency with transparency. TLSC design combines NIR fluorescent transparent dyes with UV fluorescent transparent dyes to collect UV and NIR light, convert it into visible light, and direct it to the glass' edge where the solar cell is installed. To make cyanine salt-host blends with high atomic yields and spectrally selective NIR harvesting, canine and cyanine salt luminophore combinations are used. The fluid then drops onto a glass substrate. 0.4% and 86%, respectively, of TLSC's operations are efficient and transparent. This concept appears to be a viable approach to the challenge of making solar cells that are both efficient and easily visible.

XIII. A SOLAR CELL BASED ON PEROVSKITES

By employing an absorbent substance with a smaller band gap than photons, which allows visible light to pass through Researchers want to make organic solar cells more semi- transparent while absorbing near-infrared light. The exploration transparent materials that can boost cell efficiency, such methyl ammonium lead halide perovskite, is driven by the fact that improved visibility might have an adverse effect on efficiency. An organic transport component, a metal oxide layer composed of TiO_2 or Al_2O_3, and a metal oxide layer are typical parts of perovskite solar cells. Due to their high absorption coefficient, high transport mobility, high stability, and straight band gap, perovskites, which are common organic compounds, constitute perfect solar cell materials. As a result, perovskites are becoming increasingly utilised for creating solar cells, with DSSC no more being the substance of choice.

The University of Antioquia in Spain developed semi-transparent perovskites with 6.4% PCE - 29% AVT and 7.3% PCE - 22% AVT in 2014. The researchers used perovskite evaporation deposition, a successful method that enables the continuous deposition of layers with a low thickness (less than 40 nm). We used a 6 nm thick ultra-thin gold electrode that was encased in a LiF layer for protection and to cut down on power loss. By reducing the thickness, this approach enhanced transmission. The LiF layer alters the cell's internal electric field circulation in along with offering protection. Two 95 nm-thick layers of methyl ammonium lead halide exist between the parts that block holes and electrons. The difficulty in creating semi-transparent perovskite with high efficiency may be overcome with this novel technique, and additional study in this field is currently underway.

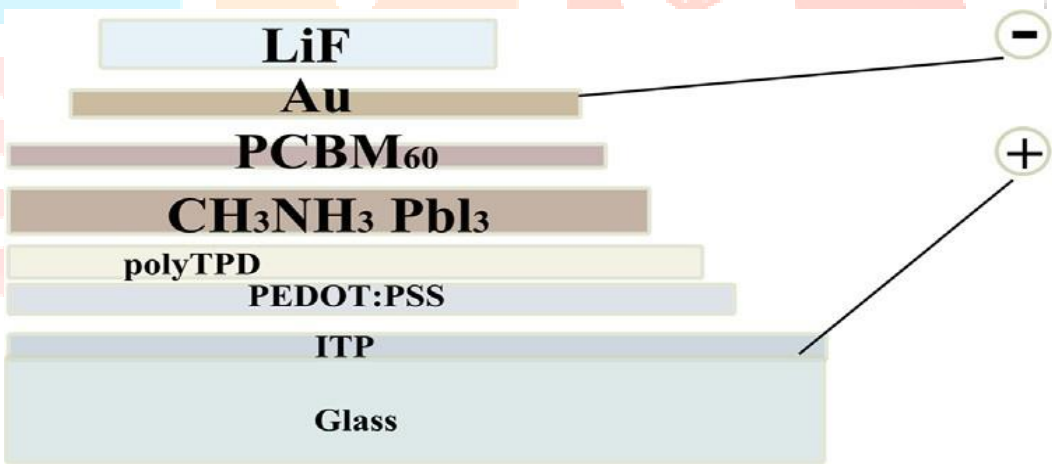

Figure 9: 8A representation of the layer order :

Electrostatic deposition

Producing thin films via electrophoretic deposition is an easy and effective technique. To deposit a thin layer on FTO glass, an approach that involves two steps is used. To drop particles on the glass, an electric field is created by first applying a direct voltage between two electrodes. Both electrodes are submerged in the atom-containing fluid, with one serving as the cathode and the other as the anode. The EPD's component pieces are shown in Figure 9 and are tightly packed. On one of the electrodes, the synthesised components mix and condense to form a thin layer of titanium dioxide. More research is being done in this area, but this method offers a viable method for accurately and efficiently creating thin films

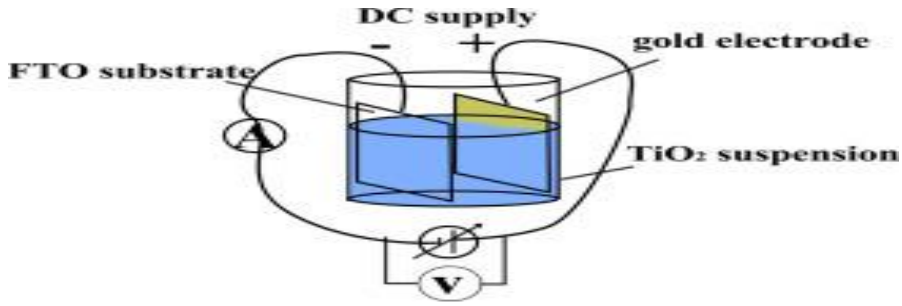

Fig-10 Electrophoretic deposition is known as EPD

Due to the capacity to create layers with lots of surface area and walls that are thin, these features are especially useful for solar cell applications. Another feature which contributes to the generated oxide's good alignment for transparency is its tubular framework. To get various degrees of transparency, you may alter the inner diameter, length, and tube thickness. The structure of the nanotubes can be observed in Figure 8 below.

Although there are additional methods of creating TiO2 nanotubes, anodization is the most effective technique. Using this technique, conducting glass is anodized at high positive potentials in an electrolyte containing fluoride to produce nanotubes.. By adjusting key electrochemical parameters including temperature, voltage, sweep rate of the potential ramp, and anodization length, you can alter the shape of the nanotubes. This strategy presents a viable way for producing TiO2 nanotubes with great precision and effectiveness, and further study in this field is going on.

XIV. Dipping coater tools

These properties are particularly advantageous for solar cell applications as they enable creating of layers with a big surface area but a thin thickness. The grown oxide is additionally tubular and has a great orientation for transparency [124,125]. To achieve multiple levels of transparency, the inside size, in length. and depth of the tube may all be varied. Fig. 8 below focuses on the nanotubes' configuration.

While there are alternative methods for producing TiO2 nanotubes, anodization is considered the most reliable approach. This method involves coating conducting glass in a chloride-containing electrolyte at high positive potentials, which causes TiO2 tubes to grow. The nanotube architecture is an essential component of a perovskite solar cell, as shown in Figure 7. This approach offers a promising solution for creating TiO2 nanotubes with high precision and efficiency, and further research in this area is ongoing.

XV. Sputter coating

Sputtering is a switch method for generating thin films of nanotube., and it is used to cover tin oxide that has been doped with fluorine FTO with a thin coating of titanium nanotube. The process entails two main steps: first, thin sheets of TiO2 nanotubes are produced via anodization and sputtering, and second, the nanotube arrays are annealed with oxygen at 459 °C. The other Ti islands are then oxidised until they turn transparent. However, as no specific inference has been drawn from this specific source, more research must be conducted to confirm the above approach for TSC.

Solar -cells with multiple exciton generations

A lot of individuals are keen on quantum dots (QDs) due to their remarkable opto-electronic characteristics. QDs can be used in solar cell applications because, depending on how thin they are cut, they exhibit a variable absorbance spectrum. With an emphasis on clear or partially transparent QD-sensitized solar cells, many manufacturing techniques are employed to create QD-based solar cells. In 2016, a report on two TSC models using QDs was released by Xiaoliang Zhang from Uppsala University in Sweden. The first kind takes use of PbS QD, a material with a variable band gap that is especially beneficial in the infrared spectrum and makes it the ideal light absorber for solar cell applications. A 9% power conversion efficiency seems to have been achieved by certain heterojunction PbS QD solar cells. PbS QD's fascinating property is its A 9% power conversion efficiency seems to have been achieved by sure heterojunction PbS QD solar cells. The ability of PbS QD to produce an enormous amount of excitation is an amazing characteristic. The challenging task of developing solar cells with high efficiency and transparency has a possible answer in this novel technique, and more research in this field is going on.

Figure 10 Quantum dots in an inorganic-organic hybrid solar cell.

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Using the keep-turning-casting method, a PbS QD with a 1.3 eV band gap energy is created layer by layer on the TiO2 sheet and acts as a light absorber. A change is made to the 3-mercaptopropionic acid (MPA) bifunctional ligand to improve the mobility of the charge carrier inside the QD. Figure 10 shows the shape of the cell before a thin coating of 10 nm Au is thermally evaporated on top of the QD layer. The PCE and AVT may be changed from 2.04% to 3.88% and 32.1% to 22.7%, respectively, by varying the thickness of the QDs. In the end, a semi-transparent solar cell made of PbS QDs is capable of generating 3.88% PCE and 22% AVT. An efficiency of 5.4% and an average apparent transmittance of 24.1% have been identified in the second model. This device's layout and manufacturing materials aid in decreasing optical loss, which eventually boosts efficiency. Applications with low transmittance requirements can use this device. The difficulty in creating solar cells with high efficiency and transparency has a potential solution in this novel technique, and more research in this area is going on.

XVI. Conversation

Transparent solar panels are a very desirable technical advancement that may be used in a variety of daily living circumstances, such as the windows of buildings, cars, trains, cell phones, computers, and other electronic gadgets. The synthesis of the transparent material used to construct the TSC and the creation of a novel TSC structure that retains high efficiency are the first two issues that must be solved so as to put this technology into practise. Selecting materials which allow visible-wavelength transmission and photon absorption in the invisible part of the wavelength is the primary challenge since these materials can be difficult to come by. The difficulty of developing solar cells with high efficiency and transparency has a potential solution in this new technique, and more research is needed in this

The active material is applied using a variety of methods, including electrophoretic deposition (EPD), dip-coating, screen-printing DSSC, and transparent solar cell fabrication. Each technique has advantages and drawbacks of its own. A 60% transmission with 9.2% efficiency can be achieved with screen printing, a 55% transmission with 7.1% efficiency is feasible with electrophoretic deposition, and a 70% transmission with 8.22% efficiency is possible with dip coating. Each method has a different level of complexity and production cost, though. The difficulty of developing solar cells with high efficiency and transparency has a potential solution in this new technique, and more research in this area is going on.

In summary, the conversion process for transparent solar cells is challenging, but ongoing research studies are being conducted to overcome these challenges. Transparent solar cells are produced using an array of active material deposition methods, each of which has advantages and drawbacks.. Further research and development are needed to improve efficiency while reducing costs and to make transparent solar cells a viable option for various applications

Table 1
comparisons of various TPV based on method.

The solar cell manufacturer	Year	V (V) [c]	T% [a]	η% [e] (%)	(%) J_{sc} [b] (mA cm^{-2})	FF [d]
Solar cell using quantum dots	2016	18.1	24%	5.4%	0.56	5.4%
Quantum Dot Colloidal Solar Cell	2016	0.58	22.74%	3.88%	12.83	0.52
Dipping apparatus	**2015**	0.738	**~70%**	**8.22%**	**16.17**	0.688
Electrophoretic painting	**2015**	**0.68**	**55%**	**7.1**	**14.8 3**	**0.71**
Perovskite-perovskite tandem cell	**2014**	**1.025**	**77^%**	**12.7%**	**17.5**	**0.71**
Hybrid perovskites	**2014**	**1.074**	**30%**	**10.30**	**14.83**	**57.9**
Transparent light solar concentrator (TLSC)	**2014**	**0.5 ± 0.01**	**87%**	**0.4 ± 0.03%**	**1.2 ± 0.1**	**0.66 ± 0.02**
Organic Solar Cell (OSC)	**2012**	**0.77**	**66%**	**4.02%**	**9.3**	**56.2**
NIR-OPV (Near-Infrared Organic Photovoltaic)	**2011**	**0.62 ± 0.02**	**58%**	**1.7 ± 0.1%.**	4.7 ± 0.3	**56.2**
Grätzel cell printed by screen printing	**2007**	0.779	**60%**	**9.2%**	**16.25**	**.073**

A. A light that transmits through the solar cell at a certain rate
B. The number refers for the solar cell's efficiency assessment.
C. Calculated by reducing the highest power by the theoretical power, the Fill factor.
D. The gear system achieved its maximum speed at 800 nm.
E. E. Voltage is related to a solar cell's one cm2 active area.
F. F. The solar cell has a short current circuit and a 1 cm2 active area.

The Lunt team at a university in the US thinks that by organising and improving the assets for the filled design of TPV, it will be possible to retain an average gear of more than 70% while achieving a 10% efficiency from TLSC. Within five years, this technology should be accessible for straightforward uses like electrical devices. Over the next nine years, significant advancements are projected that will lead to resolving global issues with transparent solar cells. Research on transparent solar cells is at the forefront, with additional nations including Switzerland, China, and Japan joining industrialised nations in this regard. The difficulty in creating solar cells with high efficiency and transparency has a potential solution in this new technique, and further investigation in this.

additional research into this creative technique's possible answer.Markets must take efficiency, transparency, and affordability into consideration when deciding which technology is ideal for use on a daily basis. Each technology's cost is broken down into three separate groups: the initial outlay for the parts required to make the solar cell, the solar cell's manufacturing cost, and the system installation cost. It is challenging to estimate the cost of system setup because this technology is still in its early phases. The price, however, varies according on the applications and the efficiency of the energy source required for those uses. Due to the structure's optimisation, it is reasonable to predict that TSC will be cheap in terms of installation and installation spaces.

The idea of merging electricity production with transparency boosts commercial operations options, with a wide range of possible uses from electronics to structures. The primary benefits of these renewable and free energy-gathering applications include improved accessibility and better utilization of available space. Although present research focuses on the size of the solar cell, it is anticipated that over the next ten years this technology will scale up to the size of transparent solar panels. Despite the difficulty of the concept, there are numerous benefits. For example, if this technology is fully utilized and replaces the bulk of the windows in a structure, it will be able to supply 25% of the power required.

XVII. Conclusion

In conclusion, it is tough to create transparent solar cells due to the intrinsic tension between transparency and photonic absorption. Although the degree of transparency needed for each application varies, TPV is a beneficial solution for a variety of purposes. This research compared the benefits and drawbacks of nine TSC technologies, which have been evaluated in the context of attempts and processes that have produced transmissions of more than 20%. Utilising transparent absorbing materials that can absorb light in the infrared and ultraviolet range or reducing the thickness of the component of the solar cell by using thin film technologies and other deposition methods were the two main recommendations. Each application made use of transparent substrates like ITO, FTO glass, or polymer. TLSC approach has the highest level of openness that has been seen (86%), yet it was only 1% effective. The greatest efficiency to transparency ratio, 8.2%:70%, was achieved using a nanotube thin film of TiO2 for transparent DSSC. TPV is currently being researched and is not yet commercially accessible, but it is anticipated that this study will eventually lead to its inclusion in the majority of electrical applications. Mobile devices will soon be able to recharge on their own, and skyscrapers won't need as much roof area for solar panels because they will need no net energy. The issue of developing solar cells with high efficiency and transparency can be overcome with this novel technique, and more study in this area is now being conducted.

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