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Recent Advances in Photovoltaic Sustainable Solar Sensing Energy Conversion

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Abstract

The important of sustainable energy supply in today's world has led to widely efforts by researchers to find an alternative source. In this paper we present a renewable resource called solar cell. Also, traditional solar cells is analysed which help us design new devices with high conversion energy. In other world to solve the problem and limitations of old solar cells devices like low efficiency, expensive operating process and not economically to use in large scale, perovskite solar cells (PVCs) proposed. Perovskite solar cells have the highest capability compared to other solar cells like Si-based photovoltaic solar cells and CFTs solar cells, with high efficiency and cost effectiveness. It is noteworthy that the discovery of new materials with unique properties such as graphene help researchers to improve solar cells efficiency. Beside this graphene-based perovskite devices are enabled rapid progress with high efficiency. Using graphene on the top of the perovskite layer in PVCs not only optimize PVCs performance to convert more light to sustainable energy but also improvement stability and PCE.. To note developed solar cells technology pave the way for easy processing, mass production and commercialization.

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1-Introduction

Recently growing worldwide energy consumption all around the world has gained a great attention. In order to supply this sustainable energy researches have emphasized on renewable energy sources which are clean without pollution and changing global climate. Among all renewable resources solar cells is one of the pioneering methods for future generation by converting sun light to electricity. Electromagnetic sensing is then to important in advanced devices and fields. It is estimated to provide 16% of global electricity, roughly about 4600 MW. In the contemporary era scientists are looking for devices and materials which are cheaper and produces more converted power [1].

According to the recent statistics, 90% of the photovoltaic devices based on silicon (Si) wafers due to their abundant and nontoxicity. But high cost of processing the exploring of new martials was considered as an urgent need to find another architecture. Some researches carried out by Si nanostructure that progress the efficiency. Whilst surface processing technique to provide mono atomic crystal is expensive. This limitation of this materials encourages researchers to seek new technique and materials. The purpose of continued exploratory research is to resolve this problem with several resource such as water and gas resource. As a result, perovskite solar cell (PSCs) proposed. Overall, two structures are suggested for PSCs, 1) mesostructured device, 2) planar device. Generally planar device gives better practical application compered to mesostructured device. Also, several factors affect the stability of perovskite solar cell like thermal treatment, light illumination and moisture [2–16].

A compression was made between perovskite solar cells and traditional solar cells that showed PSCs have remarkable properties such as direct band gap, an extraordinary rise in the efficiency, defect toleration, have rapid Power conversion sustainable energy (PCE) improvement at least 22.1%. As the desire for PCE improvement and low-cost production increase exponentially increase years much attention has been paid to integrate graphene into PCS. Therefore, the integration is important parameter. For this purpose, several numerical and experimental methods were considered. Graphene was first discovered by Andre Geim and Novoselove in 2004.

It is well known graphene is two dimensional 2D sheet with a thickness of only one carbon atom composed of 3D bulk graphite. It is the lightest material known with high mobility, high conductivity, high transparency, high flexibility and high surface to volume ratio. For this purpose, organic and inorganic pores are considered Hence graphene provide outstanding designs to boost the performance of PSLs. Several classification of techniques perovskites were proposed such as spray coating, perovskite deposited by ultrasonic spray. Dip coating, lead halide film is deposited by applying organic halide salts converted to perovskite. For above structure a laser should be determined [17].

Chemical vapor deposition. Ink-jet printing and blade coating were used to PSC fabrication. To approach high resolution screen printing has been used. Recent research interests have been concentrated on improving PSC function namely solvent engineering, interfacial engineering, band gap engineering. Given the continually developing of the research for devises and materials, several materials were proposed to obtain effective solar cell materials. Such as In and Ga, CdTe [18].

These materials not only were expensive and rare but also ineffective due to the presence of some elements. Hence to solve these limitation Cu-derived compounds were proposed. Cu based chalcogenide such as Cu_2ZnSnS_4 (CZTS) is a promising candidate for solar cell material due to their abundant and great potentials in high absorption. However, some defects like small atomic size of Cu and Zn to mix them and band grading are observed that interfere with the function of solar cells. There for many attempts were made to replace Cu or Zn with suitable elements. Accordingly, Cu_2FeSnS_4 (CFTS) in terms of its suitable properties was considered because of low-cost, decreasing of optical energy, enhancement of conductivity and providing appropriate band gap (1.28-1.050ev).

Both chemical and physical technique were used to fabricate CFTS. Some of techniques include hot injection, microwave, liquid reflux, hydro and solvothermal. More interestingly photo-catalytic dye degradation is another major achievement of CFTS. In this regard, some renewable resource is presented in Fig. 1. Also, it is noted that Antibacterial activity can be used for sustainable energy conversion.

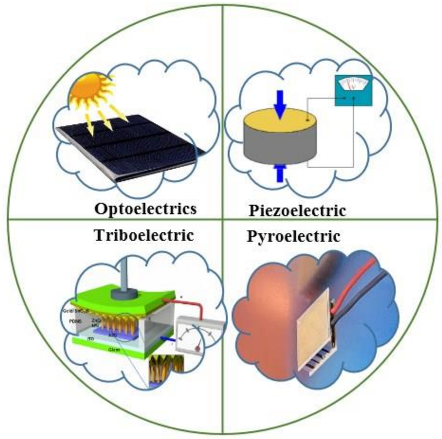

Fig. 1 The renewable resource of sustainable energy

2- Si-based photovoltaic cell

At present, Si due to its linear response, broad band solar and high thermal conductivity has always been considered in solar photovoltaic (SPV) system. It is noticeable several other materials for SPV were reported like thin photovoltaic cell TFPV and terrestrial by III-V materials, but due to their problems (poisonous material and high-cost) showed less potential in SPV. In SPV technology Si treated as a green material and have commercialized. Also, to obtain broad energy in Si is a significant for cost effectiveness the surface processing. One of the interesting points in Si technology is that to improve electrical properties nanostructures of Si dielectrics is proposed. Likewise, thin dielectrics and eco-friendly materials were promising step to reduce both electrical and optical loss. Also, it has proved SiO_2, Si_3N, TiO_2, AlN and thin dielectric materials were more efficiency. As can be seen in Fig.2, structure of devices tends to smaller scale, whereas their efficiencies improved.

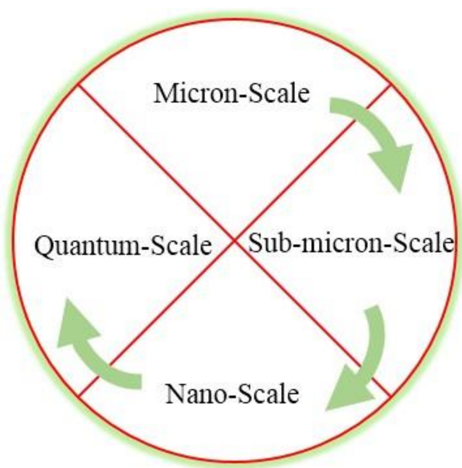

Fig. 2 The structure scale of solar cells

During this investigation velocity of SI cell decreased by using mentioned materials. Moreover, some materials are used to increase conversion efficiency such as SiO_2, SiC, Si_3N_4, ZnO, GaAs, MoS_2, Al_2O_3, Ga_2O_3 and nano thin film conjunction between Nano thin film and Si enhance the efficiency. Also, Si Hetro junction tandem cell (HJTC) and Si Hetro junction cell (HJC) were performed to boost up efficiency. A great deal of study found to solve electrical loss and high energy photons (surface defects), Nano layer passivation are suitable. In one hand materials with higher band gap are considered as supportive field.

Minimize defects and decreasing surface velocity. Generally Nano structures are desirable to improve absorption and photo current. Nano structures not only provide high refractive index RI which appropriate for sub wave length but also maximize absorption. Interestingly absorption in two forms of nano structures and nano layers are different. It has shown nano cone unlike nano structure is able to absorb at all different angles. However different shapes of nano structures like nano wires, nano pillars and Nano pikes enhance efficiency significantly. Additionally, was found applying Si nano wires and Nano crystals at Si-SiO_x juncture extend absorption to 4ev. Resent research has found nano structures-based Si HJC are more advanced in solar cells generation. Some researchers have designed quantum dots QDs on P and N.

Surprisingly crystal Si HJC introduced as a promising technique to obtain high efficiency. Also, open circuit voltage with selective layer of silicon nano structure proposed for future work. It is anticipated thin film Si and crystalline Si due to their iso-electric property are good candidate to enhance efficiency. A researcher group discovered nitride has higher adjustable band gap if replaced by Si in Si HTC structure will increase spectrum absorption. To overcome tunnelling process III-N proposed due to their high conductivity wide band gap and high carrier transport. Also, nitride materials have large piezoelectric effect which convert them to a suitable choice for photonic applications. On other hand III materials (Ga,In) provided a variable RI and InGaN provides wide solar absorption with a band gap in the range of (0.7-3.4ev). It is noteworthy GaN/GaN Nano structure minimize surface defects. The main concern about InGa (Al)N is electron accumulation. That is found that Si doping in GaN improve solar efficiency. According to the report's Si based hetro-structure using SiO_x due to the decreasing electrical property and oxygen at the surface is not promising candidate for Si SPV. Further nano-stoichiometric carbid, nitride or oxide used in Si nanostructure could be effective to minimize surface defects. It is predictable that all of Si HJC is an issue. The Nano structure in different dimensions 3D, 2D, 1D and 0D were applied for efficiency progress. 3D structure improves quantum efficiency. 2D structure enhance photonic and electrical effect. 1D structure absorb high energy with attractive electrical properties. 0D structures such as dots and cons absorb photons in different angles and wavelength. It can be concluded by decreasing nano structures dimension opto-electronic properties increase remarkably. It is evident from results that HJTC has more practical potential than HJC. Majority of experiment has proved high cost of Si wafers in solar cells application is considered as a major problem for mass product for this reason Cu_2FeSnS_4 CFTS proposed. Also, for sensing of light several advanced works were proposed.

3- CFTs Crystals

Cu_2FeSnS_4 Crystals which is made of metallic cluster and dark gray minerals has unit cell arrangement of 4Cu, 2Fe, 2Sn and 8S. In general Cu based chalcogenide like Cu_2ZnSnS_4 and Cu_2FeSnS_4 are two common form. Different techniques like hot-injection, solvo-hydrothermal, microwave and reflux were employed to prepare CFTS nano particles which have wide range of advantages including ease of production, low cost with high performance for large scale manufactures. Synthesis routs mentioned below.

- Hot-injection

The synthesis of CFTs nano crystals by by hot-injection method was first formed by Yan group. They synthesis tetragonal CFTs with dimensional 13nm and band gap about 1.28ev. This process is done by injection reactants into a heated reactor which mono dispersed CFTs is synthesized. Also, wurtzite and zinc blende which are two kinds of CFTs with band gap range roughly 1.5ev were synthesized. Further Oley amine (OLA) and 1-octadeccene (ODE) and oleic acid (OA) respectively applied to synthesis of wurtzite and zinc baleen CFTs nanostructure. Other authors dissolved Cu acetate, Fe acetate and thin chloride in 5 ml of dodecane thiol (DDT) at 120c. Then injection of solution prepared into a mixture of

DDT and OLA were performed at 240c. Finally, when the temperature was at 240c the solution become black and nano structure in the range of 7nm obtained. The Raman modes appeared at 286,318 and 350 1/cm. researchers have done some studies for plasmon-enhanced photocatalytic hydrogen by applying CFTs which prepared in heated reactor. It has proved in numerous experiments that presence of Au cores in the CFTs shell enhanced the photocatalytic hydrogen generation.

- Microwave

This method has gained great attention due to its cost-effective and controllable in size and phase. In a decade ago for the first-time microwave was employed to form nanoparticles. In this synthesis of CFTs nanotubes with a diameter of 400-800 nm was executed. (Alcohol benzyl was solvent). Later CFTs micro sphere and nano particles of CFTs in 5 nm were proposed. To clear contaminated water from dye, hierarchical porous of CFTs reported.

- Solvo hydrothermal

Synthesis of different morphologies of CFTs carried out by this method. Solvothermal and hydrothermal are similar to each other except in the solution used (solution is not aqueous). 15 years ago, mixtures of 2Mm $CuCL_2$, 1mM FeC_{l3}, 1Mm SnC_{l4} and 5Mm of NH_2CSNH_2 added to autoclave at 220c for 14-20h, finally squamous CFTs was synthesized via hydrothermal method. A considerable amount of efforts has been made to report modern colloidal precursor conversion to constitute CFTs. After 10 years tetragonal CFTs nanoparticles by using dimethylformamide DMF soluble. After that 3D CFTs by using 1-cystinean amino acid and sulfuric synthesized by solvothermal method. Moreover, CFTs nano spheres was synthesized by employing ethylene glycol EG and polyvinylpyrrolidone PVP and surface ligand. Also, nano spellers produced in the range of o.4-0.6 micro meter. In this process It was found different concentration of EG and PVP lead to the production of different dimensional particles. Meanwhile in other studies CFTs nano crystals in the range of 3-7nm synthesized by using 1-octa decan amine, thiourea and ethanol. Furthermore 2 different structures of CFTs stannite and wurtzite synthesized on glasses.

- Other methods

In reflux method Fe,Cu, thiourea in to triethylenetetramine TETA and Sn under atmospheric pressure to synthesis CFTs. In addition, mixture of EG and TETA were employed to CFTs synthesis. The templating polymer which is made of acrylonitrile PAN via electrospinning reported to CFTs nanofiber synthesis. In electrospinning time and temperature play an important role during this experiment. Another shape of CFTs procurement was reported in the form of powder at 400c by grinding metal acetate, nitrate thiourea and SnC_{l2} with zirconia balls triturated. Recently an investigator group proposed ball milling no need to amines, organic solvent and catalysts.

Here some solar cells based CFTs have been named: to yield suitable CFTs based solar cells prepared by n-type chalcogenide with precursors like CdS, Ag_2S and Bi_2S_3. A group of authors proposed colour-sensitive solar cells as electrodes. Further CFTs thin film as a counter electrode in dye sensitized solar cells DSS was reported. Lately, an economically and environmentally option promoted as perovskite solar cells PVCs which has dramatically increased the power conversion efficiency from 3.8% to 23.7%. Perovskite structure include active perovskite layer which is located between electron-transporting ETI and hole-transporting layer HTL.

When light pass through ETL the ni-p structure is formed. It is noticeable PSCs structures divided to two basic structure. Firstly, mesoscopic which has n-i-p structure. Secondly, planner type has two configurations n-i-p and p-i-n planner technique. In general, ni-p struggles with depositing material of perovskite onto transparent layer which a layer made of TiO_2 covered this layer. With the difference that in p-i-n manufacturing, transparent layer covered with an HTL for instance poly (3,4-ethylene dioxythiophene). Generally, these two structures have shown high stability. Perovskite solar cells devices have exhibited a huge number of advantages like low-cost, simple processing, high sustainable energy conversion, and high performance. Here we discuss instability problem of PCVs technique:

- Humid existence

It is noticeable that in humid environment PCVs lose the ability to function properly. It is considered as a significant problem. Water or moisture are distractive factors due to the high polarity of water molecules that lead to reduction sensitivity and damage to fabricate of PVCs and most importantly loss of electronic properties. Recently studies have been done that showed 2 dimensional 2D PSCs have better stability. Also mixed dimensional MD perovskite generate conversion energy as large as 12.52%. Additionally, suggested adding 2D perovskite into 3D perovskite which modified moisture stability and high carrier transport will obtain. It has been proved that 2D perovskite was the best known for environmental stability. An interesting experiment was designed to compere two modified and unmodified perovskite solar cells at the same conditions including room temperature and humidity of about 45%. It illustrated that pure perovskite film loss 65% of its initial efficiency but modified perovskite maintains over 95% of its initial efficiency after 2000 hour. • UV Light Another important factor is UV light. The results of investigations demonstrated that encapsulated devices with UV filter were degraded later than non-encapsulated devices under 1.5 illumination. A researcher group during various studies showed methyl ammonium MA free perovskite have more stability. Due to increasing stability inorganic materials as HTL like CUSCN were suggested. • High temperature. Stability of PVCs devices in high temperature is a serious concern. To improve the stability of perovskite thermally resistant material are a promising option. Recently investigation emphasize on using formamidine with high band gap (1.48ev) which enhanced stability. Also using methylammonium as a light absorber proposed with good sustainable energy conversion. 2D perovskite demonstrated high stability over 1000 h. it is noteworthy that 2D perovskite and 3D perovskite are stable at temperature above 250. It is necessary to mentioned organic cation MA and FA are temperature unstable. Whilst adding pure inorganic cerium illustrated dramatically stability. • Structural stability among the different key factors that improve sustainability, structure of solar cells is a significant factor and has different affect in PVCs structure such as tolerance factor. To note tolerance factor in PVCs system should be in the range of between 0.8 and 1, for another solar cells structures it can be higher than 1 and lower than 0.71. Among a large number of different materials with different tolerance factor $FApbI_3$ is a promising candidate which not only have high thermal stability at 230 but also high PCE about 16.8% also is stable in moisture condition.

• Effect of ion displacement

It has been proved in perovskite structure that ion migration declines the long-term stability of material in different condition like: under illumination, stress and electrical basis. Different methods have been utilized to decrease ion diffusion. Several evidences showed applying graphite carbon nitride into active layer restricted. Ion migration with PCE about 19.14%. a research team employed 2D perovskite to enhance stability of $FAPbI_3$ and PCE measured at the range of 21.07%.

4-Role of electrode materials

Electrode used as superior layer which is close to the surrounding in PVS configuration. Some authors employed stocky carbon electrode that obtained high proficiency of approximately 12.8% and excellent stability under UV light. In different researches have been showed gold electrode because of its diffusion lead to invariable degradation in perovskite system. To solve this problem Ag, carbon nano tube, polymer and graphene electrode proposed to achieve high efficiency. To note some metal materials like: Ag and Al due to erosion reaction can decline the PCE. Most importantly researcher to enhance the interface resistance proposed Cr. Especially presenting carbon electrode not only achieve mass production but also provide high stability under UV light. Recently silver nano wires AgNW received great attention and become one of the popular materials in solar cells. Another improvement that carried out in PSCs was intergradation of two-layer including Cr_2O_3/Cr, MoOm/Al with zinc oxide/aluminium.

5-Encapsulation

An effective factor for modifying solar cell devices is encapsulation process. Noteworthy encapsulated devices have longer lifespan than non-encapsulated devices in different circumstances such as long-term UV light, moisture and water existence in environment. The encapsulation process take place with a thin flat piece of glass that cover devices. One of the promising encapsulation processes was organic light emitting diode OLED. Also, multilayer scruff in organic PVCs were proposed. Much work has been done to increase lifetime of perovskite devices like using amorphous Teflon layer on upper surface of device. A huge number of materials have been used in this process namely poly methyl methacrylate, Al_2O_3 and polycarbonate. One of the reliable materials is ethylene vinyl acetate. Also, ethylene-methyl acrylate is a good candidate with high chemical resistance and temperature stability. Poly vinyl butyral used widely as an encapsulating material which is can provide longer lifetime. Moreover tantalum-silicon-oxygen presented good moisture stability.

6-Graphene-based perovskite solar cell

Regarding to the extraordinary properties of the perovskite solar cells mentioned and due to the importance of this technique application in the science, extensive efforts have been made to improve and expand this type of sustainable energy conversion (see the structure of graphene in Fig. 3). Recently novel material has been proposed to enhance PVCs performance. Especially using graphene play an exponentially role in protection, improvement and advancement of PVCs system which is explain below: In recent years graphene has been used as electrode in terms of high stability and good tolerance factor. First time it was introduced by Yan group.

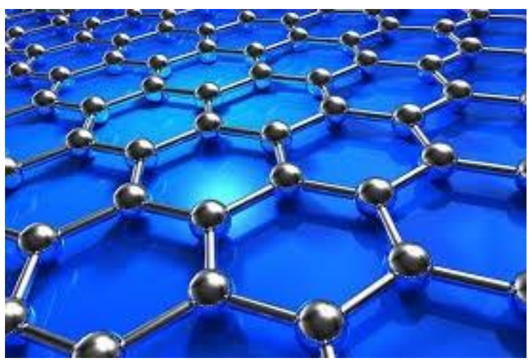

Fig. 3 The hexagonal structure of graphene.

They prepared graphene by CVD method and coated top of the graphene with D-sorbitol for 3 reasons a) decreasing graphene resistance b) used Sorbitol as an adhesion sheet c) more holes doping induction occurred. Also, they observed the efficiency achieved above of 12.37%. A group of investigators have discovered applying molybdenum trioxide which hold transparent material on the surface of graphene could be a way to approach high efficiency about 17.1%. In addition, doping the anodic surface of graphene with gold chloride enhance the propagation length of holes. On the other hand, to increase efficiency used graphene as transporting material in PVCs devices. It was found when graphene into the zinc oxide PVCs advice magnitude of PCE increased from 0.66% to 0.18%. Also, it was determined by employing thin film of perovskite on the graphene lattice in the nanocrystals ZnO yield above 44% are available. A comparison was done between combinations of pure TiO2 nanocomposite and graphene Nano flakes. The results showed PCE of about 90% AND 15.15.6% were received respectively.

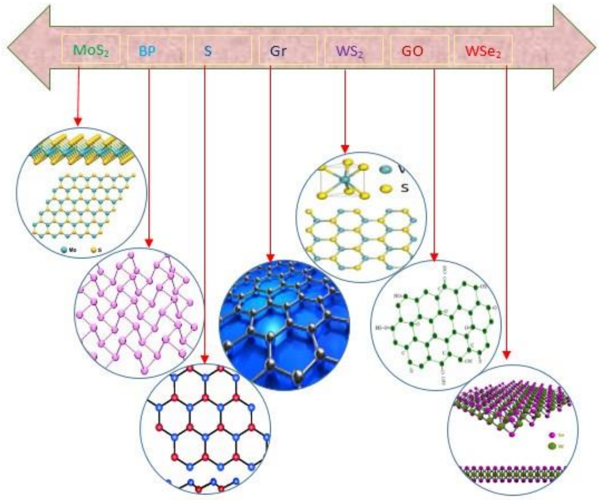

Fig. 4 The advanced materials used for improving solar spectrum.

In addition, it has been proved that perovskite thin film could be easily degraded against moisture. To overcome this crucial issue proposed covering top of the perovskite thin film with a layer of graphene. This is because of the hydrophobic properties of graphene which is protect the perovskite film and prevented reaction between layer of structure and humid in environment. Also in high temperature graphene provide thermal stability by preventing diffusion of atoms in the metal electrode like Ag and Au. According to the reported results of an experiment determined that graphene (produced by CVD method) on the upper layer of perovskite can maintained 94% of initial efficiency at humidity of about 45% and temperature about 8 for 12h. Surprisingly doping graphene with perthiolated tri-sulfuric-annulated hexa—peri hexabenzocoronene TSHBC exhibited high ability to retain 90% of the initial energy when kept in 45% humidity which lasted 10 days. Beside the graphene, several advanced materials are introduced for solar cells, as shown in Fig. 4. Besides, some new two-dimensional materials including metamaterials and metasurface recently give more attention [19–22]. It is worth to mentioning that to optimized the results some important methods are proposed including deep learning, fuzzy algorithm and so on. Several attempts have been done in the previous works to detect of failure behaviours and to obtain the vulnerability of concrete structure with lateral impact loads. It is more important to decrease air-pollutant which by green energy can be achieved [23,24]. Also, green energy is considered in control of homogeneous multiagent systems and UAV systems [25–27]. In Table 1 a comparison between some materials used in solar cells is provided.

Table 1. Solar cells with their efficiency

Si/InGaN nanostructures on Si cells	Efficiency	Improvement results
Nano crystalline silicon QDs based hybrid solar cells [28]	13.73%	Surface of nano crystal and QDs increased absorption and carrier transport respectively
Micro crystalline Si thin film based photovoltaic cells [29]	9.6%	Absorbing of photon increased with poor quality in low-cost
Using graphene quantum dots with Si-hetero junctions as electrode [30]	12.3%5	High conduction of 2D structure enhanced absorption
InGaN/Si double junction solar cells [31]	38.3%	High efficiency approached by recombination with surface and monitoring carrier life time
Integration of monolithically InGaN/Si solar cells [32]	8.3%	Monolithically surface lead to effective PN junction

This table demonstrated some effective factors in different materials.

Table 2. Application of different advanced materials in Solar cells.

Materials	Eff%	Vac(v)	Jsc(mAcm)	F.F. (%)	Area(CM)	Eg(ev)
Cu_2O[33]	3.97	1.204	7.37	44.70	0.15	2.2
PbS[34]	9.88	0.635	21.6	71.9	0.05	NA
Bi_2S_3[35]	3.3	0.700	10.7	45.0	0.18	1.2
GeSe[36]	1.5	0.240	14.5	42.6	0.09	1.1-1.2
$AgBiS_2$[37]	6.31	0.450	22.1	63.0	0.017	1.3
Cu_2FeSnS_4[38]	3.0	0.610	9.3	52.0	0.1	1.5
(In,Ga)N[33]	3.0	1.8	2.6	64.0	0.046	NA

7-Conclusion

In conclusion, some main solar cells have been defined including Si-based solar cells, CFTs-based solar cells and perovskite solar cells. It has been demonstrated that in spite of the fact that Si-based photovoltaic solar cells PVs are suitable and have good potential to produce clean energy without emitting any polluting particles into the environment. But the process of preparing raw materials for use in solar cells is costly which is not commercially viable and, in some case, showed low power conversion sustainable energy. Perovskite solar cells by having many advantageous like low cost effective, availability of device, rapid energy conversion, high stability and high PEC overcome limitations like defects on the surface, high cost and low practical efficiency proposing new material like graphene due to its high surface-to-volume ratio with high optical properties enhanced the performance of solar cells devices. Using graphene on the top of the perovskite layer in PVCs not only optimize PVCs performance to convert more light to sustainable energy but also improvement stability and PCE.

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