Study of Perovskite Solar Cell And Its Efficiency

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Abstract- *Solar power is a fast developing industry as a part of renewable energy in India. The country's solar installed capacity was 40.09Gigawatt(GW) as on 31 March 2021.But still India is 5th among the top 8 countries for installations and total installed capacity in 2019 for cumulative capacity according to the International Energy Agency. But due to some of the reasons like high cost, weather dependency and inefficiency to convert energy is making it hard to scale and adapt in India. But due to the ongoing research and innovation in the solar cells that are being used there are many solutions to overcome this problem. In the same view we have developed an idea to use Perovskite Solar Cells(PSCs) that have high efficiency in converting solar energy, great light absorption potential that would enable people to use solar power thus leading to a sustainable future. It would be low cost and very much efficient than the conventional solar cells and very much effective. This review will give a path on the requirements and address the main issues of PSCs.*

Keywords- Perovskite, solar cell.

I. INTRODUCTION

A Perovskite Solar Cell(PSCs) is a type of solar cell which is commonly made of hybrid organic-inorganic lead or tin halide based material. In recent years the PSCs have got a increased from 3.8% in 2009 to 25.5% in 2020[1].They also gained a lot of attention as a potential replacement of the silicon photo devices. Perovskite solar cells are becoming commercially attractive because of its lot of attention because of the drastic development in its efficiency, which has potential to achieve higher efficiency and low production cost compared to traditional silicon solar cells. The perovskite materials have a large band gap from 1.5ev to 2.3ev[2] and great light absorption coefficient(higher than $104cm^{-1}$)[3].The low cost and convenient fabrication technique have an advantage over the silicon-based devices, which require complicated and costly high-vacuum deposition methods. The meaning of "perovskite "was about the crystal structure of calcium titanate, which was discovered by German mineralogist Gustav Rose and was named by the Russian mineralogist Lev Perovskite perovskite light absorption layer have general formula ABX3.A is an organic cation like, methyl-ammonium $CH_3NH_3^+$,B stands for metal cation (Pb^{2+}) and X is halide anion (I^-).this was based on dye sensitized solar cell architecture, and generated power conversion efficiency of 3.8%.This cell was stable for only few minutes as liquid corrosive electrolyte was used here. Using the same dye-sensitized concept, Park et al. achieved a PCE of 6.5% in the year 2011.The first record of perovskite –based solar cell efficiency was reported by Miyasaka et al.They reported an efficiency of 3.8% based on DSSC structure. In the year 2012 Lee et al. reported a efficiency of 10.9% having open-circuit voltage greater than 1.1V.

Wang et al. [4] introduced graphene into PSCs and acquired an efficiency of 15.6% in 2013 and the application of another perovskite material, formamidinium iodide ($HC(NH_2)_2PbI_3$) together with poly-triarylamine (PTAA) as a new HTM brought a remarkable 20.1% efficiency in 2015 . Seong SikShon et al. recorded the efficiency of 21.2% in the year 2016 and also accomplished a long term stable efficiency of 21.2% in another work [5]. According to the theoretical calculations based on Shockley-Queisser limit, The PSCs containing ($CH_3NH_3PbI_{3-x}Cl_x$)can achieve the efficiency range of 25-27%.There are two measure obstacles which are blocking the improvement and they are hysteresis of current density-voltage and the device performance. PSCs are not adequate for the commercialization with the long-term efficiency measurements (>1000 h).PSCs must pass a series of testing under extreme conditions and environments for the similar duration. The toxicity from the lead in solar cell could be the another problem during manufacturing, using recycling of perovskite[6]. Currently several trials on applying non-toxic alternative metal ions have been reported but their device efficiency is still not promising. It is positive that PSCs can replace si cells because of its amazing electrical, structural ,optical properties.

II. STRUCTURE

2.1Crystal Structure

The perovskite materials have a general crystal structure described as ABX_3, where "A" and "B" are cations with varied sizes and "X" is an anion. A typical unit cell structure of a basic perovskite compound is shown in Figure 1 Organo-metallic halide perovskites include an organic cation (e.g., methyl-ammonium $CH_3NH_3^+$, ethyl-ammonium $CH_3CH_2NH_3^+$, formamidinium $NH_2CH{=}NH_2^+$), a metal cation

of carbon family (i.e., Ge^{2+}, Sn^{2+}, Pb^{2+}) and a halogen anion (i.e., F^-, Cl^-, Br^-, I^-). Among them, methyl-ammonium-lead-iodide ($MAPbI_3$) is the most widely used perovskite light absorber. Some recent research efforts also replaced lead with other metal ions due to the concern of toxicity of lead during device fabrication, especially for the future large-scale manufacturing [7]. In addition, several organic cations ($CH_3NH_3^+$ and $NH_2CH{=}NH_2^+$), inorganic cations (Cs^{2+} and Sn^{2+}) and halide anions (Br^-, Cl^- and I^-) have been used to improve the efficiency and stability [8]

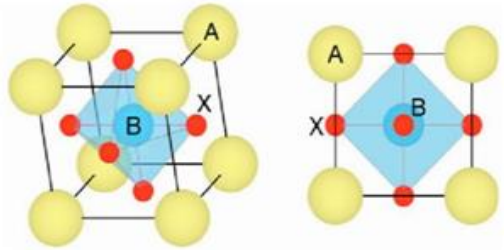

Figure 1-A generic perovskite crystal structure of the form ABX_3 (Jain A., Castelli I.E., Hautier G., Bailey D.H., Jacobson K.W. Performance of genetic algorithms in search for water splitting perovskites. J. Mater. Sci. 2013;48:6519–6534.)

As the changes in the temperature occur ,the different phased of perovskite materials are observed .At temperature lower than 100 k, orthorhombic phase (γ) was observed in perovskite .

And when the temperature is increased to 160 k, the tetragonal phase(β) started to appear [9].as the temperature increases to 330 k, another stable phase was observed that is cubic phase(α).In figure 2 All the three crystal structures are shown. The β to α transition at higher temperature influenced the thermal stability of crystal structures. Moreover, a recent report suggested that light soaking could also trigger the reversible phase transition of perovskite materials[10].

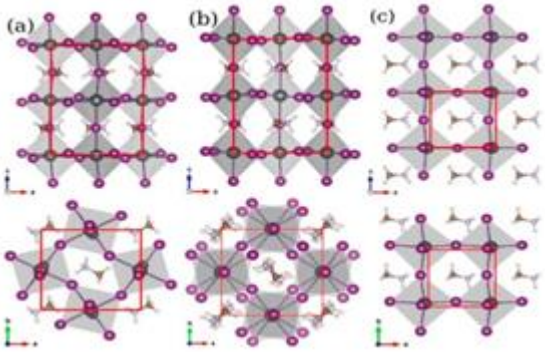

Figure2-Comparision of (a)orthorhombic;(b) tetragonal and (c) cubic phases(source:Korshunova K.,Winterfeld L.,Beeken W.J.D., Runge E. Thermodynamic stability of mixed Pb:Sn methyl-ammonium halide perovskites. Phys. Status Solidi. 2016;253:1907–1915. doi: 10.1002/pssb.20160013 [Google Scholar])

2.2 PSC layers composition:

In the recent years, different perovskite solar cell structures have been developed . we can see the general configuration and different layers of perovskite solar cell. Which usually comprises of tin-doped indium oxide i.e.(TIO) or the fluorine-doped tin oxide(FTO) substrate. There are hole transport layers (HTL) and electron transport layer (ETL) along with metal electrode. And there is photoactive layer of perovskite material.[11]

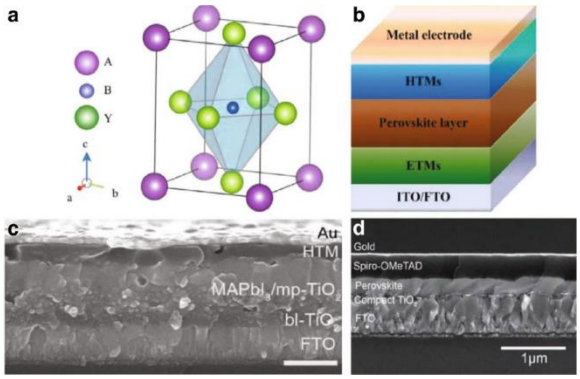

Figure3-*Crystal structure of a perovskite. **b** Schematic diagram of general device. **c** Cross-section scanning electron microscopy (SEM) images of a meso-superstructured perovskite solar cell . **d** Cross-section SEM images of a normal planar perovskite solar cells with the presence of an HTL and an ETL (source: He Tang1,2 , Shengsheng He and Chuangwei Peng,Nanoscale research letters[2017])*

The study of different compositions in perovskite based solar cells in still in process. to make these solar cells industrially available, the problems of perovskite layers must be solved such as to prevent the decomposition of perovskite layer when exposed in UV for long time. Modifying the layers of perovskite solar cells will result in better efficiency. And hopefully PSCs will replace Si solar cells in future.

III. FACTORS AFFECTING STABILITY AND EFFICIENCY PSCS

As there is extraordinary development in the field of perovskite based cells, It is also facing some issues which needs to be solved .there are some factors which contributes to lesser efficiency of PSC.The low stability results in low efficiency. Low stability and toxic elements in cell retards the industrial existence of PSCs. We will discuss those factors one by one briefly.

3.1 UV exposure:

When the perovskite solar cells are exposed to UV light for the long duration ,there was a significant degradation in the perovskite layer of PSC. Although, Degradation was recovered by 1 sun light soaking. Solar cell having initial efficiency 12.2% was degraded to 1.32% during UV exposure and then recovered to 10.5% with continuous 1-sun light soaking.[12] .following figure shows the effect of UV light on the perovskite layer of perovskite based solar cell.

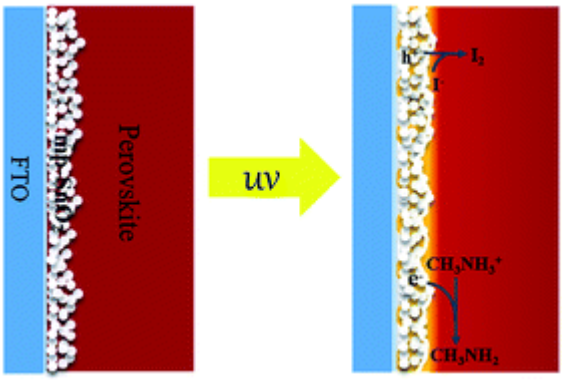

Figure 4 :Degradation of perovskite layer under UV exposure(source:RSC publishing)

3.2 Moisture and oxygen:

Perovskite solar cells are currently facing a problem that they cant stand moisture and oxygen for longer duration. Degradation in $MAPbI_3$ layer is mostly affected because of oxygen. The organic cations that are used in perovskite solar cells are hygroscopic[13]

Perovskite crystal structure decomposes with enough moisture penetration there are some reactions which are responsible for non-reversible degradation in perovskite.

$$CH_3NH_3PbI_3 \longleftrightarrow CH_3NH_3PbI + PbI_2$$

$MAPbI_3$ aq.MAPBI Lead Iodide

$$CH_3NH_3PbI \longleftrightarrow CH_3NH_2 + HI$$

Aq.MAPbI Methylamine hydroiodic Acid

$$O_2 + 4HI \longleftrightarrow 2I_2 + 2H_2O$$

Hydroiodic acid Iodine

The solution for protecting the degradation of layers in perovskite solar cell due to moisture is to increase the strength of bonds between metal halides and the organic compounds. Or one way another solution is to introduce hydrophobic layer in the perovskite based solar cell structure ,that way the both moisture and oxygen will stay away from main functioning layers of PSCs .,as hydrophobic layer will protect those layers .It it may lead in increasing the efficiency as well as the stability of those perovskite solar cell

3.3 Temperature :

Although the solar cells should ideally bear the heat or temperature of the environment ,there are some issues with the perovskite based solar cells. The solar concentration increases the number of photons which are incident on solar cell but on the other side it also increases the temperature of PSCs. Exposure to higher temperature to PSCs decreases the stability of them because of degradation of layers. The degradation due to temperature is much lesser than that of the UV light .but still it needs to be solved. This issue may be fixed by adding coolant layer to maintain the internal temperature of panel, and hence the
greater efficiency and stability.

So, these are the factors which are limiting the performance of PSCs .As there is a fast development in the improvement or efficiency of PSCs ,issues like this will also be resolved in coming period.

IV. LATEST EFFORTS MADE TO INCREASE THE EFFICIENCY OF PSCS:

4.1 Use of molecular glue :

The scientists from brown university came up with concept of “molecular glue” that holds the bond and prevents the degradation of PSC layer. Although ,this process is still in progress. Scientists claimed that the efficiency can be increased with the help of it.

The weak interface is between the perovskite layer and the electron transport layer in PSCs, electron transport layer keeps the current flow in solar cell. If we have to increase the stability and overall performance ,this bond or interfacing must be strong enough [14]. These scientists started experimenting on compounds known as self-assembled mono-layers (SAM).to work out the concept of molecular glue on perovskite solar cell

4.2 Use of reducing agent:

The group of scientists from china, Canada ,Australia had came up with the idea of use of reducing agent in perovskite solar cell .They decided to add something in tin to prevent it from oxidizing or to prevent the degradation of layers in PSCs. so they came up with zwitterionic antioxidant

inhibiter known as FSA. when this reducing agent is added to the mix ,researchers manage to make lead-tin perovskite cell without oxidation or degradation, that too with improved efficiency[15]

4.3 Low Concentrating Photovoltaic systems:

Researchers have studied the perovskite solar cell under the different range of solar concentration like 160W/m^2,390 W/m^2,530 W/m^2,1000 W/m^2 .They studied the different parameters such as effect of temperature, concentration and its respective stability. The following figure 5 shows the graphical representation of changes observed under different illumination. The maximum power under ,1000 W/m^2 was observed to be 15.88mW with CPV unit (Concentrator Photovoltaic system) which was 8.4 times higher than without CPV.

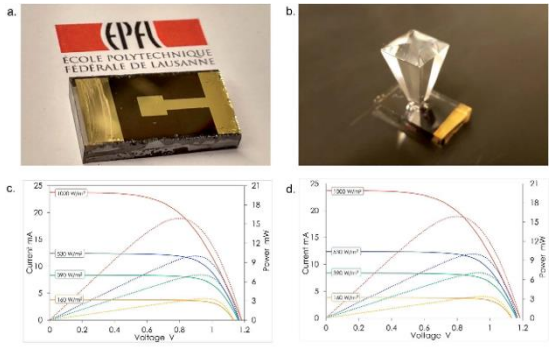

Figure 5-different results obtained under varying illumination(Source:Interdisciplinary research for the development of sustainable energy technologies rsc.li/sustainable-energy,V4 No.2,page:432-954)

V. SCOPE OF USING PSC

a) PSCs can lower the cost of solar energy. As there is significant amount of increase in the efficiency of this solar cell in very few years there are chances that it will replace our existing solar panels .Higher the efficiency of solar cell lower is the cost of solar energy.

b) Higher is the frequency of light shorter is the wavelength ,and high frequency contributes more ejection of possessed electrons. Perovskite solar can react to different range of wavelength, which allows the solar cell to absorb more light and convert into electric energy.

c) Another advantage of PSC is their energy utilization ,utilization refers to amount of photon's energy is lost in the conversion process from light energy to electricity .PSCs are approaching the same level of photon energy utilization as the silicon or GaAs cell.

d) One of the main advantages of PSCs over existing solar cell is they are flexible, semi-transparent, light in weight etc. These are the factors which grabs the attention of many people.

e) Unlike Si solar cells perovskite solar cells have thin more structure .The layers in PSCs can be 15 to 50 nanometers. The cell harvests the electron between the layers to make electricity. The electron transport is very efficient and causes minimal loss.

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