A view on Perovskite Solar Cells: An Emerging Technology

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Abstract – *The need for solar cells is growing rapidly due to its technological advancements and ever-growing efficiency. Perovskite is one such material which in future offers the potential to surpass the Silicon material based solar cells. Its also because of the depletion of fossil fuels which often would result in energy crisis and because of the emission of greenhouse gases resulting in huge production of CO_2 gases, and so there is a high stream of demand in utilizing the solar energy which is a form of renewable sources of energy. Solar energy, if utilized to generate electricity instead of depending upon fossil fuels, then it helps to get rid of the air pollution by almost 90% as per the data given by the US environmental Protection Agency. This paper further emphasizes on the overview of Perovskite cells, fabrication process, comparisons to other materials in terms of efficiency, cost per watt, lifetime analysis, prototype example of implementing the design on the rooftop of vehicles, manufacturing, recycling, and applications.*

Key Words: Perovskite Solar Cells, Fabrication Procedure, Comparisons to other alternative materials, Design Implementation, Manufacturing, Recycling and Applications.

1.INTRODUCTION

Perovskite was named after Russian mineralogist L.A Perovski. It is a hybrid compound structure made of inorganic and organic lead halide material. In the early 2009, efficiency was found to be 3.8% and this phenomenally increased to 26% in 2022. As per National Renewable Energy Laboratory, Australia, the basic structure of perovskite material has a molecular cation of atom lead (Pb) in the middle of the cube, and this cube with 4 corners has the cations of atom Iodine (I). The positions of cation Pb and cation I are reversible, and an equivalent structure can be formed. The material offers higher device efficiency, significant low cost, industry scalable technology, However, due to stability concerns, perovskite have been more prone towards climatic conditions offering less operational and sometimes complete degradation. Much of the work currently is being focused on improving the lifespan of the device in terms of understanding the surrounding environment. Merit is that perovskites can be tuned to respond to various colors in the solar spectrum by tuning the material composition, and a variety of formulations have demonstrated high performance. The flexibility in the bandgap opens another useful application.

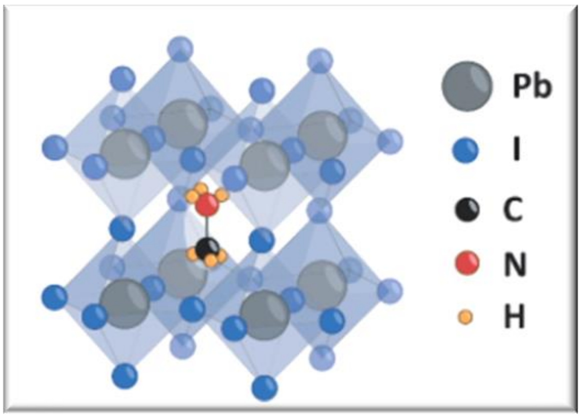

Figure-1: Perovskite (Methyl ammonium lead triiodide)

(NREL: National Renewable Energy Laboratory)

1.1 Fabrication and its material properties

The following figure (Figure 2) highlights the procedure involved in fabricating the Perovskite Solar Cells (PSCs). The manufacturing process is cheaper to produce and offers very simplicity in the development stage. PSCs provides high absorption co-efficient, excellent charge carrier transport, a thickness of about 500nm is sufficient to absorb solar energy. This can be manufactured with simpler chemistry techniques within the laboratory environments unlike for the Silicon based solar cells. Perovskite solar cells are manufactured by Solvent and Vapor deposition techniques. Bandgaps are tunable and optimization can be easily applied as per the solar spectrum. The fabrication process of PSCs is primarily initiated with Florine-doped Tin Oxide Substrate followed by spin coating, annealing, doping and finally electrode deposition.

1.2 Evaluation of Alternatives to other materials

Table1 lists the various solar cell material-based technologies showing the efficiency, cost and the lifespan of each in comparison with Perovskite solar cells. Perovskite material has the highest module efficiency which is about 20-22.1% and 25.7% research efficiency, lower cost per watt and lowest possible lifespan which is just 1 to 2 years.

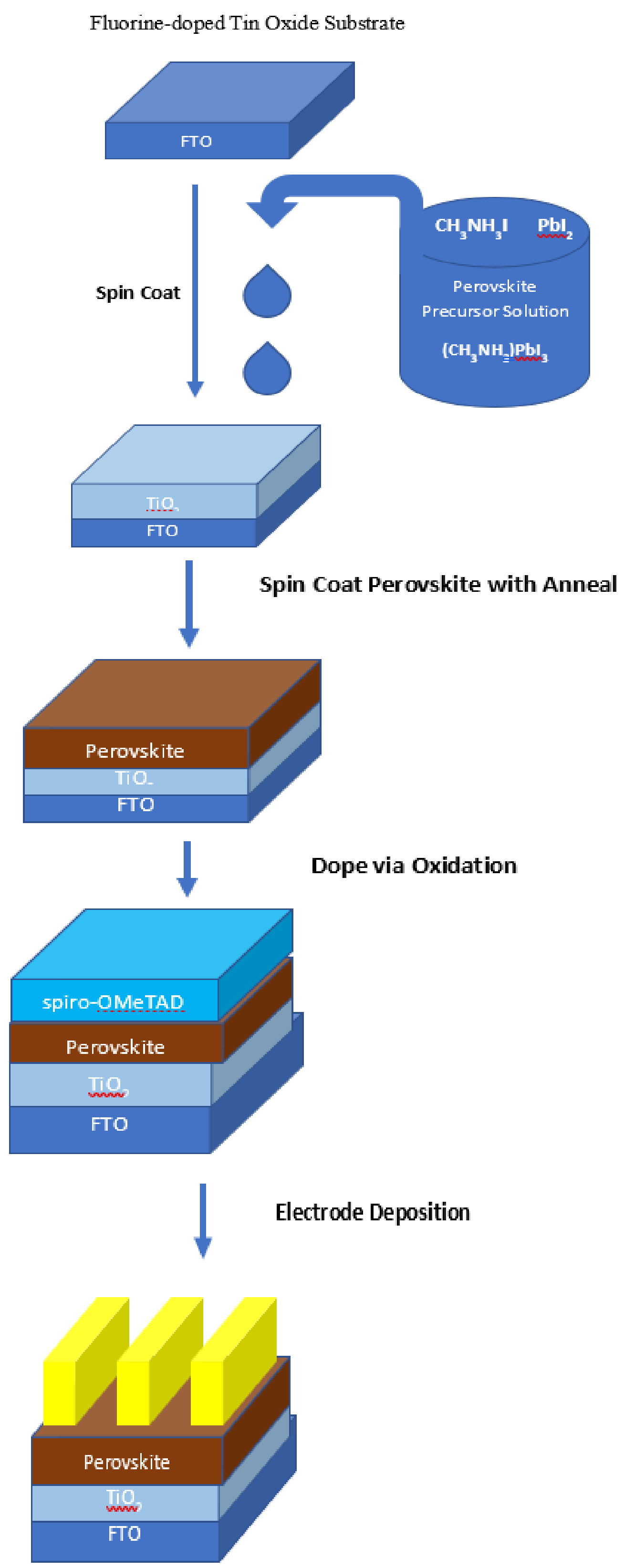

Figure-2: Fabrication Process of a Perovskite Solar Cells (Source: Wenchun Feng, Rutgers University)

Solar Cell Technologies	**Typical Module Efficiency (%)**	**Best Research Efficiency (%)**	**Cost per Watt ($)**	**Lifespan in years**
Monocrystalline	15-20	25	0.75	25
Polycrystalline	13-16	20.40	0.62	25
Amorphous	6-8	13.40	0.69	10-25
CdTe	9-11	18.70	0.57	10-15
CiGs	10-12	20.40	0.40	10-15
Dye Sensitized	4-11	11	0.50	5-10
Perovskite	20-22.1	26	0.26	1-2

Table-1: Solar-cell Comparison of various materials

1.3 Design Implementation and associated costs

Perovskite solar cells (PSCs) can be designed and implemented on the roof top of vehicles, preferably 4-wheelers. The design is carried out on Solar energy concept model by analyzing and constituting the dimension required for each solar panel. The cost is derived considering the power per m^2 of 1000watts. Dimension found is as follows:

- 1st Panel: 100cm X 33.3cm X 3.81cm
- 2nd Panel: 100cm X 33.3cm X 3.81cm
- 3rd Panel: 100cm X 33.3cm X 3.81cm

Solar Cell materials	**Efficiency In (%)**	**Cost per Watt ($)**	**Rated Watt per m^2 of panel**	**Total Cost ($) per panel**
Monocrystalline	15	0.75	150	112.5
Polycrystalline	13	0.62	130	80.6
CdTe	9	0.57	90	51.3
CiGs	10	0.40	100	40
Perovskite	26	1000	260	67.6

Table-2: Design implementation costs of various materials

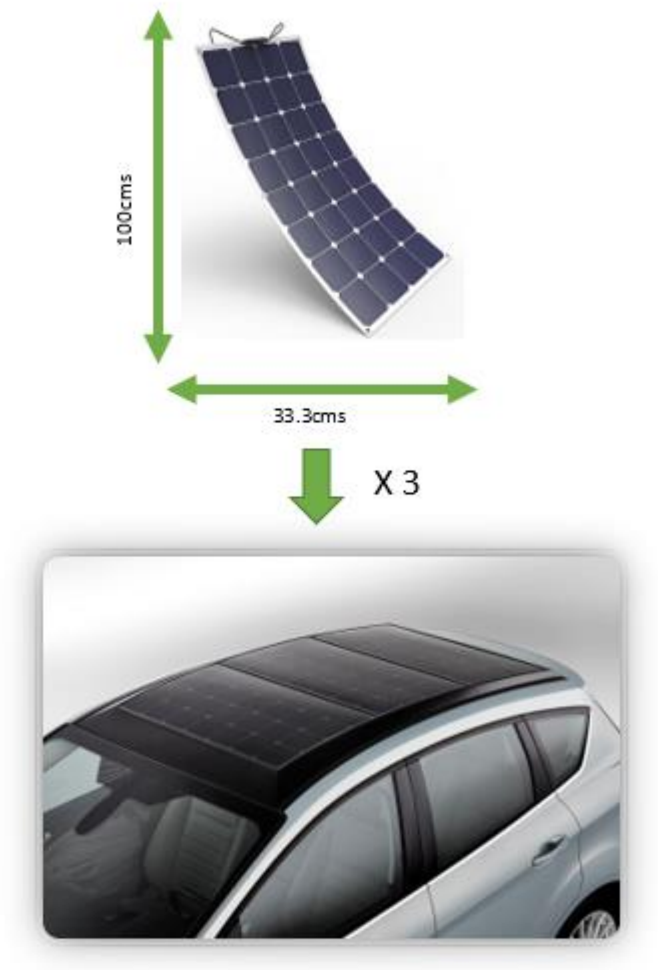

Figure-3: Design Implementation

1.4 Manufacturing of PSCs

Figure-4: Manufacturing Process

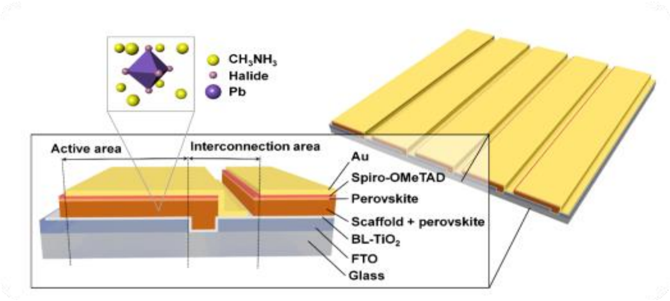

Figure-5: PSCs Manufacturing Process showing active and interconnection Area

The manufacturing of solar cells based on Perovskite material is show in figure4 and figure5. The procedure primarily involves Component Production, Module Manufacturing, Module Use, Disposal.

1.5 Recycling of PSCs

Reuse of the gold electrodes by removing the perovskite layers. Reusing the TiO2 coated transparent conducting substrate. Decomposition of perovskites layer in polar aprotic solvents and cations. HTL are gold electrodes are deposited which are present on substrate. During recycling the HTL dissolve when fabricated solar cell is immersed in polar aprotic solvent. The resultant solution contains recycled gold electrode mp-TiO2 coated TCG substrate. Rinsing and drying of selectively dissolved mp-TiO2 coated substrate HTL and gold electrode gets redeposited to yield a recycled PSC.

1.6 Applications

Perovskite solar cells can be implemented on car roof tops, on the building exterior walls, cellphones, laptops, watches, airplanes and in the house roof tiles like the solar cells integrated with a roof tile.

2. CONCLUSION

Materials of perovskite exhibits excellent absorption of photons, higher charge-carrier mobilities, and lifetimes, leading to high device efficiencies with opportunities to realize a low-cost, industry-scalable technology. However, achieving this amount of potential will deems the requirement in overcoming barriers related to the stability and environmental compatibility, but if these concerns are addressed, perovskite-based technology holds transformational potential for rapid power scale solar deployment. The perovskite materials in combination with hybrid perovskite semiconductors offers a broader class of energy applications that span traditional electronic systems.

REFERENCES

[1] Jian Gong, Seth B. Darling and Fengqi You, "Perovskite photovoltaics: life-cycle assessment of energy and environmental impacts", *Energy Environ. Sci.*, 2015,**8**, 1953-1968.

[2] NREL's 'Best Research-Cell Efficiencies'. Available at: https://www.nrel.gov/pv/assets/pdfs/pv-efficiencies-07-17-2018.pdf. (Accessed: 14th December 2018)

[3] *Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide Perovskites*., M. M. Lee *et al.*, Science, Vol. 338, p643–647 (2012)

[4] Nam-Gyu Park, Perovskite solar cells: an emerging photovoltaic technology, Materials Today, Volume 18, Issue 2, 2015, Pages 65-72, ISSN 1369-7021

[5] Dr Xiaoxi He, "Perovskite Photovoltaics 2018-2028 – Technologies, Markets, Players" article, by IDTechEx.

[6] Teddy Salim, Shuangyong Sun, Yuichiro Abe, Anurag Krishna, Andrew C. Grimsdale and Yeng Ming Lam, "Perovskite-Based Solar cells: Impact of Morphology and Device Architecture on Device Performance", *J. Mater. Chem. A*, 2015,3, 8943-8969.