Project Research paper
Perovskite Tracking Solar Cell (PTSC)
STEM Egypt School for Boys

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FULL RESEARCH PAPER

Perovskite Tracking Solar Cells (PTSCs) a new photovoltaic Technology for solving Energy Crisis

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Abstract — The world's needs for energy have been growing sharply, so Egypt is struggling to meet its own needs especially concerning fossil fuels. Solar energy plays an important role to reduce energy consumption. Based on Organolead halide perovskite solar cells (PSCs) show great promise as a new large-scale and cost-competitive photovoltaic technology. The power conversion efficiencies (PCE) have achieved over 15% within 18 months of development, and thus perovskite materials have attracted great attention in photovoltaic research. However, the manufacture of PSCs raises environmental concerns regarding the over-production of raw lead ore, which has harmful health and ecological effects. Herein, we report an environmentally-responsible process to fabricate efficient PSCs by reusing car batteries to simultaneously avoid the disposal of toxic battery materials and provide an alternative, readily-available lead sources for PSCs. Moreover, we made tracking system by using electronics to make our PSC follow the sun like so the sun radiation always perpendicular on the cell. Overheat, dust and humidity impact negatively on PSC because it changes the chemical structure of perovskite film, hence we coated **Polydimethylsiloxane (PDMS)** which makes our cell hydrophobic, has excellent temperature resistance and good resistance to certain acids and solvents so energy crisis can be solved by what is considered as **(PTSC).**

Key Words — Perovskite, Band gap, Tracking system and Polydimethylsiloxane (PDMS)

1. INTRODUCTION

Energy is exceedingly crucial to our economy and the quality of our life; it is not surprising to find energy issues in the daily news. In addition, the world's increasing population is rapidly depleting the planet's limited energy resources. Hence, we need to orient our efforts towards renewable energy. Currently, Egypt consumes approximately 35 terawatts, while only 11 % of the consumed energy is from renewable resources. Although using renewable energy does not aggravate global warming, it has demerits such as its vulnerability to environmental conditions. For Example, photovoltaic solar power and wind turbines rely on phenomena such as sunlight and the windrespectively.

In order to address our design requirements, we have developed an integrated energy system which depends on a new type of solar cells with high efficiency and low cost as one of the cleanest renewable energy sources. In addition, Our project provides a technical approach to reducing energy consumption. Old car batteries are widely abundant in Egypt considered as a problem. However, it can be used to overcome energy problems besides using inexpensive materials with effectual assets to construct our project. All searches and the other solutions that have already tried to overcome energy crisis and blackouts made us thinking about the Idea: PTSC (Perovskite Tracking Solar Cell).

Perovskite has a specific crystal structure with the (ABX3) formula (X = oxygen, halogen). The larger (A) cation occupies a cubo-octahedral site shared with twelve X anions while the smaller (B) cation is stabilized in an octahedral site shared with six (X) anions. The most studied perovskites are oxides due to their electrical properties of ferroelectricity or superconductivity. Based mainly on lead as a result of recycling car batteries lead Pb (Anode) and lead oxide PbO2 (cathode) to form Lead Iodide PbI2 which finally mixed with (CH3NH3I) to form perovskite stabile structure CH3NH3PbI3 (active layer instead of silicon). Herin we reported Zinc Oxide (ZnO) instead of Tatinum dioxide (TiO2) as an electron injection layer (EIL), aslo we Cupper Iodide (CuI) as a Hole Transporting Material (HTM). In order to address our Design Requirements (High efficiency – Low cost), we also made a tracking system to keep the incoming rays always perpendicular to the panel. Moreover, we put PDMS that made our solar cell hydrophobic and decreases the heat. Our Modified solar cells have reached a perfect efficiency around (45%-50%). In contrast, PSCs not only solve Energy Crisis, also reduce the emission of CO2 causes the global warming and eradicating of toxic lead in old car batteries for serving Solar Energy.

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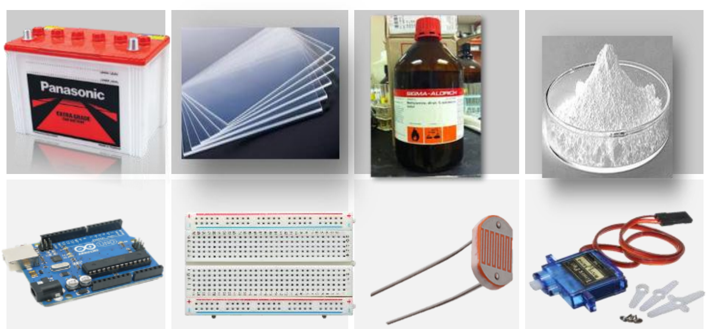
2. MATERIALS

➢ **Dry Car battery:** Contains lead (Pb) in the anode and lead oxide (PbO_2) in the cathode.
➢ **Hydroiodic acid (HI):** Acts as a reactant to produce methyl ammonium iodide (CH_3NH_3I).
➢ **Methylamine (CH_3NH_2) in methanol:** Used to produce (CH_3NH_3I).
➢ **Nitric acid (HNO_3):** Used to produce lead ions
➢ **Acetic acid (CH_3COOH):** Used to produce lead ions from lead oxide (PbO_2).
➢ **Potassium iodide (KI):** used to precipitate PbI_2
➢ **Fluorine-dope tin oxide (FTO) glass :**(100 x 100 x 2.2 mm) was dipped in methyl ammonium
iodide (CH_3NH_3I) to produce Organolead halide perovskite ($CH_3NH_3PbI_3$).
➢ **N, N-dimethylformamide (DMF):** Common solvent for PbI_2.
➢ **Isopropyl alcohol (IPA):** solvent for methyl ammonium iodide (CH_3NH_3I).
➢ **Cupper Iodide (CuI):** Holes Transporting Layer (HTL)
➢ **Zinc Oxide (ZnO):** Electrons Transporting Layer (ETL)



3. EXPERIMENTAL SECTION:

The following procedures describe the fabrication methods for organolead halide perovskite ($CH_3NH_3PbI_3$): -

3.1 Harvesting material from the anodes (Pb) and cathodes (PbO_2) of car battery:

We brought dry battery and got rid of the electrolyte (sulfuric acid H_2SO_4). **CAUTIONS:** the electrolyte contains concentrated sulfuric acid (~4.2 M), and gloves, safety glasses, and lab coat are highly required during this process. As a result, lead from anode and lead oxide from cathode were prepared in order to be washed by HCl (0.1M).

3.2 Synthesizing of lead iodide (PbI_2) from the collected Car battery electrodes':

Firstly, PbO_2 powder was first heated at 600 °C for 5 hours to decompose it into PbO, and the color of the powder was changed from dark-brown to yellow. Secondly, we dissolved PbO in acetic acid (1.9M) and Pb in nitric acid (0.8M). Thirdly, both solutions were mixed with KI individually, thus PbI_2 precipitated.

3.3 Preparation of methylammonium iodide (CH_3NH_3I):

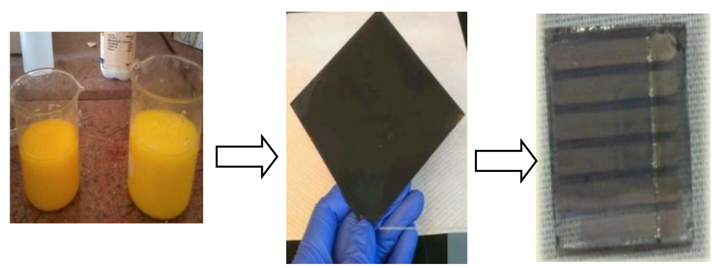
Firstly, HI was mixed with Methylamine (CH_3NH_2) in methanol and stirred in ice bath until white crystals were formed. Secondly, methanol was removed then the solution was filtrated to produce white crystals of CH_3NH_3I.

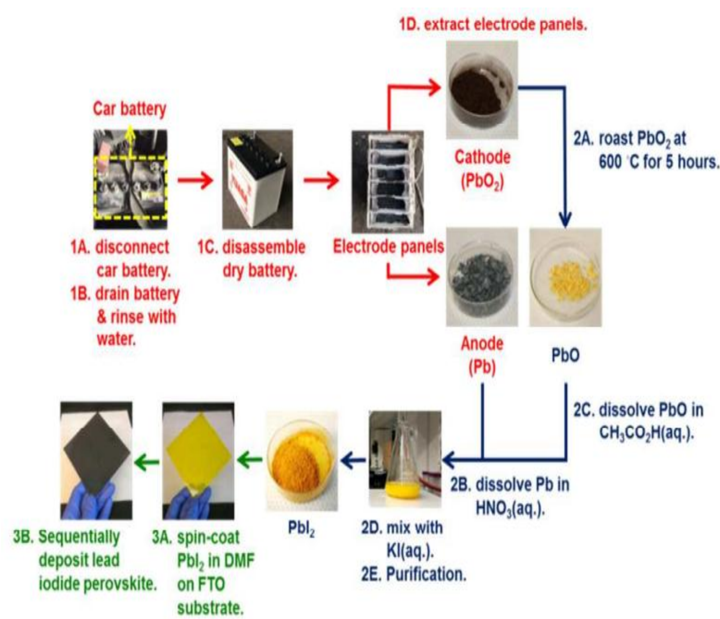
3.4 Production of Organolead halide perovskite Structure (CHNH3PbI3):

Firstly, PbI_2 was dissolved in DMF (1M). Secondly, compact ZnO/FTO glass was infiltrated with solution of PbI_2 then dried. The substrate was dipped in methylammonium iodide (CH_3NH_3I) in IPA (Isopropyl alcohol). Then, organolead halide perovskite ($CH_3NH_3PbI_3$) was produced with simple friendly method and it can achieve an efficiency of 15% which is considered an acceptable one.

3.5 Device fabrication:

- <u>First Layer</u>**:** FTO-coated glass substrates, we used voltameter to know the conductor face.
- <u>Second Layer:</u> ZnO (EIL) coated on the conductor face of FTO by using the spin-coating method at 3000 r.p.m.
- <u>Third layer</u>: Lead iodide perovskite nanocrystals ($CH_3NH_3PbI_3$) was deposited on the ZnO films according to the procedure above.
- <u>Forth layer:</u> CuI (HTL) was then deposited by spin-coating at 4000 r.p.m. for 30 seconds.
- <u>Last layer</u> 80 nm of gold or silver was thermally evaporated on top of the device.





4. TEST PLAN

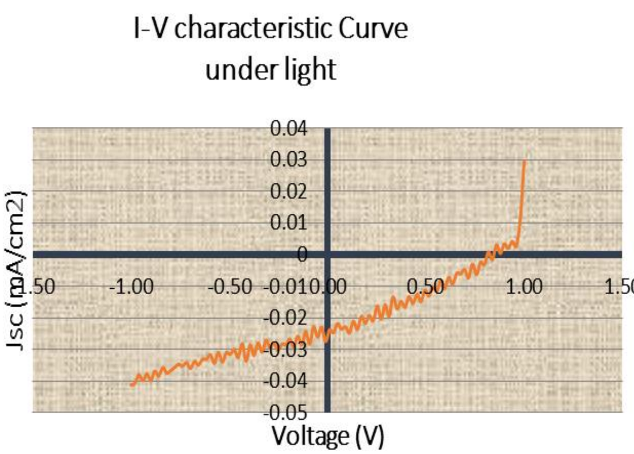
To prove that our project has met the design requirements (High efficiency and Low Cost) as we mentioned before, we applied some tests on the prototype such as:

1. We measured voltage and current of our cell at six times, Calculated the power in the watt and made IV curve. It helps us to calculate the efficiency of Perovskite Solar Cell.
2. We measured the power in watt of our cell at four times during the day with the Tracking System. Also without tracking System and compared the results.
3. We tested the efficiency of PSC under different Temperature conditions.

5. RESULTS

We calculated the efficiency of our cell by using IV-Curve characteristics as shown in the following table..

Cell Performance	
Voc (V)	0.859v (±0.1)
Isc (mA)	-0.03mA (±0.1)
Fill Factor	0.201
Power input	10 watt (1cm^2)
Efficiency	0.71%

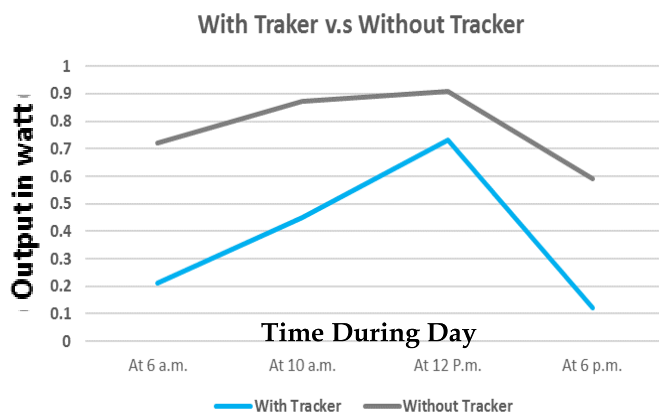


$$\text{Efficiency} = \frac{\text{Power output}}{\text{Power Input}} \qquad \eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

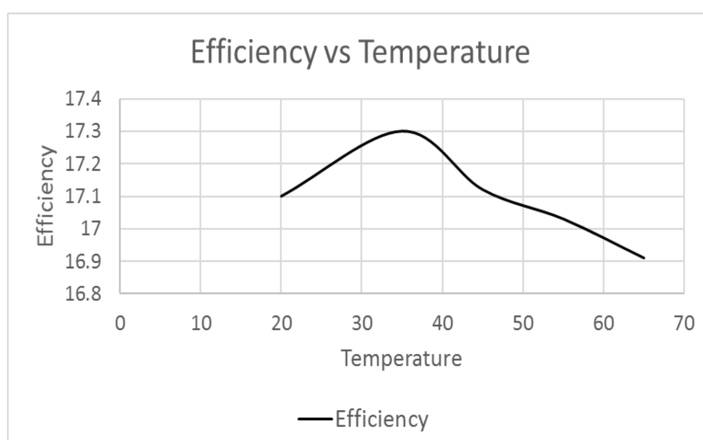
2. The tracking system provided more efficiency %20. Represent a comparison between solar cell with track and without it under varies times and calculating power according to equation 2 **P = AW sin θ Eq.2**

P = power generated by the solar panel
A = Area of the solar panel
W = solar constant =1340 W/m2 θ = the angle of the incoming light
Error (±0.1)

Time during day	Without Tracker	With Tracker
At 6 a.m.	0.21 watt	0.72 watt
At 10 a.m.	0.45 watt	0.874 watt
At 2 p.m.	0.73 watt	0.91 watt
At 6 p.m.	0.12 watt	0.59 watt



- We test our cell under various temperatures to determine the optimal temperature which provides the maximum efficiency. When the band gapenergy reaches 1.4 eV, the cell achieves the maximum efficiency graph (6) which occurs at 35oC.



6. DISCUSSION

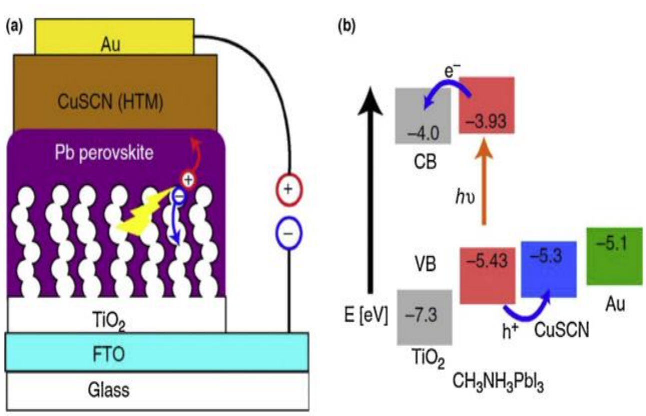
6.1 Recycling dry car batteries:

To synthesize PbI2 with high yields, the as-obtained lead and PbO2 powders are treated with different synthetic pathways. Because of the low reactivity of PbO2 in HNO3, the generation of Pb2+ is inefficient and the yield is lower than 5% (equation 1).

PbO2(s) ⟶ PbO(s) + ½ O2 (g) (1)
PbO (s) + 2CH3COOH(aq) ⟶ (CH3COO) 2Pb (aq) + H2O(l) (2)
Pb (s) + 4HNO3 (aq) ⟶ Pb(NO2(3 (aq) + 2NO2 (g) + 2H2O(l) (3)
Pb(NO2(3(aq) + 2KI(aq) ⟶ PbI2(s) + 2KNO3(aq) (4)
(CH3COO) 2Pb(aq) + 2KI(aq) ⟶ PbI2(s) + 2CH3COOK (aq) (5)

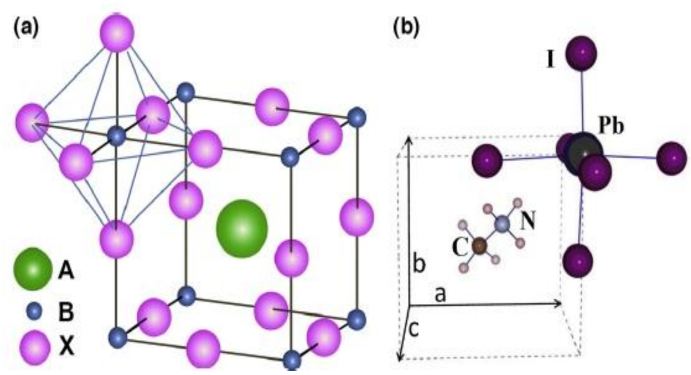
6.2 Working principle of perovskite structure:

According to PIN junction Principle, When the photons lies on perovskite solar cell electrons (negative charge) move from valence band (V.B) to Conduction band in perovskite layer (active layer) and that's distance in called the band gap. they leave their place empty and that's called a hole (positive charge). Then electrons jump to the next layer which is less in Conduction (i.e. electrons jump from the high conduction to the low conduction) Zinc Oxide layer (Electron Injection Layer), then jump to FTO glass substrate (anode) of our solar cell.
In the same way holes jump to Cupper Iodide (Hole Injection Layer), then to Silver (Ag) cathode of our solar cell.
Now we can use electrons to make a circuit and generate a current (I) constantly.



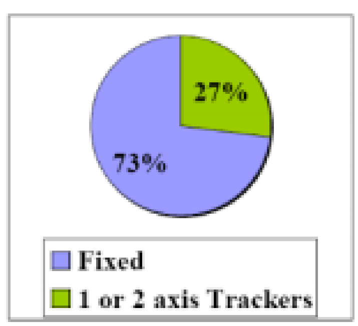
6.3 Crystal structure of perovskite:

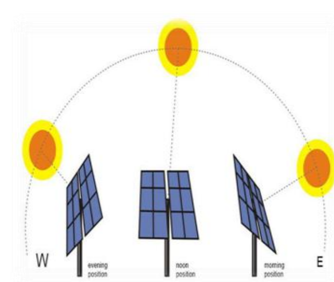
Based on a geometric tolerance factor (t), t = (rA + rX)/[H2(rB + rX)], where rA, rB and rX are the effective ionic radii for A, B and X ions, respectively. For transition metal cations containing oxide perovskite, an ideal cubic perovskite is expected when t =1 while octahedral distortion is expected when t < 1. Symmetry also decreases for t < 1, which may affect electronic properties. For alkali metal halide perovskite, formability is expected for 0.813 < t < 1.107. The rA in APbX3 (X = Cl, Br, I) perovskite was calculated for t = 0.8 and t = 1 based on effective ionic radii [18]. A cation with radii between 1.60 A ˚ and 2.50 A ˚ were found to form perovskite structures. Thus, methylammonium cation is suitable for lead halide perovskite because its ionic radius is 1.8 A ˚. Since the tolerance factor of CH3NH3PbI3 was calculated as 0.83



6.4 Dual-axis Solar Tracker:

In such systems, the panels are able to move along both east-west and north-south directions; therefore, they are always perpendicular to the sun radiation's direction and receive the maximum amount of the power of the PV module. We deduced it raise systems energy output by 20 to %25 that is an additional %6 on average compared with the single axis trackers.





Prototype of Designed Tracker:

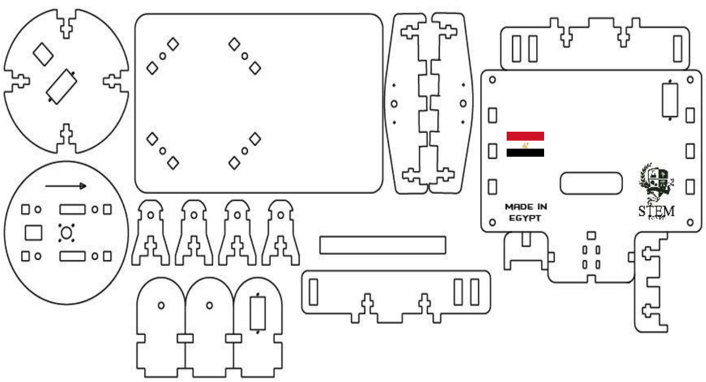
The major components those are used in the prototype are given below: -

- Microcontroller (Arduino UNO)
- Micro servo
- Light dependent resistor (LDR) sensor

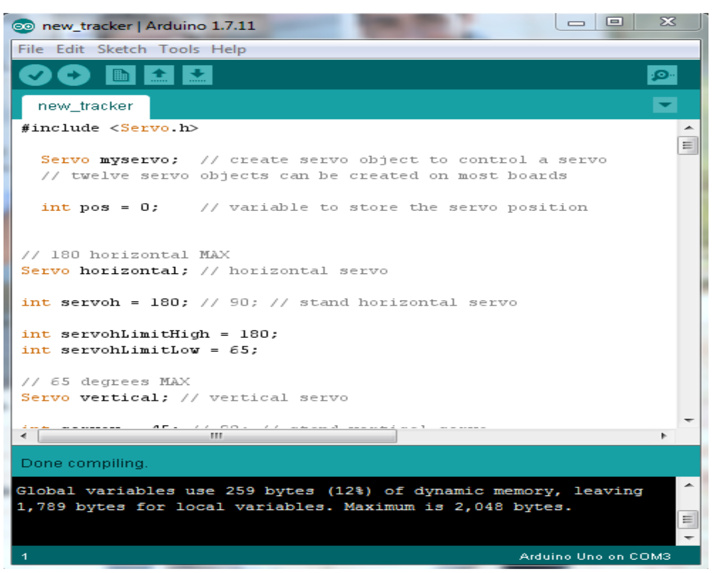
Methods of constraction:

1. We cut the wood in the Fab Lab by using laser cuter.
2. we collected the parts together with the micro servo.
3. We wrote the code of this system by using the language of Arduino C to make it Tracker for the sun.
4. We connected LDRs (Light sensor) with arduino board using breadboard and some jumpers and uploaded the code to the arduino board using the USB cable.

(Design of Solar Tracker)

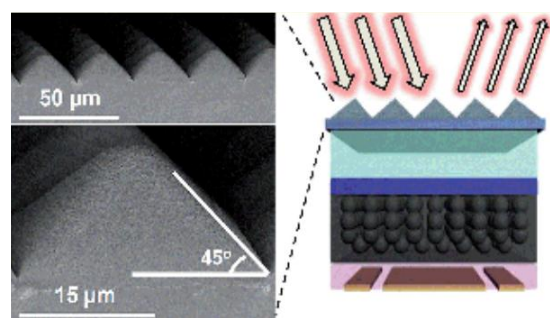


(During upolding code)



6.5 Antireflection and Self-cleaning function layer of Polydimethylsiloxane (PDMS):

We report CH3NH3PbI3 planar perovskite solar cells with multifunctional inverted micro-pyramidal structured (IMPS) polydimethylsiloxane (PDMS) antireflection (AR) layers for enhancing the device efficiency. These IMPS-PDMS films were fabricated via a facile and cost-effective soft lithography using micro-pyramidal structured silicon (Si) master molds formed by alkaline anisotropic wet-etching treatment of (100)-oriented monocrystalline Si substrates. The IMPS (PDMS) laminated on the bare glass (i.e., IMPS-PDMS/glass) exhibited a higher solar weighted transmittance (TSW) value of 95.2% (or the lowest solar weighted reflectance (RSW) of 4.7%). Until now, most research studies on perovskite solar cells have been focused on improving power conversion efficiency by developing new processes for the formation of pin-hole free perovskite thin □lms and designing new materials via compositional engineering. Micro-pyramidal structures have been generally realized on a silicon (Si) surface using a potassium hydroxide (KOH) alkaline etchant solution. The micro-structured AR layer can effectively enhance light absorption in solar cells by reducing the surface reflection due to the linearly gradient effective-refractive-index profile and the extension of effective optical light paths, showing high total and diffuse transmissions simultaneously. Furthermore, the micro-structure PDMS layer with a self-cleaning ability, which can prevent the degradation of device performance because of its surface contamination, is also very useful in outdoor solar systems. Therefore, it is very meaningful to investigate the photovoltaic performance of perovskite solar cells with the micro-structured PDMS as the AR protection layer, including the analyses of its optical properties and water wetting behaviors



6.6 Centralization of Our project:

Herein we reported a comprehensive analysis about our recommended station. Calculating the area of the solar panel that will be fabricated, energy generation and number of houses that will be powered by the solar panels.

A=709.25N A: area of solar panel (M2)
E = 878.82N E: electricity generated (KWH day-1)
H= 32.9N H: number of houses that can be powered by the solar panels.

7 CONCLUSION

As, has been noted that the integration has been achieved in the whole solution for Perovskite Tracking Solar Cell (PTSC) as a new photovoltaic technology. Reusing old car batteries with Eco-friendly method for providing Lead (Pb) element. PDMS for self cleaning which help us not losing %50 of our cell efficiency due to the dust and antireflection. Tracking System to increase the efficiency. Unlike the other solutions in this field like the wind turbines that are gigantic in size with high cost. Also, sillicon solar cells that are etremely expensive with has harmful impacts. Our solution is recognized to be efficient after being tested as it offers a new Type of Solar Cells with efficiency value which is ...% for area 1cm*1cm for providing electricity and low in cost as its constructing materials are available in the country, promising for Solving energy crisis and blackouts if it is applied.

8 RECOMMENDATION

We have just made a primary prototype. There are variety of further modifications to improve this kind of solar energyharvesting methods. Firstly, the bond distance and angle of X–Pb–X in CH3NH3PbX3 can be modified to achieve %30 efficiency and strengthen the structure of the solar cell itself. Secondly, Molybdenum(Mo) can be used to make wires as shown in Fig. (14) due to high electric conductivity and ability to bear high pressure and temperature. Also, it decreases the electric loss from %22.5 to %12.5. In addition to new types of motors and Light dependent sensors with high efficiency and low cost.

9 ACKNOWLEDGMENT

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