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SYNTHESIS AND OPTICAL CHARACTERIZATION OF PEROVSKITE LAYER AND TiO_2 LAYER FOR SOLAR CELL APPLICATION

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ABSTRACT

This work focuses on the synthesis and characterization of a thin perovskite layer and TiO_2 layer for solar cell application. To this end, a novel organometal halide perovskite was synthesized by a solution-process. The perovskite layer was characterized using optical spectroscopy, and the results were used to determine the optical properties of the layer. The TiO_2 layer was formed by chemical bath deposition method from a 70mm solution of titanium tetrachloride,and the optical properties were determined by UV-visible spectroscopy.The results of the study show a good agreement in terms of absorbance, transmittance and reflectance values. The optical bandgap of the perovskite layer was confirmed to be approximately 1.7 eV. The TiO_2 layer exhibited good optical absorption properties across the visible and UV range, with a bandgap of approximately 2.0 eV. The combination of the two layers showed good optical properties ideal for photovoltaic applications. Overall, the study provides insight into the synthesis and characterization of a thin perovskite layer and TiO_2 layer for solar cell application. The combined properties of the layers were found to be acceptable for photovoltaic applications. Further studies are needed to explore the optimization of the layers for different photovoltaic devices.

KEY WORD:* *Perovskite, Titanium dioxide, optical properties, solar cell, band gap, absorbance, transmittance, layer.

INTRODUCTION

The development of human society now depends on the utilization of clean, renewable energy sources. One of the most promising new power sources is without a doubt solar electricity. With its capacity to convert sunlight into electricity, solar cells have long been a mainstay of the renewable energy movement. Although individual cells are quite tiny, when upgraded to modules, they can power lights and recharge batteries. If they were installed side by side, they may one day serve as the primary energy source for buildings. But when compared to more conventional power sources, silicon-based solar cells today are more expensive to assemble. Perovskite, a highly good replacement material, enters the picture in this situation. When tucked into a solar cell's core, this crystalline structure converts light into electricity just as well as silicon, but at a far lower price. Additionally, rigid and flexible substrates may be used to create perovskite-based solar cells, which makes them lighter, more flexible, and more affordable. However, these prototypes need to increase in size, efficiency, and longevity in order to be helpful in the real world. Perovskites are a class of substances with a distinctive crystal structure that take their name from the mineral that displays it. They have demonstrated potential for excellent performance and low production costs when used to create solar cells. Perovskite solar cells have drawn a lot of attention ever since the initial reports of ten percent efficiency solid-state cells using methylammonium lead iodide ($CH_3NH_3PbI_3$) as the active component [6]. Since then, considerable advancements have been made in improving efficiency (currently over 20%) by optimizing both material and device architecture and by comprehending the underlying mechanisms of these devices [8]. In spite of the fact that long-term stability is essential for practical applications, much less research has been done on understanding degradation and enhancing device stability than on boosting efficiency [8]. It is well known that stability, particularly under light, is a serious problem in perovskite devices despite encouraging preliminary findings demonstrating good cell stability in the ambient environment over a 500-hour period [8]. According to Aldibaja[4], cells held in light-free environments often have much worse stability than cells maintained in dark environments. Data on the effects of light on stability are few [5], and periodic testing with storage in ambient without continuous illumination are typical instability examinations of perovskite films or devices [4]. In addition to UV radiation, perovskite films and devices are particularly sensitive to moisture [9]. The presence of intrinsic instabilities, particularly when exposed to sunlight, is unquestionably a severe concern in a solar cell material, despite the fact that sophisticated encapsulation techniques may be able to address sensitivity to ambient air. Higher temperatures and humidity are thought to hasten the breakdown of $CH_3NH_3PbI_3$ into PbI_2 in both air and vacuum. The most popular and cutting-edge solar energy conversion technology is photovoltaics (PV). Even while PV installation has increased significantly over the world, it still only accounts for a small portion of our current energy supply. Only around 1.2% of the energy we use is generated by PV, and the cost is still the main barrier. Although it has already dropped significantly over the past several decades, the PV module price still accounts for between 25% and 50% of the system cost. To make PV more competitive in our current electricity grid, module costs must be continually reduced. Solar energy may be harnessed in a variety of ways. The solar water heater is one of the uses for its direct conversion to thermal energy. Using concentrated solar power (CSP) is an additional method. In CSP, sunlight is focused onto a tiny area using reflector arrays, where it is converted to heat and used to power an enginetypically a steam engineto produce electricity. The most common and technically advanced solar energy conversion technique is photovoltaics (PV), which is also the most expensive. Despite the benefits offered by PV technology, PV was recognized as a costly Photovoltaic alternative to existing fossil fuels, which restricts its deployment. Photovoltaic power generation uses numerous solar panels made up of a number of solar cells. Fortunately, PV costs have dramatically decreased over the past 40 years. A significant rise in PV installation has resulted from the drop in PV prices. PV installation has greatly improved globally, although it still only makes up a small part of the world's total installed PV capacity. Despite significant advancements in PV installation around the globe, just a small percentage of the power we consume today is generated by PV [7].

MATERIALS AND METHODS

Preparation of the Perovskite Material

The chemicals used for the perovskite layer are Formamidinium Iodide (FAI, Sigma-Aldrich Chemie GmbH Germany), Methylammonium bromide (MABr, Sigma-Aldrich Chemie GmbH Germany), Lead iodide (PbI_2, Sigma-Aldrich Chemie GmbH Germany), Lead bromide (PbBr2, Sigma-Aldrich Chemie GmbH Germany) and they were dissolved in a mixture of N,N-Dimethylformamid (DMF, Aldrich) and Dimethyl sulfoxide (DMSO, Aldrich) with a volume ratio of 4:1. The molar ratio for the $FAI:PbI_2:MABr:PbBr_2$ perovskite precursor solution was 1:1.1:0.2:0.2. For interfusion of the chemicals and solvents to a single solution, the molar concentrations for each constituent were increased by two. Before mixing, the iodide compounds ($FAI+PbI_2$) and the bromide compounds ($MABr+PbBr_2$) were dissolved with DMF: DMSO in separate vials. Then equal volume amount from $FAPbI_3$ and $MAPbBr_3$ was added together to get the wanted molar concentration. The colour of the solution was yellow, and the following reaction illustrates how perovskite is formed:

$CH_3NH_3PbBr_2 + PbI_2 \xrightarrow{\qquad} CH_3NH_3Br_2PbI_3$

The procedure steps for deposition of the materials are seen below.

1. Cleaning: The FTO/glass substrates need to be cleaned before the different layer dispositions can commence because even a small dust particle on the surface will affect the performance of the final cell.
2. Compact (blocking layer) preparation; the blocking layer of the FTO glass substrates for the samples was prepared by electrospinning and calcination from the precursor of a total volume of 40ml, which has a concentration of 0.1M of titanium isopropoxide, 0.4M of acetylacetone and methanol. Two drops of the originator solution were added onto the FTO glass substrates and spin-dried for 20 seconds. The black tapes were removed and the samples were annealed to 450^0C for 30 minutes [1]
3. The Titanium dioxide (TiO_2) electron transport layer was deposited onto the fluorine-doped tin oxide glass substrates by the chemical bath deposition method from a 70mm solution of titanium tetrachloride (Solaronix Titanium tetrachloride) outlining it on the active area. The samples were annealed at 70^0C. After annealing, the samples were allowed to cool down for 30 minutes.
4. The perovskite solution was spin-coated to obtain a thickness of 100-500 nm. In the second step, chlorobenzene (CB) was added when it was 15 seconds left of the spin-coating program. The chlorobenzene helps with the perovskite film formation by distributing the solution evenly and is a crucial step for obtaining high performance.

Characterization

Profilometry Measurements

The result is analyzed by recording the height of the probe at each point on the scratched surface. Determining the Profilometry (thickness) of the perovskite and TiO_2 layers was carried out using a profilometer (Dektak 150 from Veco instrument TMCU.S. A).

Optical Characterization of the Samples

A (UV 752) ultraviolet-visible-Near Infra-Red (UV-VIS-NI) spectrophotometer U.K was used to carry out the optical study of the cells at the wavelength interval of 230 nm to 1100 nm. A spectrophotometer is an instrument that measures the number of photons (the intensity of light) absorbed after it passes through the sample solution.

RESULTS AND DISCUSSION

Results of Profilometry Characterization

Figure 1 – 2 below showed the thickness of the active layers in the perovskite solar cell. The thickness was measured as: FTO layer = 2000 nm, TiO_2 layer = 200 nm, perovskite layer = 200 nm, and elcocarb layer = 3000 nm. The result of the thickness of the perovskite layer (200nm) is within the range (300 – 900nm) reported by Momblona et al., (2014), this suggest that the I_{sc} of the solar cells increases with increasing perovskite layer thickness, fast up to 300 nm, and more slowly for devices with layers going from 300 to 900 nm. However, due to a decreasing fill factor (FF) for cells with perovskite layers in excess of 300 nm, the power conversion efficiency (PCE) is reduced for the thicker devices.

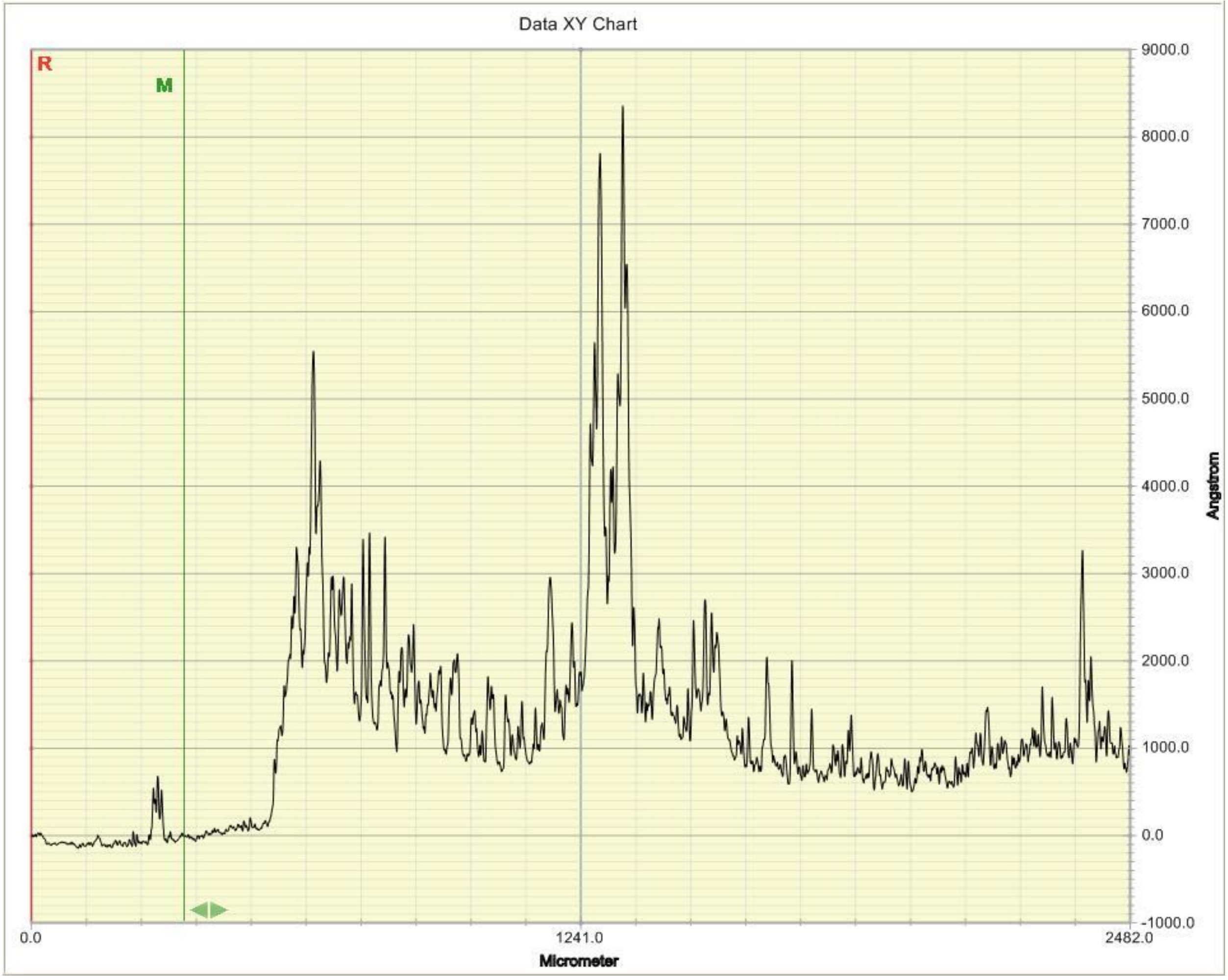

Figure 1: Profilometry image of the Perovskite Layer thickness

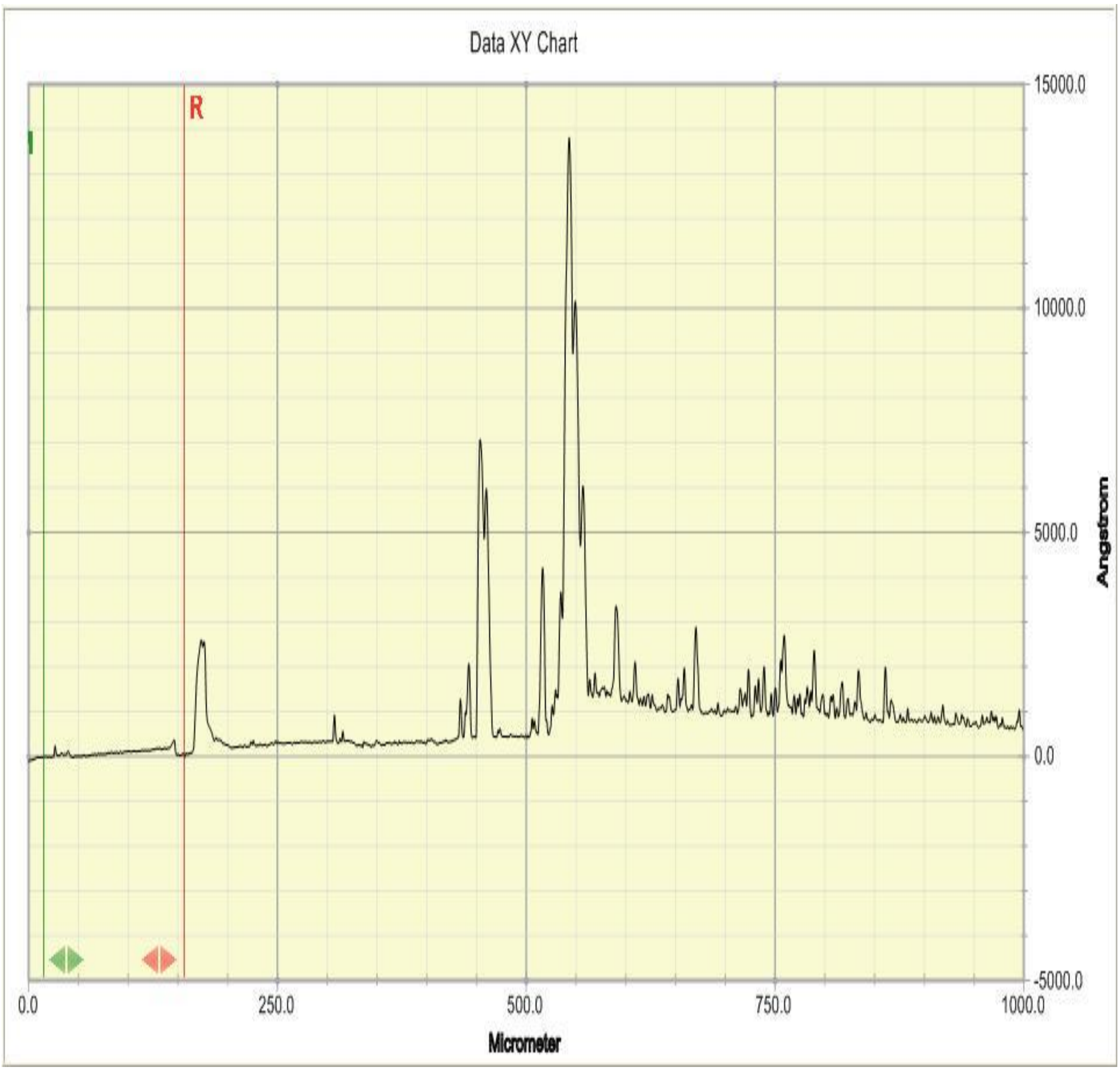

Figure 2: Profilometry Image of the TiO_2 Layer thickness

Results of Optical characterization

Figure 3 - 7 showed the result of the optical properties for perovskite and the TiO_2. The graphical representations of the Absorbance, transmittance, reflectance, and optical bandgap for the perovskite and TiO_2 layers are presented.

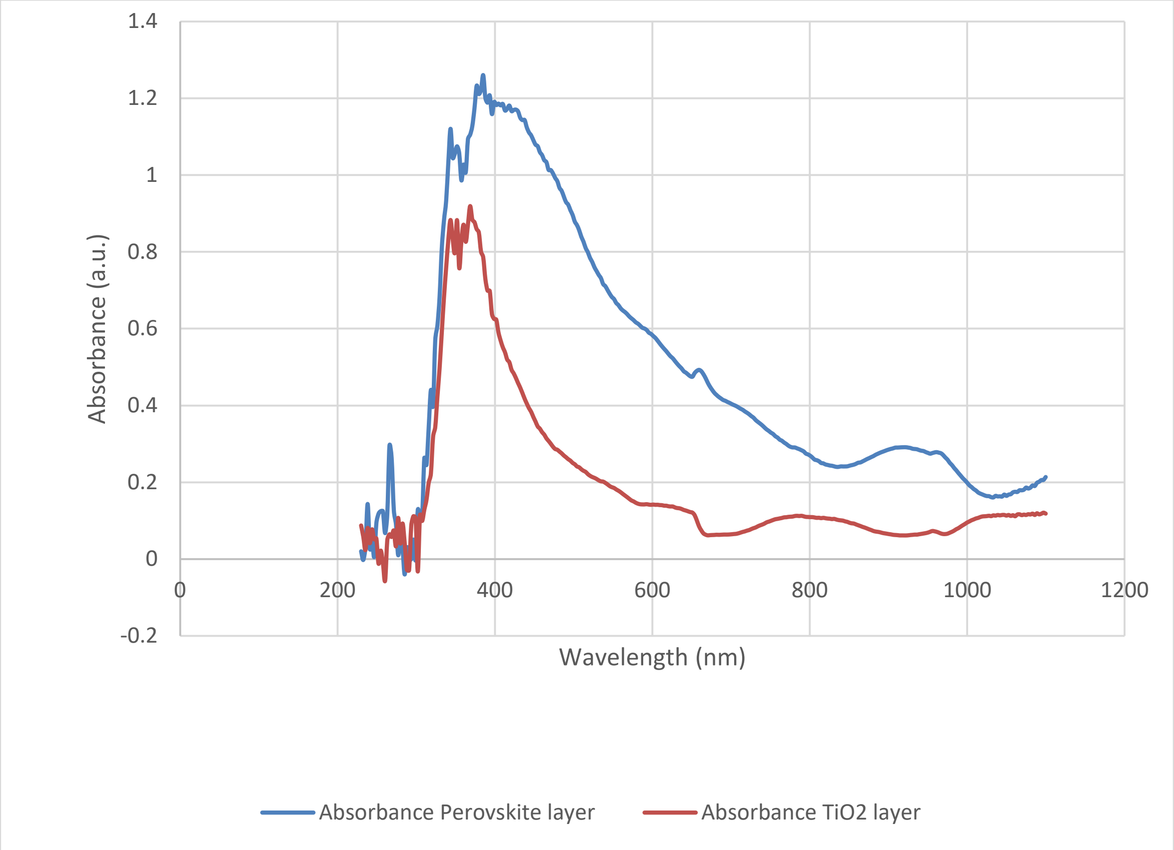

Figure 3: Uv-vis- Absorbance Spectra of Perovskite and TiO_2 Layer

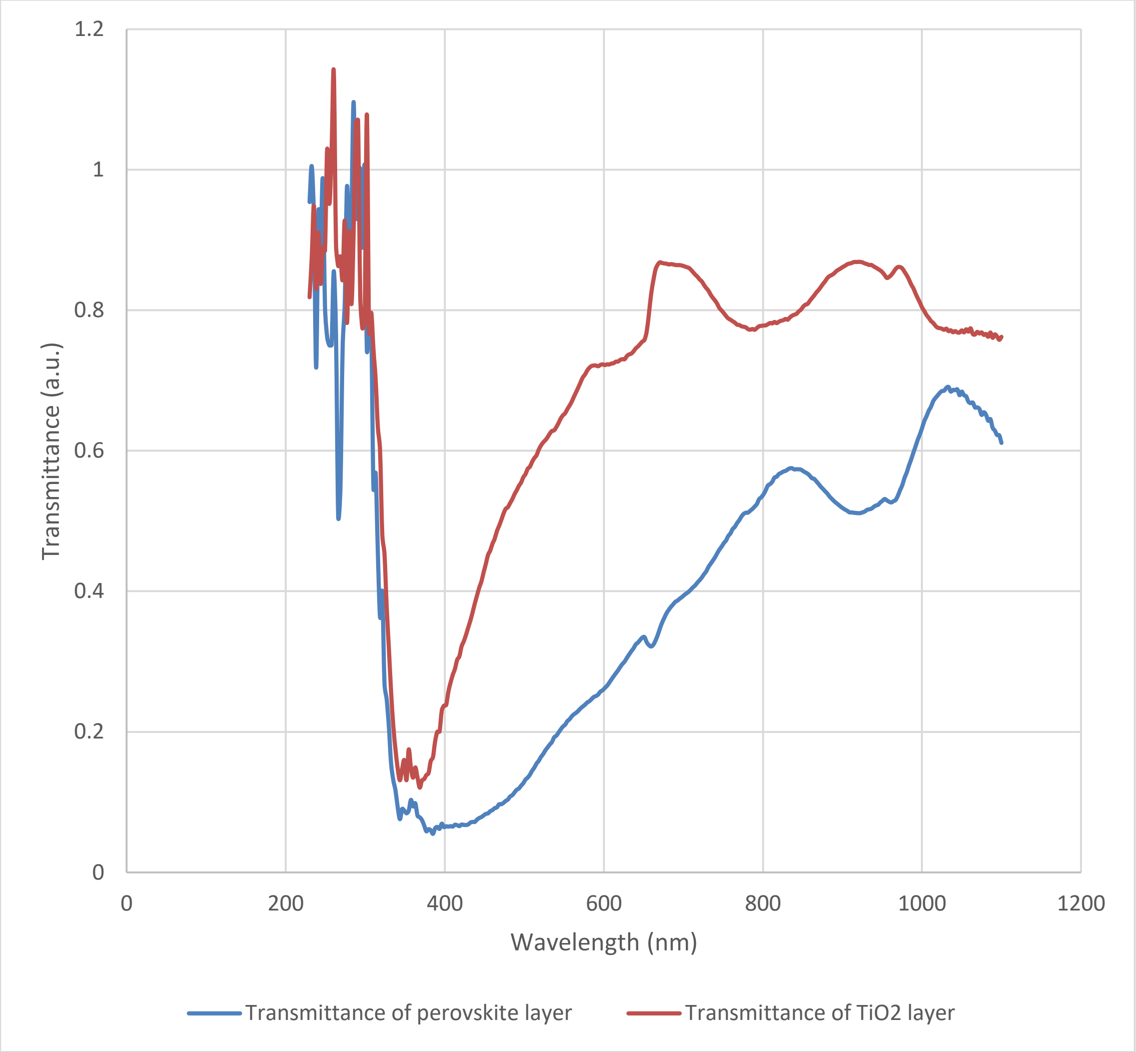

Figure 4: Uv-vis- Transmittance Spectra of Perovskite and TiO_2 Layer

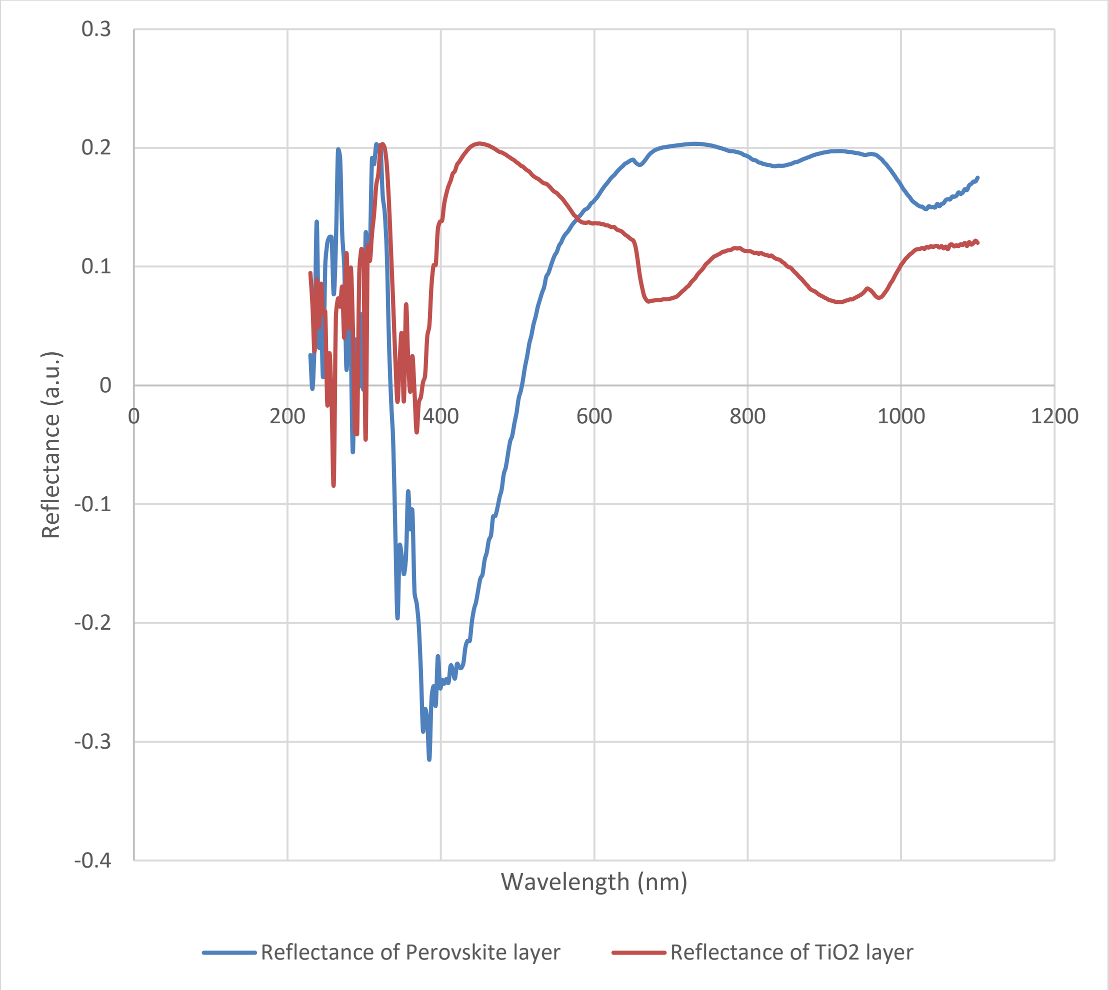

Figure 5: Uv-vis- Reflectance Spectra of Perovskite and TiO_2 Layer

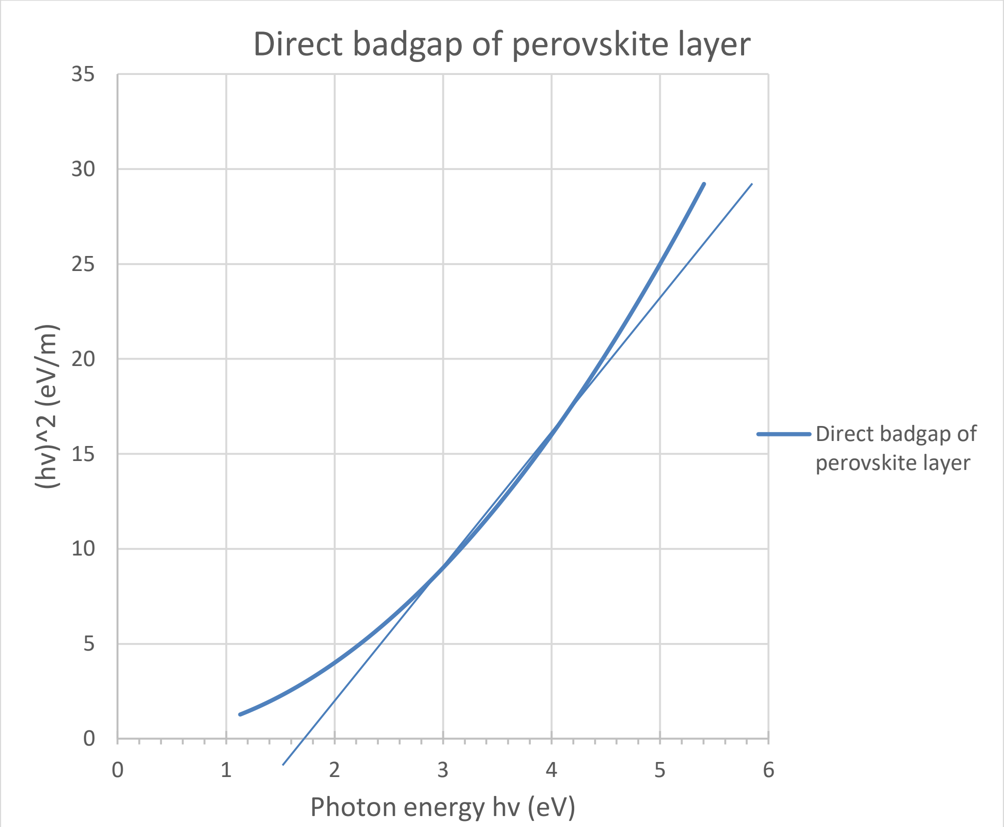

Figure 6: Direct Optical band gap of the PerovskiteLayer

Figure 7: Direct Optical band gap of the TiO_2 Layer

Figure 3 showed the UV-vis absorption spectra of the perovskite and TiO_2 of the PSCs. The figure shows the presence of distinct absorption peaks in the visible region, the absorption peaks of the perovskite layers can be seen at about 350 nm to 500 nm. This indicates that the perovskite layer has higher absorption spectra wavelength within the visible spectrum. In the wavelength longer than 600nm, both the films showed little absorption, allowing most of the incident light to reach other active layers.

The optical transmission spectra recorded in the wavelength 280-1100 nm are presented in figure 4. The figure shows that the optical transmittance (fraction of radiant energy that passes through the TiO_2 layer and Perovskite layer) was averaged over the wavelength range of 300-1100 nm. index, extinction coefficient and direct optical bad gap of the perovskite and TiO_2 layer

The direct optical band-gap for the perovskite layer was estimated to be 1.7eV by extrapolating the linear portion of the curve $(hv)^2$ against (hv), and also the direct optical band-gap for the TiO_2 layer was estimated to be 2.0 eV by extrapolating the linear portion of the curve $(hv)^2$ against (hv).

CONCLUSION

The current study is primarily focused on the synthesis and characterization of perovskite film and TiO_2 films as an absorber layer that is deposited over FTO coated glass. To characterize its optical properties, the iodide compounds ($FAI+PbI_2$) and the bromide compounds ($MABr+PbBr_2$) were dissolved with DMF: DMSO in separate vials. Then equal volume amount from $FAPbI_3$ and $MAPbBr_3$ was added together to get the wanted molar concentration to produce perovskite film for compatibility in solar cells. Perovskite thin films made with DMF: DMSO solvent have narrower band gaps and greater solar spectrum absorption than the TiO_2 layer, making them perfect for solar cell applications. In conclusion, this indicates that the perovskite layer has higher absorption spectra wavelength within the visible spectrum. In the wavelength longer than 600nm, both the films showed little absorption, allowing most of the incident light to reach other active layers.

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