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A review on stability challenges and probable solution of perovskite–silicon tandem solar cells

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ABSTRACT

Perovskite-silicon tandem solar cells have shown great potential in increasing the efficiency of solar cells, with efficiencies reaching as high as 25%. However, the stability of these cells remains a major challenge that must be addressed before they can be commercialized. This review focuses on the stability challenges of perovskite-silicon tandem solar cells and possible solutions to address these challenges. Author's performed systematic review of the literature for Stability Challenges and Probable Solution of Perovskite–Silicon Tandem Solar Cells. The main stability issues include the instability of the perovskite layer, the degradation of the silicon layer, and the failure of the interfaces between the layers. One solution is to use more stable perovskite materials, such as methylammonium lead iodide ($MAPbI_3$) or formamidinium lead iodide ($MAPbI_3$), which have shown better stability than traditional perovskite materials. Another solution is to use passivating layers, such as titanium dioxide, to protect the perovskite layer from degradation. Another solution is to use silicon heterojunction (SHJ) solar cells, which have shown better stability than traditional silicon solar cells. In addition, the use of encapsulation techniques, such as using a barrier layer or a hermetic seal, can help to protect the tandem solar cell from environmental degradation. In order to improve the stability of perovskite-silicon tandem solar cells, it is important to continue research on the development of more stable perovskite materials, passivating layers, and encapsulation techniques. Perovskite-silicon tandem solar cells are of significant interest due to several reasons. It has high efficiency, Complementary absorption properties, Cost-effectiveness, Versatility and scalability, Potential for high power output. Despite their immense promise, perovskite-silicon tandem solar cells still face challenges such as long-term stability, material compatibility, and large-scale manufacturing which need to be addressed in the near future. Additionally further research is needed to understand the mechanisms of degradation and to develop methods for monitoring and mitigating the degradation of the tandem solar cells.

1. Introduction

Perovskite-silicon tandem solar cells have emerged as a promising technology for increasing the efficiency of solar cells. These cells combine the use of a perovskite layer with a silicon layer to achieve a higher power conversion efficiency compared to traditional single-junction solar cells like Sb_2S_3 [1], SnS [2]. The perovskite layer absorbs high-energy photons and generates a flow of electrons, while the silicon layer absorbs lower-energy photons and also generates a flow of electrons.

The two layers are connected by an electron selective layer, allowing for the flow of electrons from the top perovskite layer to the bottom silicon layer.

Despite the potential of perovskite-silicon tandem solar cells, their stability remains a major challenge that must be addressed before they can be commercialized [2]. The stability issues include the instability of the perovskite layer, the degradation of the silicon layer, and the failure of the interfaces between the layers. These issues can lead to a reduction in the efficiency and lifetime of the tandem solar cells.

This review focuses on the stability challenges of perovskite-silicon tandem solar cells and possible solutions to address these challenges. The review will cover the latest research on the development of more stable perovskite materials, passivating layers, and encapsulation techniques. Additionally, the review will discuss the mechanisms of degradation and methods for monitoring and mitigating the degradation of the tandem solar cells. The review aims to provide a comprehensive understanding of the stability challenges facing perovskite-silicon tandem solar cells and potential solutions to overcome these challenges. Additionally, the review will discuss the various techniques used for the fabrication and characterization of perovskite-silicon tandem solar cells. This includes the different methods for depositing the perovskite and silicon layers, such as spin-coating and chemical vapor deposition, as well as techniques for measuring the performance and stability of the cells, such as current-voltage measurements and spectroscopic techniques.

Another important aspect that will be discussed in the review is the impact of environmental factors on the stability of perovskite-silicon tandem solar cells. Factors such as humidity, temperature, and exposure to light can have a significant effect on the performance and lifetime of the cells. The review will explore various methods for protecting the cells from environmental degradation, including the use of encapsulation techniques and protective coatings. Furthermore, the review will also discuss the progress made in the field of perovskite-silicon tandem solar cells in terms of efficiency and power output. It will also highlight the current state-of-the-art results and the potential for further improvement.

Overall, the review aims to provide a comprehensive understanding of the stability challenges facing perovskite-silicon tandem solar cells and the potential solutions to overcome these challenges. It will also provide an overview of the current state-of-the-art in terms of fabrication techniques, characterization methods, environmental stability, and efficiency. Perovskite-silicon tandem solar cells are a promising technology for increasing the efficiency of solar cells, but they face several stability challenges. One issue is that the perovskite layer is sensitive to moisture and air, which can degrade the material and reduce the performance of the solar cell. Additionally, the perovskite layer can also degrade over time due to exposure to light and heat. Another stability challenge is the interface between the perovskite and silicon layers, as this can lead to recombination of charge carriers and a reduction in the overall efficiency of the solar cell. Researchers are currently working on developing methods to improve the stability and durability of perovskite-silicon tandem solar cells, such as encapsulation techniques and new materials.

A tandem solar cell is a type of solar cell that consists of two or more layers of photovoltaic material stacked on top of each other [3]. Each layer is tuned to absorb a different portion of the solar spectrum, resulting in higher efficiency and power output compared to single-junction solar cells. Tandem solar cells are typically made using a combination of silicon and other semiconductor materials, such as perovskite or dye-sensitized materials. They are a promising technology for use in solar power systems due to their high efficiency and potential for low cost. Tandem solar cells are made by stacking two or more layers of photovoltaic material on top of each other. Each layer is designed to absorb a different portion of the solar spectrum, with the top layer absorbing the higher energy, short-wavelength photons and the bottom layer absorbing the lower energy, long-wavelength photons. This results in a higher overall efficiency, because more of the solar energy is being converted into electricity. The most common type of tandem solar cell is made of silicon and perovskite [4]. Silicon is used as the bottom cell due to its high efficiency and stability, while perovskite is used as the top cell due to its high absorption coefficient and low cost. The efficiency of this kind of tandem solar cells can reach up to 25%.

Another type of tandem solar cells is using two or more different semiconductors materials, such as silicon and III-V materials, to form the different layers [5]. This allows for a wider range of the solar spectrum to be absorbed, leading to even higher efficiencies. Tandem solar cells are a promising technology for use in solar power systems, as they have the potential to achieve high efficiencies at a relatively low cost. They can be integrated into solar panels for use on rooftops, in solar farms, and in other applications. They could also be used in portable electronic devices, such as smartphones and laptops, to extend battery life.

A normal perovskite solar cell (PSC) is a type of solar cell that uses a thin layer of perovskite material as the active layer for absorbing light and converting it into electricity. A tandem solar cell, on the other hand, consists of two or more layers of photovoltaic material stacked on top of each other, with perovskite being one of the materials used. The main difference between a normal PSC and a tandem solar cell is in their efficiency. A normal PSC typically has an efficiency of around 20%, while a tandem solar cell can have an efficiency of 25% or higher. This is because the tandem structure allows for a wider range of the solar spectrum to be absorbed, resulting in more of the solar energy being converted into electricity.

Another difference is the materials used. A normal PSC is made up of only perovskite material while a tandem solar cell is made up of a combination of silicon and perovskite, or other semiconductor materials. The silicon material is used as the bottom cell due to its high efficiency and stability, while perovskite is used as the top cell due to its high absorption coefficient and low cost. In summary, a normal PSC uses only perovskite material and has a lower efficiency compared to a tandem solar cell, which uses a combination of materials and has a higher efficiency.

Perovskite-silicon tandem solar cells in particular have the potential to make a big impact on the renewable energy sector. Tandem solar cells. The commercialization of tandem solar cell technology is actively being pursued, despite the fact that there are still issues to be resolved, such as long-term stability and scalability. With increasing market opportunities, lower costs, and improved efficiency, tandem solar cells have the potential to have a substantial impact on the renewable energy sector. In order to accomplish various Sustainable Development Goals (SDGs), tandem solar cells, notably perovskite-silicon tandem cells, can be extremely important. Tandem solar cells can help increase the efficiency and lower the cost of solar energy generation, resulting in a more widespread adoption of inexpensive and clean energy. Utilizing tandem solar cells can boost the economy and open up job opportunities. Tandem solar cells are a cutting-edge technology in the field of renewable energy like Solar, Wind and Vibration energy [5]. Tandem solar cells can greatly reduce greenhouse gas emissions, which helps to combat climate change. Tandem solar cells can significantly help with a number of SDGs, especially those that encourage access to affordable, clean energy, economic growth, and innovation.

The main contribution of Perovskite-silicon tandem solar cells is that they can achieve higher power conversion efficiencies than traditional monolithic devices, as well as reduce cost per watt due to their smaller size and lower manufacturing costs. Additionally, these types of cells have been shown to be able to withstand extreme temperatures better than other PV technologies which makes them ideal for use in harsh environments such as deserts or high altitudes where temperature fluctuations occur frequently throughout the day. Furthermore, by combining two different materials with varying bandgaps into one unit it allows for the capture of more wavelengths resulting in increased efficiency compared to single material photovoltaic systems.

2. Tandem Solar Cell

A tandem solar cell is a type of photovoltaic cell that consists of two or more individual solar cells stacked on top of each other to increase efficiency. Each cell is optimized to capture a different portion of the solar spectrum, allowing the tandem cell to convert more of the incoming sunlight into electricity. Tandem cells typically have higher conversion efficiencies compared to single-junction cells and are used in high-performance photovoltaic applications such as space satellites and concentrated photovoltaic systems [6].

Tandem solar cells work by using multiple solar cell materials, each with a different bandgap energy, to capture more of the sun's spectrum [7]. The top cell, which has a higher bandgap, absorbs the higher-energy photons and the lower cell, which has a lower bandgap, absorbs the lower-energy photons. This way, the tandem cell can convert more of the incoming light into electricity.

The main advantage of tandem solar cells is their higher conversion efficiency compared to single-junction cells [8]. This means that they can produce more electricity per unit area of solar cell material, making them more cost-effective. They also have the potential to reduce the cost of solar power systems by using less semiconductor material compared to single-junction cells.

The main limitation of tandem solar cells is their complexity compared to single-junction cells. They require precise fabrication techniques and multiple layers of material, making their production more difficult and expensive [9]. Additionally, the efficiency of tandem cells can be affected by shading and temperature, which can limit their performance in certain applications.

Tandem solar cells are commonly used in high-performance photovoltaic applications, such as space satellites and concentrated photovoltaic systems. They are also being researched for use in terrestrial solar power systems, where their higher conversion efficiency can help to increase the overall efficiency of the system and reduce its cost.

3. Methodology for Tandem Solar Cell

Tandem solar cells are typically made using a combination of different semiconductor materials. The most common materials used in tandem solar cells include:

- Silicon (Si) - used as the bottom cell due to its high efficiency and stability.
- Perovskite - used as the top cell due to its high absorption coefficient and low cost.
- III-V materials - such as Gallium Arsenide ($GaAs$) and Indium Phosphide (InP), these materials have a wider bandgap than silicon and are used to absorb the high energy, short-wavelength photons.
- Dye-sensitized materials - such as titanium dioxide ($TiO2$) or zinc oxide (ZnO) which can be used as the bottom cell.
- Organic materials - such as polymers or small molecules, used as the active layer to form the solar cell.

The tandem cell's construction is shown in Fig.1 [10]. It appears to be a stack. The front transparent electrode, perovskite solar cell, tunnel junction, silicon solar cell, and back contact make up the stack's elements. Tandem silicon solar cells are the subject of our research. This solar cell offers the best efficiency at a reasonable price. Artificial intelligence employs a variety of learning techniques, including supervised learning, unsupervised learning, and reinforcement learning. For the modeling and simulation of tandem silicon solar cells, we favor a supervised learning technique.

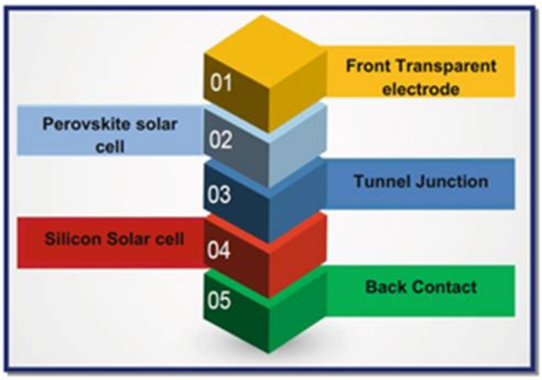

Fig. 1. General structure of the tandem cell

The combination of materials is chosen based on the desired efficiency and cost of the solar cell. The choice of materials also depends on the application, for example, for portable electronic devices, a flexible and lightweight material such as organic materials is preferred. It's worth mentioning that the tandem solar cells are a rapidly evolving field and new materials are being researched and developed to improve the performance and cost efficiency of the tandem solar cells. A perovskite-silicon tandem solar cell is a type of solar cell that combines the use of a perovskite layer with a silicon layer to increase the overall efficiency of the cell. The efficiency of these cells can reach as high as 25%, with the perovskite layer absorbing the high-energy photons and the silicon layer absorbing the lower-energy photons.

To maximize performance and increase efficiency, tandem solar cells can be created using supervised learning approaches. Regression analysis is a popular supervised learning method applied in this situation. In order to establish connections between input factors (such as material qualities, device dimensions, and manufacturing circumstances) and output performance measures (such as power conversion efficiency), regression models are trained using historical data. Researchers and engineers can acquire insights into the complicated correlations between input parameters and tandem solar cell performance by utilizing supervised learning techniques like regression analysis. As a result, tandem solar cells are developed and optimized faster, resulting in higher efficiency and more energy production.

A block diagram representation of the perovskite-silicon tandem solar cell typically includes the following components:

- The top layer, which is made of perovskite material, absorbs high-energy photons and generates a flow of electrons.
- The bottom layer, which is made of silicon, absorbs lower-energy photons and also generates a flow of electrons.
- An electron selective layer, which allows for the flow of electrons from the top perovskite layer to the bottom silicon layer.
- A hole selective layer, which allows for the flow of holes (positively charged carriers) from the bottom silicon layer to the top perovskite layer.
- Electrodes, which collect the flow of electrons and holes generated by the two layers to produce electricity.

4. Types of Tandem Solar Cell

There are several types of tandem solar cells that are being researched and developed, each with its own unique advantages and challenges. Each of these types of tandem solar cells has its own unique advantages and challenges, and researchers are working to improve the efficiency, stability, and cost-effectiveness of these cells. However, perovskite-silicon tandem solar cells are currently the most promising type of tandem solar cells as they have the potential to achieve efficiencies above 30% can be seen in Table 1.

4.1. Perovskite-Silicon Tandem Solar Cells

Perovskite-silicon tandem solar cells consist of a perovskite layer on top of a silicon layer [11]. The perovskite layer absorbs the high-energy photons, while the silicon layer absorbs the lower-energy photons, resulting in higher overall efficiency.

4.2. $CIGS$-Silicon Tandem Solar Cells

CIGS-silicon tandem solar cells consist of a $CIGS$ (copper indium gallium selenide) layer on top of a silicon layer [12]. $CIGS$ is a type of thin-film solar cell that is known for its high efficiency and stability. By combining it with a silicon layer, the overall efficiency of the solar cell is increased.

4.3. $CdTe$-Silicon Tandem Solar Cells

$CdTe$-silicon tandem solar cells consist of a $CdTe$ (cadmium telluride) layer on top of a silicon layer [13]. CdTe is another type of thin-film solar cell that has a high efficiency and stability. By combining it with a silicon layer, the overall efficiency of the solar cell is increased.

4.4. III-V-Si Tandem Solar Cells

These cells are based on semiconductors such as $GaAs$ and InP, these cells have a higher efficiency potential than perovskite-Si [14] or $CIGS - Si$ cells but are more complex to manufacture.

4.5. Organic-Inorganic Tandem Solar Cells

These cells consist of an organic layer on top of an inorganic layer. The organic layer absorbs the high-energy photons [15], while the inorganic layer absorbs the lower-energy photons, resulting in higher overall efficiency.

Table 1. Comparative table of tandem solar cells

Tandem Solar Cell	Top Cell Material	Bottom Cell Material	Efficiency Potential	Stability	Cost
Perovskite-Silicon	Perovskite	Silicon	29%+ [16]	Low	Moderate
$CIGS$-Silicon	$CIGS$	Silicon	25%+ [17]	High	Moderate
$CdTe$-Silicon	$CdTe$	Silicon	26%+ [18]	High	Low
III-V-Si	$GaAs/InP$	Silicon	34%+ [19]	High	High
Organic-Inorganic	Organic	Inorganic	25%+ [20]	Moderate	Low

5. Perovskite-silicon tandem solar cell

A perovskite-silicon tandem solar cell is a type of solar cell that combines the use of a perovskite layer with a silicon layer to increase the overall efficiency of the cell. The perovskite layer, which is made of a material with the same crystal structure as calcium titanium oxide, absorbs high-energy photons and generates a flow of electrons. The silicon layer, on the other hand, absorbs lower-energy photons and also generates a flow of electrons.

The two layers are connected by an electron selective layer, which allows for the flow of electrons from the top perovskite layer to the bottom silicon layer [21]. A hole selective layer is also used to allow for the flow of holes (positively charged carriers) from the bottom silicon layer to the top perovskite layer.

The HZB team, under the direction of physicist Steve Albrecht, investigated a different method of managing light using texturing in conjunction with solar photovoltaic (PV) cells. Their cell's silicon layer was etched on the backside, and the perovskite layer was then spin-coated onto the smooth silicon front. After that, a polymer light management (LM) foil was placed on the device's front. The team was able to take use of the front-side texture and still produce a high-quality perovskite coating on the flat surface. The structure of Perovskite-silicon tandem solar cells has been shown in Fig.2 [22].

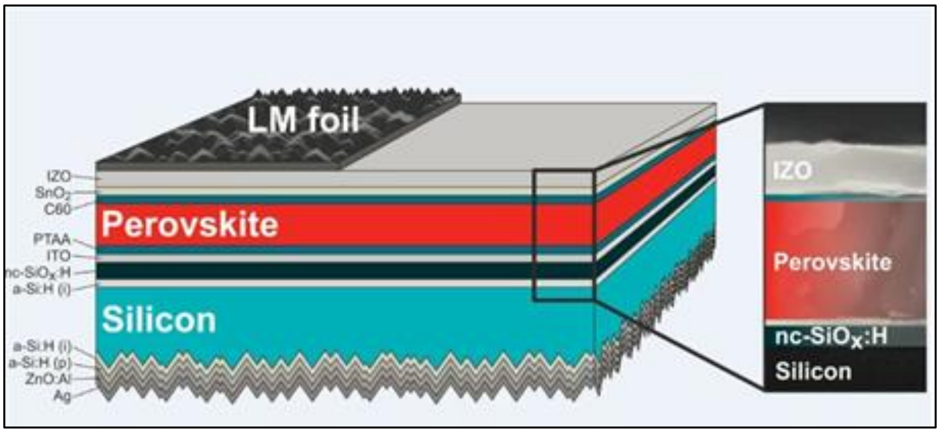

Fig. 2. Structure of Perovskite-silicon tandem solar cells

The tandem structure allows for a greater absorption of photons, leading to a higher power conversion efficiency compared to traditional single-junction solar cells. In addition, perovskite solar cells can be made using low-cost solution-processing techniques, making them a potentially cost-effective option for large-scale solar power generation.

The efficiency of these cells can reach as high as 25%, with the perovskite layer absorbing the high-energy photons and the silicon layer absorbing the lower-energy photons. However, Perovskite-Silicon tandem solar cells are still in research and development stage, and are not yet commercialized.

6. Formation of perovskite-silicon tandem solar cell

A perovskite-silicon tandem solar cell is typically formed through a process called deposition [23]. This process involves depositing thin layers of the perovskite and silicon materials onto a substrate, such as glass or a flexible plastic material.

The process typically begins by cleaning the substrate to remove any impurities or contaminants. Next, the perovskite layer is deposited onto the substrate using a method such as spin-coating, in which the substrate is placed on a spinning platform and a solution containing the perovskite material is applied to the substrate. The spinning motion helps to evenly distribute the solution and form a thin, uniform layer.

Once the perovskite layer is in place, the substrate is then heated to a high temperature to allow the perovskite material to crystallize and form a solid layer. The next step is to deposit the silicon layer. This is typically done using a process called chemical vapor deposition (CVD), in which silicon-containing gases are heated to a high temperature, causing them to react and form a silicon layer on the substrate.

After the silicon layer is in place, the substrate is then cooled down, and the electron and hole selective layers are deposited. The electron selective layer allows for the flow of electrons from the top perovskite layer to the bottom silicon layer, while the hole selective layer allows for the flow of holes (positively charged carriers) from the bottom silicon layer to the top perovskite layer.

Finally, the electrodes are deposited, one on the top of the perovskite layer and the other on the bottom of the silicon layer, to collect the flow of electrons and holes generated by the two layers to produce electricity. The result is a tandem solar cell with the perovskite layer on top, the electron selective layer, the silicon layer, the hole selective layer and electrodes on the bottom.

7. Challenges of Perovskite-Silicon Tandem Solar Cell

Another challenge for perovskite-silicon tandem solar cells is the mismatch in the bandgap between the perovskite and silicon layers [24]. The perovskite layer typically has a higher bandgap than silicon, which can lead to a loss of efficiency due to poor charge carrier collection. Researchers are working on developing new perovskite materials with a bandgap that is better matched to silicon to improve the efficiency of the tandem solar cell.

Another key challenge is the lead content of the perovskite material. Lead is toxic, and there are concerns about its environmental and health impacts. Researchers are working on developing lead-free perovskite materials, but these materials are not yet able to achieve the same performance as lead-based perovskites. Additionally, perovskite solar cells, currently, have a lower lifetime compared to silicon solar cells, due to their tendency to degrade over time, this is a major concern for their implementation on large scale.

Overall, perovskite-silicon tandem solar cells have great potential for increasing the efficiency of solar cells, but there is still significant stability [25] and durability challenges that need to be addressed before they can be widely adopted. The current research focus is mainly on developing new materials, encapsulation techniques and methods to improve the stability and durability of perovskite-silicon tandem solar cells. There are several solutions that researchers are currently exploring to address the stability challenges of perovskite-silicon tandem solar cells.

Encapsulation: One of the key solutions is to encapsulate the perovskite layer to protect it from moisture and air, and to extend its lifetime. Researchers have developed a variety of encapsulation methods, such as using polymeric materials or inorganic coatings, to protect the perovskite layer [26]. Materials: Another solution is to develop new perovskite materials that are more stable and durable. Researchers are working on developing perovskite materials that are less sensitive to moisture and air, and that can withstand exposure to light and heat for longer periods of time [27]. Interface Engineering: Researchers are also working on improving the interface between the perovskite and silicon layers to reduce recombination of charge carriers, which can lead to a reduction in the efficiency of the solar cell [28]. Lead-free perovskite: Researchers are also working on developing lead-free perovskite materials that can be used to produce solar cells without the environmental and health concerns associated with lead [29]. Stabilizing the perovskite layer: Researchers also have been working on stabilizing the perovskite layer by modifying its chemical composition or adding a protective layer on top to improve its lifetime [30]. Doping the perovskite layer: Doping the perovskite layer with specific elements can also improve the stability of the perovskite-silicon tandem solar cells [31].

It should be noted that each of these solutions are in various stage of development, and it's yet to be seen which one will be most effective in improving the stability of perovskite-silicon tandem solar cells. The research is ongoing and the goal is to develop a more stable, durable and efficient solar cell.

Another solution that is being researched is the use of tandem solar cells with multiple layers of perovskite cells, instead of just one. This can help to increase the overall efficiency of the solar cell by absorbing a wider range of wavelengths of light. This approach also allows for better balance of the bandgap of each perovskite layer, and thus reducing the loss of efficiency caused by the mismatch in bandgap between perovskite and silicon layers.

Another solution is to improve the stability of the perovskite solar cells by using new fabrication methods. Researchers are developing new methods for growing the perovskite layer, such as using vapor deposition or solution processing, that can produce a more stable and durable perovskite layer. Additionally, using new substrate materials such as glass, metal or flexible substrate can also improve the stability and durability of perovskite solar cells.

Additionally, researchers are also focusing on the use of perovskite solar cells in tandem with other types of solar cells such as $CIGS$ [32] or $CdTe$, which can also improve the overall efficiency of the solar cell. It's important to note that although these solutions are being researched, they are still in development stages and it is yet to be seen which one will be most effective in solving the stability challenges of perovskite-silicon tandem solar cells. The research is ongoing, and scientists are exploring new ways to improve the performance, stability and efficiency of perovskite-silicon tandem solar cells.

8. Discussion

An important review article titled "Stability Challenges and Probable Solutions of Perovskite-Silicon Tandem Solar Cells" analyzes the stability problems related to perovskite-silicon tandem solar cells and suggests probable answers to these problems. Understanding and resolving stability concerns is key for the broad adoption of perovskite-based solar cells since stability is a critical component for their commercial viability. The review on stability concerns of perovskite-silicon tandem solar cells and possible solutions offers helpful insights into the stability problems that these devices confront as well as possible remedies. Researchers and engineers can significantly advance the commercialization of perovskite-silicon tandem solar cells and pave the road for their general use in the renewable energy sector by comprehending and addressing stability concerns.

Perovskite-silicon tandem solar cells are a topic of current study and development with regard to their economic and commercial feasibility. Although they show great promise, there are a number of elements and potential obstacles that need be taken into account before they are widely adopted. Perovskite-silicon tandem solar cells' price is a key determinant of their commercial viability. Low-cost solution-based processing methods can be used to process perovskite materials, but scaling up production and lowering material prices are still difficult tasks. Tandem solar cells have the potential to outperform single-junction solar cells in terms of conversion efficiency. The careful tuning of the perovskite and silicon layers as well as their interfaces is necessary for the creation of effective tandem solar cells. Perovskite-silicon tandem solar cells must have their production methods scaled up for general deployment. Despite these difficulties, current research and development projects are working to overcome these obstacles and improving the perovskite-silicon tandem solar cells' economic and commercial viability. To get beyond these obstacles and utilize this technology to its full potential in the renewable energy sector, continued improvements in efficiency, stability, production techniques, and cost reduction are essential.

9. Conclusion

Stability challenges in perovskite-silicon tandem solar cells include degradation of perovskite layer, poor adhesion to silicon substrate, and moisture and heat sensitivity. Probable solutions to these challenges include incorporating more stable perovskite materials, using better encapsulation techniques, and incorporating anti-degradation layers. Further research and development is necessary to improve the stability of perovskite-silicon tandem solar cells for practical applications. Other solutions include improving the device design, such as reducing the perovskite layer thickness and optimizing the charge selective layers. Additionally, combining perovskite with other materials, such as metal oxides, can also enhance stability. Additionally, the use of stabilized zinc oxide or tin dioxide as the electron transport layer may help prevent degradation. Finally, post-fabrication treatments such as thermal annealing can also improve the stability of perovskite-silicon tandem solar cells. Several experimental approaches can be investigated to enhance the stability of perovskite-silicon tandem solar cells. Research could be conducted using some important strategies, including encapsulation and moisture barriers, interface engineering, device architecture optimization, and long-term stability testing. The stability of perovskite-silicon tandem solar cells can be significantly improved by investigating these experimental techniques, say researchers. In turn, this will help them become more commercially viable and open the door for a broad adoption in the renewable energy sector.

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