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Analysis of Methods of Fabricating Perovskite Photovoltaic Cells

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Abstract- Perovskite solar cells (PSCs) are a promising photovoltaic technology utilizing organometal halides for high-efficiency, low-cost solar energy conversion. They have the potential to revolutionize renewable energy as a result of their outstanding photovoltaic performance and a surge in their efficiency advancements. with unprecedented progress on certified power conversion efficiency (PCE) from 3.8% to over 25% within a decade. However, large-scale, cost-effective fabrication remains a hurdle for commercialization The Objective of the research is to investigate various Perovskite Solar Cells (PSC) fabrication methods with the goal of identifying scalable and efficient fabrication methods for commercially viable PSCs.

Index Terms- Perovskite Solar Cells, Power Conversion Efficiency, large-area perovskite films

I. INTRODUCTION

Perovskites can be fabricated using robust methods. Devices with high efficiency have been demonstrated employing sequential deposition, spin coating, vacuum evaporation, or CVD to deposit the perovskite film. Perovskite absorbers have a strong absorption coefficient over a broad wavelength range, which enables comparatively thin absorber layers. These materials have a comparatively low rate of non-radiative recombination. This lowers the bandgap-voltage offset ($\frac{E_q}{q} - V_{oc}$), allowing for higher V_{oc}. Many studies have shown V_{oc} values of 41V[1], which is greater than for efficient polymer solar cells. This is especially noteworthy given that the new material was produced using solution procedures rather than expensive crystal formation methods. Furthermore, these perovskite materials have high carrier mobilities and long diffusion lengths, which allow them to efficiently transport charge to be collected at the electrodes.

Due to their low cost of production and high efficiencies, perovskite photovoltaics (PV), as a relatively new form of solar cell, will in the future become a possible replacement for conventional silicon-based solar cells[2]. Perovskite cells are made from a combination of organic and inorganic materials and can be manufactured using different fabrication methods, including solution processing, spin coating, and ink-jet printing.

Various fabrication methods have been developed for the production of perovskite PV cells. These methods however differ in their process parameters, such as the deposition technique, annealing conditions, and precursor materials used. Each method has its advantages and disadvantages, there is therefore an essential need to analyze and compare them in order to arrive at the optimal method for perovskite PV cell production.

II. SOLUTION PROCESSED METHODS

1. Spin Coating

It is a quick and inexpensive fabrication technology that enables fast iteration and manufacture of small samples in laboratories. It is the simplest and least expensive solution-processed method for uniformly depositing the perovskite layers of PSCs.

The method is mostly used to produce small-area solar cells. usually after spin coating, the film is baked to form well-crystallized layers of perovskite, as baking results in strong adhesion and bonding between metal cations and halogen anions [3].

A layer of a specified thickness can be produced by quickly spinning a substrate that has a pool of mixed precursor inks (solutions made of the perovskite precursors AX and BX2 dissolved in volatile solvents) poured on it. The speed of rotation can be adjusted in relation to the viscosity and surface tension of the precursor ink. Following spinning, the coated substrate is heated to crystallize the precursors and drive off any leftover solvent, completing the creation of the perovskite layer.

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According to E. H. Anaraki *et al* in [4], the spin-coating technique which is a solution processed method can achieve high power conversion efficiencies of up to 22.1% for PSCs.

The spin-coating technology has a very high efficiency, but its drawback is that it cannot produce a homogenous film across larger regions. Additionally, with larger substrates, the film thickness varies mostly from the middle to the end of the substrate. When working with smaller module sizes, this approach achieves very high efficiency with strong reproducibility and morphological control.

Challenges with the Spin Coating Method
Non-uniform Coating Thickness:
The final coating thickness is determined by balancing the centripetal force produced during spin-coating against the viscosity and surface tension of the perovskite precursor ink.

A position-varying force is produced on the substrate as the size of the substrate is increased, with the force being greater in the portions that are farther from the Centre, there are differences in coating thickness throughout the substrate as a result of this uneven force distribution, lower force areas build up thicker coatings, however higher force areas could have thinner or broken coatings if centripetal forces are greater than ink surface tension.

Wastage:
Spin-coating requires intense spinning in order to remove surplus material and leave behind a thin layer, the process is inherently untidy.

Precursor ink is significantly wasted during spin coating considering the strong centrifugal forces used, maybe up to 50 times more than with other coating techniques. In addition to raising material prices, this waste raises environmental issues with the way surplus in and solvents are disposed of.

2. Drop Casting
A simple and affordable technique for making PSCs is drop casting. The main distinction between this method and spin coating is that it doesn't involve spinning of the substrate.

Additionally, the volume of the dispersion and concentration affect the thickness and characteristics of the film. The rate at which evaporation occurs, the drying process, and substrate wetness are other factors that impact the film structure.

In general, volatile solvents that have the ability to moisten the substrate are favored for this approach. Less material wastage is one benefit over spin coating. However, this approach has a number of drawbacks, such as difficulty controlling film thickness and uneven film production on big wafers.

3. Blade-Coating Technique
This involves depositing a perovskite solution on a substrate using a blade and then annealing the film to form a crystalline perovskite structure. often referred to as doctor-blading and knife-overedge coating, the technique involves a blade moving across a surface, or vice versa in the case of roll-to-roll coating[5]. The most prevalent synthesis method for fabricating large-area perovskite films is this method. It has been employed to create high-performing cells with surfaces larger than 10 cm^2 in multiple PSC experiments. Studies have shown that adjusting the processing temperature can improve the quality of the perovskite films. Additives have been used recently to achieve homogenous crystal shape and reduced pinholes in dense perovskite films.

Advantages of Blade-Coating:
Precise control of the distance between the blade and substrate: Blade coating enables exact control of the spacing between the substrate (where the film is deposited) and the blade (which disperses the perovskite solution).

Regulating the temperature of treatment: In order for perovskite films to develop and crystallize, temperature is essential. In order to achieve the required crystalline structure and morphology of the perovskite layer, blade coating provides the ability to control the treatment temperature during the coating process.

Simplicity: Spray coating and spin coating are two examples of other coating techniques that are thought to be more complex than blade coating. It is reasonably simple and economical, involving running a blade across the substrate to distribute the perovskite solution evenly.

Affordability: Blade coating is regarded as one of the most affordable techniques for producing small-scale PSCs. It is economical for both small-scale and research and development production because it needs little equipment and is simple to scale up for mass production.

Cost-effective and flexible film deposition: Blade coating provides the ability to fine-tune the film thickness and morphology by modifying the deposition parameters, such as substrate temperature, solution concentration, and blade speed. Its adaptability guarantees cost-effectiveness in terms of processing and material utilization, and it is appropriate for a range of applications.

Challenges with blade coating method:
Inconsistency in Coating Quality: The blade-coating method's propensity to yield coatings with notable quality variations is one of its main disadvantages. Variations in the coating process's blade speed, pressure, and angle are some of the causes of this discrepancy.

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Lack of Fully Enclosed Ink Reservoir: Blade coating usually does not make use of a fully enclosed ink reservoir, due to this design flaw, the procedure may be more vulnerable to outside influences like humidity or dust, which could unintentionally contaminate the ink or alter its viscosity during coating.

Control Difficulties in Solution Chemistry: To attain the required film qualities, such as optimal grain development, nucleation temperature, and crystallization temperature, blade coating demands exacting control over the solution chemistries.

Grain growth and crystallization control: Managing the crystallization temperature and guaranteeing uniform grain development provide special challenges when it comes to blade coating. The nucleation and growth kinetics of perovskite crystals can be affected by changes in solvent evaporation kinetics, drying rates, and ink spreading, which can result in non-uniform film microstructure and performance.

Limited Scalability: Although blade coating is more straightforward and economical than some other deposition methods, its scalability may be constrained by the difficulties in attaining uniform coating quality and repeatability at higher production volumes. When scaling up the process, the requirement for exact control over coating parameters and ink chemistry becomes even more, which could make it more difficult to achieve high throughput and uniformity across large-area substrates.

4. The inkjet printing

The ink-jet printing method is a non-contact printing technique that allows for direct control over ink deposition, resulting in a significant reduction in waste and resource consumption. A microfluidic cavity is subjected to a pressure change during the process, which causes the solution to jet (or shoot) out of a microfluidic nozzle. Several techniques, such as heat and structural factors interacting with the microfluidic nozzle, can produce this pressure shift.

Advantages Associated with Inkjet Printing

Direct Modelling and Elimination of Laser Etching: Photoactive films that are normally etched using a laser during the production of photovoltaic modules can now be directly modelled thanks to inkjet printing. This streamlines the production process and might lower expenses of manufacturing.

Improved Deposit Morphology: Two-step inkjet processes, which are comparable to spray coating, result in larger grains and better deposit morphology than single-step deposition techniques, which may create poor morphology. This guarantees more consistent and effective energy conversion within the photovoltaic cells.

Customized cell styles: Wearable electronics, small utility power sources, and building-integrated photovoltaics are just a few of the applications for which sophisticated, customized cell forms may be created thanks to inkjet printing. This adaptability creates new opportunities for industry use and design.

Compatibility with diverse Surfaces: Physical contact or a certain amount of space between the jet and the substrate are not necessary for inkjet printing systems, including continuous and other variations. Because of this, they may be printed on curved, uneven, or pressure-sensitive surfaces, increasing their potential applications and enabling integration into a variety of goods and structures.

Flexibility in substance Selection: Any sufficiently soluble solute in a conducting fluid or substance that is sufficiently fluid and conductive may be used in this manner. The ability to choose a variety of materials allows for flexibility in adjusting the printed layer's attributes to match desired qualities and performance characteristics.

Faster turnover and flexibility in system creation: Inkjet printing provides a faster turn-around time than other techniques, which facilitates the iteration and refining of designs more quickly. Furthermore, instantaneous creation or modification of systems improves their responsiveness and flexibility to evolving needs or technological breakthroughs. This flexibility is especially useful in sectors that are changing quickly, like electronics manufacturing and renewable energy.

Disadvantages associated with the Ink-Jet Printing Coating Methods

Sol-Gel Precursor Ink Hydrolysis and Nozzle Blockage: The hydrolysis of sol-gel precursor ink at room temperature presents a difficulty to the inkjet printing procedure used to create compact TiO2 films. The gel-like materials that may emerge as a result of this hydrolysis process have the potential to obstruct printing nozzles. As a result, this may interfere with the printing process, causing uneven layer deposition.

Difficulty in Depositing Films That Are Thin and Defect-Free: This is an obstacle when creating a thin, flawless, continuous, and unbroken coating on the rough surface of the FTO (fluorine-doped tin oxide) substrate. Ensuring consistent coverage of the TiO2 layer is challenging due to the rough surface of FTO substrates, which is a prerequisite for effective charge transport and collection in the solar cell device. Additionally, it is said that the film destabilizes and becomes inhomogeneous when it dries, which makes the deposition procedure much more difficult.

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Inkjet Material Waste and Contamination: The inevitable wastage of inkjet material during deposition is a significant disadvantage of the inkjet printing method. Contamination persists even with efforts to gather and recycle unwanted printing material droplets.

III. VACUUM BASED METHODS

A number of vacuum based fabricating methods are discussed in detail below

1. **Vacuum Flash-Assisted Solution Method**
Vacuum flash-assisted solution technique enables quick and precise solvent removal. By doing this, it promotes the perovskite precursor phase to crystallize quickly. There are numerous important processes in the Vacuum-Flash Assisted Solution Processing (VASP) method for producing perovskite films. First, a perovskite precursor solution with the appropriate content is made. DMSO with a certain lead to DMSO ratio, FA0.81MA0.15PbI2.51Br0.45, and other components are commonly found in this solution[6]. Next, a mesoporous TiO2 film substrate is spin-coated with the produced solution.

The coated film next goes through an important vacuum-flash treatment. This step is essential for accelerating the intermediate perovskite phase's crystallization process. Through a brief vacuum environment treatment, residual solvents—mostly GBL and DMF—are successfully eliminated from the film. This quick solvent clearance promotes the production of the perovskite coating and affects the general shape and quality of the material. 20 Pa is the ideal pressure to use throughout this operation, which is carefully regulated.

Advantages of the Vacuum Flash Assisted Method:
Highly oriented and Crystalline Perovskite Films: The precursor phase obtained from the Vacuum Flash-Assisted Solution (VAS) process yields highly aligned and crystalline perovskite films upon thermal annealing. Excellent electronic quality is exhibited by these films, which is essential for the effectiveness and functionality of many optoelectronic devices.

Compatibility with different substrates: Perovskite films can grow on a variety of substrates when using the VAS method. Its adaptability to various device architectures and production methods is improved by this

High degree of scalability to industrial scale: Scalability is crucial for large-scale production, which enables commercial applications and the mass production of devices based on perovskites.

Elimination of Hysteresis in J-V Curves: The VAS method's ability to remove hysteresis from current-voltage (J-V) curves for perovskite-based devices is a noteworthy benefit. Device stability and efficiency can be impacted by hysteresis; eliminating it enhances overall device performance.

Flexibility with regard to precursor components and perovskite composition: The VAS approach is adaptable with regard to precursor components and variations in perovskite composition. Because of its adaptability, perovskite characteristics can be adjusted to meet the demands of certain devices and performance goals.

Inherent Purity of Sublimed Materials: The inherent purity of sublimed materials is advantageous for perovskite thin films formed using vacuum techniques. This purity guarantees that there are few contaminants in the film, improving stability and device performance.

Controlled Film Thickness: The VAS technique allows for exact control over perovskite film thickness. Maintaining homogeneity over large-area substrates and optimizing device performance depend on controlled film thickness.

Low Substrate-Fabrication Temperature: The low substrate-fabrication temperature attained with the VAS approach makes perovskite technology compatible with plastic electronics and facilitates the manufacture of lightweight, flexible devices. The production of lightweight, flexible devices—including tandem devices using conventional inorganic solar cells—requires this feature.

Disadvantage associated with the Vacuum Flash Assisted Method
Charge carrier transport within perovskite films is severely hampered: this is by the creation of amorphous or weakly crystalline structures. This limitation results from the disordered configuration of atoms or molecules, which makes it more difficult for electrons and holes to flow through the perovskite layer effectively.

2. Chemical vapor Deposition Method
This technique utilizes gases. chemical vapor deposition (CVD) is a well-researched, inexpensive, and highly effective technique to fabricate a variety of semiconductor materials. CVD procedures yield much superior device performance than the spin coating method.

The vapor-solid reaction, the vapor-assisted technique, and dual-source evaporation are the variations of CVD. High vacuum and temperature requirements apply to this technique. As an alternative, the low-temperature vapor-solid reaction approach can be employed to deposit the perovskite film.

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Advantages of the Chemical Vapor Deposition (CVD)

Uniform Thickness: Chemical vapor Deposition (CVD) creates films across a wide surface area that are all the same thickness. For many applications, especially in electronics and optics, where consistency is essential for dependability and performance, this uniformity is vital.

Potential for complex Perovskite Compositions: Growing films with more complex perovskite compositions may be possible through the commercial application of this technique. This is especially important for high-performance PSCs, since the stability and efficiency of the solar cell are significantly influenced by the composition of the perovskite layer.

Accurate control with multizone CVD: Multizone CVD provides precise control over various parameters such as pressure, gas flow rate, precursor temperature (e.g. Methylammonium Iodide (MAI) temperature), and substrate temperature. This level of control enhances the reproducibility of the deposition process, leading to consistent quality and performance of the deposited films.

Precise management using multizone CVD: Pressure, gas flow rate, precursor temperature (such as the temperature of methylammonium iodide, or MAI), and substrate temperature can all be precisely controlled with multizone CVD. This degree of control makes the deposition process more repeatable, which results in films that are produced with consistent quality and functionality.

Optimization of crystallization kinetics with atmospheric pressure air as carrier gas: For commercial production, deploying atmospheric pressure air as the carrier gas in CVD has advantages. The primary method used to optimize the kinetics of crystallization is annealing in an organic vapor atmosphere. The production of superior films with desired characteristics, such as increased crystallinity and decreased defect density, is facilitated by this optimization.

Disadvantages of the Chemical Vapor Deposition Method

Presence of amorphous perovskite films: Chemical vapor deposition (CVD) perovskite films typically have an amorphous structure and a defective crystalline nature. It is possible for this poorly defined crystallinity to result in subpar material characteristics, such as decreased charge-carrier transport. Device performance may be impacted by the lack of a well-ordered crystalline lattice, which can impede the flow of charge carriers through the material.

Impact on Charge Carrier Transport: Another disadvantage is that, the charge-carrier transport characteristics of perovskite films made by chemical vapor deposition can be greatly affected by their imperfect crystalline structure. A material with low crystallinity may have more flaws and grain boundaries, which can trap charge carriers and impede their movement.

Control of vacuum pressures during the deposition process: Chemical vapor deposition techniques demand exact control of vacuum pressures during the deposition process. It can be difficult to achieve and maintain these particular hoover settings, and it could take specialized tools and knowledge**.**

3. Sequential Evaporation Method

The sequential evaporation method entails the separate vapor deposition of several film layers atop one another, followed by the diffusion and recrystallization of these numerous film layers. the metal halide layer is first deposited on top of the conductive glass and subsequently on the organic halides.

Advantages of Sequential Evaporation Method

High Efficiency: The Sequential Evaporation Method has the potential to attain significant efficiency, as much as 15.4% for small-area devices, with optimization which is a great advantage. This implies that it is capable of manufacturing perovskite solar cells (PSCs) with excellent performance.

Dense and homogeneous Films: Dense and homogeneous films are produced by vacuum evaporation. This feature guarantees close thickness control and improves replicability, both of which are essential for solar cells to operate consistently.

Multilayer film manufacture: The process enables the creation of multilayer films without causing the primary layers to change chemically. This characteristic is very helpful for creating high-performing heterojunction devices, which increases the adaptability of solar cell designs.

Suitability for Tandem Cell Structure: Tandem cell structures can be created with the Sequential Evaporation Method. It is significant because it aids in preventing solvent damage to the layers beneath the perovskite film, which is essential for preserving the device's integrity and operation.

Disadvantages of Sequential Evaporation Method:

Scalability: Increasing the Sequential Evaporation Method's volume of production for profit may present difficulties. The alternating evaporation processes' throughput and material consumption could slow down utilization, which would affect the scalability and efficiency of manufacturing.

High Cost: The Sequential Evaporation method's intrinsic vacuum application leads to expensive expenditures. Similar to other vapor-based techniques, this one necessitates energy-intensive procedures and specialized equipment, which raises the cost of production. Its widespread implementation may be

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hampered by these high prices, particularly in large-scale production settings.

4. **Co-Evaporation Method**

For a variety of applications, this vacuum-based method is the most suitable. The precursor solutions are placed into different crucibles and heated to the correct sublimation temperatures in order to prepare the perovskite films in a high-vacuum chamber operating at a pressure of (10−5– 10−6) mbar. Modules with co-vapor-deposited PSC films achieve high PCEs of 16.5% and are smooth and homogenous. Furthermore, the technique makes it possible to manufacture multilayer films and works flawlessly with traditional semiconductor manufacturing techniques.

Advantages of the Co-evaporation Method:

Small Perovskite crystallite grain size: Smoother films are produced by using this process, which produces notably smaller perovskite crystallite grains. Smoother films improve the overall performance and efficiency of solar cells or other optoelectronic devices.

High Pure Sublimated chemicals by Nature: Sublimated chemicals are used in co-evaporation, and they are high-purity by nature. This purity makes it easier to precisely regulate the perovskite film's chemistry and thickness, guaranteeing reliable and consistent performance.

No need for thermal treatment: If the inorganic–organic precursors are stoichiometrically balanced, the perovskite film can be synthesized entirely without any heat treatment. This characteristic broadens the possible applications and is essential for substrates that are sensitive to temperature, such as plastic foils.

Adherent and homogeneous films: Compared to films made by spin-coating, those made by co-evaporation are higher adhesion to substrates and more homogeneous. Furthermore, they have fewer pores and are denser, which improves device performance and makes them compatible with planar solar cells.

Disadvantages of the Co-Evaporation Method

Challenge of Control of MAI Vaporization Rate: Because of its high vapor pressure, methylammonium iodide (MAI) is difficult to control in terms of vaporization rate. To achieve the desired film qualities, it is imperative to maintain exact control over this parameter.

process slowness and calibration: To maintain the deposition rate and precursor ratio, the co-evaporation process necessitates precise periodic calibrations. This necessitates close observation and modification, which could lengthen and complicate production.

Cost of Vacuum Technology: The process's overall cost is increased by the need for vacuum technology. Because of this, co-evaporation may be an expensive method, especially when producing large quantities.

Partial Condensation of Organic Cation Precursors: Outside of the evaporation cone zone, partial condensation of organic cation precursors, such as MAI, might occur. This can result in uneven film deposition and possibly impair device performance.

Infrastructure Needed for Commercial manufacturing: Vapor-based techniques, such as co-evaporation, require advanced infrastructures that are not presently typical for the manufacturing of perovskite optoelectronics for commercial use. This restricts the method's capacity to scale.

5. Flash Evaporation Method

The perovskite components are placed on a metallic heater and placed under a vacuum in the flash evaporation method. The metal heater conducts a high-current voltage that activates the entire perovskite material, enabling it to quickly evaporate and condense onto a substrate to produce a thin perovskite film. When depositing perovskite materials, the flash evaporation process is used[5].

Advantages of the Flash Evaporation Method

Controlled film Thickness: To guarantee uniformity and consistency in the perovskite film deposition process, the final film thickness is carefully controlled by the thickness of the bulk precursor film.

High degree of homogeneity and a low level of surface roughness: which are essential qualities for the effective use of PSCs in optoelectronic devices. Better performance and longer device life are ensured by this.

Appropriate for powder precursor hybrid perovskite layers: This technique may be used to deposit powder precursor hybrid perovskite layers, which allows for the creation of different perovskite structures for different uses.

Quick Conversion to Crystalline Films: Under low vacuum settings (1–10 mbar), lead halide layers can be quickly transformed into highly crystalline perovskite films, allowing for quicker production procedures.

Produces High Efficiency Solar Cells: Flash evaporation-produced perovskite absorbers have been used in solar cells with Power Conversion Efficiencies (PCEs) greater than 16%, proving the method's efficacy in creating high-performance solar cells.

Preparation of composite structures: The utilization of flash evaporation technologies facilitates the creation of composite

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structures that integrate various organic and inorganic elements. This is advantageous in the development of tandem solar cells that exhibit increased efficiency and functionality.

Disadvantage of the Flash Evaporation Method
High Vacuum Requirements and Cost: Similar to other vapor-based techniques, flash evaporation necessitates a certain vacuum level, which raises the expense of equipment and operations. Its broader adoption may be hampered by this, making it inaccessible to facilities with fewer resources or size.

6. Vacuum Thermal Evaporation Method
Technique of Vacuum Thermal Evaporation is achieved by heating materials at high vacuum conditions (pressures less than or equal to 106 Pa)[7], and allowing the resulting vapor to condense onto a cooler substrate, materials can be sublimated using this process. In a high vacuum, the evaporating particles are expanded.

Advantages of Vacuum Thermal Evaporation Method
Ease of use and wide applicability: The vacuum thermal evaporation technique is easy to use and widely applied across a range of industries.

Scalability: This technique is scalable, Perovskite Solar Cells (PSCs) can be manufactured industrially using it.

It is Solvent-Free: Vacuum thermal evaporation eliminates the need for solvents, which eases the process and lessens environmental impact compared to some other fabrication techniques.

Production of consistent coating: To ensure uniformity in film deposition, materials can be coated on substrates consistently, particularly in ultrathin layers.

Accurate Management of Film Thickness: The film's thickness can be precisely controlled by keeping a careful eye on each precursor substance's deposition rate.

Compatibility with Characterization Methods: Under ultrahigh vacuum conditions, the procedure works well with characterization techniques.

Disadvantages of the Vacuum Thermal Evaporation Method
Increase in the distance between the substrate and the source: this occurs due to the use of bigger vacuum which results in decreased deposition rates and more material waste.
Fluctuating Deposition Rate: Materials tend to deposit at different rates, which can be a major disadvantage as it might impact the consistency and caliber of the films that are deposited.

High cost of vacuum technology: Compared to alternative fabrication techniques, this method may be less economically attractive due to the high cost of vacuum technology.

Lower power conversion efficiencies (PCEs) than Solution-Processed Counterparts: At the moment, PSCs synthesized by vacuum thermal evaporation might be less efficient at PCEs than their counterparts that undergo solution processing.
Difficulty in Applying Stability-Enhancing Techniques: A lot of PSC stability-enhancing techniques rely on additives, which make them challenging to apply during vacuum thermal evaporation.

Perovskites Degradation: Vacuum exposure can lead to the breakdown of both 2D and 3D perovskites, which can impact PSC stability and overall performance.

Negative Effect of Remaining Solvent: The performance of the solar cell device may be adversely affected by any solvent that remains in the final perovskite layer.

IV. CONCLUSION

In conclusion, Investigation into methods of fabricating perovskite solar cells has shown a wide range of processes, each with its own set of advantages and drawbacks. Solution-processed technologies, such as spin coating and inkjet printing, are simple and scalable, but have concerns with film homogeneity and material waste. In contrast, vapor-based deposition technologies like as chemical vapor deposition (CVD) and physical vapor deposition (PVD) provide exact control over film characteristics but are expensive to operate and have limited scalability.

Nonetheless, despite tremendous progress, several hurdles remain in perovskite production. Concerns about stability, repeatability, and the toxicity of precursor materials remain significant barriers. Additionally, there is a pressing need to optimize device architecture in order to improve both performance and durability.

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