Illuminating Innovations: A Comprehensive Literature Review of Emerging Photovoltaic Materials

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Abstract

This literature review provides an overview of the rapid change in the comprehensive field of photovoltaic (PV) material, the most critical sector for shifting towards renewable energy. The article has critically selected and highlighted some of the key developments recently reported in various photovoltaic materials, including graphene, ferroelectric materials, biogenic photovoltaic materials, and organic semiconductors, by critically looking at the recent research and developments. Each of the following sections of materials is therefore presented by summarizing about synthesis, properties, application in PV systems, environmental issues, and economic considerations resulting from their integration into PV systems. In this review, the author describes opportunities and challenges essential to be addressed, which play the most important role for these materials in efficiency, sustainability, and scalability of solar cells. The possible future research directions and potential commercial applications that will overcome the current barriers to harness these innovating materials in a broader adoption for solar technologies are also discussed. This synthesis has well defined the current state of the research in photovoltaic materials; however, it also guides future works that are about to revolutionize the solar energy conversion.

Keywords

Photovoltaic Material, Graphene, Ferroelectric Material, Solar Energy, Biogenic Photovoltaic Material

1. Introduction

1.1 Brief Overview of the Importance and Development of Photovoltaic Materials

Photovoltaic (PV) materials are of prime importance with the shift to renewable sources of energy, since they play a pivotal role in the conversion of solar energy into electrical power. This class of materials has undergone a dramatic evolution from the first technologies based on crystalline silicon to those more innovative, able to use novel materials ensuring higher efficiencies and manufacturing processes friendlier to nature. Recent works, however, of Aleksandar M. Mitrašinović et al. and of Ming-Chung Wu et al. give evidence of how research in photovoltaics is pointing to an intense activity finalized at the improvement of efficiency and environmental footprints of a PV system through the introduction of new materials. (Mitrašinović & Radosavljević, 2022; Wu & Chang, 2018) This has, in turn, fueled the explorations of 2D materials, such as graphene with outstanding electrical properties and mechanical strength, as discussed by Sarvesh Kumar Srivastava et al., while biogenic materials are being sought as an alternate sustainable approach to photovoltaic production, as highlighted by Sonali Das et al. (Srivastava et al., 2018; Das et al., 2018)

1.2 Objectives of the Literature Review

This paper consolidates and critically reviews the recent advances of materials used for photovoltaic from separate analyses in time past. The main objectives are that:

- Examine the latest developments in photovoltaic materials, focusing on their synthesis, properties, and applications.
- Trends and patterns will be defined with respect to the material performance improvement, efficiency gains, and stability enhancements.
- Highlight the environmental and economic impacts of new photovoltaic material technologies.
- Offer insights into future research directions and potential commercial applications of these innovative materials.

1.3 Summary of the Types of Photovoltaic Materials Covered in the Review

The review covers a diverse range of photovoltaic materials, each offering unique properties and applications:

- **Graphene and Other 2D Materials**: This category of materials has reached the helm of photovoltaic research due to their excellent electrical conductance and mechanical properties.
- **Ferroelectric Materials**: A new study about ferroelectric materials in photovoltaics found that the research emphasizes their potential in sustaining polarization that may contribute to improvements in the efficiency of solar cells.
- **Biogenic Photovoltaic Materials**: Biogenic photovoltaic materials, as outlined by Sonali Das et al., are the ones that emanate from natural processes and substances, bringing in the classical photovoltaic material a green alternative. (Das et al., 2018)
- **Organic Semiconductor Photovoltaic Materials**: Organic semiconductor photovoltaic materials are really important, since they are being used for the fabrication of flexible and lightweight solar cells, low in cost with their improved absorption spectra, as discussed in detail by Zhi-Guo Zhang. (Zhang, 2015)

This paves the way for a more in-depth discussion of each type of material and its development with respect to larger efforts in the sustainability and efficacy of the solar power technologies. From there, the review moved to the specific contributions of the studies of each of the respective authors and, in a sense, gave a basis from which to understand the current landscape and future trajectory of photovoltaic material research.

2. Graphene and Other 2D Materials

2.1 Introduction to Graphene and 2D Materials in Photovoltaics

Graphene and other two-dimensional (2D) materials are emerging as radical components of the photovoltaic (PV) sector because of their unique properties. Material related to this promising generally atomic-thin character and showing outstanding electrical, thermal, and mechanical properties, pointing to the limitations of traditional PV materials. Sarvesh Kumar Srivastava et al. stated that graphene acts importantly by enhancing conductive properties inside the solar cell with faster mobility of electron movement, which is vital for furthering the efficiency of the solar cell. In addition to graphene, other two-dimensional materials have also been included in PV cells. (Srivastava et al., 2018) Other materials like transition metal dichalcogenides (TMDs) and black phosphorus have been researched in combining 2D materials in a PV cell for its interesting optical and electronic properties. (Zhao et al., 2022)

2.2 Synthesis and Modification Techniques

The 2D materials are thus synthesized using the photovoltaic methods devised herein. Several adopted methods are taken into account to tune properties for the enhancement of solar cell performance. Notably, among these methods is chemical vapor deposition (CVD), as detailed by Sarvesh Kumar Srivastava et al., who are outstanding in the preparation of high-quality graphene. (Srivastava et al., 2018) The other methods that were used included exfoliation, epitaxial growth, and atomic layer deposition, among others, to fabricate 2D materials for different device architectures. The doping and functionalization techniques, including a critical role that should be applied, adjusted the electronic properties of 2D materials for optimal photovoltaic performance.

2.3 Recent Advancements in Efficiency and Stability

Recent advances in the field have witnessed great progress in the efficiency and stability of PV cells, such as those made by Srivastava et al. using 2D materials. Graphene - with rather good transparency and flexibility - does offer quite good prospects for replacing traditional materials, such as indium tin oxide (ITO), in transparent conductive electrodes. Further, stacking of 2D materials has already shown that it can produce heterojunctions which may be very useful for solar energy conversion because of their tunable bandgaps and enhanced charge carrier separation. This allows the possibility of stacking different 2D materials to make a 3D material. All these improvements make the solar cells efficient, long-lived, and stable for durability under different environmental conditions in the long term.

2.4 Challenges and Potential Solutions

For all their promises, graphene and other 2D materials come along with several challenges when it comes to photovoltaic application. Foremost is the scalability of the production method in 2D material synthesis. (Santhiran et al., 2021) It is another challenging task to incorporate these into the current architectures of solar cells without degrading device integrity and performance. Here again, it would be a synthesis technology that can form large scales of material free from defects that may present possible solutions. It may also lead to the design of new hybrid structures that 2D materials can form with other photovoltaic materials, be it of new generations or the traditionally popular ones, in order to capture the benefits from each class. 2D materials bring with it both scientific and technological promise for a vast range of applications, and as such, Srivastava et al. have suggested that taking an interdisciplinary approach to some of these challenges can surely put further merit in the application of 2D materials in photovoltaics to have more efficient and a larger impact on commercially viable solar energy solutions.

These sections put together outline the critical role that graphene and other 2D materials are playing in the redefinition of photovoltaic technologies, focusing on contemporary research and calling for novel solutions required to bring the whole capability effectively.

3. Ferroelectric Materials

3.1 Basics of Ferroelectric Materials for Solar Energy Applications

Ferroelectric materials are known for some of the special electric properties, such as spontaneous polarization of the material. The material becomes polar even after one eliminates an external electric field. (Lai, 2022) Here is the main characteristic that can be applicable to photovoltaic applications, giving rise to improved charge separation to stop recombination, hence more efficacy. Luo et al. further explored the application of ferroelectric materials in the manufacture of solar cells and explained how intrinsic electric fields in the respective material could assist in facilitating charge carriers' free movement for enhancement of the open-circuit voltage, hence increasing overall efficiency. (Luo et al., 2020)

3.2 Material Properties Influencing Photovoltaic Effects

Its main factors affecting the photovoltaic effects of the ferroelectric materials are polarization properties, domain structure, and dielectric constant. (Liu et al., 2016) On the other hand, for such classes of materials, an equally important functionality is their ability to align domains and electric-field-oriented changes in polarization directions, which help in guiding effectively, and eventually separating, the charge carriers in a solar cell. In addition, high dielectric constants have the advantage of reducing charge carrier recombination. Xinshu Luo et al. have therefore been keen in appreciating that with the pronounced importance held by the material's crystal structure and that of its domain engineering in achieving the optimized photovoltaic performance, the purity of the material in question should be very high. (Luo et al., 2020)

3.3 Key Studies and Results on Ferroelectric Photovoltaic Materials

For example, some of the most recent researches, as discussed in the review of Xinshu Luo et al., have provided a major breakthrough in the field of ferroelectric photovoltaics. (Luo et al., 2020) For example, some perovskite ferroelectrics have been found to hold a lot of promise, as they exhibit a very strong ferroelectric property and just the right band gap. (Borisevich et al., 2010) These materials are used to fabricate junctions in which their ferroelectric polarization effects result in large enhancements of the photovoltaic output by enhancing the internal electric fields driving charge separation. Other studies further probe the effects of layering ferroelectric material with other semiconductor materials to form heterojunctions, which further increases efficiency and stability.

3.4 Future Prospects and Limitations

The opening of such new and attractive possibilities for the further development of solar cells by ferroelectric materials does, however, have to be faced with big challenges and limitations. Another major disadvantage is that the ferroelectric materials normally have a wide bandgap, which is hence limited in the efficient absorption of solar radiation across the spectrum. (Guo et al., 2022) In addition, the problem of how to fabricate high-quality ferroelectric materials in an ordered domain over a large area is also a challenging task. Potential research directions that Xinshu Luo et al. pointed out include the development of new ferroelectric materials with narrower band gaps and development in nanostructuring techniques to effectively manipulate the domain structures. (Luo et al., 2020) These approaches could pave the way for the next generation of high-efficiency, ferroelectric-based solar cells.

To sum up, this is an emerging area dealing with the use of ferroelectric material combined with the needs for efficient solar energy conversion and offering unique potential features they can enable. As many authors highlight, in the case of Xinshu Luo, each was focused on bringing out the fact that it is with continuing research and development that the limitations of today can be overcome to open the full potential of these materials for practical deployment in solar applications. (Luo et al., 2020)

4. Biogenic Photovoltaic Materials

4.1 Overview of Biogenic Materials in Photovoltaic Systems

The use of biogenic materials in solar systems is getting much attention nowadays for its eco-friendliness and sustainability. According to Sonali Das et al., such materials contain a complex of organic compounds, including chlorophyll, carotenoids, and other pigments for photosynthesis, which are responsible for allowing plants the ability to capture light energy and convert it into electric energy. (Das et al., 2018) These bring forth the biology-technology odd coupling: renewable resource photovoltaic materials that could possibly have the capability of reducing the environmental footprint associated with photovoltaic manufacturing processes.

4.2 Case Studies on the Use of Biogenic Components

A case in point is the work of Sonali Das et al., who found promising results in case studies performed on biogenic photovoltaic materials. (Das et al., 2018) Thus, the photosynthetic proteins, when biologically modified and embedded within nanostructured electrodes, have been reported to produce an electric current by carrying out the function of the natural photosynthetic process. (Lu et al., 2006) In another case study on the bacterial pigments used in the dye-sensitized solar cells for the substitution of synthetic ones during the generation of eco-friendly solar panels, the natural sensitizer was used. (Orona-Navar et al., 2021) This is to say that the described case studies demonstrate the application of the biogenic materials to actual tasks.

4.3 Comparative Analysis of Efficiency with Traditional Materials

The disadvantage of biogenic materials, however, lies most of the time in that efficient transformation of sunlight into electricity falls short by far, as compared to traditional materials such as silicon or thin films. (Solak & Irmak, 2023) Existing efficiencies of the biogenic photovoltaic systems have much less optimized charge transport and short life of organic materials, as discussed by Sonali Das et al. However, continuous research is further made to enhance the stability and efficiency of such biogenic material by means of advanced biochemical and nanotechnology techniques. (Das et al., 2018)

4.4 Environmental Impact and Sustainability Considerations

The environmental footprint of photovoltaic materials is under sharp consideration, though aligning with the greater aims to global sustainability. This feature ensures that biogenic photovoltaic materials bring large benefits to this side since they come from renewable sources and are often biodegradable, reducing resource depletion and the environmental impact at the end of their life. Sonali Das et al. brought out that, in such materials, the generation of toxic waste could reduce to a great extent from the conventional photovoltaics manufacturing process. (Das et al., 2018) Further, the carbon footprint specified for the production and disposal of biogenic materials is very small compared to the case of conventional alternatives and, in fact, supports worldwide environmental sustainability practices. (W. Liu et al., 2017)

In conclusion, while the biogenic photovoltaic materials produced today have problems of efficiency and durability, their potential for a smaller environmental and resource impact does indeed show possibilities for future research. This is where, according to Sonali Das et al., the research comes to find a way through which these barriers could be overcome and the potential of biogenic material in revolutionizing the photovoltaic industry could be unleashed to provide greener options against conventional solar technology. (Das et al., 2018)

5. Organic Semiconductor Photovoltaic Materials

5.1 Introduction to Organic Semiconductor Materials

For this reason, as well as the intention of low-cost manufacture possibility and the flexibility of application, organic semiconductor materials have turned into one of the focal points of photovoltaic (PV) technologies. According to Zhang Zhi-Guo, such materials consist of small molecules or polymers that carry the ability to absorb light, therefore able to transport the charge, thus they represent a light and flexible alternative for cells based on monocrystalline silicon. (Zhang, 2015) Organic semiconductors have attracted attention to their solution processability - something new for the possibility of use in their manufacturing techniques. Techniques like printing or coating are in use for them, which allows the production of large-area photovoltaic panels at lower costs.

5.2 Recent Developments in Material Composition and Layering

Zhi-Guo Zhang has taken an important advance in organic semiconductors and emphasized in his work on how new compositions of material and layering in structure led to an increase in light absorption and electrical properties. (Zhang, 2015) Recent developments have included the synthesis of new donors and acceptor materials designed for the optimization of photovoltaic performance, improved spectral absorption, and improved molecular ordering. Inserting non-fullerene acceptors in such cells has been a big game-changer since it offers stability and better efficiency compared to fullerene ones. Material layering to form bulk heterojunctions has, in addition, been perfected to better the interface quality so as to enable better charge separation of the carriers and thereby reduce recombination losses.

5.3 Improvements in Power Conversion Efficiency and Production Methods

Certainly, the power conversion efficiency (PCE) of organic semiconductor photovoltaics with material engineering and device architecture developments has displayed a remarkable increase. (Wang et al., 2021) These would include new materials with high mobilities of charge carriers and tandem cell structures, which accumulate many layers of organic materials in order to expand the spectrum of solar radiation. Also, the focus is on scaling the production methods with which continuous processing techniques, like roll-to-roll printing, are evolving as a viable method for mass production, which will bring down the cost per unit of power generated by a great margin.

5.4 Current Challenges and Research Directions

However, some challenges are still observed that organic semiconductor photovoltaics need to overcome in order to become commercially viable. Zhang Zhi-Guo discusses the long-term durability of organic materials under environmental exposure and their lower efficiency, afflicted by intrinsic stability, compared with inorganic options. (Zhang, 2015) The search for solutions to such problems is, therefore, actively chased. This has then called for research efforts focusing on the development of new materials with better thermal and photochemical stability and encapsulation techniques to prevent active layers from oxidative degradation. (Uddin et al., 2019) Additionally, what seems promising in this approach is the design of hybrid systems that combine organic materials with inorganic nanostructures and which may finally enable a breakthrough not just towards high-efficiency but also high-stability devices.

Organic semiconductor materials are, therefore, a very dynamically developing field within photovoltaics research. Other innovations in material science and device engineering, such as the ones offered by the team of Zhi-Guo Zhang, are indispensable toward overcoming the present bottlenecks and in the direction of fully realizing the potentiality of these materials in the prospective solar energy systems.

6. Other Innovative Photovoltaic Materials

6.1 Brief on Other Materials

With the prior materials at the base of the previous sections, modern classes of photovoltaic materials to be included will be perovskites and quantum dots, which are getting explored for their unique properties that can bring a revolution in the solar industry. (Huang et al., 2023) It is the subject of subsequent studies: material characteristics and applications by Yongbo Yuan et al., and by Aleksandar M. Mitrašinović et al. On the other hand, perovskites have presented excellent light absorption and facilitate the fabrication of the whole cell. Quantum dots, in turn, have the characteristic of size tunable bandgaps and can show excellent light harvesting. This is a rather big step for the photovoltaic technology.

6.2 Innovations and Experimental Results

Particularly promising are the strides made by perovskites in efficiencies, which Yongbo Yuan et al. point out have quite literally been on overdrive in recent developments and are now at par with traditional silicon-based cells. (Yuan et al., 2014) Innovations include achieving film uniformity, developing more stable and less-toxic perovskite variants, and integrating the compound into tandem cells. Whereas, as expressed by Aleksandar M. Mitrašinović et al., quantum dots are also being applied in quantum-dot-sensitized solar cells (QDSSCs) due to the tunability of their optical properties in relation to efficient multi-bandgap energy conversion, which exceeds by far the ability of any conventional material. (Mitrašinović & Radosavljević, 2022)

6.3 Comparative Advantages Over More Traditional Materials

On the positive side, perovskites pose relative advantages over traditional silicon-based types of photovoltaic materials. (Roy et al., 2022) The technology is said to claim high efficiency, along with the added advantage of the manufacturing costs being at a relatively low expense. This could bring the cost levels of solar energy down by more than half. Quantum dots provide compact spectral versatility, which opens new applications unachievable with bulkier traditional materials, while promising transparent and flexible solar cells. (Pan et al., 2018) Such materials can also be synthesized, thus enabling rapid experimentation and iteration in the laboratory, which raises the innovation and pace of adoption in the solar industry.

In a word, the photovoltaic materials being developed by Yongbo Yuan, Aleksandar M. Mitrašinović, and other authors are oriented exactly toward the development of up-to-date solar technologies. Eliminating some of the drawbacks that are characteristic of traditional photovoltaic materials and allowing the properties that can be harnessed, these innovative materials improve not only the performance of solar panels but also offer wide potential application of solar energy in modern technology.

7. Comparative Analysis

7.1 Cross-Comparison of Different Material Types Regarding Efficiency, Cost, Stability, and Scalability

This section of the literature review discusses comparatively the covered different photovoltaic materials regarding four critical parameters: efficiency, cost, stability, and scalability. The works of various authors like Zhi-Guo Zhang, Sarvesh Kumar Srivastava, Xinshu Luo, Sonali Das, Yongbo Yuan, and Aleksandar M. Mitrašinović argue in general that any type of material does come with some unique advantages and bears its own share of challenges.

- **Efficiency**: Where silicon is the benchmark efficiency for high-efficiency solar cells, perovskite and organic semiconductors have steep efficiency improvement curves and are closing in on parity in laboratories. Graphene and 2D, although used primarily for their photovoltaic properties, actually improve the efficiency of other materials with its hybrid structures.

- **Cost**: Organic semiconductors and perovskites bring only small production costs compared to traditional silicon, from lower material costs to processing. Biogenic materials may become the cheapest and most cost-effective since they can be renewable in terms of their source but so far in their very early stage of photovoltaic application.
- **Stability**: Presently, silicon and perovskites are head-to-head in stability. Further developments on the perovskite encapsulation are in the process for protection against moisture penetration. The stability of organic materials, in general, and that of the biogenic components is of much lesser quality, mostly at the expense of long-term use.
- **Scalability**: Silicon has a very high scalability with well-structured international chains of production. On its part, perovskites and organic semiconductors offer promise for process scalability, mainly arising from their simpler process of fabrication that could be adapted to roll-to-roll production. Graphene and other 2D materials, on their part, also suffer from the same point, i.e., from big-batch syntheses.

7.2 Table Summarizing Key Performance Metrics

The same is summarized in the table below with reference to some of the key performance metrics and their relative strengths and weaknesses:

Table 1

Material Type	Efficiency (%)	Cost (Relative)	Stability (Years)	Scalability
Silicon	15-22	High	20-25	High
Perovskites	13-25	Medium	5-10*	Medium
Organic Semiconductors	15-Oct	Low	10-May	Medium
Graphene/2D Materials	Not Applicable	High	Varies	Low
Biogenic Materials	3-Jan	Very Low	<5	Low

*Note: Stability for perovskites is improving with new encapsulation techniques and material innovations.

In a sense, this comparison provides a summary of the current status of photovoltaic materials, and in another sense, it can afford insight into places where additional research and development can provide high payoffs. Some well-proven, reliable materials hold sway on the market today, with perovskites and organic semiconductors opening possibilities for creating more accessible and versatile solutions for solar energy.

8. Future Trends and Directions

8.1 Predictions Based on Current Research Trajectories

All those tendencies, as it has been elaborated in the works of the team of Zhi-Guo Zhang, Sarvesh Kumar Srivastava, and Xinshu Luo among other researchers, will be forming the future of photovoltaic materials. Both perovskite and organic-based semiconductor technologies are progressing well, and the development trends with these technologies clearly indicate that perovskite- and organic-based semiconductors could soon compete with or outpace the traditional crystalline silicon-based module technologies. As Yuan et al. describe, the improvements in material stability and efficiency of perovskites are so large and so fast that they point to commercial viability arriving imminently. (Yuan et al., 2014) Similarly, new designs of organic semiconductors are likely to emerge in the next few years to enable them to surmount the existing barriers to efficiency and stability.

8.2 Gaps in Current Research and Opportunities for New Studies

While there has been a huge breakthrough, still lots of gaps remain in the current study, showing the potential for further research. For example, one of the main challenges in long-term stability of perovskites under realistic environmental conditions is still to be addressed, as stressed by Yongbo Yuan et al. (Yuan et al., 2014) Further research is needed to develop more robust encapsulation techniques and moisture-resistant materials. Further, as Das et al. opined, the photovoltaic applications using biogenic materials are still at their early stages, and much more needs to be explored towards the optimization of mentioned biogenic materials for higher efficiency and be incorporated into existing solar technologies. (Das et al., 2018) Where there is one area ripe for further exploration, it is the large-scale synthesis of high-quality graphene and other 2D materials. This process, according to Srivastava et al., presently bottlenecks the materials' wider application in the field of photovoltaics. (Srivastava et al., 2018)

8.3 Potential for Commercialization and Impact on Renewable Energy Targets

Thus, the potential for such commercialization of the emerging photovoltaic technologies is huge, most especially keeping in view the international targets that are being set for the renewable energies. (Ghosh & Yadav, 2021) It represents a new opportunity that could help bring down the cost of solar power to new unprecedented levels. Zhang Zhi-Guo mentioned that perovskites and organic semiconductors are produced through low-cost roll-to-roll processing. (Zhang, 2015) This can accelerate the diffusion of solar energy all over the world, mostly in developing regions, where one of the great obstacles is that of costs. Adding sustainable materials within photovoltaic systems, for example, biogenic components, could serve to reinforce the life cycle-based sustainability of photovoltaic systems against the increasing regulatory and consumer pressure for green solutions. (Laghari et al., 2020)

Future trends in the research of photovoltaic materials, therefore, would lead to an even more diversified landscape of technologies that could compliment - or even replace - some of the traditional applications of silicon. These are likely developments not only in delivering cost savings from greater efficiency but also playing a substantial part in global renewable targets through making solar more affordable and sustainable.

Conclusion

Thus, this literature review walked the expansive ground of the photovoltaic materials that have been brought to light, particularly by other researchers such as Zhi-Guo Zhang, Sarvesh Kumar Srivastava, Xinshu Luo, Sonali Das, Yongbo Yuan, Aleksandar M. Mitrašinović, and many others. From the conventional silicon to the emerging biogenic and organic material types, each now holds quite unique opportunities and challenges to the pathway of solar technology.

What happens here is that though silicon still remains constant in the market due to high reliability and efficiency, what has emerged quite fast is the rise of perovskites and the organic semiconductors. Such materials seem to not only promise improved efficiency and cheaper cost of solar cells but also open up new applications in the realm of flexible, scalable manufacturing processes. As researchers and engineers across the world further this technology, chances are high that the next game-changer will be in the way completely solar cells are built, bringing in a new innovation with graphene and 2D materials to usher in more efficient and durable systems. In contrast, biogenic materials offer the same sustainable alternative but are currently lagging in efficiency, needing further research before they can be applied for commercial use.

All these strides in the development of photovoltaic materials look encouraging. Every stride forward brings the field a small bit closer to mitigating the tremendous number of limitations linked to current solar technologies. Such is the rapid progress in photovoltaic research that soon enough such a source of energy may become just not available but used in lots of different uses and be taking a much bigger share in renewable energy.

The message to the researchers is clear: much more testing has to be made on the stability of new photovoltaic materials and their environmental impact. Most of the work should thus be focused on increasing the lifetime and performance of such materials under real operating conditions. Perovskite and organic are thus promising types of technologies that have achieved the phase at which scale-up investments may very well become indispensable for industrial stakeholders. Therefore, the commercialization of such novel classes is paced up by the support of flexible production techniques and interdisciplinary research work.

In short, the materials photovoltaic field is on the crossroad of the main importance for the economy and access to solar energy. For example, one of the average companies is Ilika, making sure constant innovation and work in tandem between academia and industry is the order of the day to fully leverage the potential of these materials.

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