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Carbon Nanotubes for Solar Energy Applications: The State of Play for Recent Research

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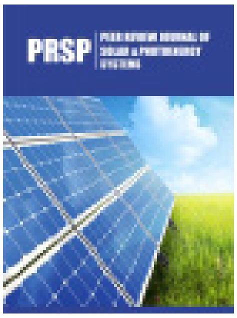

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Abstract

The potential of Carbon Nanotubes (CNTs) in photovoltaic technology has led to an interest in CNT-based solar cells as a sustainable and efficient alternative to traditional energy sources. However, the commercial use of CNTs in the solar market is still complex, and research challenges such as cost-effectiveness and production-line changes need to be addressed. The number of publications in this area has remained consistent over the years, the highest between 2016-2020, with China dominating in research contributions. Ongoing research is focused on improving the efficiency, stability, and cost-effectiveness of CNT-based solar cells. This short critical analysis is on the publications based on CNT-based solar cells.

Introduction

The global community has been grappling with the increasing urgency of transitioning towards sustainable and clean energy sources. This pressing need has been further compounded by the ongoing conflict between Russia and Ukraine, which has led to unprecedented uncertainty in the global supply of fossil fuels. As a result, energy prices have skyrocketed and there is a growing risk of potential energy shortages. Additionally, the negative environmental impacts of conventional energy sources, such as greenhouse gas emissions and pollution, have heightened the urgency to shift towards renewable and green energy alternatives [1,2]. Carbon-based materials, such as graphitic carbon nitride, carbon quantum dots, Carbon Nanotubes (CNTs) and graphene, are attracting considerable attention due to their unique physicochemical properties, low-cost, natural abundance of carbon, non-toxicity and compatibility with large-scale solution synthesis [2-5]. Among these, CNTs are particularly appealing due to their large specific surface area, tunable band gap, high optical transmittance in the visible region, competitive electrical conductivity, high charge carrier mobility, excellent flexibility and superior mechanical, thermal and chemical stability [3-9]. Carbon nanotube-based solar cells offer a promising solution [10]. These solar cells have the potential to revolutionize the way we generate and store energy, providing a sustainable and efficient alternative to traditional energy sources.

CNT Potential

In the realm of photovoltaic technology, CNTs have shown great potential as a versatile material, particularly for various components of solar cells such as light-sensitive elements and carrier-sensitive contacts [2,10]. CNTs also have the potential to replace layers used for passivation, which provides metals with a thin coating on the surface, rendering them inert. The use of CNTs can also replace transparent conducting films that require materials enabling electrical conductivity. Due to their optical transparency and versatility, CNTs are suitable alternatives for these applications [1-4,8,10]. The chemical stability and conductivity of CNTs, particularly SWCNTs, make them ideal for generating novel solar cells and light-sensitive components [4,10]. However, the commercial use of CNTs in the solar market is still complex and further research is necessary before they can be considered a viable option.

Publication Numbers

The data shows that the number of publications in the area of CNT-based solar cells has been relatively consistent over the years (Figure 1). Both Clarivate and Scopus databases show a steady number of publications in the field, with Clarivate having slightly higher numbers for most years. However, there are some years, such as 2019 and 2020, where Scopus has more publications recorded. It is important to note that these differences may be due to variations in the coverage of the two databases, as well as differences in their indexing and search algorithms. The number of publications in the field of CNT-based solar cells has remained relatively consistent over the past few years, with slight fluctuations. In 2022, there were 110 publications, which is similar to the 109 publications in 2021 and the 118 publications in 2020. The peak year for the number of publications was 2019, with 122 publications. The steady number of publications in this area of research suggests that interest in CNT-based solar cells has plateaued. This could be due to the challenges associated with scaling up the technology from lab to commercial production, as well as the emergence of other solar cell technologies that have garnered more attention. However, it is worth noting that CNTs are still an area of active research, and ongoing studies are focused on improving the efficiency, stability, and cost-effectiveness of CNT-based solar cells. Some of the recent research in this area includes the development of new synthesis methods for CNTs, exploration of different device architectures, and the incorporation of novel materials into CNT-based solar cells.

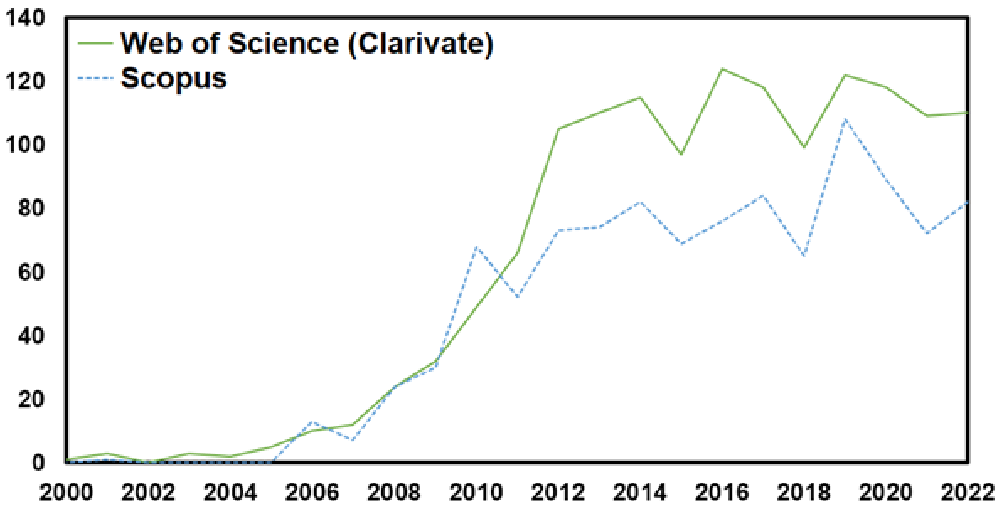

Figure 1: Number of publications based on CNTs and solar cells.
Search criteria: 'CNT*' and 'solar cell*'.

Dominating Geographies

Table 1 displays the leading ten nations in terms of publications in this field. The number of publications in the field of CNT based solar cells has been dominated by China, with 477 publications in this field. This is significantly higher than the United States, which is the second-highest contributor with 247 publications. The high number of publications from China in this field suggests that the country is investing heavily in CNT-based solar cell research, possibly due to its focus on developing renewable energy technologies. India, South Korea, and Germany are also among the top contributors, indicating that CNT-based solar cells are an area of global interest. However, it is worth noting that the number of publications from some countries, such as Japan and Australia, is relatively low compared to their research capabilities. This could indicate that there is less focus on CNT-based solar cells in these countries, or that research in this area is less funded or less established.

Table 1: Geographic origin of publications.

China	477
USA	247
India	173
South Korea	162
Germany	104
Japan	95
Italy	76
Iran	69
Taiwan	67
Australia	52

Search criteria: 'CNT*' and 'solar cell*'.

Source: Web of Science (Clarivate).

Research Challenges

Incorporating CNTs into photovoltaic technology has been shown to be a promising approach, particularly in enhancing the performance of solar cells [1-5,8-10]. To achieve this, various research efforts are focused on improving the separation, purification and enrichment of CNTs, as well as their integration into photosensitive elements for use as organic or silicon solar cells [2]. However, introducing CNTs into the commercial industry requires addressing issues such as cost-effectiveness and changes to production lines. One challenge faced by researchers is the inability to selectively create Single-Walled CNTs (SWCNTs) of an arbitrary chirality level, which is determined by their atomic structure [6,8-10]. To overcome this challenge, research is ongoing to achieve chiral-specific growth through methods such as metal-catalyst-free nanotube cloning of single-chirality seeds and using bimetallic solid alloy catalysts. While advanced processing procedures can ensure the yield and chirality of pure CNTs are more optimum for photovoltaic applications, the high cost of these pure CNTs remains a disadvantage for companies seeking low-cost alternatives [1-6,8].

Conclusion

CNTs have shown great potential as a versatile material in the development of solar cells, particularly for light-sensitive elements and carrier-sensitive contacts. The use of CNTs can replace layers used for passivation and transparent conducting films and their optical transparency and versatility make them suitable alternatives for these applications. The steady number of publications in the field of CNT-based solar cells over the years suggests that interest in this area has plateaued, possibly due to the challenges associated with scaling up the technology from lab to commercial production and the emergence of other solar cell technologies that have garnered more attention. The dominance of China in CNT-based solar cell research, followed by the United States, India, South Korea and Germany, indicates that CNT-based solar cells are an area of global interest. However, addressing challenges such as cost-effectiveness and changes to production lines will be crucial for the commercial use of CNT-based solar cells. Ongoing research efforts are focused on improving the efficiency, stability, and cost-effectiveness of CNT-based solar cells through the development of new synthesis methods for CNTs, exploration of different device architectures, and incorporation of novel materials into CNT-based solar cells.

References

1. Pandey S, Karakoti M, Bhardwaj D, Tatrari G, Sharma R, et al. (2023) Recent advances in carbon-based materials for high-performance perovskite solar cells: Gaps, challenges and fulfilment. Nanoscale Advances 5(6): 1492-1526.
2. Muchuweni E, Mombeshora ET, Martincigh BS, Nyamori VO (2022) Recent applications of carbon nanotubes in organic solar cells. Front Chem 9: 733552.
3. Dong ZJ, Li WP, Wang HL, Jiang XY, Liu HC, et al. (2022) Carbon nanotubes in perovskite-based optoelectronic devices. Matter 5(2): 448-481.
4. Li YT, Sun K, Luo D, Wang YM, Han L, et al. (2021) A review on low-dimensional novel optoelectronic devices based on carbon nanotubes. AIP Advances 11(11): 110701.
5. Veeman D, Shree MV, Sureshkumar P, Jagadeesha T, Natrayan L, et al. (2021) Sustainable development of carbon nanocomposites: synthesis and classification for environmental remediation. Journal of Materials 2021: 1-21.
6. Okhay O, Tkach A (2021) Graphene/ reduced graphene oxide-carbon nanotubes composite electrodes: From capacitive to battery-type behaviour. Nanomaterials 11(5): 1240.
7. Wang TT, Lu KK, Xu ZH, Lin ZM, Ning HL, et al. (2021) Recent developments in flexible transparent electrode. Crystals 11(5): 511.
8. Omprakash P, Viswesh P, Bhat PD (2021) A review of 2D perovskites and carbon-based nanomaterials for applications in solar cells and photodetectors. ECS Journal of Solid State Science and Technology 10(3): 1-13.
9. Wu X, Mu FW, Zhao, HY (2020) Recent progress in the synthesis of graphene/CNT composites and the energy-related applications. Journal of Materials Science and Technology 55: 16-34.
10. Obaidullah M, Esat V, Sabah C (2018) Single-and multi-walled carbon nanotubes for solar cell applications. International Journal of Modern Physics B 32(21): 1830007.