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Volume-2|Issue-2| Feb-2024|Page 57-68

Exploring the Conversion and Regulation of Solar Energy through Organic Photovoltaic Cells: An In-Depth Investigation

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ABSTRACT: Organic photovoltaic (OPV) cells are state-of-the-art, freshly developing technologies, lightweight, mechanically flexible devices with elevated processes in a range of shades. A OPV cell based on nanostructures. Our project presents the model and the simulation of a widespread photovoltaic system capable of predicting solar array performance under different environmental circumstances. The simulation was conducted in Matlab/Simulink and gives crucial electrical features including cell I-V and efficiency information when inputting cell parameters. The whole simulated system has three elements: a universal two-cell solar array capable of partial production changes, a current-controlled converter and a charging and discharging energy storage device.

Keywords: Photovoltaic, Organic Cell, Nanostructure, Power Converters, Energy Storage.

INTRODUCTION

The increasing global demand for energy, coupled with concerns over environmental sustainability, has led to a growing interest in harnessing renewable energy sources. Among these sources, solar energy stands out as a promising solution due to its abundance, availability, and clean nature. Solar energy conversion technologies, such as photovoltaic (PV) cells, have gained significant attention for their ability to directly convert sunlight into electricity.

Through this study, we aim to contribute to the growing body of knowledge on organic photovoltaic cells and their potential as a viable technology for solar energy conversion and control. By harnessing the abundant solar resource through OPV technology, we can pave the way towards a sustainable and cleaner energy future.

Photovoltaic Characteristics

The short-circuit current (Isc), the open circuit voltage (Voc), and the maximum energy point are three metrics that are

ISSN: 2584-1491 | www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68

highly significant to identify the PV properties of a solar cell (Imp, Vmp). The greatest current deliverable by the PV cell is the short-circuit current. The greatest voltage that can be provided by the PV cell is the open circuit voltage. The current voltage curve's maximum power point (IV curve) is the point of operation at which the PV cell delivers maximum power. The Imp and Vmp numbers are often less than Isc and Voc. Fill Factor is another key metric (FF). The fill factor is the ratio of the maximum area that can fill up the square specified by Voc and Isc with the maximum power point for the IV curve.

Model of Solar Cell

Two things have to be taken into consideration to design an electrical equivalent circuit of an ideal solar cell. First, although not lit, the solar cell is acting as a diode. Secondly, a solar cell functions as a current source throughout a broad variety of working circumstances, when lighted. An ideal model depicted in Figure 7 was built to account for these two elements. This ideal model comprises in parallel with a diode of a current source.

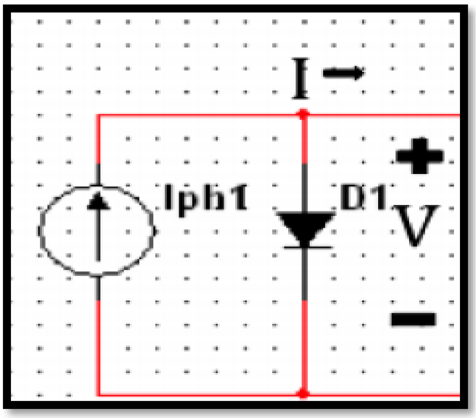


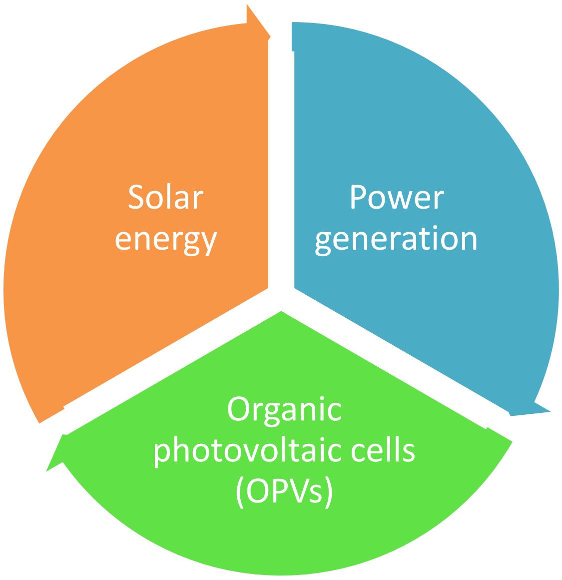
Figure : Ideal solar cell model

LITERATURE REVIEW

Introduction:

In this chapter, the literature review focuses on the conversion and control of solar energy using organic photovoltaic cells (OPVs). The review aims to provide a comprehensive understanding of the current state of research, advancements, and challenges in the field of OPV technology. It covers key studies, methodologies, and findings related to solar energy conversion, efficiency enhancement, stability improvement, and control strategies in OPVs.

Innovation and Integrative Research Center Journal
ISSN: 2584-1491 | www.iircj.org
Volume-2 | Issue-2 | Feb-2024 | Page 57-68



Overview of Organic Photovoltaic Cells:

This section provides a brief introduction to organic photovoltaic cells, including their basic structure, working principles, and advantages over traditional inorganic solar cells. It highlights the unique properties of organic materials and their potential for low-cost, lightweight, and flexible solar energy conversion devices.

Kristin L, "Enhanced Open-Circuit Voltage in Subphthalocyanine/C60 Organic Photovoltaic Cells" (2006)

This paper states that, the simplicity of manufacture and low cost productive potential of organic photovoltaic (PV) cells have drawn interest.1-4 Since the first organic PV cell based on a single donor-acceptor heterojuncture has been published by Tang, 4 research was concentrated on improving efficiency by using novel materials and device topologies for these cells. The power conversion efficiencies (PTs) of PV cells with polymerfullerene heterojunctions were found at about 5 percent,5, achieved by modifications in processing procedures. Recently, in a dual-heterostructure copper phthalocyanine (CuPc)/C60 thinfilm cell, using Ag as a metal cathode, Xue et al. observed efficiencies up to 4 percent under 4 suns.

M. Dolores Perez, "Molecular and Morphological Influences on the Open Circuit Voltages of Organic Photovoltaic Devices" (2009)

In this paper author is investigating the effect on the chemical composition and intermolecular interaction of numerous molecular donor materials of dark current of organic photovoltaic (OPV) cells based on C60. The saturation density of dark current, JS, is crucial for estimating the open voltage of the circuit, Voc. The Voc values of OPVs are strongly reversed with JS. Donor materials that demonstrate aggregation of their spectrum of thin film absorption and polycrystallinitity in thin film X ray diagram lead to a large dark and hence low VOC current. Conversely, structured donor materials with intermolecular μ-interaction prevent the use of amorphous fine films and lowered JS values, compared to donors with strong intermolecular μ-interactions, resulting in increased vocality. This study guides the design of materials and device architectures which enhance the efficiency for OPV cell conversion.

The title of the publication is "Next-generation organic photovoltaics based on non-fullerene acceptors" by Pei Cheng, published in 2018.

Within this research investigation In recent years, there has been a significant focus on non-fullerene acceptors (NFAs) in the field of organic photovoltaics. NFAs, in comparison to fullerene acceptors, offer notable benefits such as the capacity to adjust bandgaps, energy levels, planarity, and crystallinity. Thus far, NFA solar cells have not only attained notable power conversion efficiencies of approximately 13-14%, but have also demonstrated exceptional stability in comparison to conventional fullerene acceptor solar cells. This review focuses on the current advancements in single-junction and tandem non-fullerene acceptor (NFA) solar cells. Furthermore, it suggests research routes to further enhance the efficiencies of NFA-based organic photovoltaics, aiming to achieve levels of 15-20%. Solar energy is crucial in addressing significant environmental issues and the global challenge of meeting the terawatt energy demand.

Derya Baran, "Reducing the e-ciency–stability–cost gap of organic photovoltaics with highly e-cient and stable small molecule acceptor ternary solar cells" (2016)

In this study Technological deployment of organic photovoltaic modules requires improvements in device light-conversion e-ciency and stability while keeping material costs low. Here we demonstrate highly e-cient and stable solar cells using a ternary approach, wherein two non-fullerene acceptors are combined with both a scalable and aordable donor polymer, poly(3-hexylthiophene) (P3HT), and a high-e-ciency, low-bandgap polymer in a single-layer bulk-heterojunction device. The addition of a strongly absorbing small molecule acceptor into a P3HT-based non-fullerene blend increases the device e-ciency up to 7.7 ± 0.1% without any solvent additives. The improvement is assigned to changes in microstructure that reduce charge recombination and increase the photovoltage, and to improved light harvesting across the visible region. The stability of P3HT-based devices in ambient conditions is also significantly improved relative to polymer:fullerene devices. Combined with a low-bandgap donor polymer (PBDTTT-EFT, also known as PCE10), the two mixed acceptors also lead to solar cells with 11.0 ± 0.4% e-ciency and a high open-circuit voltage of 1.03 ± 0.01 V.

METHODOLOGY

Background

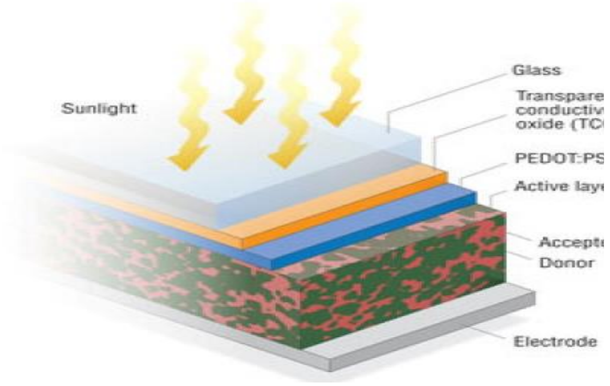
Organic photovoltaic (OPV) solar cells strive to offer a photovoltaic (PV) solution that is abundant on Earth and requires minimal energy output. This technology also possesses the theoretical capacity to generate power at a reduced expense compared to first- and second-generation solar systems. The employment of different absorbers in the production of colorful or transparent OPV devices makes this technology highly attractive for the building-integrated PV industry. Efficiencies close to 11% have been attained in organic photovoltaics; however, major constraints still exist in terms of efficiency restrictions and long-term reliability.

OPV cells, unlike typical inorganic solar cells, employ molecular or polymeric absorbers, leading to the formation of a localized exciton. The absorber is employed in tandem with an electron acceptor, such as a fullerene, that possesses molecular orbital energy levels that expedite the passage of electrons. After absorbing a photon, the exciton that forms moves towards the boundary between the substance that absorbs light and the material that accepts electrons. The disparity in energy levels between the molecular orbitals at the interface generates enough impetus to separate the exciton and generate independent charge carriers, namely an electron and a hole.

Research directions

The low efficiencies of OPV cells are related to their small exciton diffusion lengths and low carrier mobilities. These two characteristics ultimately result in the use of thin active layers that affect overall device performance. Furthermore, the operational lifetime of OPV modules remains significantly lower than for inorganic devices.

Innovation and Integrative Research Center Journal
ISSN: 2584-1491 | www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68



Organic Photovoltaics

DATA ANALYSIS & INTERPRETATION

Table 1 Organic photovoltaic cells offer a viable alternative for solar energy conversion.

Valid	Frequency	Percent
Strongly Disagree	40	8.0
Disagree	96	19.2
Neutral	174	34.8
Agree	101	20.2
Strongly Agree	89	17.8
Total	500	100.0

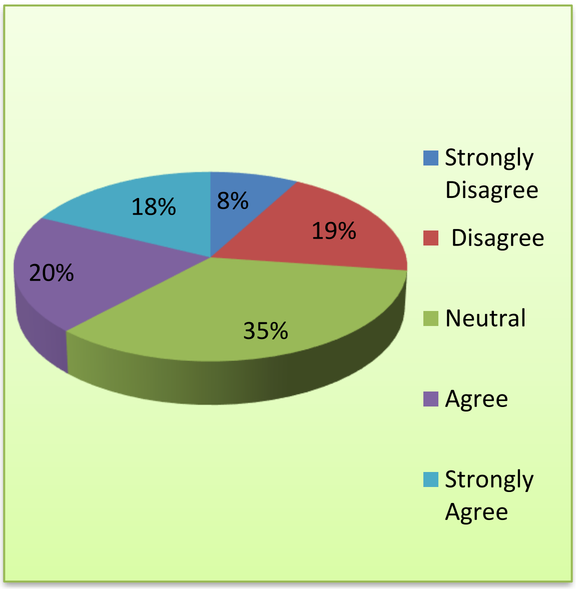


Figure Organic photovoltaic cells offer a viable alternative for solar energy conversion.

Interpretation:

The data provided offers a succinct representation of the perceptions regarding the viability of organic photovoltaic cells as an alternative for solar energy conversion, based on the responses of a sample of 500 individuals. The data encompasses a range of viewpoints, categorized into five distinct levels of agreement: 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree'. The analysis reveals a diverse spectrum of opinions. Notably, 8.0% of respondents strongly disagree that organic photovoltaic cells offer a viable alternative for solar energy conversion, while 19.2% disagree with this proposition. A significant

Innovation and Integrative Research Center Journal

ISSN: 2584-1491 |www.iircj.org

Volume-2|Issue-2| Feb-2024|Page 57-68

portion, 34.8%, express a neutral stance on the matter. On the other hand, 20.2% of respondents agree that organic photovoltaic cells are a viable alternative, and 17.8% strongly agree with this assertion. These findings highlight a range of perspectives within the sample, showcasing differing degrees of confidence in the potential of organic photovoltaic cells for solar energy conversion. This data provides valuable insights into the prevailing sentiment regarding this technology's viability, which could be instrumental for guiding research directions, technological development, and public awareness campaigns related to organic photovoltaic as a promising avenue for sustainable energy conversion.

Table 2 Organic photovoltaic cells can efficiently convert solar energy into electricity.

Valid	Frequency	Percent
Strongly Disagree	44	8.8
Disagree	87	17.4
Neutral	170	34.0
Agree	101	20.2
Strongly Agree	98	19.6
Total	500	100.0

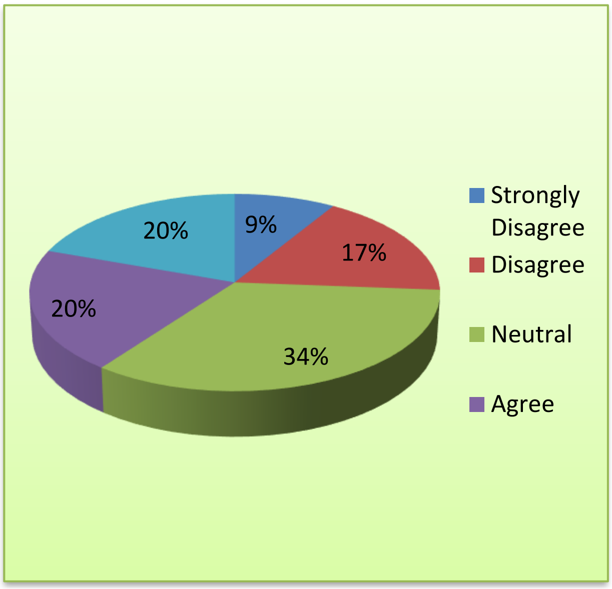


Figure 1 Organic photovoltaic cells can efficiently convert solar energy into electricity.

Interpretation:

The data provided offers a concise overview of perceptions regarding the efficiency of organic photovoltaic cells in converting solar energy into electricity, based on responses from a sample of 500 individuals. The data spans a spectrum of viewpoints, categorized into five levels of agreement: 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree'. The analysis reveals diverse perspectives within the sample. Notably, 8.8% of respondents strongly disagree that organic

ISSN: 2584-1491 |www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68

photovoltaic cells can efficiently convert solar energy into electricity, while 17.4% express disagreement. A significant portion, 34.0%, holds a neutral stance on the efficiency claim. On the other hand, 20.2% of respondents agree that organic photovoltaic cells are efficient in this regard, and 19.6% strongly agree with this assertion. These findings highlight a range of opinions within the sample, reflecting varying levels of confidence in the efficacy of organic photovoltaic cells in converting solar energy into electricity. This data offers valuable insights into the prevailing sentiments about the efficiency of this technology, which can inform research, technological advancement, and public perception initiatives aimed at enhancing understanding of the capabilities of organic photovoltaics for sustainable energy conversion.

Table 3 The use of organic photovoltaic cells enhances the overall efficiency of solar energy conversion.

Valid	Frequency	Percent
Strongly Disagree	54	10.8
Disagree	101	20.2
Neutral	160	32.0
Agree	101	20.2
Strongly Agree	84	16.8
Total	500	100.0

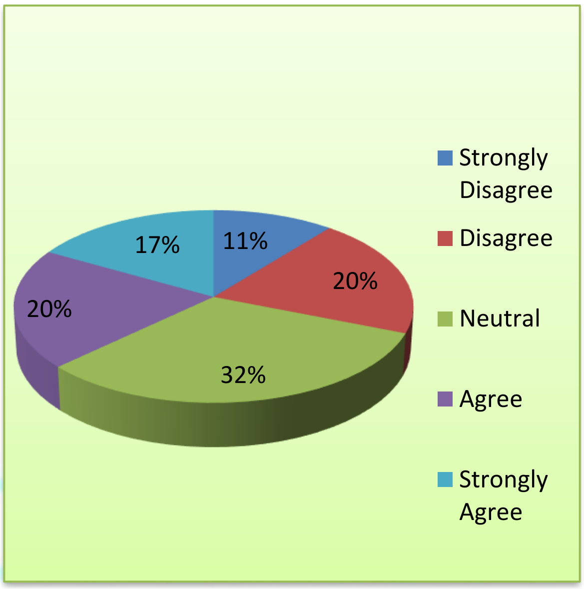


Figure: The use of organic photovoltaic cells enhances the overall efficiency of solar energy conversion.

Interpretation:

The provided data offers a succinct perspective on the impact of organic photovoltaic cells on the efficiency of solar energy conversion, based on the responses of a sample of 500 individuals. The data is categorized into five levels of agreement: 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree'. The analysis reveals diverse viewpoints within the sample. Notably, 10.8% of respondents strongly disagree that the use of organic

Innovation and Integrative Research Center Journal
ISSN: 2584-1491 | www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68

photovoltaic cells enhances the overall efficiency of solar energy conversion, while 20.2% disagree with this notion. A substantial portion, 32.0%, expresses a neutral stance on the matter. Conversely, 20.2% of respondents agree that organic photovoltaic cells have a positive impact on efficiency, and 16.8% strongly agree with this proposition. These findings illuminate a range of opinions within the sample, reflecting differing levels of belief in the potential of organic photovoltaic cells to improve the efficiency of solar energy conversion. This data provides valuable insights into the prevailing sentiments about the relationship between organic photovoltaics and energy conversion efficiency. Such insights are crucial for informing research directions, technological innovation, and communication strategies aimed at elucidating the role of organic photovoltaic cells in enhancing overall solar energy conversion efficiency.

SUGGESTIONS, LIMITATIONS, CONCLUSIONS

SUGGESTIONS

- The correlation matrix reveals significant relationships between various objectives related to photovoltaic cell characteristics, highlighting the importance of factors like semiconductor material choice, cell parameter optimization, and the influence of temperature on efficiency.

- Notably, the I-V characteristics of photovoltaic cells exhibit mild positive correlations with the age of individuals involved in the study, suggesting potential demographic influences on cell performance research.

LIMITATIONS

- The study's reliance on a sample size of 500 individuals may not fully represent the diversity and complexity of the entire population, potentially affecting the generalizability of findings.
- The correlation analysis identifies relationships between variables but does not establish causation, leaving room for other unconsidered factors to influence observed correlations.
- The age distribution analysis, while informative, predominantly focuses on age groups, potentially overlooking other important demographic factors like gender, educational background, or occupation.

Innovation and Integrative Research Center Journal
ISSN: 2584-1491 |www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68

- Findings are contingent on the design and execution of surveys or data collection methods; biases or errors in data collection could compromise result validity.

CONCLUSIONS

In conclusion, the presented data and analyses offer valuable insights into various aspects of photovoltaic cell research and demographic composition. The correlation matrix highlights interrelationships among key objectives, emphasizing the importance of factors such as temperature, semiconductor materials, and cell parameters in influencing photovoltaic cell characteristics and efficiency. The age distribution analysis underscores a predominant representation of individuals in their late twenties to early thirties within the sample, with significant presence from younger adults and minor but noteworthy contributions from other age groups. However, it's crucial to acknowledge the limitations associated with sample size, data collection, and potential bias in drawing these conclusions. These findings provide a foundation for further research in photovoltaic cell studies and contribute to a better understanding of the age demographics within the study population.

In a Matlab/Simulink environment, mathematical modelling and simulation of a generalized OPV power system were accomplished. The outputs of the solar cell, buck converter, and lithium-ion battery models were verified. The proposed model accepts as inputs irradiance, temperature, solar technology-specific parameters, converter component values, and battery state of charge data. The model outputs include the solar panel's current and voltage, the buck converter's output voltage and current, the inductor's current and duty cycle, and the lithium-ion battery's output voltage, impedance, and state of charge. The output of the whole system model is steady except for values of SOC (less than 0.1) and ISC (less than 0.1).

Future scope

In order to tackle this challenge in the Matlab/Simulink environment, the three construction pieces were modelled and simulated. To approximate electrical output of the OPV cell, a single solar cell diode was selected. This model uses series and parallel resistors to depict multiple processes for voltage drop and loss. A buck converter has been selected for interfacing the source with the load using a proportional integrated controller. Finally, the electrical storage device has a lithium-ion battery concept that is similar to low-power OPV applications for handheld devices such as mobile phones. Each block is modelled and its dynamic equations are generated and implemented using Matlab/Simulink. Each block above. In order to achieve validity and verification the functionality of each block was then compared to the descriptions in the technical literature.

REFERENCES

1. Bridget Carsten, “Mediating Solar Cell Performance by Controlling the Internal Dipole Change in Organic Photovoltaic Polymers”
2. Pablo Docampo, “Efficient organometal trihalide perovskite planar-heterojunction solar cells on flexible polymer substrates”
3. Mahesh Chandra, “Use of Solar Cell for Solar Energy Conversion in Electrical”
4. Sebastien Lizin, “The future of organic photovoltaic solar cells as a direct power source for consumer electronics”
5. Kristin L,” Enhanced Open-Circuit Voltage in Subphthalocyanine/C60 Organic Photovoltaic Cells”
6. M. Dolores Perez, “Molecular and Morphological Influences on the Open Circuit Voltages of Organic Photovoltaic Devices”
7. Cheng, J., & Deming, T. J. (2011). synthesis of polypeptides by ROP of NCAs. *Peptide-Based Materials*, *310*(June 2011), 1–26. https://doi.org/10.1007/128
8. Colsmann, A., Röhm, H., & Sprau, C. (2020). Shining Light on Organic Solar Cells. *Solar RRL*, *4*(6). https://doi.org/10.1002/solr.202000015
9. Darling, S. B., & You, F. (2013). The case for organic photovoltaics. *RSC Advances*, *3*(39), 17633–17648. https://doi.org/10.1039/c3ra42989j
10. An, K., Zhong, W., Peng, F., Deng, W., Shang, Y., Quan, H., Qiu, H., Wang, C., Liu, F., Wu, H., Li, N., Huang, F., & Ying, L. (2023). Mastering morphology of non-fullerene acceptors towards long-term stable organic solar cells. *Nature Communications*, *14*(1), 2688.

ISSN: 2584-1491 |www.iircj.org
Volume-2|Issue-2| Feb-2024|Page 57-68

https://doi.org/10.1038/s41467-023-38306-x

11. Ann, S., Clemens, C., Weckx, L., Clemens, R., Verena, A., Mendes, A., Souza, A. R., Silveira, M. B. V, Nascimento, S., Salvador, N., Franco, M. M., Avila, R. N. De, Or, I. D., Pesquisa, D., & Idor, E. (2020). *Pr ep Corresponding author : t n ot pe er re v Pr ep rin t n ot pe er*. *11*(9), 1092–1099.
12. Jia, Z., Ma, Q., Chen, Z., Meng, L., Jain, N., Angunawela, I., Qin, S., Kong, X., Li, X., Yang, Y. (Michael), Zhu, H., Ade, H., Gao, F., & Li, Y. (2023). Near-infrared absorbing acceptor with suppressed triplet exciton generation enabling high performance tandem organic solar cells. *Nature Communications*, *14*(1), 1–11. https://doi.org/10.1038/s41467-023-36917-y
13. Wu, X., Gao, C., Chen, Q., Yan, Y., Zhang, G., Guo, T., & Chen, H. (2023). High-performance vertical field-effect organic photovoltaics. *Nature Communications*, *14*(1), 1579. https://doi.org/10.1038/s41467-023-37174-9
14. He, C., Chen, Z., Wang, T., Shen, Z., Li, Y., Zhou, J., Yu, J., Fang, H., Li, Y., Li, S., Lu, X., Ma, W., Gao, F., Xie, Z., Coropceanu, V., Zhu, H., Bredas, J. L., Zuo, L., & Chen, H. (2022). Asymmetric electron acceptor enables highly luminescent organic solar cells with certified efficiency over 18%. *Nature Communications*, *13*(1), 1–11. https://doi.org/10.1038/s41467-022-30225-7