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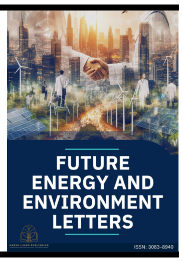

Silicon Solar Cells for Indoor Photovoltaic Applications

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ABSTRACT

The rapid adoption of Internet of Things (IoT) devices, smart home appliances, and wireless electronics has created a growing demand for energy sources that can operate reliably and sustainably indoors. While traditional batteries provide a temporary solution, they are constrained by limited lifespans and the need for frequent maintenance or replacement. Indoor photovoltaics (IPVs), which convert artificial indoor lighting into electrical energy, have emerged as a compelling alternative. Among the materials explored for IPVs, silicon stands out due to its commercial maturity and excellent long-term stability. Although originally developed for outdoor use, silicon solar cells are now being adapted to function under low-intensity and narrow-spectrum indoor lighting. This review examines the performance, advantages, and challenges of silicon solar cells in indoor environments. It highlights recent innovations in materials and device architectures, explores real-world applications, and discusses future directions that can enhance efficiency and integration. Despite certain limitations such as spectral mismatch and form factor constraints, silicon remains a promising platform for enabling maintenance-free, sustainable energy harvesting in indoor settings.

1. Introduction

The proliferation of smart electronics and the Internet of Things (IoT) has fundamentally changed how energy is consumed and managed in indoor environments [1]. From smart thermostats and wearable health monitors to wireless sensor networks, the demand for continuous and autonomous power sources has increased exponentially. Traditional battery-powered solutions, while effective, pose significant limitations, including finite lifespans, maintenance requirements, and environmental concerns related to disposal and recycling. This has led researchers and technologists to explore alternative energy sources that can sustainably support indoor electronic devices.

One of the most promising approaches is the use of photovoltaic (PV) technology, which has diverse applications in building-integrated PV (BIPV), portable and off-grid power systems, space satellites, agrivoltaics, and bifacial panel designs [2-6]. A specific branch of this technology is indoor

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PV (IPVs), which harvest energy from ambient artificial light sources such as LED and fluorescent lamps[7]. Figure 1 shows some of the real-life applications of IPVs available in market.

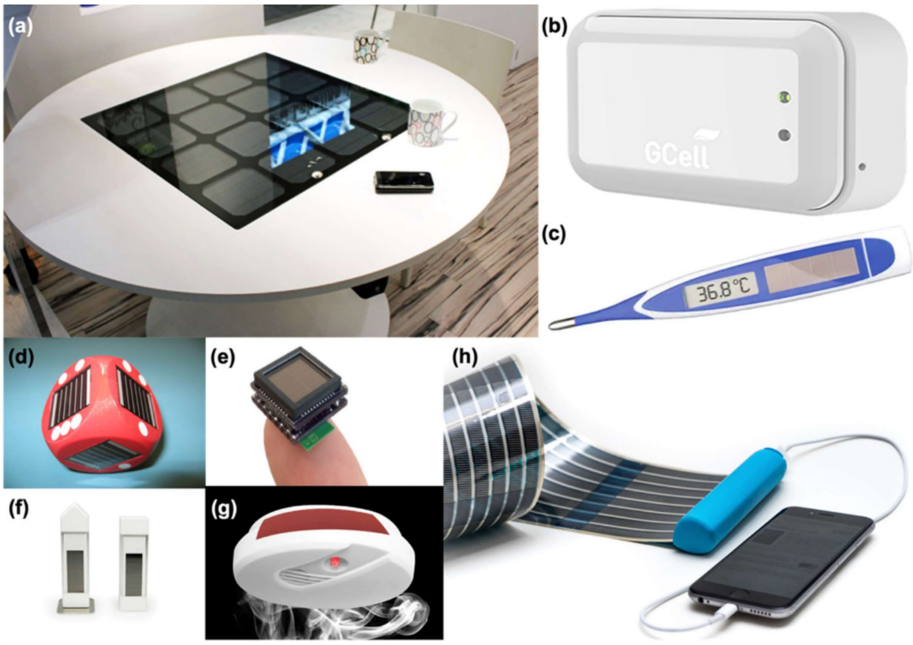

Fig. 1. Example of IPV application in real-world. (a) Inductive charging table by Panasonic, (b) iBeacon device by GCell, (c) Digital thermometer by Geratherm Medical AG, (d) Wireless solar-powered IoT dice, (e) Power management IC with 1 cm^2 PV module for wireless sensor nodes, (f) Battery-less wireless temperature and humidity sensor by Afriso, (g) Smoke detector with integrated dye-sensitized solar cell by 3GSolar, (h) HeLi-on flexible solar charger using organic PV technology by InfinityPV. Figure compilation reproduced from [8]. Copyright (2024), Elsevier

IPVs are distinguished from traditional solar PVs by their operating conditions. Unlike outdoor environments, where sunlight is intense and broadband with a spectrum reaching into the near-infrared, indoor lighting is generally of lower intensity and narrower in spectral distribution, often concentrated in the visible range (400-700 nm). Additionally, indoor lighting conditions are more stable and predictable compared to the variable and sometimes harsh conditions outdoors. This difference in operating environment necessitates careful consideration of material properties, device architecture, and electronic integration for photovoltaic systems intended for indoor use.

Among the variety of PV technologies including dye-sensitized solar cells (DSSCs) [9], organic PV (OPVs) [10-17], and perovskite solar cells (PSCs) [18-22], silicon remains a material of interest due to its established commercial infrastructure, abundance, and exceptional stability [23]. Although traditionally optimized for outdoor use under the AM1.5G solar spectrum, silicon solar cells are now being adapted for indoor lighting conditions[24]. These adaptations include physical restructuring, optical optimization, and system-level integration strategies.

Despite not being spectrally ideal for indoor conditions, silicon solar cells have several inherent advantages. They are already mass-produced at a low cost, benefit from decades of research and development, and offer long-term operational stability [25]. Furthermore, they are available in miniaturized or customized modules that can be seamlessly integrated into indoor environments[26]. These factors make silicon solar cells a compelling option for enabling sustainable, maintenance-free indoor energy harvesting.

This review explores the viability and current advancements of silicon solar cells for indoor applications. It begins with an examination of their performance under artificial lighting conditions, followed by a discussion of key advantages and limitations. Recent innovations and practical use cases of indoor silicon photovoltaics are then highlighted. Finally, the review outlines future research directions and technological developments that could further improve their applicability and efficiency.

2. Silicon Solar Cell Performance Indoors

The performance of silicon solar cells in indoor environments is markedly different from their behavior under outdoor sunlight. This discrepancy arises primarily due to the spectral and intensity differences between natural sunlight and artificial indoor lighting. Silicon, with its indirect bandgap of approximately 1.1 eV, is optimized for broadband solar radiation that includes significant near-infrared content [27]. In contrast, artificial light sources such as LEDs and fluorescent lamps emit a narrower spectrum of light, primarily in the visible range [28]. Moreover, the intensity of indoor light is typically one to two orders of magnitude lower than sunlight, with typical values ranging from 100 to 1000 lux, corresponding to irradiance levels of 10 to 100 µW/cm^2[29]. Figure 2 illustrates the AM1.5 solar spectrum compared to representative spectra of common indoor light sources, including cool LEDs and fluorescent lamps. Unlike the AM1.5 spectrum, which spans from ultraviolet to infrared, artificial light sources lack the infrared component and exhibit much narrower spectral widths. These fundamental differences in spectral distribution and intensity pose unique challenges for photovoltaic technologies designed for indoor environments.

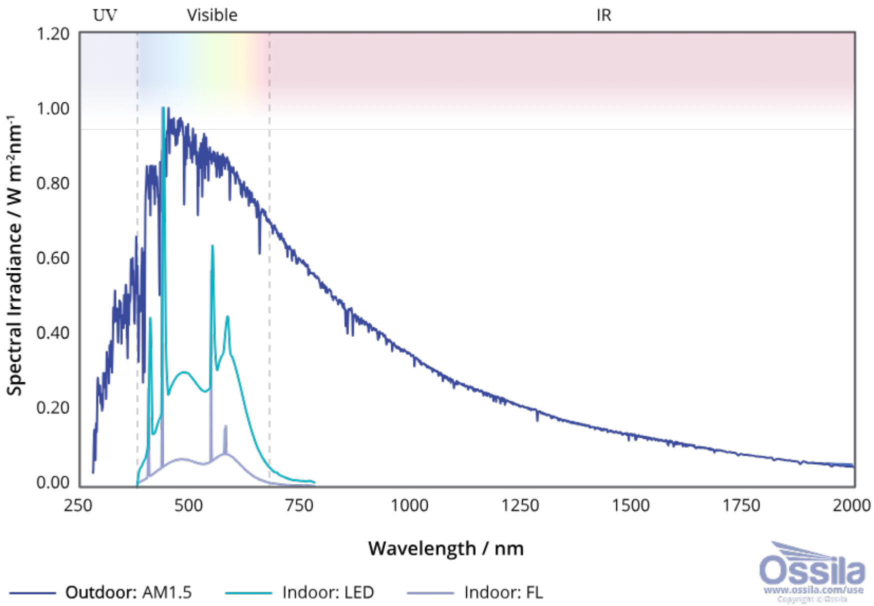

Fig. 2. Comparison of indoor light spectra (cool LED and typical fluorescent) with the standard AM1.5G solar spectrum (dark blue). Image sources: https://www.ossila.com

Under such low-light conditions, several aspects of silicon solar cell behavior change. The open-circuit voltage (Voc) decreases logarithmically with light intensity, leading to significantly lower voltages indoors. The fill factor (FF) and short-circuit current density (Jsc) are also adversely affected by parasitic resistances and recombination losses, which become more pronounced at lower light levels[1]. As a result, the overall power conversion efficiency (PCE) of silicon cells drops significantly indoors[30]. Despite these challenges, recent advancements have shown the IPV performance of crystalline and amorphous silicon solar cell as tubulised in Table 1. The table compiles recent research on the IPV performance of crystalline silicon (c-Si) and amorphous silicon (a-Si) solar cells under various artificial lighting conditions. Across the reported studies, c-Si cells often achieve superior Jsc, particularly under high illuminance (for example 126.0 mA/cm^2 at 1000 lx in 2020 and 119.2mA/cm^2 at 1000 lx in 2023), which contributes to competitive PCEs even in artificial lighting. The table also shows a clear upward trend in PCE for both technologies over the years, with recent studies reporting notable efficiency improvements such as 16.3% for a-Si and 15.5% for c-Si in 2023, indicating material and design advancements tailored for indoor applications. Differences in active area, Voc, FF, and light source type further highlight the importance of optimising device architecture and testing conditions to maximise indoor energy harvesting performance.

Table 1
IPVs performance of crystalline (c) and amorphous (a) of silicon solar cells

Year	Devices	Light Type/ Illuminance (lx)	Voc (V)	Jsc (mA/cm^2)	FF (%)	PCE (%)	Area (cm^2)	Ref
2015	c-Si	LED / 890	0.43	0.12	71	9.65	1	[31]
	a-Si	LED / 200	2.46	14.2	57.2	7.51	3.18	[32]
2016	a-Si	FL / 1000	2.9	20	-	3.68	3.49	[33]
2017	a-Si	LED / 1000	0.63	83.85	58	-	3.60	[34]
2018	c-Si	LED / 1000	0.33	102.29	-	-	1.93	[35]
2019	a-Si	LED / 200	0.63	21.8	68	12.2	1.04	[36]
2020	c-Si	LED / 1000	0.43	126.0	67.0	12.5	4	[37]
2021	c-Si	LED / 1000	1.18	41.73	59	9.3	48	[38]
2023	c-Si	LED / 1000	0.519	119.2	71.3	15.5	4	[39]
	a-Si	LED / 1000	0.71	89.4	73.1	16.3	7.65	

3. Advantages and Limitations

Silicon solar cells offer a unique blend of advantages that make them a valuable contender in the field of indoor photovoltaics. Foremost among these is their commercial maturity [40]. Silicon-based PV technologies benefit from decades of development, extensive global manufacturing infrastructure, and economies of scale that significantly reduce cost per watt. Their widespread availability and compatibility with standard semiconductor processing techniques also facilitate rapid prototyping and customization for various form factors. Another critical advantage is durability. Silicon solar cells are highly stable under ambient conditions, with proven lifespans of 25 years in outdoor installations. Indoors, where temperature fluctuations, humidity, and UV exposure are minimized, their operational stability is expected to be even higher. This makes them ideal for long-term applications such as wireless sensor nodes, building automation systems, and energy-harvesting consumer electronics.

However, several limitations restrict the indoor performance of silicon solar cells. Chief among these is spectral mismatch. Silicon's bandgap and absorption profile are best suited for the full solar spectrum, which includes significant near-infrared components. Indoor light sources, particularly LEDs and compact fluorescents, emit narrower spectra concentrated in the visible region. This limits the number of photons silicon can absorb and convert efficiently. Another issue is reduced electrical performance under low-light conditions. As light intensity drops, the Voc, Jsc and FF of silicon cells decline disproportionately, leading to lower power output. Form factor is also a challenge. Conventional c-Si modules are rigid and thick, making them less suited for applications requiring flexibility or ultra-compact design. Although thin-film silicon and micro-scale cell arrays address this partially, they often come at the cost of reduced efficiency or higher fabrication complexity.

While silicon solar cells have many strengths such as mature technology, environmental safety, and excellent durability, they must overcome challenges related to spectral mismatch, low-light electrical losses, and integration constraints to fully realize their potential in indoor applications.

4. Future Direction

One promising direction is spectral optimization. To bridge the spectral mismatch between silicon and indoor light sources, researchers are exploring the use of optical coatings, photonic structures, and surface texturing that enhance light absorption in the visible range. These techniques aim to minimize reflectance and increase the number of photons absorbed per unit area, thus improving efficiency under low-intensity, narrow-spectrum lighting.

Tandem cell architectures represent another exciting avenue. By stacking a high-bandgap top cell such as perovskite above a silicon bottom cell, the overall device can harvest a broader range of the visible spectrum, enhancing performance under indoor lighting.

Materials engineering efforts are also focused on developing low-cost, ultra-thin silicon wafers and flexible substrates that maintain reasonable efficiency while enabling new form factors. Roll-to-roll processing and heterojunction designs are being explored to support lightweight and mechanically compliant modules suitable for integration into wearables, packaging, and non-planar surfaces.

Finally, sustainability considerations are gaining prominence. As demand grows for eco-friendly electronics, silicon's abundance, non-toxicity, and recyclability become even more attractive. Research is increasingly oriented toward circular design, where modules are designed for easy disassembly and material recovery, minimizing their environmental footprint.

5. Conclusion

Silicon solar cells, though historically tailored for outdoor photovoltaic applications, are steadily proving their relevance in indoor environments. Their resilience, cost-effectiveness, and environmental safety profile give them a strong foundation upon which enhancements can be made for indoor use. As this review has shown, silicon solar cells are already achieving indoor power conversion efficiencies of 3–16%. While not ideally suited to the spectral characteristics of artificial indoor lighting, ongoing innovations in optical engineering, tandem structures, and low-light power management are bridging the gap between traditional silicon cell design and the requirements of indoor energy harvesting.

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Conflict of Interest Statement
The author declares that there are no conflicts of interest related to the publication of this manuscript.

Author Contributions Statement
S.S. was responsible for the conceptualization, validation, formal analysis, investigation, resources, visualization, original draft preparation, review and editing of the manuscript, and project administration.

Data Availability Statement

No datasets were generated or analysed during the current study.

Ethics Statement

This study did not involve human participants, animals, or sensitive data, and therefore did not require ethical approval.

References

[1] Do, Young-Jun, Muhammad Ahsan Saeed, Shafidah Shafian, Jisoo Kim, Sang Hyeon Kim, Sung Hyeon Kim, Kyungkon Kim, and Jae Won Shim. 2021. Energy Recycling under Ambient Illumination for Internet-of-Things Using Metal/Oxide/Metal-Based Colorful Organic Photovoltaics. Nanotechnology 32 (46): 465401. https://doi.org/10.1088/1361-6528/ac13e7

[2] Shafian, Shafidah, Jieun Son, Youngji Kim, Jerome K. Hyun, and Kyungkon Kim. 2019. Active-Material-Independent Color-Tunable Semitransparent Organic Solar Cells. ACS Applied Materials & Interfaces 11 (21): 18887–95. https://doi.org/10.1021/acsami.9b03254

[3] Kim, Bo Youn, Shafidah Shafian, and Kyungkon Kim. 2023. High-Performance Semitransparent Color Organic Photodiodes Enabled by Integrating Fabry-Perot and Solution-Processed Distributed Bragg Reflectors. Advanced Materials Interfaces 10 (31): 2300421. https://doi.org/10.1002/admi.202300421

[4] Shafian, Shafidah. 2025. A Review of Bifacial Perovskite Solar Cells. Future Energy and Environment Letters 3 (1): 36–49. https://doi.org/10.37934/feel.3.1.3649

[5] Shafian, Shafidah. 2025. Semitransparent and Colorful Solar Cell for Architectural Application. Future Energy and Environment Letters 2 (1): 13–32. https://doi.org/10.37934/feel.2.1.1332

[6] Shafian, Shafidah. 2025. Semitransparent Solar Cells for Agriculture Application. Future Energy and Environment Letters 3 (1): 1–18. https://doi.org/10.37934/feel.3.1.118

[7] Li, Meng, Femi Igbari, Zhao-Kui Wang, and Liang-Sheng Liao. 2020. Indoor Thin-Film Photovoltaics: Progress and Challenges. Advanced Energy Materials 10 (28): 2000641. https://doi.org/10.1002/aenm.202000641

[8] Chakraborty, Abhisek, Giulia Lucarelli, Jie Xu, Zeynab Skafi, Sergio Castro-Hermosa, A. B. Kaveramma, R. Geetha Balakrishna, and Thomas M. Brown. 2024. Photovoltaics for Indoor Energy Harvesting. Nano Energy 128: 109932. https://doi.org/10.1016/j.nanoen.2024.109932

[9] Upadhyaya, Hari M., S. Senthilarasu, Min-Hung Hsu, and D. Kishore Kumar. 2013. Recent Progress and the Status of Dye-Sensitised Solar Cell (DSSC) Technology with State-of-the-Art Conversion Efficiencies. Solar Energy Materials and Solar Cells 119: 291–95. https://doi.org/10.1016/j.solmat.2013.08.031

[10] Hong, Minjeong, Jiyae Youn, Ka Yeon Ryu, Shafidah Shafian, and Kyungkon Kim. 2023. Improving the Stability of Non-Fullerene-Based Organic Photovoltaics through Sequential Deposition and Utilization of a Quasi-Orthogonal Solvent. ACS Applied Materials & Interfaces 15 (16): 20151–58. https://doi.org/10.1021/acsami.3c02071

[11] Ryu, Ka Yeon, Shafidah Shafian, Jongchan Shin, Yu Jin Lee, Minjae Lee, and Kyungkon Kim. 2022. Linear Polyurethane Ionenes for Stable Interlayer of Organic Photovoltaics. Journal of Power Sources 542: 231772. https://doi.org/10.1016/j.jpowsour.2022.231772

[12] Shin, Solbi, Shafidah Shafian, Ka Yeon Ryu, Young-Kyo Jeon, Won-Suk Kim, and Kyungkon Kim. 2022. Solution-Processed TiO_2 Nanoparticles Functionalized with Catechol Derivatives as Electron Transporting Layer Materials for Organic Photovoltaics. Advanced Materials Interfaces 9 (14): 2200118. https://doi.org/10.1002/admi.202200118

[13] Kim, Hyunkyoung, Ye-Jin Kong, Won-Suk Kim, Shafidah Shafian, and Kyungkon Kim. 2024. Enhancing Reproducibility in Organic Solar Cell Fabrication via Static Sequential Deposition with Cross-Linked Polymer Donor and Nonfullerene Acceptor. ACS Applied Polymer Materials 6 (10): 5814–21. https://doi.org/10.1021/acsapm.4c00477

[14] Shafian, Shafidah, Fitri Norizatie Mohd Salehin, Sojeong Lee, Azlan Ismail, Shuhaida Mohamed Shuhidan, Lin Xie, and Kyungkon Kim. 2025. Development of Organic Semiconductor Materials for Organic Solar Cells via the Integration of Computational Quantum Chemistry and AI-Powered Machine Learning. ACS Applied Energy Materials 8 (2): 699–722. https://doi.org/10.1021/acsaem.4c02937

[15] Shafian, Shafidah. 2025. Optical and Structural Analysis of Layer Thickness Effects on Transmission in Semitransparent Colorful Organic Photovoltaics. PaperASIA 41 (4b): 1–10. https://doi.org/10.59953/paperasia.v41i4b.569

[16] Salehin, Fitri Norizatie Mohd, Puvaneswaran Chelvanathan, Adamu Ahmed Goje, Norasikin Ahmad Ludin, Mohd Adib Ibrahim, and Shafidah Shafian. 2025. Design of Blue, Green and Red Colorful Semitransparent Films Using Ag/SnO_2/Ag Color Filter for Integrated into Solar Cells. Results in Physics 70: 108172. https://doi.org/10.1016/j.rinp.2025.108172

[17] Kim, Hyunkyoung, Yuchan Heo, Yeji Na, Shafidah Shafian, BongSoo Kim, and Kyungkon Kim. 2024. Cross-Linking-Integrated Sequential Deposition: A Method for Efficient and Reproducible Bulk Heterojunctions in Organic Solar Cells. ACS Applied Materials & Interfaces 16 (41): 55873–80. https://doi.org/10.1021/acsami.4c13237

[18] Qi, Shuwen, Chenghao Ge, Peng Wang, Bin Wu, Yuping Zhao, Rongjun Zhao, Shafidah Shafian, Yong Hua, and Lin Xie. 2024. Improving Perovskite Solar Cell Performance and Stability via Thermal Imprinting-Assisted Ion Exchange Passivation. ACS Applied Materials & Interfaces 16 (38): 51037–45. https://doi.org/10.1021/acsami.4c08538

[19] Wang, Peng, Shafidah Shafian, Feng Qiu, Xiao Zhang, Yuping Zhao, Bin Wu, Kyungkon Kim, Yong Hua, and Lin Xie. 2025. Improving Redox Reactions of Spiro-OMeTAD via p-Type Molecular Scaffold to Reduce Energy Loss at Ag-Electrode in Perovskite Solar Cells. Journal of Energy Chemistry 102: 151–60. https://doi.org/10.1016/j.jechem.2025.02.019

[20] Zhang, Xiao, Linqing Wang, Shafidah Shafian, Peng Wang, Yuping Zhao, Pengcheng Wang, Bin Wu, et al. 2025. Crosslinking-Driven Chemical Homogeneity Enhances Performance of Pre-Seeded Perovskite Solar Cells. Small 21 (6): 2408362. https://doi.org/10.1002/smll.202408362

[21] Shafian, Shafidah, Mohd Nizam Husen, Lin Xie, and Kyungkon Kim. 2025. Predicting High-Performance Perovskite Solar Cells Using AI-Based Machine Learning Models. Materials Today Sustainability: 101176. https://doi.org/10.1016/j.mtsust.2025.101176

[22] Lee, Sojeong, Young Seon Yoon, Shafidah Shafian, Jin Young Kim, and Kyungkon Kim. 2025. Sequential Co-Deposition of Perovskite Film: An Effective Way of Tailoring Bandgap in All Vacuum Processed Perovskite Solar Cells. Small Methods: 2500104. https://doi.org/10.1002/smtd.202500104

[23] Wenham, Stuart R., and Martin A. Green. 1996. Silicon Solar Cells. Progress in Photovoltaics: Research and Applications 4 (1): 3–33. https://doi.org/10.1002/(SICI)1099-159X(199601/02)4:1<3::AID-PIP117>3.0.CO;2-S

[24] Kim, Gayoung, Jung Wook Lim, Jieun Kim, Sun Jin Yun, and Min A. Park. 2020. Transparent Thin-Film Silicon Solar Cells for Indoor Light Harvesting with Conversion Efficiencies of 36% without Photodegradation. ACS Applied Materials & Interfaces 12 (24): 27122–30. https://doi.org/10.1021/acsami.0c04517

[25] Ballif, Christophe, Franz-Josef Haug, Mathieu Boccard, Pierre J. Verlinden, and Giso Hahn. 2022. Status and Perspectives of Crystalline Silicon Photovoltaics in Research and Industry. Nature Reviews Materials 7 (8): 597–616. https://doi.org/10.1038/s41578-022-00423-2

[26] Park, Suhyeon, Shafidah Shafian, Juhwan Lee, Seungyun Jo, Seungbae Jeon, Seungjae Lee, Ding Shangxian, Hyungju Ahn, Kyungkon Kim, and Du Yeol Ryu. 2023. High-Efficiency Structural Coloration Enabled by Defect-Free Block Copolymer Self-Assembly for a Solar Cell Distributed Bragg Reflector. Advanced Optical Materials 11 (24): 2301357. https://doi.org/10.1002/adom.202301357

[27] Tao, Meng. 2008. Inorganic Photovoltaic Solar Cells: Silicon and Beyond. The Electrochemical Society Interface 17 (4): 30. https://doi.org/10.1149/2.F03084IF

[28] Aman, M. M., G. B. Jasmon, H. Mokhlis, and A. H. A. Bakar. 2013. Analysis of the Performance of Domestic Lighting Lamps. Energy Policy 52: 482–500. https://doi.org/10.1016/j.enpol.2012.09.068

[29] Islam, Mohammad Shahidul, Rajendra Dangol, Mikko Hyvärinen, Pramod Bhusal, Marjukka Puolakka, and Liisa Halonen. 2015. User Acceptance Studies for LED Office Lighting: Lamp Spectrum, Spatial Brightness and Illuminance. Lighting Research & Technology 47 (1): 54–79. https://doi.org/10.1177/1477153513514425

[30] Virtuani, Alessandro, Harald Müllejans, and Ewan D. Dunlop. 2011. Comparison of Indoor and Outdoor Performance Measurements of Recent Commercially Available Solar Modules. Progress in Photovoltaics: Research and Applications 19 (1): 11–20. https://doi.org/10.1002/pip.977

[31] Mori, Shigehiko, Takeshi Gotanda, Yoshihiko Nakano, Mitsunaga Saito, Kenji Todori, and Masahiro Hosoya. 2015. Investigation of the Organic Solar Cell Characteristics for Indoor LED Light Applications. Japanese Journal of Applied Physics 54 (7): 071602. https://doi.org/10.7567/JJAP.54.071602

[32] De Rossi, Francesca, Tadeo Pontecorvo, and Thomas M. Brown. 2015. Characterization of Photovoltaic Devices for Indoor Light Harvesting and Customization of Flexible Dye Solar Cells to Deliver Superior Efficiency under Artificial Lighting. Applied Energy 156: 413–22. https://doi.org/10.1016/j.apenergy.2015.07.031

[33] Aoki, Yoichi. 2016. Polymer Solar Cells for Indoor Energy Harvesting. MRS Advances 1 (14): 931–36. https://doi.org/10.1557/adv.2016.64

[34] Aoki, Yoichi. 2017. Photovoltaic Performance of Organic Photovoltaics for Indoor Energy Harvester. Organic Electronics 48: 194–97. https://doi.org/10.1016/j.orgel.2017.05.023

[35] Saito, Hidenori, Daisuke Aoki, Shinichi Magaino, Katsuhiko Takagi, and Shuzi Hayase. 2018. Performance Evaluation Method of Organic Photovoltaics under Indoor Light Condition. Electrochemistry 86 (6): 363–70. https://doi.org/10.5796/electrochemistry.18-00027

[36] Arai, Ryota, Seiichi Furukawa, Yu Hidaka, Hideaki Komiyama, and Takuma Yasuda. 2019. High-Performance Organic Energy-Harvesting Devices and Modules for Self-Sustainable Power Generation under Ambient Indoor Lighting Environments. ACS Applied Materials & Interfaces 11 (9): 9259–64. https://doi.org/10.1021/acsami.9b00018