
REFERENCES

- [1] “Renewable-vs-nonrenewable-energy-resources12071170@sciencing.com,” 2020 . [Online]. Available: <https://sciencing.com/renewable-vs-nonrenewable-energy-resources-12071170.html>.
- [2] Z. L. Wang and W. Wu, “Nanotechnology-enabled energy harvesting for self-powered micro-/nanosystems,” *Angew. Chemie - Int. Ed.*, vol. 51, no. 47, pp. 11700–11721, 2012.
- [3] “8c6657c74af31ecc277be217d899f91919d2d078@ www.renewableenergyworld.com,” 2020. [Online]. Available: <https://www.renewableenergyworld.com/types-of-renewable-energy/what-is-solar-energy/#gref>.
- [4] A. Mohammad Bagher, “Types of Solar Cells and Application,” *Am. J. Opt. Photonics*, vol. 3, no. 5, p. 94, 2015.
- [5] R. Williams, “Becquerel photovoltaic effect in binary compounds,” *J. Chem. Phys.*, vol. 32, no. 5, pp. 1505–1514, 1960.
- [6] Goleman et al., “The Action of Light on Selenium,” *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2019.
- [7] Latimer Clark et al., “Effect of light on selenium during the passage of an electric current,” *Nature*, vol. 7, no. 173. p. 303, 1873.
- [8] W. Gryllis et al., “Scientific american supplement,” *Sci. Am. INC.*, vol. 492, no. 492, pp. 7854–7856, 1885.
- [9] “Einstein-and-the-photoelectric-effect @ www.britannica.com.” 2020.
- [10] R. S. Oh, “LIGHT-SENSTIVE ELECTRIC DEVICE,” *UNITED STATES Pat. Off.*, 1946.

- [11] D. M. Chapin, C. S. Fuller, and G. L. Pearson, “A new silicon p-n junction photocell for converting solar radiation into electrical power [3],” *J. Appl. Phys.*, vol. 25, no. 5, pp. 676–677, 1954.
- [12] C. M. Kearns D., “Photovoltaic effect and photoconductivity in laminated organic systems.,” *J.Chem.Phys.*, vol. 29, pp. 950–951, 1958.
- [13] C. W. Tang, “Two-layer organic photovoltaic cell,” *Appl. Phys. Lett.*, vol. 48, no. 2, pp. 183–185, 1986.
- [14] A. I. Science, “New world record for solar cell efficiency at 46%,” *Fraunhofer Inst. Sol. Energy Syst. ISE*, no. 26, pp. 1–4, 2014.
- [15] Ansari et al., “Frontiers, opportunities, and challenges in perovskite solar cell: A critical review,” *J. Photochem. Photobiol. C Photochem. Chem.*, vol. 35, pp. 1–24, 2018.
- [16] A. Khatibi, F. Razi Astaraei, and M. H. Ahmadi, “Generation and combination of the solar cells: A current model review,” *Energy Sci. Eng.*, vol. 7, no. 2, pp. 305–322, 2019.
- [17] S. Gharibzadeh *et al.*, “Record Open-Circuit Voltage Wide-Bandgap Perovskite Solar Cells Utilizing 2D/3D Perovskite Heterostructure,” *Adv. Energy Mater.*, vol. 9, no. 21, pp. 1–10, 2019.
- [18] A. S. R. Bati, M. Batmunkh, and J. G. Shapter, “Emerging 2D Layered Materials for Perovskite Solar Cells,” *Adv. Energy Mater.*, vol. 10, no. 13, pp. 1–21, 2020.
- [19] A. Walsh, “Principles of Chemical Bonding and Band Gap Engineering in Hybrid Organic – Inorganic Halide Perovskites,” *J. Phys. Chem. C*, vol. 119, p. 5755–5760, 2015.
- [20] “52c44350d83bfd4f4be39fa7355698d2a3ba1e4 @ www.osa-opn.org,” 2021. [Online]. Available: https://www.osaopn.org/home/articles/volume_31/november_2020/features/perovskite_photovoltaics_the_road_ahead/.

- [21] A. R. Chakhmouradian and P. M. Woodward, “Celebrating 175 years of perovskite research: A tribute to Roger H. Mitchell,” *Phys. Chem. Miner.*, vol. 41, no. 6, pp. 387–391, 2014.
- [22] H.L. Wells, “Cesium and Potassium Lead Halides,” *Sheff. Sci. Sch.*, pp. 121–134, 1892.
- [23] E. Sandor and W. A. Wooster, “Crystal Structure and Photoconductivity of Caesium Plumbohalides,” *Nature*, vol. 1, no. 1955, p. 1958, 1958.
- [24] D. Weber, “ $\text{CH}_3\text{NH}_3\text{PbX}_3$, a Pb(II)-System with cubic Perowskite structure,” *Z. Naturforsch., B J. Chem. Sci.*, vol. 1445, no. August, pp. 1443–1445, 1978.
- [25] Z. Yi, N. H. Ladi, X. Shai, H. Li, Y. Shen, and M. Wang, “Will organic-inorganic hybrid halide lead perovskites be eliminated from optoelectronic applications?,” *Nanoscale Adv.*, vol. 1, no. 4, pp. 1276–1289, 2019.
- [26] B. A. Al-Asbahi, S. M. H. Qaid, M. Hezam, I. Bedja, H. M. Ghaithan, and A. S. Aldwayyan, “Effect of deposition method on the structural and optical properties of $\text{CH}_3\text{NH}_3\text{PbI}_3$ perovskite thin films,” *Opt. Mater. (Amst.)*, vol. 103, no. March, pp. 1–9, 2020.
- [27] R. Swartwout, M. T. Hoerantner, and V. Bulović, “Scalable Deposition Methods for Large-area Production of Perovskite Thin Films,” *Energy Environ. Mater.*, vol. 2, no. 2, pp. 119–145, 2019.
- [28] K. Liang, D. B. Mitzi, and M. T. Prikas, “Synthesis and Characterization of Organic-Inorganic Perovskite Thin Films Prepared Using a Versatile Two-Step Dipping Technique,” *Chem. Mater.*, vol. 10, no. 1, pp. 403–411, 1998.
- [29] T. Miyasaka, “Lead halide perovskites in thin film photovoltaics: Background and perspectives,” *Bull. Chem. Soc. Jpn.*, vol. 91, no. 7, pp. 1058–1068, 2018.
- [30] G. E. Eperon, S. D. Stranks, C. Menelaou, M. B. Johnston, L. M. Herz, and H. J. Snaith, “Formamidinium lead trihalide: A broadly tunable perovskite for efficient planar heterojunction solar cells,” *Energy Environ. Sci.*, vol. 7, no. 3, pp. 982–

988, 2014.

- [31] L. Peng, A. Tang, C. Yang, and F. Teng, “Size-controlled synthesis of highly luminescent organometal halide perovskite quantum dots,” *J. Alloys Compd.*, vol. 687, pp. 506–513, 2016.
- [32] P. Fan *et al.*, “High-performance perovskite $\text{CH}_3\text{NH}_3\text{PbI}_3$ thin films for solar cells prepared by single-source physical vapour deposition,” *Sci. Rep.*, vol. 6, no. July, pp. 1–9, 2016.
- [33] M. T. Neukom, “Charge Carrier Dynamics of Methylammonium Lead-Iodide Perovskite Solar Cells,” Albert-Ludwigs-University Freiburg, 2016.
- [34] S. Agarwal and P. R. Nair, “Device engineering of perovskite solar cells to achieve near ideal efficiency,” *Appl. Phys. Lett.*, vol. 107, no. 12, 2015.
- [35] H. Hu, “The fabrication, characterization and simulation of inverted perovskite solar cells,” 2019.
- [36] A. Dubey *et al.*, “A strategic review on processing routes towards highly efficient perovskite solar cells,” *J. Mater. Chem. A*, vol. 6, no. 6, pp. 2406–2431, 2018.
- [37] J. Burschka *et al.*, “Sequential deposition as a route to high-performance perovskite-sensitized solar cells,” *Nature*, vol. 499, no. 7458, pp. 316–319, 2013.
- [38] D. Zhou, T. Zhou, Y. Tian, X. Zhu, and Y. Tu, “Perovskite-Based Solar Cells: Materials, Methods, and Future Perspectives,” *J. Nanomater.*, vol. 2018, 2018.
- [39] M. Konstantakou, D. Perganti, P. Falaras, and T. Stergiopoulos, “Anti-solvent crystallization strategies for highly efficient perovskite solar cells,” *Crystals*, vol. 7, no. 10, pp. 1–21, 2017.
- [40] A. E. Shalan, “Challenges and approaches towards upscaling the assembly of hybrid perovskite solar cells,” *Mater. Adv.*, vol. 1, no. 3, pp. 292–309, 2020.
- [41] J. Albero, A. M. Asiri, and H. García, “Influence of the composition of hybrid perovskites on their performance in solar cells,” *J. Mater. Chem. A*, vol. 4, no.

- 12, pp. 4353–4364, 2016.
- [42] T. Zhang, N. Guo, G. Li, X. Qian, L. Li, and Y. Zhao, “A general non-CH₃NH₃X (X = I, Br) one-step deposition of CH₃NH₃PbX₃ perovskite for high performance solar cells,” *J. Mater. Chem. A*, vol. 4, no. 9, pp. 3245–3248, 2016.
- [43] B. Cai, W. H. Zhang, and J. Qiu, “Solvent engineering of spin-coating solutions for planar-structured high-efficiency perovskite solar cells,” *Cuihua Xuebao/Chinese J. Catal.*, vol. 36, no. 8, pp. 1183–1190, 2015.
- [44] N. J. Jeon, J. H. Noh, Y. C. Kim, W. S. Yang, S. Ryu, and S. Il Seok, “Solvent engineering for high-performance inorganic-organic hybrid perovskite solar cells,” *Nat. Mater.*, vol. 13, no. 9, pp. 897–903, 2014.
- [45] R. Wei, “Modelling of Perovskite Solar Cells,” Queensland University of Technology, 2018.
- [46] J. Kang and J. H. Cho, “Organic-inorganic hybrid perovskite electronics,” *Phys. Chem. Chem. Phys.*, vol. 22, no. 24, pp. 13347–13357, 2020.
- [47] A. Kojima, “Novel Photoelectrochemical Cell with Mesoscopic Electrodes Sensitized by Lead-halide Compounds (11),” *ECS Meet. Abstr.*, no. 5, 2008.
- [48] A. Kojima, K. Teshima, Y. Shirai, and T. Miyasaka, “Organometal halide perovskites as visible-light sensitizers for photovoltaic cells,” *J. Am. Chem. Soc.*, vol. 131, no. 17, pp. 6050–6051, 2009.
- [49] Z. Chu *et al.*, “Impact of grain boundaries on efficiency and stability of organic-inorganic trihalide perovskites,” *Nat. Commun.*, vol. 8, no. 1, pp. 1–8, 2017.
- [50] W. T. Wang, S. K. Das, and Y. Tai, “Fully Ambient-Processed Perovskite Film for Perovskite Solar Cells: Effect of Solvent Polarity on Lead Iodide,” *ACS Appl. Mater. Interfaces*, vol. 9, no. 12, pp. 10743–10751, 2017.
- [51] S. H. Turren-Cruz *et al.*, “Enhanced charge carrier mobility and lifetime suppress hysteresis and improve efficiency in planar perovskite solar cells,” *Energy*

- Environ. Sci.*, vol. 11, no. 1, pp. 78–86, 2018.
- [52] N. Arora *et al.*, “Perovskite solar cells with CuSCN hole extraction layers yield stabilized efficiencies greater than 20%,” *Science (80-.).*, vol. 358, no. 6364, pp. 768–771, 2017.
- [53] “Cell-Efficiency@Www.Nrel.Gov,” 2020. [Online]. Available: <https://www.nrel.gov/pv/cell-efficiency.html>.
- [54] E. C. S. M. Abstracts, “Novel Photoelectrochemical Cell with Mesoscopic Electrodes Sensitized by Lead-halide Compounds (11),” *ECS Meet. Abstr.*, no. 11, 2008.
- [55] J. A. Chang *et al.*, “High-performance nanostructured inorganic–organic heterojunction solar cells,” *Nano Lett.*, vol. 10, no. 7, pp. 2609–2612, 2010.
- [56] J. H. Im, C. R. Lee, J. W. Lee, S. W. Park, and N. G. Park, “6.5% Efficient Perovskite Quantum-Dot-Sensitized Solar Cell,” *Nanoscale*, vol. 3, no. 10, pp. 4088–4093, 2011.
- [57] H. S. Kim *et al.*, “Lead iodide perovskite sensitized all-solid-state submicron thin film mesoscopic solar cell with efficiency exceeding 9%,” *Sci. Rep.*, vol. 2, pp. 1–7, 2012.
- [58] M. Liu, M. B. Johnston, and H. J. Snaith, “Efficient planar heterojunction perovskite solar cells by vapour deposition,” *Nature*, vol. 501, no. 7467, pp. 395–398, 2013.
- [59] Bisquert, Juan and V. et al. Gonzalez-pedro, “General Working Principles of CH₃ NH₃ PbX₃ Perovskite Solar Cells,” *Nano Lett.*, vol. 14, pp. 2–5, 2013.
- [60] A. K. Jena, A. Kulkarni, and T. Miyasaka, “Halide Perovskite Photovoltaics: Background, Status, and Future Prospects,” *Chem. Rev.*, vol. 119, no. 5, pp. 3036–3103, 2019.
- [61] J. H. Im *et al.*, “Nanowire perovskite solar cell,” *Nano Lett.*, vol. 15, no. 3, pp.

2120–2126, 2015.

- [62] V. E. Madhavan *et al.*, “CuSCN as Hole Transport Material with 3D/2D Perovskite Solar Cells,” *ACS Appl. Energy Mater.*, vol. 3, no. 1, pp. 114–121, 2020.
- [63] G. Niu, X. Guo, and L. Wang, “Review of recent progress in chemical stability of perovskite solar cells,” *J. Mater. Chem. A*, vol. 3, no. 17, pp. 8970–8980, 2015.
- [64] Z. Ning *et al.*, “Quantum-dot-in-perovskite solids,” *Nature*, vol. 523, no. 7560, pp. 324–328, 2015.
- [65] H. S. Jung and N. G. Park, “Perovskite solar cells: From materials to devices,” *Small*, vol. 11, no. 1, pp. 10–25, 2015.
- [66] G. Yang, H. Tao, P. Qin, W. Ke, and G. Fang, “Recent progress in electron transport layers for efficient perovskite solar cells,” *J. Mater. Chem. A*, vol. 4, no. 11, pp. 3970–3990, 2016.
- [67] Jhong-Ciao Ke *et al.*, “Effect of temperature annealing treatments and acceptors in CH₃NH₃PbI₃ perovskite solar cell fabrication,” *J. Alloys Compd.*, pp. 2453–2457, 2017.
- [68] C. Zhang, L. Gao, S. Hayase, and T. Ma, “Current advancements in material research and techniques focusing on lead-free perovskite solar cells,” *Chem. Lett.*, vol. 46, no. 9, pp. 1276–1284, 2017.
- [69] F. Anwar, R. Mahbub, S. S. Satter, and S. M. Ullah, “Effect of Different HTM Layers and Electrical Parameters on ZnO Nanorod-Based Lead-Free Perovskite Solar Cell for High-Efficiency Performance,” *Int. J. Photoenergy*, vol. 2017, 2017.
- [70] W. S. Li *et al.*, “Effect of substrate preheating on the photovoltaic performance of ZnO nanorod-based perovskite solar cells,” *Jpn. J. Appl. Phys.*, vol. 57, no. 6, 2018.

- [71] P. S. Chandrasekhar, A. Dubey, and Q. Qiao, “High efficiency perovskite solar cells using nitrogen-doped graphene/ZnO nanorod composite as an electron transport layer,” *Sol. Energy*, vol. 197, no. December 2019, pp. 78–83, 2020.
- [72] S. Zheng, G. Wang, T. Liu, L. Lou, S. Xiao, and S. Yang, “Materials and structures for the electron transport layer of efficient and stable perovskite solar cells,” *Sci. China Chem.*, vol. 62, no. 7, pp. 800–809, 2019.
- [73] K. Mahmood, S. Sarwar, and M. T. Mehran, “Current status of electron transport layers in perovskite solar cells: materials and properties,” *RSC Adv.*, vol. 7, no. 28, pp. 17044–17062, 2017.
- [74] Y. Wang, J. Wan, J. Ding, J. S. Hu, and D. Wang, “A Rutile TiO₂ Electron Transport Layer for the Enhancement of Charge Collection for Efficient Perovskite Solar Cells,” *Angew. Chemie - Int. Ed.*, vol. 58, no. 28, pp. 9414–9418, 2019.
- [75] Q. Jiang, X. Sheng, Y. Li, X. Feng, and T. Xu, “Rutile TiO₂ nanowire-based perovskite solar cells,” *Chem. Commun.*, vol. 50, no. 94, pp. 14720–14723, 2014.
- [76] H. Y. Yang, W. Y. Rho, S. K. Lee, S. H. Kim, and Y. B. Hahn, “TiO₂ nanoparticles/nanotubes for efficient light harvesting in perovskite solar cells,” *Nanomaterials*, vol. 9, no. 3, 2019.
- [77] D. Huh, K. S. Oh, M. Kim, H. J. Choi, D. S. Kim, and H. Lee, “Selectively patterned TiO₂ nanorods as electron transport pathway for high performance perovskite solar cells,” *Nano Res.*, vol. 12, no. 3, pp. 601–606, 2019.
- [78] J. Choi, S. Song, M. T. Hörantner, H. J. Snaith, and T. Park, “Well-Defined Nanostructured, Single-Crystalline TiO₂ Electron Transport Layer for Efficient Planar Perovskite Solar Cells,” *ACS Nano*, vol. 10, no. 6, pp. 6029–6036, 2016.
- [79] A. Alberti *et al.*, “Structural and Optical Behaviour of MAPbI₃ Layers in Nitrogen and Humid Air: (Hybrid perovskite stability can be improved?),” *IEEE 4th Int. Forum Res. Technol. Soc. Ind. RTSI 2018 - Proc.*, pp. 2–6, 2018.

- [80] O. A. Lozhkina *et al.*, “Invalidity of Band-Gap Engineering Concept for Bi³⁺ Heterovalent Doping in CsPbBr₃ Halide Perovskite,” *J. Phys. Chem. Lett.*, vol. 9, no. 18, pp. 5408–5411, 2018.
- [81] J. Wan *et al.*, “Hydrothermal etching treatment to rutile TiO₂ nanorod arrays for improving the efficiency of CdS-sensitized TiO₂ solar cells,” *Nanoscale Res. Lett.*, vol. 11, no. 1, pp. 1–9, 2016.
- [82] A. Priyadarshi *et al.*, “A large area (70 cm²) monolithic perovskite solar module with a high efficiency and stability,” *Energy Environ. Sci.*, vol. 9, no. 12, pp. 3687–3692, 2016.
- [83] L. L. Gao, C. X. Li, C. J. Li, and G. J. Yang, “Large-area high-efficiency perovskite solar cells based on perovskite films dried by the multi-flow air knife method in air,” *J. Mater. Chem. A*, vol. 5, no. 4, pp. 1548–1557, 2017.
- [84] B. S. Witkowski, “Applications of ZnO nanorods and nanowires — A review,” *Acta Phys. Pol. A*, vol. 134, no. 6, pp. 1226–1246, 2018.
- [85] M. S. Selim, A. M. Elseman, and Z. Hao, “ZnO Nanorods: An Advanced Cathode Buffer Layer for Inverted Perovskite Solar Cells,” *ACS Appl. Energy Mater.*, 2020.
- [86] Y. Zhang, M. K. Ram, E. K. Stefanakos, and D. Y. Goswami, “Synthesis, characterization, and applications of ZnO nanowires,” *J. Nanomater.*, vol. 2012, 2012.
- [87] Y. Xu *et al.*, “Preparation and photovoltaic properties of perovskite solar cell based on ZnO nanorod arrays,” *Appl. Surf. Sci.*, vol. 388, no. 3, pp. 89–96, 2016.
- [88] V. Siva *et al.*, “Mapping the structural, electrical, and optical properties of hydrothermally grown phosphorus-doped zno nanorods for optoelectronic device applications,” *Nanoscale Res. Lett.*, vol. 14, 2019.
- [89] M. B. Agarwal, M. Malaiadurai, A. Sharma, and R. Thangavel, “Effect of Al doping on hydrothermal growth and physical properties of doped ZnO

- nanoarrays for optoelectronic applications," *Mater. Today Proc.*, vol. 21, pp. 1781–1786, 2020.
- [90] D. Y. Son, K. H. Bae, H. S. Kim, and N. G. Park, "Effects of seed layer on growth of ZnO nanorod and performance of perovskite solar cell," *J. Phys. Chem. C*, vol. 119, no. 19, pp. 10321–10328, 2015.
- [91] K. Mahmood, B. S. Swain, and H. S. Jung, "Controlling the surface nanostructure of ZnO and Al-doped ZnO thin films using electrostatic spraying for their application in 12% efficient perovskite solar cells," *Nanoscale*, vol. 6, no. 15, pp. 9127–9138, 2014.
- [92] X. Dong, H. Hu, B. Lin, J. Ding, and N. Yuan, "The effect of ALD-Zno layers on the formation of CH₃NH₃PbI₃ with different perovskite precursors and sintering temperatures," *Chem. Commun.*, vol. 50, no. 92, pp. 14405–14408, 2014.
- [93] Shirazi Narzieh, Dariani, Reza, and M. R. Toroghinejad, "Efficiency enhancement of hole-conductor-free perovskite solar cell based on ZnO nanostructure by Al doping in ZnO," *J. Alloys Compd.*, vol. 692, pp. 492–502, 2017.
- [94] P. Sahoo, A. Sharma, and R. Thangavel, "Hydrothermal synthesis, structural and optical investigations of undoped and Mg doped ZnO nanorods," *AIP Conf. Proc.*, vol. 2100, no. April, 2019.
- [95] P. Wang, J. Zhao, W. Liu, Z. Liu, L. Guan, and G. Cao, "Stabilization of organometal halide perovskite films by SnO₂ coating with inactive surface hydroxyl groups on nanorods," *J. Power Sources*, no. 339, pp. 51–60, 2017.
- [96] J. Zhang, E. J. Juárez-Pérez, I. Mora-Seró, B. Viana, and T. Pauporté, "Fast and low temperature growth of electron transport layers for efficient perovskite solar cells," *J. Mater. Chem. A*, vol. 3, no. 9, pp. 4909–4915, 2015.
- [97] J. Zhang and T. Pauporté, "Effects of Oxide Contact Layer on the Preparation and Properties of CH₃NH₃PbI₃ for Perovskite Solar Cell Application," *J. Phys.*

- Chem. C*, vol. 119, no. 27, pp. 14919–14928, 2015.
- [98] Z. Qiu *et al.*, “The Influence of Physical Properties of ZnO Films on the Efficiency of Planar ZnO/Perovskite/P3HT Solar Cell,” *J. Am. Ceram. Soc.*, vol. 100, no. 1, pp. 176–184, 2017.
- [99] M. M. Tavakoli, R. Tavakoli, Z. Nourbakhsh, A. Waleed, U. S. Virk, and Z. Fan, “High Efficiency and Stable Perovskite Solar Cell Using ZnO/rGO QDs as an Electron Transfer Layer,” *Adv. Mater. Interfaces*, vol. 3, no. 11, pp. 1–10, 2016.
- [100] F. J. Ramos *et al.*, “Perovskite solar cells based on nanocolumnar plasma-deposited ZnO thin films,” *ChemPhysChem*, vol. 15, no. 6, pp. 1148–1153, 2014.
- [101] A. Dualeh, N. Tétreault, T. Moehl, P. Gao, M. K. Nazeeruddin, and M. Grätzel, “Effect of annealing temperature on film morphology of organic-inorganic hybrid perovskite solid-state solar cells,” *Adv. Funct. Mater.*, vol. 24, no. 21, pp. 3250–3258, 2014.
- [102] H. Zhou *et al.*, “Low-temperature processed and carbon-based ZnO/CH₃NH₃PbI₃/C planar heterojunction perovskite solar cells,” *J. Phys. Chem. C*, vol. 119, no. 9, pp. 4600–4605, 2015.
- [103] J. You *et al.*, “Improved air stability of perovskite solar cells via solution-processed metal oxide transport layers,” *Nat. Nanotechnol.*, vol. 11, no. 1, pp. 75–81, 2016.
- [104] M. H. Kumar, N. Yantara, S. Dharani, M. Graetzel, P. P. Boix, and N. Mathews, “Flexible, low-temperature, solution processed ZnO-based perovskite solid state solar cells,” *Chem. Commun.*, vol. 49, no. 94, pp. 11089–11091, 2013.
- [105] K. H. Solangi, M. R. Islam, R. Saidur, N. A. Rahim, and H. Fayaz, “A review on global solar energy policy,” *Renew. Sustain. Energy Rev.*, vol. 15, pp. 2149–2163, 2011.
- [106] A. Mhamdi, W. Boukhili, M. Raissi, M. Mahdouani, L. Vignau, and R. Bourguiga, “Simulation and optimization of the performance of organic

- photovoltaic cells based on capped copolymers for bulk heterojunctions,” *Superlattices and Microstructures*, vol. 96, pp. 241–252, 2016.
- [107] Z. Li *et al.*, “Scalable fabrication of perovskite solar cells,” *Nat. Rev. Mater.*, vol. 3, pp. 1–20, 2018.
- [108] C. Zuo, H. J. Bolink, H. Han, J. Huang, D. Cahen, and L. Ding, “Advances in perovskite solar cells,” *Adv. Sci.*, vol. 3, no. 7, pp. 1–16, 2016.
- [109] A. Hima, N. Lakhdar, B. Benhaoua, A. Saadoune, I. Kemerchou, and F. Rogti, “An optimized perovskite solar cell designs for high conversion efficiency,” *Superlattices and Microstructures*, vol. 129, pp. 240–246, 2019.
- [110] W. J. Yin, T. Shi, and Y. Yan, “Unique properties of halide perovskites as possible origins of the superior solar cell performance,” *Adv. Mater.*, vol. 26, no. 27, pp. 4653–4658, 2014.
- [111] V. D’Innocenzo *et al.*, “Excitons versus free charges in organo-lead tri-halide perovskites,” *Nat. Commun.*, vol. 5, pp. 1–6, 2014.
- [112] A. M. Askar and K. Shankar, “Exciton Binding Energy in Organic–Inorganic Tri-Halide Perovskites,” *J. Nanosci. Nanotechnol.*, vol. 16, no. June, pp. 1–12, 2016.
- [113] Y. Wang, M. Zhong, and L. Chai, “Effects of the concentration of PbI₂ and CH₃NH₃I on the perovskite films and the performance of perovskite solar cells based on ZnO-TiO₂ nanorod arrays,” *Superlattices and Microstructures*, vol. 123, pp. 189–200, 2018.
- [114] R. K. Upadhyay, S. Member, A. P. Singh, and D. Upadhyay, “BiFeO₃/CH₃NH₃PbI₃ Perovskite Heterojunction Based Near-Infrared Photodetector,” *IEEE Electron Device Lett.*, vol. 40, no. 12, pp. 1961–1964, 2019.
- [115] R. K. Upadhyay, A. P. Singh, D. Upadhyay, S. Ratan, C. Kumar, and S. Jit, “High-Performance Photodetector Based on Organic – Inorganic Perovskite,” *IEEE Photonics Technol. Lett.*, vol. 31, no. 14, pp. 1151–1154, 2019.

- [116] D. K. Jarwal *et al.*, “Efficiency Improvement of TiO₂ Nanorods Electron Transport Layer Based Perovskite Solar Cells by Solvothermal Etching,” *IEEE J. Photovoltaics*, vol. PP, pp. 1–9, 2019.
- [117] K. G. Stamplecoskie, J. S. Manser, and P. V. Kamat, “Dual nature of the excited state in organic-inorganic lead halide perovskites,” *Energy Environ. Sci.*, vol. 8, no. 1, pp. 208–215, 2015.
- [118] A. Kumar, S. Ratan, D. K. Jarwal, A. K. Mishra, and C. Kumar, “Effect of PQT-12 interface layer on the performance of PCDTBT : PCBM bulk heterojunction solar cells Effect of PQT-12 interface layer on the performance of PCDTBT : PCBM bulk heterojunction solar cells,” *Mater. Res. Express*, vol. 6, no. 115514, pp. 1–9, 2019.
- [119] U. Mandadapu, S. V. Vedanayakam, and K. Thyagarajan, “Simulation and Analysis of Lead based Perovskite Solar Cell using SCAPS-1D,” *Indian J. Sci. Technol.*, vol. 10, no. 11, pp. 1–8, 2017.
- [120] X. Sun, R. Asadpour, W. Nie, A. D. Mohite, and M. A. Alam, “A Physics-Based Analytical Model for Perovskite Solar Cells,” *IEEE J. Photovoltaics*, vol. 5, no. 5, pp. 1389–1394, 2015.
- [121] X. Wei *et al.*, “Numerical simulation and experimental validation of inverted planar perovskite solar cells based on NiOx hole transport layer,” *Superlattices Microstruct.*, vol. 112, pp. 383–393, 2017.
- [122] T. Minemoto and M. Murata, “Device modeling of perovskite solar cells based on structural similarity with thin film inorganic semiconductor solar cells,” *J. Appl. Phys.*, vol. 116, no. 054505, pp. 1–5, 2014.
- [123] A. Mebadi, M. Houshmand, M. H. Zandi, and N. E. Gorji, “Numerical Analysis of TiO₂/Cu₂ZnSnS₄ Nanostructured PV Using SCAPS-1D,” *Nano Hybrids*, vol. 8, pp. 27–38, 2014.
- [124] S.Farzad and N.Mina, “Optimization of Structure of Solar Cells Based on Lead

- Perovskites ($\text{CH}_3\text{NH}_3\text{PbX}_3$, X: I, Br) Via Numerical Simulation,” *J. Sol. Energy Res.*, vol. 24, no. 1, pp. 315–321, 2017.
- [125] D. B. Khadka, Y. Shirai, M. Yanagida, J. W. Ryan, and K. Miyano, “Exploring the effects of interfacial carrier transport layers on device performance and optoelectronic properties of planar perovskite solar cells,” *J. Mater. Chem. C*, vol. 5, no. 34, pp. 8819–8827, 2017.
- [126] F. Anwar, R. Mahbub, S. S. Satter, and S. M. Ullah, “Effect of Different HTM Layers and Electrical Parameters on ZnO Nanorod-Based Lead-Free Perovskite Solar Cell for High-Efficiency Performance,” *Int. J. Photoenergy*, vol. 2017, pp. 1–9, 2017.
- [127] L. Lin, L. Jiang, Y. Qiu, and Y. Yu, “Modeling and analysis of HTM-free perovskite solar cells based on ZnO electron transport layer,” *Superlattices and Microstructures*, vol. 104, pp. 167–177, 2017.
- [128] M. Sreemany and S. Sen, “A simple spectrophotometric method for determination of the optical constant and band gap energy of multiple layer TiO₂ thin films,” *Mater. Chem. Phys.*, vol. 83, pp. 169–177, 2004.
- [129] O. A. Jaramillo-Quintero *et al.*, “Recombination reduction on lead halide perovskite solar cells based on low temperature synthesized hierarchical TiO₂ nanorods,” *Nanoscale*, vol. 8, no. 12, pp. 6271–6277, 2016.
- [130] U. K. Thakur, A. M. Askar, R. Kisslinger, B. D. Wiltshire, P. Kar, and K. Shankar, “Halide perovskite solar cells using monocrystalline TiO₂ nanorod arrays as electron transport layers: Impact of nanorod morphology,” *Nanotechnology*, vol. 28, no. 27, 2017.
- [131] C. Liu *et al.*, “Investigation of high performance TiO₂ nanorod array perovskite solar cells,” *J. Mater. Chem. A*, vol. 5, no. 30, pp. 15970–15980, 2017.
- [132] G. Niu, X. Guo, and L. Wang, “Review of recent progress in chemical stability of perovskite solar cells,” *J. Mater. Chem. A*, vol. 3, pp. 8970–8980, 2015.

- [133] S. M. H. Al-Jawad, O. N. Salman, and N. A. Yousif, “Influence of growth time on structural optical and electrical properties of TiO₂ nanorod arraya deposited by hydrothermal method,” *Surf. Rev. Lett.*, vol. 26, no. 3, pp. 1–9, 2019.
- [134] P. Zhao *et al.*, “Device simulation of inverted CH₃NH₃PbI_{3-x}Cl_x perovskite solar cells based on PCBM electron transport layer and NiO hole transport layer,” *Sol. Energy*, vol. 169, no. April, pp. 11–18, 2018.
- [135] A. Fakharuddin, F. Di Giacomo, I. Ahmed, Q. Wali, T. M. Brown, and R. Jose, “Role of morphology and crystallinity of nanorod and planar electron transport layers on the performance and long term durability of perovskite solar cells,” *J. Power Sources*, vol. 283, pp. 61–67, 2015.
- [136] J. Joo *et al.*, “Large-scale synthesis of TiO₂ nanorods via nonhydrolytic sol-gel ester elimination reaction and their application to photocatalytic inactivation of E. coli,” *J. Phys. Chem. B*, vol. 109, no. 32, pp. 15297–15302, 2005.
- [137] M. Y. Liao, L. Fang, C. L. Xu, F. Wu, Q. L. Huang, and M. Saleem, “Materials Science in Semiconductor Processing Effect of seed layer on the growth of rutile TiO₂ nanorod arrays and their performance in dye-sensitized solar cells,” vol. 24, pp. 1–8, 2014.
- [138] J. Qin, Z. Zhang, W. Shi, Y. Liu, H. Gao, and Y. Mao, “The optimum titanium precursor of fabricating TiO₂ compact layer for perovskite solar cells,” *Nanoscale Res. Lett.*, vol. 1, no. 12, p. 640, 2017.
- [139] G. Rawat, D. Somvanshi, H. Kumar, Y. Kumar, C. Kumar, and S. Jit, “Ultraviolet Detection Properties of p-Si/n-TiO₂ Heterojunction Photodiodes Grown by Electron-Beam Evaporation and Sol–Gel Methods: A Comparative Study,” *IEEE Trans. Nanotechnol.*, vol. 15, no. 2, pp. 193–200, 2016.
- [140] J. Wan *et al.*, “Hydrothermal Etching Treatment to Rutile TiO₂ Nanorod Arrays for Improving the Efficiency of CdS-Sensitized TiO₂ Solar Cells,” *Nanoscale Res. Lett.*, vol. 10, no. 1, pp. 1–9, 2016.

- [141] B. El Cohen and L. Etgar, “Parameters that control and influence the organometal halide perovskite crystallization and morphology,” *Front. Optoelectron.*, vol. 9, no. 1, pp. 44–52, 2016.
- [142] M. M. Lee, J. Teuscher, T. Miyasaka, T. N. Murakami, and H. J. Snaith, “Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide Perovskites,” no. October, pp. 1–6, 2012.
- [143] M. Sreemany and S. Sen, “A simple spectrophotometric method for determination of the optical constants and band gap energy of multiple layer TiO₂ thin films,” *Mater. Chem. Phys.*, vol. 83, no. 1, pp. 169–177, 2004.
- [144] M. Kim, B. Kim, and J. Kim, “Effective Variables To Control the Fill Factor of Organic Photovoltaic Cells,” vol. 1, no. 6, pp. 1–6, 2009.
- [145] H. Kumar *et al.*, “Heating Effects of Colloidal ZnO Quantum Dots (QDs) on ZnO QD/CdSe QD/MoO_x Photodetectors,” *IEEE Trans. Nanotechnol.*, vol. 16, no. 6, pp. 1073–1080, Nov. 2017.
- [146] H. Kim *et al.*, “High Efficiency Solid-State Sensitized Solar Cell-Based on Submicrometer Rutile TiO₂ Nanorod and CH₃NH₃PbI₃ Perovskite Sensitizer,” *Nano Lett.*, vol. 13, no. 6, p. 2412–2417, 2013.
- [147] C. S. Shim, H. K. Park, J. Heo, P. S. Patil, and C. K. Hong, “Ultrathin Atomic Layer Deposited TiO₂ for Surface Passivation of Hydrothermally Grown 1D TiO₂ Nanorod Arrays for Efficient Solid- State Perovskite Solar Cells,” *Chem. Mater.*, vol. 27, p. 1541–1551, 2015.
- [148] G. S. Han *et al.*, “Reduced Graphene Oxide / Mesoporous TiO₂ Nanocomposite Based Perovskite Solar Cells,” *ACS Appl. Mater. Interfaces*, vol. 7, p. 23521–23526, 2015.
- [149] J. Hu *et al.*, “TiO₂ nanotube/TiO₂ nanoparticle hybrid photoanode for hole-conductor-free perovskite solar cells based on carbon counter electrodes,” *Opt. Mater. Express*, vol. 7, no. 9, p. 3322, 2017.

- [150] X. Sun *et al.*, “Influence of the Porosity of the TiO₂ Film on the Performance of the Perovskite Solar Cell,” *Int. J. Photoenergy*, vol. 2017, p. 4935265, 2017.
- [151] L. Li, C. Shi, X. Deng, Y. Wang, and L. Ni, “High-crystallinity and large-grain CH₃NH₃PbI₃ thin films for efficient TiO₂ nanorod array perovskite solar cells,” *Micro Nano Lett.*, vol. 13, no. 1, pp. 131–134, 2017.
- [152] W. Ye, J. Xiang, F. Huang, and D. Zhong, “Towards large-area perovskite solar cells : the influence of compact and mesoporous TiO₂ electron transport layers,” *Mater. Res. Express*, vol. 5, p. 085506, 2018.
- [153] A. Imanah, P. Ekanayake, A. Wakamiya, H. Nakajima, and ming chee lim, “Enhanced performance of CH₃NH₃PbI₃-based perovskite solar cells by tuning the electrical and structural properties of mesoporous TiO₂ layer via Al and Mg doping,” *Sol. Energy*, vol. 177, pp. 374–381, 2019.
- [154] D. Y. Son, J. H. Im, H. S. Kim, and N. G. Park, “11% efficient perovskite solar cell based on ZnO nanorods: An effective charge collection system,” *J. Phys. Chem. C*, vol. 118, no. 30, pp. 16567–16573, 2014.
- [155] A. Mahesh, “Photovoltaic performance of ZnO nanosheets solar cell sensitized with beta-substituted porphyrin,” *J. Nanomater.*, vol. 2011, no. 9, pp. 1787–1793, 2011.
- [156] V. Consonni, J. Briscoe, E. Kärber, X. Li, and T. Cossuet, “ZnO nanowires for solar cells: A comprehensive review,” *Nanotechnology*, vol. 30, no. 36, 2019.
- [157] E. Peksu and H. Karaagac, “Synthesis of ZnO Nanowires and Their Photovoltaic Application: ZnO Nanowires/AgGaSeThin Film Core-Shell Solar Cell,” *J. Nanomater.*, vol. 2015, 2015.
- [158] L. Li *et al.*, “High-yield synthesis of single-crystalline zinc oxide nanobelts and their applications in novel Schottky solar cells,” *Chem. Commun.*, vol. 47, no. 29, pp. 8247–8249, 2011.
- [159] D. Cao, S. Gong, X. Shu, D. Zhu, and S. Liang, “Preparation of ZnO

- Nanoparticles with High Dispersibility Based on Oriented Attachment (OA) Process," *Nanoscale Res. Lett.*, vol. 14, 2019.
- [160] H. R. Ghorbani, F. P. Mehr, H. Pazoki, and B. M. Rahmani, "Synthesis of ZnO nanoparticles by precipitation method," *Orient. J. Chem.*, vol. 31, no. 2, pp. 1219–1221, 2015.
- [161] Y. Kumar *et al.*, "Colloidal ZnO quantum dots based spectrum selective ultraviolet photodetectors," *IEEE Photonics Technol. Lett.*, vol. 29, no. 4, pp. 361–364, 2017.
- [162] Z. Liu, J. Ya, and E. Lei, "Effects of substrates and seed layers on solution growing ZnO nanorods," *J. Solid State Electrochem.*, vol. 14, no. 6, pp. 957–963, 2010.
- [163] M. Sreemany and S. Sen, "A simple spectrophotometric method for determination of the optical constants and band gap energy of multiple layer TiO₂ thin films," *2004*, vol. 83, pp. 169–177.
- [164] H. Kumar *et al.*, "Heating Effects of Colloidal ZnO Quantum Dots Heating Effects of Colloidal ZnO Quantum Dots," *Ieee Trans. Nanotechnol.*, vol. 16, no. 6, pp. 1073–1080, 2017.
- [165] G. Rawat, D. Somvanshi, Y. Kumar, H. Kumar, C. Kumar, and S. Jit, "Electrical and Ultraviolet-A Detection Properties of E-Beam Evaporated n-TiO₂ Capped p-Si Nanowires Heterojunction Photodiodes," *IEEE Trans. Nanotechnol.*, vol. 16, no. 1, pp. 49–57, 2017.
- [166] T. H. Schloemer, J. A. Christians, J. M. Luther, and A. Sellinger, "Doping strategies for small molecule organic hole-transport materials: impacts on perovskite solar cell performance and stability," *Chem. Sci.*, vol. 10, no. 7, pp. 1904–1935, 2019.
- [167] S. R. Meher, L. Balakrishnan, and Z. C. Alex, "Analysis of Cu₂ZnSnS₄/CdS based photovoltaic cell: A numerical simulation approach," *Superlattices*

- Microstruct.*, vol. 100, pp. 703–722, 2016.
- [168] X. Deng, Y. Wang, Z. Cui, L. Li, and C. Shi, “Y-doping TiO₂ nanorod arrays for efficient perovskite solar cells,” *Superlattices Microstruct.*, vol. 117, pp. 283–287, 2018.
- [169] H. Xi *et al.*, “Performance Enhancement of Planar Heterojunction Perovskite Solar Cells through Tuning the Doping Properties of Hole-Transporting Materials,” *ACS Omega*, vol. 2, no. 1, pp. 326–336, 2017.
- [170] D. K. Jarwal *et al.*, “Fabrication and TCAD simulation of TiO₂ nanorods electron transport layer based perovskite solar cells,” *Superlattices Microstruct.*, vol. 140, p. 106463, 2020.
- [171] H. Kumar *et al.*, “Heating Effects of Colloidal ZnO Quantum Dots (QDs) on ZnO QD/CdSe QD/MoO_x Photodetectors,” *IEEE Trans. Nanotechnol.*, vol. 16, no. 6, pp. 1073–1080, 2017.
- [172] S. Wang *et al.*, “Unveiling the Role of tBP-LiTFSI Complexes in Perovskite Solar Cells,” *J. Am. Chem. Soc.*, vol. 140, no. 48, pp. 16720–16730, 2018.
- [173] A. Kumar *et al.*, “Effect of PQT-12 interface layer on the performance of PCDTBT: PCBM bulk heterojunction solar cells,” *Mater. Res. Express*, vol. 6, no. 11, 2019.
- [174] M. Fathi, M. Abderrezek, F. Djahli, and M. Ayad, “Study of Thin Film Solar Cells in High Temperature Condition,” *Energy Procedia*, vol. 74, pp. 1410–1417, 2015.
- [175] M. A. Cappelletti, G. A. Casas, A. P. Cédola, E. L. Peltzer y Blancá, and B. Marí Soucase, “Study of the reverse saturation current and series resistance of p-p-n perovskite solar cells using the single and double-diode models,” *Superlattices and Microstructures*, vol. 123, pp. 338–348, 2018.
- [176] E. Karimi and S. M. B. Ghorashi, “Investigation of the influence of different hole-transporting materials on the performance of perovskite solar cells,” *Optik*,

- vol. 130, pp. 650–658, 2017.
- [177] W. J. Chi, P. P. Sun, and Z. S. Li, “How to regulate energy levels and hole mobility of spiro-type hole transport materials in perovskite solar cells,” *Phys. Chem. Chem. Phys.*, vol. 18, no. 39, pp. 27073–27077, 2016.
- [178] H. Dixit, D. Punetha, and S. K. Pandey, “Improvement in performance of lead free inverted perovskite solar cell by optimization of solar parameters,” *Optik (Stuttg.)*, vol. 179, no. October 2018, pp. 969–976, 2019.
- [179] N. Sakai, T. Miyasaka, and T. N. Murakami, “Efficiency enhancement of ZnO-based dye-sensitized solar cells by low-temperature TiCl₄ treatment and dye optimization,” *J. Phys. Chem. C*, vol. 117, no. 21, pp. 10949–10956, 2013.
- [180] J. A. Christians, R. C. M. Fung, and P. V. Kamat, “An inorganic hole conductor for Organo-lead halide perovskite solar cells. improved hole conductivity with copper iodide,” *J. Am. Chem. Soc.*, vol. 136, no. 2, pp. 758–764, 2014.
- [181] S. K. Dwivedi *et al.*, “Fabrication and properties of P3HT: PCBM/Cu₂SnSe₃ (CTSe)nanocrystals based inverted hybrid solar cells,” *Sol. Energy*, vol. 187, no. May, pp. 167–174, 2019.
- [182] Y. Li *et al.*, “Efficient inorganic solid solar cells composed of perovskite and PbS quantum dots,” *Nanoscale*, vol. 7, no. 21, pp. 9902–9907, 2015.
- [183] C. Kumar, G. Rawat, H. Kumar, Y. Kumar, R. Prakash, and S. Jit, “Electrical and Optical Characteristics of PQT-12-Based Organic TFTs Fabricated by Floating-Film Transfer Method,” *IEEE Trans. Nanotechnol.*, vol. 17, no. 6, pp. 1111–1117, 2018.

AUTHOR'S RELEVANT PUBLICATIONS

Journals:

1. **Deepak Kumar Jarwal.**, Amit Kumar, Ashwini Kumar Mishra, Smrity Ratan, Kumar, C., Upadhyay, D., Mukherjee, B. and Jit, S. Efficiency Improvement of TiO₂ Nanorods Electron Transport Layer Based Perovskite Solar Cells by Solvothermal Etching. IEEE Journal of Photovoltaics, vol. 9(6), pp.1699-1707, 2019.
2. **Deepak Kumar Jarwal**, Ashwini Kumar Mishra, Amit Kumar, Smrity Ratan, Abhinav Pratap Singh, Chandan Kumar, Bratindranath Mukherjee, and Satyabrata Jit, “Fabrication and TCAD Simulation of TiO₂ Nanorods Electron Transport Layer Based Perovskite Solar Cells,” Superlattice and Microstructure, vol. 140, pp. 106463, 2020.
3. **Deepak Kumar Jarwal**, Amit Kumar, Ashwini Kumar Mishra, Smrity Ratan, Rishibrind Kumar Upadhyay, Chandan Kumar, Bratindranath Mukherjee, and Satyabrata Jit, “ Fabrication and TCAD validation of ambient air-processed ZnO NRs/CH₃NH₃PbI₃/Spiro-OMeTAD solar cells,” Superlattice and Microstructure, vol. 143, pp. 106540, 2020.

Conferences:

1. **Deepak Kumar Jarwal**, Ashwini Kumar Mishra, Amit Kumar, Smrity Rtan, Manas Ranjan Tripathy, Nitin Kumar Suyan, Bratindranath Mukherjee and Satyabrata Jit’ “Performance Analysis and Experimental Validation of ZnO Nanorods ETL based Hybrid Perovskite Solar Cell,” ICONRER-2019, Jaipur, India, 2019.
2. **Deepak Kumar Jarwal**, Ashwini Kumar Mishra, Amit Kumar, Smrity Rtan, Rishibrind Upadyay, Bratindranath Mukherjee and Satyabrata Jit’ “Thickness

variation effect of different layer of perovskire solar cell on the performance of solar cell" ICONN-2021, Chennai, India, 2021.