

## **Reference**

1. Apergis, N. & Payne, J. E. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Econ.* 2012; 34: 733–738.
2. Banos, R. et al. Optimization methods applied to renewable and sustainable energy: A review. *Renew. Sustain. energy Rev.* 2011; 15: 1753–1766.
3. Wurfel, P. The chemical potential of radiation. *J. Phys. C Solid State Phys.* 1982; 15: 3967.
4. Solanki, C. S. Solar photovoltaics: fundamentals, technologies and applications. Phi learning pvt. Ltd. 2015.
5. Smith, W. Effect of Light on Selenium. *Nature.* 1873; 7: 303.
6. Chapin, D. M., Fuller, C. S. & Pearson, G. L. A new silicon p-n junction photocell for converting solar radiation into electrical power. *J. Appl. Phys.* 1954; 25: 676–677.
7. Rühle, S. Tabulated values of the Shockley–Queisser limit for single junction solar cells. *Sol. Energy.* 2016; 130: 139–147.
8. Shockley, W. & Queisser, H. J. Detailed Balance Limit of Efficiency of p-n Junction Solar Cells. *J. Appl. Phys.* 1961; 32: 510–519.
9. Zweibel, K., Mason, J. & Fthenakis, V. A solar grand plan. *Sci. Am.* 2008 298: 64–73.
10. Shah, A., Torres, P., Tscharner, R., Wyrsch, N. & Keppner, H. Photovoltaic technology: the case for thin-film solar cells. *Science.* 1999; 285: 692–698.
11. Bag, S. et al. Low band gap liquid-processed CZTSe solar cell with 10.1% efficiency. *Energy Environ. Sci.* 2012; 5: 7060–7065.
12. Katagiri, H. et al. Development of CZTS-based thin film solar cells. *Thin Solid Films.* 2009; 517: 2455–2460.
13. Guo, Q. et al. Fabrication of 7.2% efficient CZTSSe solar cells using CZTS nanocrystals. *J. Am. Chem. Soc.* 2010; 132: 17384–17386.

14. Cheng, Y.-J., Yang, S.-H. & Hsu, C.-S. Synthesis of conjugated polymers for organic solar cell applications. *Chem. Rev.* 2009; 109: 5868–5923.
15. Gong, J., Liang, J. & Sumathy, K. Review on dye-sensitized solar cells (DSSCs): Fundamental concepts and novel materials. *Renew. Sustain. Energy Rev.* 2012; 16: 5848–5860.
16. Kamat, P. V. Quantum dot solar cells. Semiconductor nanocrystals as light harvesters. *J. Phys. Chem. C*. 2008; 112: 18737-18753.
17. Niu, G., Guo, X. & Wang, L. Review of recent progress in chemical stability of perovskite solar cells. *J. Mater. Chem.* 2015; A 3: 8970–8980.
18. Tao, Y. & Rohatgi, A. High-Efficiency Front Junction n-Type Crystalline Silicon Solar Cells. *Nanostructured Sol. Cells.* 2017; 93.
19. Saga, T. Advances in crystalline silicon solar cell technology for industrial mass production. *npg asia Mater.* 2010; 2: 96–102.
20. Carlberg, T., King, T. B. & Witt, A. F. Dynamic oxygen equilibrium in silicon melts during crystal growth by the czochralski technique. *J. Electrochem. Soc.* 1982; 129: 189.
21. Abrosimov, N. V., Rossolenko, S. N., Thieme, W., Gerhardt, A. & Schröder, W. Czochralski growth of Si-and Ge-rich SiGe single crystals. *J. Cryst. Growth.* 1997; 174: 182–186.
22. Hahn, G. & Schönecker, A. New crystalline silicon ribbon materials for photovoltaics. *J. Phys. Condens. Matter.* 2004; 16: R1615.
23. Fujiwara, K. et al. Growth of structure-controlled polycrystalline silicon ingots for solar cells by casting. *Acta Mater.* 2006; 54: 3191–3197.
24. Franke, D., Rettelbach, T., Hässler, C., Koch, W. & Müller, A. Silicon ingot casting: process development by numerical simulations. *Sol. energy Mater. Sol. cells.* 2002; 72: 83–92.
25. Aberle, A. G. Thin-film solar cells. *Thin Solid Films.* 2009; 517: 4706–4710.
26. Bloss, W. H., Pfisterer, F., Schubert, M. & Walter, T. Thin-film solar cells. *Prog.*

Photovoltaics Res. Appl. 1995; 3: 3–24.

27. Chopra, K. L. & Das, S. R. Why thin film solar cells? in Thin film solar cells. Springer, 1983;1–18.
28. Garnett, E. C. & Yang, P. Silicon nanowire radial p– n junction solar cells. J. Am. Chem. Soc. 2008; 130: 9224–9225.
29. Bergmann, R. B. Crystalline Si thin-film solar cells: a review. Appl. Phys. 1999;A 69: 187–194.
30. Dennler, G., Scharber, M. C. & Brabec, C. J. Polymer-fullerene bulk-heterojunction solar cells. Adv. Mater. 2009;21: 1323–1338.
31. Yan, B. et al. Innovative dual function nc-SiO<sub>x</sub>: H layer leading to a> 16% efficient multi-junction thin-film silicon solar cell. Appl. Phys. Lett. 2011; 99: 113512.
32. Green, M. A. Thin-film solar cells: review of materials, technologies and commercial status. J. Mater. Sci. Mater. Electron. 2007; 18: 15–19.
33. Ramanathan, K. et al. Properties of 19.2% efficiency ZnO/CdS/CuInGaSe<sub>2</sub> thin-film solar cells. Prog. Photovoltaics Res. Appl. 2003;11: 225–230.
34. Britt, J. & Ferekides, C. Thin-film CdS/CdTe solar cell with 15.8% efficiency. Appl. Phys. Lett. 1993; 62: 2851–2852.
35. Romeo, N., Bosio, A., Canevari, V. & Podesta, A. Recent progress on CdTe/CdS thin film solar cells. Sol. Energy. 2004; 77: 795–801.
36. Jackson, P. et al. New world record efficiency for Cu(In,Ga)Se<sub>2</sub> thin-film solar cells beyond 20%. Prog. Photovoltaics Res. Appl. 2011; 19: 894–897.
37. Green, M. A. Third generation photovoltaics. 2006.
38. Chen, C.-C. et al. An Efficient Triple-Junction Polymer Solar Cell Having a Power Conversion Efficiency Exceeding 11%. Adv. Mater. 2014; 26: 5670–5677.
39. Aernouts, T. et al. Printable anodes for flexible organic solar cell modules. Thin Solid Films.

2004; 451–452: 22–25.

40. Hiramoto, M., Fujiwara, H. & Yokoyama, M. Three-layered organic solar cell with a photoactive interlayer of codeposited pigments. *Appl. Phys. Lett.* 1991; 58: 1062–1064.
41. Thompson, B. C. & Fréchet, J. M. J. Polymer–Fullerene Composite Solar Cells. *Angew. Chemie Int. Ed.* 2008; 47: 58–77.
42. Guarnera, S. et al. Photo-active integrated getters for stable dye-sensitized solar cells. *RSC Adv.* 2013; 3: 2163–2166.
43. Brabec, C., Scherf, U. & Dyakonov, V. *Organic photovoltaics: materials, device physics, and manufacturing technologies*. John Wiley & Sons. 2011.
44. Lanzani, G. *The photophysics behind photovoltaics and photonics*. John Wiley & Sons. 2012.
45. Frenkel, J. On the transformation of light into heat in solids. I. *Phys. Rev.* 1931;37: 17.
46. Wannier, G. H. The structure of electronic excitation levels in insulating crystals. *Phys. Rev.* 1937; 52: 191.
47. Braun, C. L. Electric field assisted dissociation of charge transfer states as a mechanism of photocarrier production. *J. Chem. Phys.* 1984; 80: 4157–4161.
48. Zhou, H. et al. Development of fluorinated benzothiadiazole as a structural unit for a polymer solar cell of 7% efficiency. *Angew. Chemie.* 2011; 123: 3051–3054.
49. Verreet, B. et al. A 4% efficient organic solar cell using a fluorinated fused subphthalocyanine dimer as an electron acceptor. *Adv. Energy Mater.* 2011;1: 565–568.
50. Collavini, S., Völker, S. F. & Delgado, J. L. Understanding the outstanding power conversion efficiency of perovskite-based solar cells. *Angew. Chemie Int. Ed.* 2015;54: 9757–9759.
51. Kojima, A., Teshima, K., Shirai, Y. & Miyasaka, T. Organometal halide perovskites as visible-light sensitizers for photovoltaic cells. *J. Am. Chem. Soc.* 2009; 131: 6050–6051.

52. Xiao, Z. et al. Efficient, high yield perovskite photovoltaic devices grown by interdiffusion of solution-processed precursor stacking layers. *Energy Environ. Sci.* 2014; 7: 2619–2623.
53. Mei, A. et al. A hole-conductor-free, fully printable mesoscopic perovskite solar cell with high stability. *Science*. 2014; 345: 295–298.
54. Lee, M. M., Teuscher, J., Miyasaka, T., Murakami, T. N. & Snaith, H. J. Efficient hybrid solar cells based on meso-superstructured organometal halide perovskites. *Science*. 2012; 338: 643–647.
55. Kazmerski, L., Gwinnner, D. & Hicks, A. Best research-cell efficiencies. *Natl. Renew. Energy Lab.* 2010;2: 0.
56. Li, Q. et al. Application of polymer gel electrolyte with graphite powder in quasi-solid-state dye-sensitized solar cells. *Polym. Compos.* 2009; 30: 1687–1692.
57. Razamin, N. A. Y., Saaid, F. I. & Winie, T. Dye-sensitized solar cell based on poly ( $\epsilon$ -caprolactone) gel polymer electrolyte and cobalt selenide counter electrode. *J. Polym. Res.* 2020; 27: 1–8.
58. Lan, Z., Wu, J., Lin, J. & Huang, M. Quasi-solid-state dye-sensitized solar cell based on a polymer gel electrolyte with in situ synthesized ionic conductors. *Comptes Rendus Chim.* 2010; 13: 1401–1405.
59. Candido, L. & Gomes, J. A. C. P. Evaluation of anode materials for the electro-oxidation of ammonia and ammonium ions. *Mater. Chem. Phys.* 2011;129: 1146–115.
60. Tan, L.-L. et al. Highly efficient and stable organic sensitizers with duplex starburst triphenylamine and carbazole donors for liquid and quasi-solid-state dye-sensitized solar cells. *J. Mater. Chem.* 2014;A: 8988–8994.
61. Tarannum, N. & Varishetty, M. M. Synthesis of organic sulfobetaine-based polymer gel electrolyte for dye-sensitized solar cell application. *Polym. Adv. Technol.* 2017;28: 1504–1509.
62. Wu, C. et al. Open-circuit voltage enhancement on the basis of polymer gel electrolyte for

- a highly stable dye-sensitized solar cell. *ACS Appl. Mater. Interfaces.* 2013; 5: 7886–7892.
63. Vogel, R., Pohl, K. & Weller, H. Sensitization of highly porous, polycrystalline TiO<sub>2</sub> electrodes by quantum sized CdS. *Chem. Phys. Lett.* 1990; 174: 241–246.
64. Vogel, R., Hoyer, P. & Weller, H. Quantum-sized PbS, CdS, Ag<sub>2</sub>S, Sb<sub>2</sub>S<sub>3</sub>, and Bi<sub>2</sub>S<sub>3</sub> particles as sensitizers for various nanoporous wide-bandgap semiconductors. *J. Phys. Chem.* 2002;98: 3183–3188.
65. Gerischer, H. & Luebke, M. A particle size effect in the sensitization of TiO<sub>2</sub> electrodes by a CdS deposit. *J. Electroanal. Chem. interfacial Electrochem.* 1986;204: 225–227.
66. Shen, Y.-J. & Lee, Y.-L. Assembly of CdS quantum dots onto mesoscopic TiO<sub>2</sub> films for quantum dot-sensitized solar cell applications. *Nanotechnology.* 2008; 19: 45602.
67. Zhu, H., Song, N. & Lian, T. Charging of Quantum Dots by Sulfide Redox Electrolytes Reduces Electron Injection Efficiency in Quantum Dot Sensitized Solar Cells. *J. Am. Chem. Soc.* 2013;135: 11461.
68. Kumar, S. et al. Quantum-sized nanomaterials for solar cell applications. *Renew. Sustain. Energy Rev.* 2017; 73: 821–839.
69. Kouhnnavard, M. et al. A review of semiconductor materials as sensitizers for quantum dot-sensitized solar cells. *Renew. Sustain. Energy Rev.* 2014;37: 397–407.
70. Sun, J.-K., Jiang, Y., Zhong, X., Hu, J.-S. & Wan, L.-J. Three-dimensional nanostructured electrodes for efficient quantum-dot-sensitized solar cells. *Nano Energy.* 2017; 32: 130–156.
71. Du, Z. et al. Carbon counter-electrode-based quantum-dot-sensitized solar cells with certified efficiency exceeding 11%. *J. Phys. Chem. Lett.* 2016;7: 3103–3111.
72. Jiao, S. et al. Nitrogen-doped mesoporous carbons as counter electrodes in quantum dot sensitized solar cells with a conversion efficiency exceeding 12%. *J. Phys. Chem. Lett.* 2017; 8: 559–564.
73. Yang, Z., Chen, C.-Y., Roy, P. & Chang, H.-T. Quantum Dot-Sensitized Solar Cells Incorporating Nanomaterials. *Chem. Commun.* 2011; 47: 9561.

74. Pan, Z. et al. High-Efficiency “Green” Quantum Dot Solar Cells. *J. Am. Chem. Soc.* 2014;136: 9203.
75. Zhang, L. et al. Copper deficient Zn–Cu–In–Se quantum dot sensitized solar cells for high efficiency. *J. Mater. Chem.* 2017;A 5; 21442–21451.
76. Li, L. et al. Highly Efficient CdS Quantum Dot-Sensitized Solar Cells Based on a Modified Polysulfide Electrolyte. *J. Am. Chem. Soc.* 2011;133; 8458–8460.
77. Lee, Y.-L. & Chang, C.-H. Efficient polysulfide electrolyte for CdS quantum dot-sensitized solar cells. *J. Power Sources*.2008; 185: 584–588.
78. Liao, Y. et al. Enhancing the efficiency of CdS quantum dot-sensitized solar cells via electrolyte engineering. *Nano Energy*.2015; 11: 88–95.
79. Pan, Z. et al. Highly Efficient Inverted Type-I CdS/CdSe Core/Shell Structure QD-Sensitized Solar Cells. *ACS Nano*.2012; 6: 3982.
80. Chou, C.-Y., Lee, C.-P., Vittal, R. & Ho, K.-C. Efficient quantum dot-sensitized solar cell with polystyrene-modified TiO<sub>2</sub> photoanode and with guanidine thiocyanate in its polysulfide electrolyte. *J. Power Sources*.2011; 196: 6595–6602.
81. Du, J., Meng, X., Zhao, K., Li, Y. & Zhong, X. Performance enhancement of quantum dot sensitized solar cells by adding electrolyte additives. *J. Mater. Chem.* 2015;A 3: 17091–17097.
82. Jiang, G. et al. Poly(vinyl pyrrolidone): a superior and general additive in polysulfide electrolytes for high efficiency quantum dot sensitized solar cells. *J. Mater. Chem.* 2016; A 4: 11416–11421.
83. Balis, N., Dracopoulos, V., Antoniadou, M. & Lianos, P. Solid-state dye-sensitized solar cells made of multilayer nanocrystalline titania and poly(3-hexylthiophene). *J. Photochem. Photobiol. A Chem.* 2010; 214: 69–73.
84. Song, H., Rao, H. & Zhong, X. Recent advances in electrolytes for quantum dot-sensitized solar cells. *J. Mater. Chem.* 2018; A 6: 4895.

85. Qian, J. et al. P3HT as hole transport material and assistant light absorber in CdS quantum dots-sensitized solid-state solar cells. *Chem. Commun.* 2011; 47: 6461–6463.
86. Dang, R. et al. Benzimidazolium salt-based solid-state electrolytes afford efficient quantum-dot sensitized solar cells. *J. Mater. Chem.* 2017; A 5: 13526–13534.
87. Barceló, I., Campiña, J. M., Lana-Villarreal, T. & Gómez, R. A solid-state CdSe quantum dot sensitized solar cell based on a quaterthiophene as a hole transporting material. *Phys. Chem. Chem. Phys.* 2012; 14: 5801–5807.
88. Brennan, T. P. et al. Efficiency enhancement of solid-state PbS quantum dot-sensitized solar cells with Al<sub>2</sub>O<sub>3</sub> barrier layer. *J. Mater. Chem.* 2013; A 1: 7566–7571.
89. Lee, H. et al. PbS and CdS Quantum Dot-Sensitized Solid-State Solar Cells: “Old Concepts, New Results”. *Adv. Funct. Mater.* 2009; 19: 2735–2742.
90. Snaith, H. J. et al. Charge collection and pore filling in solid-state dye-sensitized solar cells. *Nanotechnology*. 2008; 19; 424003.
91. Chen, J.-G., Wei, H.-Y. & Ho, K.-C. Using modified poly(3,4-ethylene dioxythiophene): Poly(styrene sulfonate) film as a counter electrode in dye-sensitized solar cells. *Sol. Energy Mater. Sol. Cells*. 2007; 91: 1472–1477.
92. Lévy-Clément, C., Tena-Zaera, R., Ryan, M. A., Katty, A. & Hodes, G. CdSe-Sensitized p-CuSCN/Nanowire n-ZnO Heterojunctions. *Adv. Mater.* 2005; 17: 1512–1515.
93. Chang, Y.-C. et al. Lead antimony sulfide (Pb<sub>5</sub>Sb<sub>8</sub>S<sub>17</sub>) solid-state quantum dot-sensitized solar cells with an efficiency of over 4%. *J. Power Sources*. 2016; 312: 86–92.
94. Zhang, X., Liu, J., Zhang, J., Vlachopoulos, N. & Johansson, E. M. J. ZnO@Ag<sub>2</sub>S core–shell nanowire arrays for environmentally friendly solid-state quantum dot-sensitized solar cells with panchromatic light capture and enhanced electron collection. *Phys. Chem. Chem. Phys.* 2015; 17: 12786–12795.
95. Feng, W., Li, Y., Du, J., Wang, W. & Zhong, X. Highly efficient and stable quasi-solid-state quantum dot-sensitized solar cells based on a superabsorbent polyelectrolyte. *J. Mater.*

Chem. 2016; A 4: 1461.

96. Chen, H.-Y. et al. Dextran based highly conductive hydrogel polysulfide electrolyte for efficient quasi-solid-state quantum dot-sensitized solar cells. *Electrochim. Acta*. 2013; 92: 117–123.
97. Huo, Z. et al. A novel polysulfide hydrogel electrolyte based on low molecular mass organogelator for quasi-solid-state quantum dot-sensitized solar cells. *J. Power Sources*. 2015; 284: 582–587.
98. Kim, H., Hwang, I. & Yong, K. Highly durable and efficient quantum dot-sensitized solar cells based on oligomer gel electrolytes. *ACS Appl. Mater. Interfaces*. 2014; 6: 11245–11253.
99. Mingsukang, M. A., Buraidah, M. H. & Careem, M. A. Development of gel polymer electrolytes for application in quantum dot-sensitized solar cells. *Ionics (Kiel)*. 2017;23: 347–355.
100. Yang, Y. & Wang, W. A new polymer electrolyte for solid-state quantum dot sensitized solar cells. *J. Power Sources*. 2015; 285: 70–75.
101. Yan, K. et al. A Quasi-Quantum Well Sensitized Solar Cell with Accelerated Charge Separation and Collection. *J. Am. Chem. Soc.* 2013;135: 9531–9539.
102. Yu, Z. et al. Highly efficient quasi-solid-state quantum-dot-sensitized solar cell based on hydrogel electrolytes. *Electrochem. commun.* 2010;12: 1776–1779.
103. Duan, J. et al. Multifunctional graphene incorporated polyacrylamide conducting gel electrolytes for efficient quasi-solid-state quantum dot-sensitized solar cells. *J. Power Sources*.2015; 284: 369–376.
104. Feng, W., Zhao, L., Du, J., Li, Y. & Zhong, X. Quasi-solid-state quantum dot sensitized solar cells with power conversion efficiency over 9% and high stability. *J. Mater. Chem. A*. 2016; 4: 14849–14856.
105. Jaudouin, O., Robin, J.-J., Lopez-Cuesta, J.-M., Perrin, D. & Imbert, C. Ionomer-based

polyurethanes: a comparative study of properties and applications. *Polym. Int.* 2012;61: 495–510.

106. Gao, R., Zhang, M., Dixit, N., Moore, R. B. & Long, T. E. Influence of ionic charge placement on performance of poly(ethylene glycol)-based sulfonated polyurethanes. *Polymer*. 2012; 53: 1203–1211.
107. Yu, W. W. & Peng, X. Formation of high-quality CdS and other II–VI semiconductor nanocrystals in noncoordinating solvents: tunable reactivity of monomers. *Angew. Chem., Int. Ed.* 2002; 41: 2368.
108. Veerathangam, K., Pandian, M. S. & Ramasamy, P. Size-dependent photovoltaic performance of cadmium sulfide (CdS) quantum dots for solar cell applications. *J. Alloys Compd.* 2018;735: 202–208.
109. Peng, Z. A. & Peng, X. Formation of high-quality CdTe, CdSe, and CdS nanocrystals using CdO as precursor. *J. Am. Chem. Soc.* 2001;123: 183.
110. Subramanian, A. et al. Improved photovoltaic performance of quantum dot-sensitized solar cells using multi-layered semiconductors with the effect of a ZnSe passivation layer. *New J. Chem.* 2017;41: 5942–5949.
111. Marcano, D. C. et al. Improved synthesis of graphene oxide. *ACS Nano*. 2010; 4: 4806–4814.
112. Patel, D. K. Functionalized Graphene Tagged Polyurethanes for Corrosion Inhibitor and Sustained Drug Delivery. *ACS Biomater. Sci. Eng.* 2017;3: 3351.
113. Datsyuk, V. et al. Chemical oxidation of multiwalled carbon nanotubes. *Carbon N. Y.* 2008;46: 833–840.
114. Chiang, Y.-C., Lin, W.-H. & Chang, Y.-C. The influence of treatment duration on multi-walled carbon nanotubes functionalized by H<sub>2</sub>SO<sub>4</sub>/HNO<sub>3</sub> oxidation. *Appl. Surf. Sci.* 2011; 257: 2401–2410.
115. Kumar, S. Functionalized Thermoplastic Polyurethane as Hole Conductor for Quantum

Dot-Sensitized Solar Cell. ACS Appl. Energy Mater. 2018;1: 4641.

116. Prakash, R. et al. Functionalized polyurethane composite gel electrolyte with cosensitized photoanode for higher solar cell efficiency using a passivation layer. *Nanoscale Adv.* 2022; doi:10.1039/D1NA00801C.
117. Jun, H. K., Careem, M. A. & Arof, A. K. Quantum dot-sensitized solar cells—perspective and recent developments: a review of Cd chalcogenide quantum dots as sensitizers. *Renew. Sustain. Energy Rev.* 2013;22: 148.
118. Yeh, M.-H. et al. Conducting polymer-based counter electrode for a quantum-dot-sensitized solar cell (QDSSC) with a polysulfide electrolyte. *Electrochim. Acta*. 2011; 57: 277–284.
119. Polizos, G. Structure and electrical conductivity in novel polyurethane ionomers. *Polym. Int.* 2000; 49: 987.
120. Lee, Y.-L. & Lo, Y.-S. Highly efficient quantum-dot-sensitized solar cell based on co-sensitization of CdS/CdSe. *Adv. Funct. Mater.* 2009; 19: 604.
121. Tian, J. et al. Enhanced performance of CdS/CdSe quantum dot cosensitized solar cells via homogeneous distribution of quantum dots in TiO<sub>2</sub> film. *J. Phys. Chem. C*. 2012; 116: 18655–18662.
122. Lin, K.-H. Charge transfer in the heterointerfaces of CdS/CdSe cosensitized TiO<sub>2</sub> photoelectrode. *J. Phys. Chem. C*. 2012; 116: 1550.
123. BO, J., Na, J. & CH, K. Synthesis of Chitosan Derivatives with Anionic Groups and Its Biocompatibility In Vitro. *J. Ind. Eng. Chem.* 2007;13: 772–776.
124. Banerjee, S. Highly efficient polyurethane ionomer corrosion inhibitor: the effect of chain structure. *RSC Adv.* 2011;1: 199.
125. Prakash, R. & Maiti, P. Functionalized Thermoplastic Polyurethane Gel Electrolytes for Cosensitized TiO<sub>2</sub>/CdS/CdSe Photoanode Solar Cells with High Efficiency. *Energy & Fuels*. 2020; 34: 16847–16857.
126. Shi, Z. & Holdcroft, S. Synthesis and proton conductivity of partially sulfonated poly

([vinylidene difluoride-co-hexafluoropropylene]-b-styrene) block copolymers. *Macromolecules*. 2005; 38: 4193.

127. Srivastava, S. Novel shape memory behaviour in IPDI based polyurethanes: Influence of nanoparticle. *Polymer*. 2017; 110: 95.
128. Fernández, C. E. Crystal structure and morphology of linear aliphatic n-polyurethanes. *Macromolecules*. 2010; 43: 4161.
129. Leonat, L., Sbarcea, G. & Branzoi, I. V. Cyclic voltammetry for energy levels estimation of organic materials. *U.P.B. Sci. Bull., Ser. B* 2013; B 75: 111.
130. Banerjee, S., Mishra, A., Singh, M. M. & Maiti, P. Effects of nanoclay and polyurethanes on inhibition of mild steel corrosion. *J. Nanosci. Nanotechnol.* 2011;11: 966.
131. Fuller, J., Breda, A. C. & Carlin, R. T. Ionic liquid-polymer gel electrolytes. *J. Electrochem. Soc.* 1997;144: L67.
132. Makuła, P., Pacia, M. & Macyk, W. How to correctly determine the band gap energy of modified semiconductor photocatalysts based on UV–Vis spectra. *The Journal of Physical Chemistry Letters* vol. 2018; 9: 6814–6817.
133. Tao, P., Li, Y., Siegel, R. W. & Schadler, L. S. Transparent luminescent silicone nanocomposites filled with bimodal PDMS-brush-grafted CdSe quantum dots. *J. Mater. Chem. C*. 2013;1: 86.
134. Brown, A. S. & Green, M. A. Detailed balance limit for the series constrained two terminal tandem solar cell. *Phys. E Low-dimensional Syst. Nanostructures*. 2002; 14: 96–100.
135. Soloviev, V. N., Eichhöfer, A., Fenske, D. & Banin, U. Size-dependent optical spectroscopy of a homologous series of CdSe cluster molecules. *J. Am. Chem. Soc.* 2001; 123: 2354–2364.
136. Tessler, N., Medvedev, V., Kazes, M., Kan, S. & Banin, U. Efficient near-infrared polymer nanocrystal light-emitting diodes. *Science*. 2002;295: 1506–1508.
137. Shevchenko, E. V et al. Self-assembled binary superlattices of CdSe and Au nanocrystals

and their fluorescence properties. *J. Am. Chem. Soc.* 2008;130: 3274–3275.

138. Huang, F. et al. Doubling the power conversion efficiency in CdS/CdSe quantum dot sensitized solar cells with a ZnSe passivation layer. *Nano Energy.* 2016; 26: 114–122.
139. Hori, K. et al. Interface passivation effects on the photovoltaic performance of quantum dot sensitized inverse opal TiO<sub>2</sub> solar cells. *Nanomaterials.* 2018; 8: 460.
140. Sambur, J. B. & Parkinson, B. A. CdSe/ZnS Core/Shell Quantum Dot Sensitization of Low Index TiO<sub>2</sub> Single Crystal Surfaces. *J. Am. Chem. Soc.* 2010;132: 2130–2131.
141. Shen, Q., Kobayashi, J., Diguna, L. J. & Toyoda, T. Effect of ZnS coating on the photovoltaic properties of CdSe quantum dot-sensitized solar cells. *J. Appl. Phys.* 2008; 103: 084304.
142. Verma, S., Kaniyankandy, S. & Ghosh, H. N. Charge Separation by Indirect Bandgap Transitions in CdS/ZnSe Type-II Core/Shell Quantum Dots. *J. Phys. Chem. C.* 2013; 117: 10901–10908.
143. Huang, F. et al. Impacts of surface or interface chemistry of ZnSe passivation layer on the performance of CdS/CdSe quantum dot sensitized solar cells. *Nano Energy.* 2017; 32: 433–440.
144. Lu, S. et al. Impacts of Mn ion in ZnSe passivation on electronic band structure for high efficiency CdS/CdSe quantum dot solar cells. *Dalton Trans.* 2018;47: 9634–9642.
145. Jovanovski, V. et al. A Sulfide/Polysulfide-Based Ionic Liquid Electrolyte for Quantum Dot-Sensitized Solar Cells. *J. Am. Chem. Soc.* 2011;133: 20156–20159.
146. Santra, P. K. & Kamat, P. V. Mn-doped quantum dot sensitized solar cells: a strategy to boost efficiency over 5%. *J. Am. Chem. Soc.* 2012;134: 2508–2511.
147. Su’ait, M. S., Rahman, M. Y. A. & Ahmad, A. Review on polymer electrolyte in dye-sensitized solar cells (DSSCs). *Sol. Energy.* 2015; 115: 452–470.
148. Fenton, D. E. Complexes of alkali metal ions with poly (ethylene oxide). *Polymer.* 1973; 14: 589.

149. Bella, F. & Bongiovanni, R. Photoinduced polymerization: an innovative, powerful and environmentally friendly technique for the preparation of polymer electrolytes for dye-sensitized solar cells. *J. Photochem. Photobiol. C Photochem. Rev.* 2013; 16: 1–21.
150. Yousefi, N. et al. Highly aligned, ultralarge-size reduced graphene oxide/polyurethane nanocomposites: mechanical properties and moisture permeability. *Compos. Part A Appl. Sci. Manuf.* 2013;49: 42–50.
151. Shamsi, R., Koosha, M. & Mahyari, M. Improving the mechanical, thermal and electrical properties of polyurethane-graphene oxide nanocomposites synthesized by in-situ polymerization of ester-based polyol with hexamethylene diisocyanate. *J. Polym. Res.* 2016; 23: 1–11.
152. Saxena, D., Rana, D., Bhoje Gowd, E. & Maiti, P. Improvement in mechanical and structural properties of poly(ethylene terephthalate) nanohybrid. *SN Appl. Sci.* 2019;1: 1363.
153. Suen, M., Lee, H., Chen, H. & Chen, C. Water remaining properties of nonwoven fabrics treated with the polyurethane polymers containing carboxylic acid group and the thermal and structural characterization of the polymers. *J. Appl. Polym. Sci.* 2008;107: 2618–2625.
154. Patel, D. K. et al. Graphene as a chain extender of polyurethanes for biomedical applications. *RSC Adv.* 2016;6: 58628–58640.
155. Jung, B.-O., Na, J. & Kim, C. H. Synthesis of chitosan derivatives with anionic groups and its biocompatibility in vitro. *J. Ind. Eng. Chem.* 2007;13: 772.
156. Wong, C. S. & Badri, K. H. Chemical analyses of palm kernel oil-based polyurethane prepolymer. 2012.
157. Chen, Y., Zhou, S., Yang, H. & Wu, L. Structure and properties of polyurethane/nanosilica composites. *J. Appl. Polym. Sci.* 2005;95: 1032–1039.
158. Wang, S.-W. & Colby, R. H. Linear Viscoelasticity and Cation Conduction in Polyurethane Sulfonate Ionomers with Ions in the Soft Segment–Single Phase Systems. *Macromolecules* 2018;51: 2757–2766.

159. Radhakrishnan, T., Georges, M. K., Sreekumari Nair, P., Luyt, A. S. & Djoković, V. Composites comprising CdS nanoparticles and poly(ethylene oxide): optical properties and influence of the nanofiller content on the thermal behaviour of the host matrix. *Colloid Polym. Sci.* 2008;286: 683–689.
160. Dwivedi, D. K., Shankar, D. & Dubey, M. Synthesis, structural and optical characterization of CdS nanoparticles. *J. ovonic Res.* 2010; 6: 57–62.
161. Duchaniya, R. K. Optical studies of chemically synthesis CdS nanoparticles. *Int. J. Mining, Metall. Mech. Eng.* Vol. 2014;2.
162. Fritzinger, B., Capek, R. K., Lambert, K., Martins, J. C. & Hens, Z. Utilizing self-exchange to address the binding of carboxylic acid ligands to CdSe quantum dots. *J. Am. Chem. Soc.* 2010; 132: 10195.
163. Kamat, P. V. Meeting the clean energy demand: nanostructure architectures for solar energy conversion. *J. Phys. Chem. C.* 2007; 111: 2834–2860.
164. Yeh, T., Syu, J., Cheng, C., Chang, T. & Teng, H. Graphite oxide as a photocatalyst for hydrogen production from water. *Adv. Funct. Mater.* 2010;20: 2255–2262.
165. Moon, M., Alam, M., Rahman, M., Hossain, J. & Ismail, A. B. M. Comparative study of the second generation a-Si: H, CdTe, and CIGS thin-film solar cells. in *Advanced Materials Research* vol. 2019; 1154: 102–111.
166. Palm, J., Probst, V. & Karg, F. H. Second generation CIS solar modules. *Sol. Energy.* 2004; 77: 757–765.
167. Conibeer, G. Third-generation photovoltaics. *Mater. today.* 2007; 10: 42–50.
168. Kamat, P. V. Boosting the efficiency of quantum dot sensitized solar cells through modulation of interfacial charge transfer. *Acc. Chem. Res.* 2012;45: 1906–1915.
169. Kongkanand, A., Tvrdy, K., Takechi, K., Kuno, M. & Kamat, P. V. Quantum Dot Solar Cells. Tuning Photoresponse through Size and Shape Control of CdSe–TiO<sub>2</sub> Architecture. *J. Am. Chem. Soc.* 2008;130: 4007.

170. Shockley, W. & Queisser, H. J. Detailed Balance Limit of Efficiency of p-n Junction Solar Cells. *J. Appl. Phys.* 1961;32: 510–519.
171. Buitrago, E., Novello, A. M. & Meyer, T. Third-Generation Solar Cells: Toxicity and Risk of Exposure. *Helv. Chim. Acta*. 2020; 103: e2000074.
172. Vainio, H., Heseltine, E., Partensky, C. & Wilbourn, J. Meeting of the IARC working group on beryllium, cadmium, mercury and exposures in the glass manufacturing industry. *Scand. J. Work. Environ. Health*. 1993; 360–363.
173. Wang, F. et al. Considerably improved photovoltaic performance of carbon nanotube-based solar cells using metal oxide layers. *Nat. Commun.* 2015;6: 1–7.
174. Appenzeller, J. et al. Field-modulated carrier transport in carbon nanotube transistors. *Phys. Rev. Lett.* 2002;89: 126801.
175. Miyauchi, Y. et al. Brightening of excitons in carbon nanotubes on dimensionality modification. *Nat. Photonics*. 2013; 7: 715–719.
176. Iijima, S. Helical microtubules of graphitic carbon. *Nature*. 1991; 354: 56–58.
177. Treacy, M. M. J., Ebbesen, T. W. & Gibson, J. M. Exceptionally high Young's modulus observed for individual carbon nanotubes. *Nature*. 1996; 381: 678–680.
178. Athanasopoulos, N., Baltopoulos, A., Matzakou, M., Vavouliotis, A. & Kostopoulos, V. Electrical conductivity of polyurethane/MWCNT nanocomposite foams. *Polym. Compos.* 2012; 33: 1302–1312.
179. Bouhamed, A., Al-Hamry, A., Müller, C., Choura, S. & Kanoun, O. Assessing the electrical behaviour of MWCNTs/epoxy nanocomposite for strain sensing. *Compos. Part B Eng.* 2017;128: 91–99.
180. Luo, Q. et al. Recent advances in carbon nanotube utilizations in perovskite solar cells. *Adv. Funct. Mater.* 2021;31: 2004765.
181. Kokal, R. K. Solar cells with PbS quantum dot sensitized TiO<sub>2</sub>–multiwalled carbon nanotube composites, sulfide-titania gel and tin sulfide coated C-fabric. *Phys. Chem. Chem.*

Phys. 2017;19: 26330.

182. Arepalli, S., Freiman, S., Hooker, S. A. & Migler, K. D. Measurement Issues in Single-Wall Carbon Nanotubes. NIST. 2008.
183. Lachman, N. et al. Raman response of carbon nanotube/PVA fibers under strain. *J. Phys. Chem. C.* 2009; 113: 4751–4754.
184. Sui, X.-M., Giordani, S., Prato, M. & Wagner, H. D. Effect of carbon nanotube surface modification on dispersion and structural properties of electrospun fibers. *Appl. Phys. Lett.* 2009; 95: 233113.
185. Xia, C. et al. One-step synthesis of near-infrared emitting and size tunable CuInS<sub>2</sub> semiconductor nanocrystals by adjusting kinetic variables. *CrystEngComm.* 2014;16: 7469–7477.
186. Liu, Y. et al. CuInS<sub>2</sub> Quantum Dots-based Off/On Probe for Detection of Cetyltrimethylammonium Bromide and L-Cysteine. *IOP Conf. Ser. Mater. Sci. Eng.* 2020;735: 12017.
187. Liu, S., Zhang, H., Qiao, Y. & Su, X. One-pot synthesis of ternary CuInS<sub>2</sub> quantum dots with near-infrared fluorescence in aqueous solution. *RSC Adv.* 2012;2: 819–825.
188. Steirer, K. X. et al. Nickel oxide interlayer films from nickel formate–ethylenediamine precursor: influence of annealing on thin film properties and photovoltaic device performance. *J. Mater. Chem.* 2015;A 3: 10949–10958.
189. Imran, M., Coskun, H., Khan, N. A. & Ouyang, J. Role of annealing temperature of nickel oxide (NiOx) as hole transport layer in work function alignment with perovskite. *Appl. Phys.* 2021;A 127: 1–8.
190. Sachtler, W. M. H., Dorgelo, G. J. H. & Holscher, A. A. The work function of gold. *Surf. Sci.* 1966;5: 221–229.
191. Merrill, E. W. High Polymer Series: Polyurethanes. Chemistry and technology. vol. 1, Chemistry. JH Saunders and KC Frisch. Interscience (Wiley), New York. 1963;140: 1083.

192. Hepburn, C. Polyurethane elastomers. Springer Science & Business Media. 2012.
193. Ionescu, M. Chemistry and technology of polyols for polyurethanes. iSmithers Rapra Publishing. 2005.
194. Heydarnezhad, H. R., Mohammadi, N., Arbe, A. & Alegria, A. How does microstructural design affect the dynamics and rheology of segmented polyurethanes? *Macromolecules*. 2020; 53: 5381–5398.
195. Akindoyo, J. O. et al. Polyurethane types, synthesis and applications—a review. *Rsc Adv.* 2016;6: 114453–114482.
196. Walker, B. M. & Rader, C. P. Handbook of thermoplastic elastomers. Springer. 1979.
197. Yoon, P. J. & Han, C. D. Effect of thermal history on the rheological behavior of thermoplastic polyurethanes. *Macromolecules*. 2000; 33: 2171–2183.
198. Lucio, B. & de la Fuente, J. L. Rheological cure characterization of an advanced functional polyurethane. *Thermochim. Acta*. 2014; 596: 6–13.
199. Díez-García, I., Keddie, J. L., Eceiza, A. & Tercjak, A. Optimization of adhesive performance of waterborne poly (urethane-urea)s for adhesion on high and low surface energy surfaces. *Prog. Org. Coatings*. 2020; 140: 105495.
200. Tenorio-Alfonso, A., Sánchez, M. C. & Franco, J. M. Synthesis and mechanical properties of bio-sourced polyurethane adhesives obtained from castor oil and MDI-modified cellulose acetate: Influence of cellulose acetate modification. *Int. J. Adhes. Adhes.* 2019;95: 102404.
201. Lei, L., Buddingh, J., Wang, J. & Liu, G. Transparent omniphobic polyurethane coatings containing partially acetylated  $\beta$ -cyclodextrin as the polyol. *Chem. Eng. J.* 2020;380: 122554.
202. Lu, X., Liang, B., Sheng, X., Yuan, T. & Qu, J. Enhanced thermal conductivity of polyurethane/wood powder composite phase change materials via incorporating low loading of graphene oxide nanosheets for solar thermal energy storage. *Sol. Energy Mater. Sol. Cells*. 2020; 208: 110391.

203. Lucio, B. & de la Fuente, J. L. Non-isothermal DSC and rheological curing of ferrocene-functionalized, hydroxyl-terminated polybutadiene polyurethane. *React. Funct. Polym.* 2016; 107: 60–68.
204. Tanner, R. I. & Walters, K. *Rheology: an historical perspective*. Elsevier. 1998.
205. Bhattacharya, P. et al. Graphene decorated with hexagonal shaped M-type ferrite and polyaniline wrapper: a potential candidate for electromagnetic wave absorbing and energy storage device applications. *Rsc Adv.* 2014;4: 17039–17053.
206. Ghobashy, M. M. & Abdeen, Z. I. Radiation crosslinking of polyurethanes: characterization by FTIR, TGA, SEM, XRD, and raman spectroscopy. *J. Polym.* 2016.
207. Trovati, G., Sanches, E. A., Neto, S. C., Mascarenhas, Y. P. & Chierice, G. O. Characterization of polyurethane resins by FTIR, TGA, and XRD. *J. Appl. Polym. Sci.* 2010;115: 263–268.
208. Curro, J. G. & Pincus, P. A theoretical basis for viscoelastic relaxation of elastomers in the long-time limit. *Macromolecules.* 1983;16: 559–562.



### **List of Publications**

1. **Ravi Prakash** & P. Maiti, Functionalized Thermoplastic Polyurethane Gel Electrolytes for Cossensitized TiO<sub>2</sub>/CdS/CdSe Photoanode Solar Cells with High Efficiency. *Energy & Fuels*. 2020; 34: 16847–16857.
2. **Ravi Prakash**, I C Maurya, P. Srivastava, S. Mondal, B. Ray and P. Maiti, Functionalized Polyurethane Composite Gel Electrolyte with Cossensitized Photoanode for Higher Solar Cell Efficiency using Passivation Layer. *Nanoscale Advances*. 2022; 4: 1199-1212.
3. **Ravi Prakash** & P. Maiti, The effect of Chemical Tagging of Graphene oxide in Thermoplastic Polyurethane on Gelation Behavior. *Polymer*, 2022; 253: 124999
4. **Ravi Prakash**, S. Das & P. Maiti, Non-Toxic CuInS<sub>2</sub> Quantum Dots Sensitized Solar Cell with CNT-Tagged Functionalized Polyurethane Gel Electrolytes. *Communicated*
5. S. Kumar, **Ravi Prakash**, P. Maiti, Redox mediation through integrating chain extenders in active ionomer polyurethane hard segments in CdS Quantum dot sensitized solar cell. *Solar energy*. 2022; 231: 985-1001
6. O. Prakash, S Bihari, Keshav, S Tiwari, **Ravi Prakash**, P Maiti Dehydrohalogenated poly (vinylidene fluoride)-based anion exchange membranes for fuel cell applications. *Mater. Today Chem.* 2022; 23: 100640.
7. S. Kumar, P.K. Yadav, **Ravi Prakash**, A, Santra, & P. Maiti, Multifunctional Graphene Oxide Implanted Polyurethane Ionomer Gel Electrolytes for Quantum Dots Sensitized Solar Cells. *Journal of Alloys and Compounds*, 2022; 922: 166121

### **Book Chapters**

1. Carbon Nanotube based Nanomaterials for Solar Energy Storage Devices. **Ravi Prakash**, Sunil Kumar, and Pralay Maiti. *Current and Future Developments in Nanomaterials, 2022, 1-18*. Bentham Science Publishers.
2. Advanced Batteries and Charge Storage Devices based on Nanowires. Sunil Kumar, **Ravi Prakash** and Pralay Maiti. *Current and Future Developments in Nanomaterials, 2022, 160-176*. Bentham Science Publishers.



### **Conference Contributions**

1. Poster presentation in international e-Conference on Materials Science and Technology (ICMT 2021) November 12-14, 2021 at mahatma Gandhi University, Kottayam, Kerala, India.
2. Poster presentation in international e-Conference on Advanced Material for Better Tomorrow (AMBT)-2021 at IIT BHU Varanasi, India.
3. Poster presentation in International Webinar on Development of Advanced materials and their Characterizations (IWDAMC) held on 15<sup>th</sup> September 2021.
4. Oral Presentation in e-Conference on Research & Industrial Conclave (RIC2022), IIT Guwahati.
5. Poster presentation in international e-Conference on Nanomaterials & Nanoengineering APA Nanoform-2022, February 24-26, 2022, IIT Delhi.