MENTORSHIP, SCHOLARSHIP, AND SERVICE: A SPECIAL ISSUE HONOURING PROFESSOR ADAMU N. BABA-KUTIGI, FNIP ON HIS RETIREMENT
FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 ANB Special Issue, 2026, pp 217 – 221
DOI: https://doi.org/10.33003/fjs-2026-10(ANB-K)-5787

Organic Encapsulation: Effect of Incorporating Pod Extract (*Cola nitida)* in CdS as Electron Transport Layer (ETL) in Perovskite Solar Cells

***Ahuome B. Abubakar, Daramola T. Busayo, Adamu M. Aminu, Samaila Muhammad and Isah, Shaibu**

Department of Physics, Federal University Dutsin-Ma, Dutsin-Ma, Katsina State, Nigeria.

*Corresponding authors' email: babubakar@fudutsinma.edu.ng

ABSTRACT

The introduction of organic perovskite solar cells has shown a remarkable development in solar energy technology. It bridges the gap posed by the hazardous and poisonous activities of the pure inorganic perovskite solar cells. This study investigates the effect of incorporating pod extract (Cola nitida) in chemical bath deposited cadmium sulfide (CdS) films as an electron transport layer (ETL) in perovskite solar cells (PSCs). The electrical properties of the encapsulated material were studied, focusing on the electrical resistivity and the measurement of the mobility of the charge carriers. The optical properties were studied using UV-VIS and near-infrared spectroscopy to characterize the material's response to photon energy. The UV spectroscopy revealed good absorbance across the visible and ultraviolet ranges, with the encapsulated films showing about a 22.7% enhancement compared to the as-deposited film. This enhancement is attributable to the bioactive phytochemicals in Cola nitida such as tannins, flavonoids, and alkaloids, which passivate the surface defects in the film and thus increase the optical path length through modification of the electronic structure. The energy bandgaps of *2.15eV* and *2.10eV* were obtained for the deposited CdS and encapsulated films respectively. These values are consistent with the widely reported direct band gap of CdS nanoparticles, which usually ranges from 2.10 to 2.5 eV for bulk CdS. The reduction in band gap energy shows agreement with the expected influence of organic encapsulation on the electronic structure of semiconductor nanoparticles.

Keywords: Perovskite Solar Cell, Electron Transport Layer, Cadmium Sulfide, Pod Extract encapsulation, Energy Bandgap

INTRODUCTION

The 4.3×10^{20} J of energy obtained from the sun in an hour is more than enough to balance the Earth's energy demand in a year of 4.1×10^{20} J (Jun *et al.,* 2013). This has paved the way for researchers to harness solar cell technology in energy generation through photovoltaic applications. Chronologically, solar cell technology has metamorphosed into three generations (Werner, 2004). The first-generation solar cells were based on single-crystal semiconductor wafers. The second generation used thin layers of polycrystalline semiconductors, and their production was highly adaptable, lightweight, and inexpensive. However, the performance is below that of the first generation. The third generation of solar cells is a new type of chemical solar cell. The third generation ranges from dye-sensitized solar cells (DSSC) up to current perovskite solar cells (PSCs) with the structure combining nanostructured electrodes and sufficient photosensitizers (O'Regan & Gratzel, 1991). PSCs have structures similar to those of dye-sensitized solar cells, with dye molecules replaced by perovskite nanocrystals as the light-harvesting material. PSCs have produced power conversion efficiency (PCE) greater than 25% in less than 11 years (Kojima *et al.,* 2009; Green *et al.,* 2014; Qu *et al.,* 2021). Such timely and extraordinary advances in PCE are achieved using several modifications in the device. This remarkable achievement resulted from different modifications across all the important layers of the PSCs. The absorber (perovskite) material is an important layer in PSCs responsible for absorption of light, creating photostimulated carriers, and transferring the carriers into the PSC network for electrical generation (Stranks *et al.,* 2015 & Xiang *et al.,* 2019). Other layers include the electron transport layer (ETL) and hole transport layers (HTL), whose carrier mobility and conductivities play a vital role in the improved performance of the PSCs (Aslam et al., 2022) (Snaith *et al.,* 2006; Crossland *et al.,* 2013; Leijtens *et al.,* 2013).

A chalcogenide material such as Cadmium sulfide (CdS) is one of the most common semiconductors widely used in recent years as an ETL. Its photoluminescence properties show good optical and electrical properties. Despite various methods (both wet and dry) of deposition of CdS, chemical bath deposition (CBD) is an attractive, simple technique that can yield highly stoichiometric thin films with excellent uniformity (Ahuome and Onimisi, 2016) and without pinholes. CdS has electron mobilities ranging between 1 and 10 $cm^2V^{-1}s^{-1}$ (Yang et al, 2008). A Sputtered CdS film has been successfully used as a replacement for compact TiO_2 in mesoporous Al_2O_3 Scaffolding structures as an ETL in organic perovskite solar cells (OPSC) (Juarez et al., 2014). The absorbance behaviour of CdS is sensitive to factors such as film thickness, surface morphology, and deposition conditions, which can lead to suboptimal light absorption when fabrication parameters are inconsistent. Prolonged environmental exposure degrades optical stability, causing shifts in band gap and reduced performance over time (Molina-Jiménez et al., 2025). Recently, performance optimization of double perovskite solar cells was carried out with different TiO_2, ZnO, CdS, ZnSe, and WS_2; CdS yielded the lowest efficiency of 11.0% compared to 21.56% for WS_2 (Dahiru et al, 2026).

CdS fits well as the window layer in high-efficiency thin-film solar cells based on cadmium telluride (CdTe) and copper indium gallium selenide ($CuIn_xGa_ySe_2$), though with power conversion efficiencies as low as 1.53%. Progressively, CdS nanorods deposited through the hydrothermal method have yielded efficiencies ranging from 8.36%, when used as ETL in perovskite solar cells (Gu et al, 2015), 11.2% when grown through a chemical process and used as ETL in all-low-

temperature-processed perovskite solar cells (Liu et al, 2015), and 15.0% (Peng et al, 2016) in OPSC.

The deployment of metallic silver nanomaterial (AgNPs) in Perovskite Solar Cells (PSCs) provides an important avenue by enabling highly efficient devices to be developed by scattering of light to longer optical path length, or through an interaction via dipole–dipole and resonant energy transfer. However, it has been demonstrated that when AgNPs make direct contact with the perovskite absorber, it results in back e.m.f. reaction, recombination, and etching of the plasmonic effects are observed (Eli *et al*., 2020). Reports have demonstrated that TiO_2, SiO_2, and P_4VP were applied as encapsulants to the perovskite absorber to prevent the effects stated above (Eli *et al*., 2020; Zhang *et al*., 2013). However, it limits the transfer of carriers generated by the perovskite to the surrounding porous semiconductor. Biogenically synthesized silver nanoparticles have shown some applications in antibacterial and antioxidant activities, and as an antimicrobial additive in paint (Jain *et al.,* 2021; Yekeen *et al.,* 2017; Lateef *et al.,* 2016). Cola *nitida* is one of the light-harvesting organic materials having a far-field light scattering effect. Encapsulating AgNPs improves the light-trapping of the devices. Properties such as electrical characteristics and light absorption are significantly enhanced due to improved optical path length. With the introduction of one coating cycle of AgNPs, the highest power conversion efficiency (PCE) of the perovskite solar cells increases from a reference value of 4.543 to 10.856% (Danladi, 2023). Incorporating green-synthesized silver nanoparticles in perovskite solar cells has seldom been reported. This work investigates the effect of incorporating biosynthesized nanoparticles (Cola nitida-encapsulated CdS) as ETL in perovskite solar cells. The properties studied include Optical properties through UV-Vis spectroscopy and electrical properties through Four-Points Probe analysis and Hall Effect Measurements.

MATERIALS AND METHODS

Cadmium Chloride ($CdCl_2$, ADRICH 99.99%), Trisodium Citrate ($Na_3C_6H_5O_7$, ADRICH 99.98%), Thiourea ($C{=}S(NH_2)_2$, BDH 99.5%). The green metal nanoparticles were extracted from the pod through Hot Aqueous Extraction (Decoction). 10 g of dried and ground pods were added to 100 mL of distilled water and heated at 70 °C for 45 minutes. The solution was allowed to cool and was filtered to obtain the green reducing agent (Kanchi & Ahmed, 2018). The filtrate was treated with the cation precursor $CdCl_2$ or Cd $(NO_3)_2$.

The deposition of Cadmium Sulphide (CdS) thin film layer through the electroless chemical deposition method was done as follows. 20 mL of 0.15 M $CdCl_2$ (cadmium Chloride), 25ml of 0.5 M $Na_3C_6H_5O_7$ (trisodium citrate), 10ml of 0.5 M KOH (Potassium Hydroxide), 25ml of 0.5 M $C{=}S$ $(NH_2)_2$ (Thiourea), and 20ml of deionized water were added together in a 100ml beaker at a reaction temperature of 70°C. With the pH value of the solution maintained between 10 and 11 and a constant stirring rate of 100rpm, the CdS thin film layer was deposited for 120 mins (Ahuome and Onimisi, 2016).

CdS layer was placed between the poles of a bar magnet, and a load voltage V_L was applied through a variable-control direct current (d.c) power supply, and the corresponding Hall voltage, V_H was then measured as shown in Figure 1a. The slope of the graph of Hall voltage against load voltage was obtained. Then the charge carrier mobility was calculated as

$$\mu = \frac{V_H L}{W V_L B} = \frac{Slope \times L}{W \times B} \quad (1)$$

Where L and B are dimensions of the area covered by the film, and B is the magnetic field strength (Onimisi and Musa 2013). The four-point probe collinear device revealed the voltage drop across the inner probes 2 and 3 with a variable current allowed to pass through the outer probes 1 and 4, as shown in Figure 1b. The slope of the graph of voltage drop against the current was obtained. Thus, the resistivity is given as,

$$\rho = 2\pi S\left(\frac{V}{I}\right) = 2\pi S \times slope \quad (2)$$

Where S is the uniform space between the probe's points (Ahuome and Onimisi, 2016).

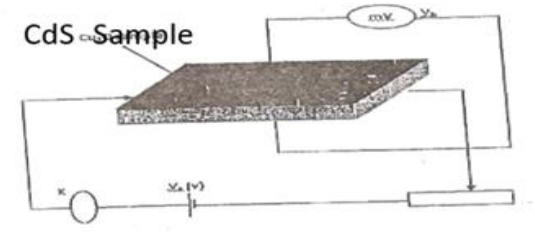


Figure 1a: Hall voltage measurement set-up

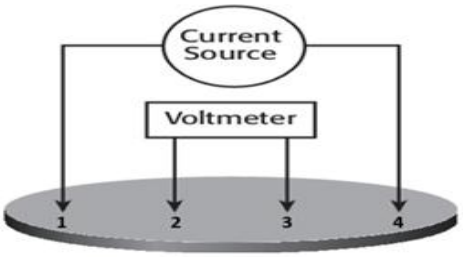


Figure 1b: Four-point probes for resistivity measurement

Bandgap energy: The absorbance of the CdS layer between the ultraviolet, visible range and near-infrared wavelength (300 nm – 680nm) was studied through the use of a JENWAY 6405 UV/VIS Spectrophotometer. A baseline was formed through baseline scanning using a blank slide in order to cancel the effect of absorption by the glass. The deposited layer was tested, and absorbances were measured as plotted in Figure 3a. The Tau'c plot revealed the band gap energies as plotted in Figure 4a and 4b.

RESULTS AND DISCUSSION

Electrical Properties of the encapsulated CdS

The current-voltage characterization in the dark was studied as shown in Figure 2. The characteristics formed the model shown by the equation $y = 12.766x + 16.622$ where y represents the voltage drop in mV, and x represents the corresponding current in μA as measured. The slope of $12.766 \times 10^3 \Omega$ was obtained. Using equation 2 with a probe spacing of $0.1cm$, the material showed the resistivity of $8.022 \times 10^3 \Omega cm$. Though with little concern, this value measured favourably with the existing literature (Chaure et al, 2003; Ahuome & Onimisi, 2016). The Hall effect measurement under a *0.5 T* magnetic field strength was graphed as shown in Figure 2b, with the trend $y = 1.4017x - 0.1036$ where y represents the Hall voltage in *V*, as measured against the load voltage in *V* represented by x. The mobility of the charge carrier of $2cm \times 1cm$ film was calculated to be $5.6068\ cm^2V^{-1}s^{-1}$. (Yang et al, 2008; Walker et al, 2015).

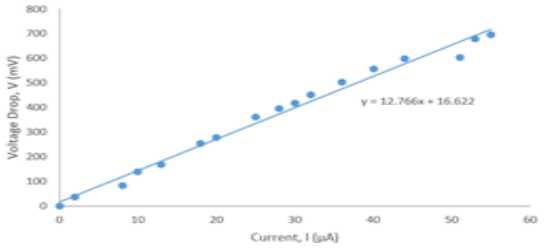


Figure 2a: I-V in Dark of Encapsulated CdS for Resistivity Calculation

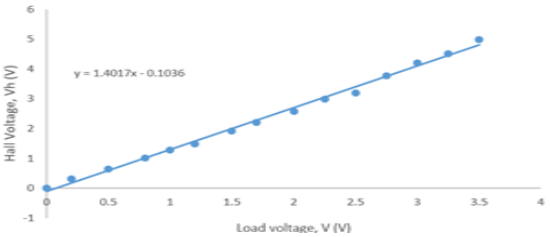


Figure 2b: Hall voltage vs Load voltage for Mobility of the Charge Carrier Calculation

Optical Properties of the Encapsulated CdS

Figure 3 gives the optical absorbance of the deposited and the encapsulated cell. It is noticeable that the optical activity of the material revealed that the absorbance values for both samples increase as wavelength decreases from 660 nm to approximately 380 nm, after which the values plateau. This activity within this range of wavelengths (UV-Visible) confirmed the semiconducting nature of the deposited CdS and the encapsulated cell. For the pure CdS, the absorbance increases from 0.6343 at 660 nm to a peak of approximately 5.2273 at 360 nm. The Cola nitida-encapsulated CdS, on the other hand, exhibits consistently higher absorbance values, rising from 0.8732 at 660 nm to a maximum of approximately 6.4151 at 360 nm. This represents an enhancement in absorbance of approximately 22.7% at 660 nm and a sustained improvement across the entire spectral range measured.

The sharp increase in absorbance between 660 nm and 480 nm for both samples indicates strong photon absorption in this region, which is consistent with the known optical behavior of CdS nanoparticles whose band gap lies within the visible to near-UV spectral range. The absorption edge onset, which corresponds to the fundamental band gap, is observed at approximately 520–540 nm for unencapsulated CdS and shows a slight red-shift to approximately 540–560 nm for the encapsulated sample. This red-shift is indicative of a slight reduction in the optical band gap due to encapsulation.

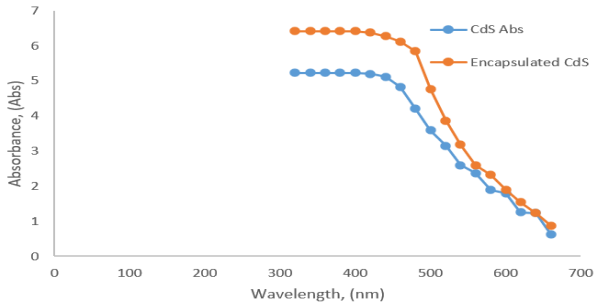
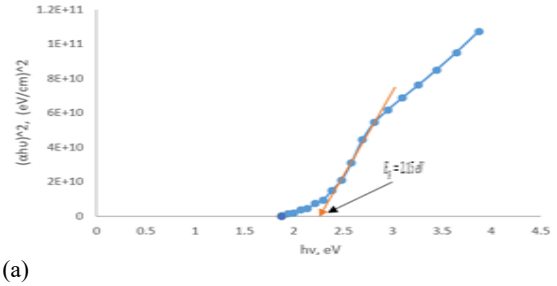
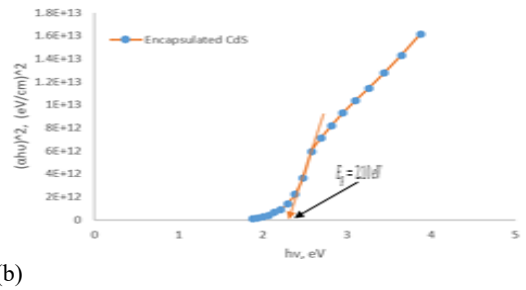


Figure 3: UV-Visible Spectroscopy for Optical Absorbance

The higher absorbance values recorded for the encapsulated sample throughout the measured spectral range suggest that the Cola nitida extract significantly enhances the optical absorption capacity of CdS nanoparticles. This enhancement is attributable to the bioactive phytochemicals in Cola nitida, the presence of tannins, flavonoids, and alkaloids, which interact with the CdS surface, passivating defects, increasing the optical path length, and modifying the electronic structure of the nanoparticles to enable stronger light-matter interaction.



(a)



(b)

Figure 4: The Tau'c plot of (a) deposited CdS, (b) Cola nitida-encapsulated CdS

The Tau'c plot in Figures 4a and 4b gives the energy bandgaps of the pristine CdS and the encapsulated CdS as 2.15 eV and 2.10 eV respectively. The reduction in the bandgap results from the improved optical activity of the encapsulated cell. This value is consistent with the widely reported direct band gap of CdS nanoparticles, which usually ranges from 2.10 to 2.5 eV for bulk CdS. The variations are attributed to modification of the surface particle size, synthesis method, and film deposition conditions (Manir et al., 2025; Ruiz-Ortega et al., 2023). The reduction in band gap energy is consistent with the expected influence of organic encapsulation on the electronic structure of semiconductor nanoparticles.

CONCLUSION

A uniform CdS film was deposited on a glass substrate via a low-cost and scalable Chemical Bath Deposition (CBD) method, and encapsulated with Cola nitida nanoparticles. The electrical properties studied through electrical resistivity and charge carrier mobility were found to be $8.022 \times 10^3 \Omega cm$

and 5.6068 $cm^2V^{-1}s^{-1}$ respectively. These values are within the literature, indicating an average conductivity of the encapsulated CdS, while the mobility shows an improved value within the range reported by Yang et al and Walker et al. The encapsulation treatment enhanced the material's optical response by 22.7% and showed a narrower bandgap energy of 2.10 eV compared to 2.15 eV of deposited CdS. In conclusion, it was demonstrated that organic encapsulants such as cola nitida can be used to obtain enhanced performance of the metal chalcogenide CdS. This has shown high stability, reproducibility, and a better optical response to photon energy.

REFERENCES

Ahuome, B. A., & Onimisi, M. Y. (2016). Effect of Annealing on Resistivity of Cadmium Sulphide (CdS) Thin-Film Layer, Deposited through Ammonia-Free Chemical Bath Deposition (CBD). *Journal of the Nigerian Association of Mathematical Physics.* Vol. 37(September 2016), pp 343-346.

Aslam, S., Farooqi, A. S., Yusri, M., Rahman, A., Azrah, S., & Samsuri, M. (2022). *Titanium-Based Vacancy-Ordered Double Halide Family in Perovskite Solar Cells*. *2100671*, 1–13. https://doi.org/10.1002/pssa.202100671

Chaure, N.B., Bordas, S., Samantilleke, A.P., Chaure, S.N., Haigh, J. & Dharmadasa I.M. (2003). Investigation of electronic quality of chemical bath deposited cadmium sulphide layers used in thin film photovoltaic solar cells. *Thin Film Solid, Science Direct, Volume 437(1–2) pg 10-17. https://doi.org/10.1016/S0040-6090(03)00671-0*

Crossland, E. J. W., Noel, N., Sivaram, V., Leijtens, T., Alexander-Webber, J. A., & Snaith, H. J. (2013). Mesoporous TiO_2 single crystals delivering enhanced mobility and optoelectronic device performance. *Nature* 495, 215–219 https://doi.org/10.1038/nature11936

Dahiru M. S, Bashir A. A. & Muhammad A. A. (2026). Performance Optimization of Double Perovskite Solar Cells Via Absorber Thickness Engineering, Charge Layer Selection, and Effects Using SCAPS- 1D Simulation. *Journal of Basics and Applied Sciences Research*, 4(3), 106-116. https://dx.doi.oru/10.4314/iobasr.v4i3.12s

Danladi, E., Ichoja, A., Onoja, E. D., Adepehin, D. S., Onwoke, E. E., Ekwu, O. M., & Alfred, D. O. (2023). Broad-band-enhanced and minimal hysteresis perovskite solar cells with interfacial coating of biogenic plasmonic light trapping silver nanoparticles. *Materials Research Innovations*, *27*(7), 521-536. https://doi.org/10.1080/14328917.2023.2204585

Eli, D., Onimisi, M. Y., Garba, S., Gyuk, P. M., Jamila, T., & Boduku, H. P. (2020, March). Improved power conversion efficiency in Perovskite solar cell using silver nanoparticles modified photoanode. In *IOP Conference Series: Materials Science and Engineering* (Vol. 805, No. 1, p. 012005). IOP Publishing. https://doi.org/10.1088/1757-899X/805/1/012005

Green, M., Ho-Baillie, A. & Snaith, H. (2014). The emergence of perovskite solar cells. *Nature Photon* **8**, 506–514 https://doi.org/10.1038/nphoton.2014.134

Gu, S., Chen, Y., Yuan, X., Wang, H., Chen, X., Liu, Y., Jiang, Q., Wu, Z., & Zeng, G. (2015). Facile synthesis of CeO_2 nanoparticle sensitized CdS nanorod photocatalyst with improved visible-light photocatalytic degradation of rhodamine B. *RSC Adv.* 5(97): 79556–9564. https://doi.org/10.1039/c5ra16114b

Jain, A. S., Pawar, P. S., Sarkar, A., Junnuthula, V., & Dyawanapelly, S. (2021). Bionanofactories for green synthesis of silver nanoparticles: Toward antimicrobial applications. *International Journal of Molecular Sciences*, *22*(21), 11993. https://doi.org/10.3390/ijms222111993

Juarez-Perez, E. J., Sanchez,R. S., Badia, L., Garcia-Belmonte, G., Kang, Y. S., Mora-Sero, I., & Bisquert, J. (2014). Photoinduced Giant Dielectric Constant in Lead Halide Perovskite Solar Cells. *J. Phys. Chem. Lett.* 3. 5 (13): 2390–2394. https://doi.org/10.1021/jz5011169

Jun, G. H., Jin, S. H., Lee, B., Kim, B. H., Chae, W.-S., Hong, S. H., & Jeon, S. (2013). Enhanced conduction and charge-selectivity by N-doped graphene flakes in the active layer of bulk-heterojunction organic solar cells. Energy & Environmental Science, 6(10), 3000. https://doi.org/10.1039/c3ee40963e

Kanchi, S., & Ahmed, S. (2018). Green Metal Nanoparticles: Synthesis, Characterization and their Applications. *Scrivener Publishing, Wiley*. ISBN: 978-1-119-41823-8

Kojima, A., Teshima, K., Shirai, Y., & Miyasaka, T. (2009). Organometal Halide Perovskites as Visible-Light Sensitizers for Photovoltaic Cells. Journal of the American Chemical Society, 131(17), 6050–6051. https://doi.org/10.1021/ja809598r

Lateef, A., Azeez, M. A., Asafa, T. B., Yekeen, T. A., Akinboro, A., Oladipo, I. C., ... & Beukes, L. S. (2016). Biogenic synthesis of silver nanoparticles using a pod extract of Cola nitida: Antibacterial and antioxidant activities and application as a paint additive. *Journal of Taibah University for Science*, *10*(4), 551-562. https://doi.org/10.1016/j.jtusci.2015.10.010

Leijtens, T., Lim, J., Teuscher, J., Park, T., Snaith, H. J. (2013). Charge-density-dependent mobility of organic hole-transporters and mesoporous TiO_2 determined by transient mobility spectroscopy: implications for dye-sensitized and organic solar cells. Advanced Materials (Deerfield Beach, Fla.). 25(23):3227-3233. https://doi.org/10.1002/adma.201300947. PMID: 23637046.

Liu, J., Gao, C., Luo, L., Ye, Q., He, X., Ouyang, L., Guo, X., Zhuang, D., Liao, C., Mei, J., & Lau, W. (2015). Low-temperature, solution processed metal sulfide as an electron transport layer for efficient planar perovskite solar cells. *J. Mater. Chem. A*. 3 (22): 11750–11755. https://doi.org/10.1039/c5ta01200g

Molina-Jiménez, J. P., Horta-Piñeres, S. D., Castillo, S. J., Izquierdo, J. L., & Avila, D. A. (2025). Ultra-Thin Films of CdS Doped with Silver: Synthesis and Modification of Optical, Structural, and Morphological Properties by the Doping Concentration Effect. *Coatings*, *15*(4), 431. https://doi.org/10.3390/coatings15040431

O'Regan, B., Grätzel, M. (1991). A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films. *Nature* **353**, 737–740. https://doi.org/10.1038/353737a0

Onimisi, M. Y., & Musa, A. O. (2013). Optimization in the Preparation of Solar Cell Materials. Germany: Lambert Academic Publishing.

Peng, W. C., Chen, Y., & Li, X. Y. (2016). MoS2/reduced graphene oxide hybrid with CdS nanoparticles as a visible light-driven photocatalyst for the reduction of 4-nitrophenol. *Journal of hazardous materials*, *309*, 173-179.

Qu, Z., Ma, F., Zhao, Y., Chu, X., Yu, S., & You, J. (2021). Updated Progresses in Perovskite Solar Cells. *Chinese Phys. Lett.* 38 (10). https://doi.org/10.1088/0256-307X/38/10/107801

Snaith, H. J., Grätzel, M. (2006). Enhanced charge mobility in a molecular whole transporter via addition of redox inactive ionic dopant: Implication to dye-sensitized solar cells. *Appl. Phys. Lett.* 25 vol. 89 (26): 262114. https://doi.org/10.1063/1.2424552

Stranks, S.D., Nayak, P.K., Zhang, W., Stergiopoulos, T. and Snaith, H.J. (2015), Formation of Thin Films of Organic–Inorganic Perovskites for High-Efficiency Solar Cells. Angew. Chem. Int. Ed., 54: 3240-3248. https://doi.org/10.1002/anie.201410214

Walker, B., Kim, G. H., Heo, J., Chae, G. J., Park, j., Seo, J. H., & Kim, J. H. (2015). Solution-processed CdS transistors with high electron mobility. *RSC Adv.* 4 (7): 3153–3157. https://doi.org/10.1039/c3ra44436h

Werner, J.H. (2004). Second and Third Generation Photovoltaics -- Dreams and Reality. In: Kramer, B. (eds) Advances in Solid State Physics. Advances in Solid State Physics, vol 44. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-39970-4_5

Xiang, W., & Tress, W. (2019). Review on Recent Progress of All-Inorganic Metal Halide Perovskites and Solar Cells. *Adv. Mater.* 31, 1902851. https://doi.org/10.1002/adma.201902851

Yang, X., Xu, C., & Giles, N. C. (2008). Intrinsic electron mobilities in CdSe, CdS, ZnO, and ZnS and their use in analysis of temperature-dependent Hall measurements. *J. Appl. Phys.* Vol. 104 (7): 073727. https://doi.org/10.1063/1.2996032

Yekeen, T. A., Azeez, M. A., Lateef, A., Asafa, T. B., Oladipo, I. C., Badmus, J. A., & Ajibola, A. A. (2017). Cytogenotoxicity potentials of cocoa pod and bean-mediated green synthesized silver nanoparticles on Allium cepa cells. *Caryologia*, *70*(4), 366-377. https://doi.org/10.1080/00087114.2017.1370260

Zhang, W. E. I., Saliba, M., Stranks, S. D., Sun, Y., Shi, X., Wiesner, U., & Snaith, H. J. (2013). Enhancement of perovskite-based solar cells employing core–shell metal nanoparticles. *Nano letters*, *13*(9), 4505-4510. https://doi.org/10.1021/nl4024287

©2026 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via https://creativecommons.org/licenses/by/4.0/ which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.