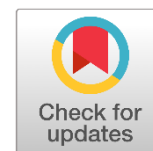




Content lists available at:  
<https://journals.irapa.org/index.php/BCS/issue/view/18>

## Biomedicine and Chemical Sciences

Journal homepage: <https://journals.irapa.org/index.php/BCS>



# Synthesis of Aluminum Oxide Nanoparticles and Their Applications in Dye-Sensitized Solar Cells as a Clean Energy

Mansour Kareem Abd Ali Al-Byati\*, Aqeel Mahdi Jreo Al-Duhaidahawi

*Department of Chemistry, College of Science, University of Kufa – Iraq*

### ARTICLE INFO

#### Article history:

Received on: November 25, 2022

Revised on: December 19, 2022

Accepted on: December 19, 2022

Published on: January 01, 2023

#### Keywords:

Aluminum Oxide  
 Efficiency  
 Electrochemical  
 Fill Factor  
 Nanoparticles  
 Solar Cell

### ABSTRACT

In this research, the aluminum oxide nanoparticles ( $Al_2O_3$  NPs) were prepared using electrochemical method. The Features of the electrochemical process are ease and speed, free side product, and economical. The prepared aluminum oxide was characterized using many techniques like x-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), ultra violet – visible (UV-Vis), energy dispersive x-ray (EDX), and atomic force microscopy (AFM). The shape of the prepared aluminum oxide was in the form of nanowire and has an energy gap of 3.9. Since fossil fuels are rapidly running out and their consumption increases the average global temperature, which has an impact on human life, the energy crisis is the main global concern. Consequently, in order to generate energy, dye sensitized solar cells (DSSCs) must be produced. The results indicate that the efficiency ( $\eta$  %) of the solar cell using methyl orange as a dye and fill factor were 1.17 and 56.8, respectively.

Copyright © 2023 *Biomedicine and Chemical Sciences*. Published by *International Research and Publishing Academy* – Pakistan, Co-published by *Al-Furat Al-Awsat Technical University* – Iraq. This is an open access article licensed under CC BY:

<https://creativecommons.org/licenses/by/4.0>

## 1. Introduction

Nanotechnology is the making of valuable materials, devices, and systems through the manipulation of matter on an atomic, molecular, and supramolecular in length size of 1-100 nanometer size, At the Nanoscale the physical, chemical, and natural properties of materials contrast in major and significant ways from the properties of individual atoms and particles or mass matter (Wang, et al., 2021). Nanotechnology is an advancing upset with enormous promise in various fields, including mechanics, medication, also, the food business. Nanoparticles inferable from having a more prominent surface region and improved paces of mass exchange appear to present higher biological and chemical activities, vulnerability, catalytic behavior,

enzymatic reactivity, and quantum properties contrasted with large particles with identical composition (Sahoo, et al., 2022). Nanotechnology took on a special status in materials and catalysts for semiconductors. Nanomaterials applied in the transformation of solar energy can be classified according to the application they propose (Manou, et al., 2022).

Nanotechnology presents another answer for cleaning the environment and improving the presentation of conventional technologies. Nanoparticles are tiny particles with unique properties which can direct medications directly to the spot where the human body needs them. They can make materials more grounded and they can change over solar energy all the more proficiently (Yadav, et al., 2020). It plays a fundamental part in advancement of groundbreaking methods to make unique items, substitute existing devices, and produce new materials and chemical compounds with high performance and less consumption of energy (Shelke & Rajbhoj, 2017). Grätzel and his group accomplished efficiencies of up to 7% in DSSCs utilizing Ru-based N749 dye furthermore,  $TiO_2$ -based photo anodes (Isaifan, et al., 2017). This method depends on enhanced interaction between the dye and the material transmitted by the charge transporter. A DSSC has three steps by which it changes over light into electrical vitality: when light falls on a color, it

\* **Corresponding author:** Mansour Kareem Abd Ali Al-Byati, Department of Chemistry, College of Science, University of Kufa – Iraq

E-mail: [mansourk.ali@uokufa.edu.iq](mailto:mansourk.ali@uokufa.edu.iq)

#### How to cite:

Al-Byati, M. K. A. A., & Al-Duhaidahawi, A. M. J. (2023). Synthesis of Aluminum Oxide Nanoparticles and Their Applications in Dye-Sensitized Solar Cells as a Clean Energy. *Biomedicine and Chemical Sciences*, 2(1), 48–52.

DOI: <https://doi.org/10.48112/bcs.v2i1.347>

begins the photo excitations and makes electrons move to the conductive band of the semiconductor (Janković, et al., 2021). Color atoms are oxidized by electrons provided by the electrolyte by redox reaction and eventually pass by the external load electrons to complete the circuit (Al-Douri, 2022). Nano-size and nano-dimensional material has drawn in numerous researchers in different fields (Micó-Vicent, et al., 2021). Aluminum oxide NPs can be synthesized utilizing solid phase methods, liquid-phase techniques and gas-phase processes (Eid, 2022). Here it is many structures of crystallographic stages, on which  $\gamma$  and  $\alpha$  structures were utilized for applications due to their unique features Aluminum Oxide nanoparticles likewise have a possible application in sensing, photonics catalysis, what's more, gadget manufacture.

Since fossil fuels are rapidly running out and their consumption is causing the average global temperature to rise, the energy crisis is the main global concern. Exploring clean and renewable energy sources is one of the challenges that agricultural activities have recently had to face. The most economically feasible green resource has historically been the generation of electrical energy using solar technology, also known as photovoltaic (PV) technology, especially in tropical nations. The antagonistic factor presents in both photovoltaic roofs and plants, however, is the most significant issue revealed by conventional PV in greenhouses (Roslan, et al., 2018).

The divergence consequently reduces the growth and productivity of the cultivated crops as a result. Thus, the Dye-Sensitized Solar Cell (DSSC) is very significant to humans because it has a number of appealing qualities. For instance, it costs little to make DSSC. Additionally, it is transparent, elastic, and light-sensitive. DSSC is a perfect candidate for energy building because of its versatility and ease of use in larger applications. In comparison to conventional PV, the DSSC technology is particularly well described in terms of solar radiation manipulation through the best selection of photosensitizer. Additionally, all the materials used for DSSC fabrication for greenhouse shading are compiled in this paper. For the purpose of sustaining growth, information on photosensitizers and light harvesting within the PAR spectrum has been provided. This technology has the potential to increase agricultural productivity while significantly lowering CO<sub>2</sub> emissions (Wang, et al., 2021). The research aims to use the electrostatic deposition method to prepare nanomaterials such as aluminum oxide with good properties and use it in solar cell applications and study the efficiency of the prepared cells. The prepared cells showed good efficiency as noted in the results.

## 2. Materials and Methods

Aluminum foil (97%) and polyvinyl alcohol (Fluka, Germany). Graphite, ethanol (99%), acetone (98%), polyethylene glycol (97%), potassium chloride (95%) and potassium iodide (97%) (CDH, India). Iodine (99%) (Thomas Baker, India).

### 2.1. Preparation of Al<sub>2</sub>O<sub>3</sub> NPS

For the preparation of Al<sub>2</sub>O<sub>3</sub> NPs by the electrochemical method, a working electrode was taken, which is an electrode made of aluminum foil, and an inert electrode, which is a graphite electrode. Power supply also used. Both cathode and anode were washed with acetone and ethanol and afterward deionized water. The electrochemical cell is filled up with a 200 mL solution which contains (5 mL of 10

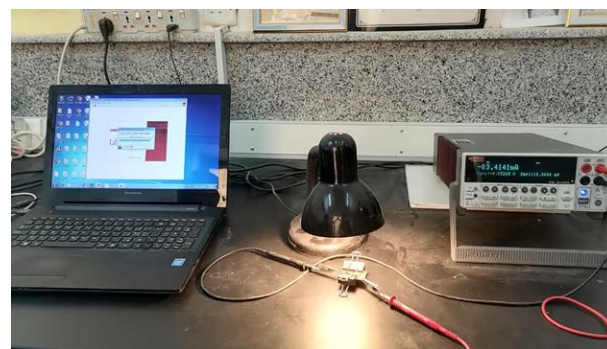
g/100 mL electrolyte (KCl) as the electrolyte, 10 mL of 10 g/100 mL of the stabilizer (Polyvinyl alcohol (PVA) and deionized water). A pure metal Al foil dimensions (1 cm x 4 cm x 0.25 mm) and inert graphite electrode (2 cm x 5 cm x 1 cm). The electrolysis reaction was performed in an undivided electrolytic cell for 60 minutes stirring at a temperature of (less than 30C°). The voltage is a range of (9-15) volt. The result white precipitate of Al<sub>2</sub>O<sub>3</sub> NPs was centrifuged washed with deionized water and ethanol a few times, it was poured into a drying vessel and dried at 60 C° for 60 minutes, then calcinated at 700C° for 60 minutes (Alfaawaz, et al., 2022).



**Fig. 1.** The electrochemical system for preparation of Al<sub>2</sub>O<sub>3</sub> NPs

### 2.2. Fabrication of DSSCs

The anode electrode, which consisted of aluminum oxide, was paste to conductive glass (ITO) and heated to 400 C° for 1 hour (Ossai, et al., 2020). The effective area of the oxide was 1 cm<sup>2</sup>. After heating, they are placed in the dye solution containing the methyl orange dye for 10 hours until the adsorption process occurs. The cathode is a graphite powder, to which polyethylene glycol (PEG) has been added, which is also pasted with conductive indium tin oxide glass and heated to a temperature of 300C°. An electrolyte solution was added between electrodes, which consisted of iodine (I<sub>2</sub>) dissolved in potassium iodide (KI) the solution whose concentration was 0.1 M. After the cell was completed, the efficiency was calculated using Keithley as shown in Figure 2 (Lee, et al., 2021).



**Fig. 2.** Image Keithley device with DSSCs

## 3. Results and Discussions

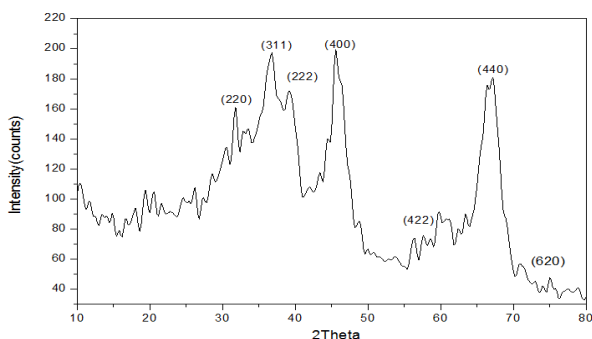
### 3.1. XRD Analysis of Al<sub>2</sub>O<sub>3</sub> NPs

The prepared Al<sub>2</sub>O<sub>3</sub> NPs strong diffraction peaks are seen at 2 $\theta$  (31.681°, 36.945°, 39.063°, 45.615°, 57.601°, 66.246°, and 76.560°) that related to (220), (311), (222), (400), (422),

(440) and (620): lattice plane of  $\text{Al}_2\text{O}_3$  respectively, in the XRD pattern have been characterized to  $\text{Al}_2\text{O}_3$  NPs (Ansari, & Husain, 2011; Pathania, Katwal, & Kaur, 2016). Shown in Figure 3. The equation which used to calculate the nanosize is Scherrer equation (1).

$$L = \frac{K\lambda}{B \cdot \cos\theta} \dots\dots (1)$$

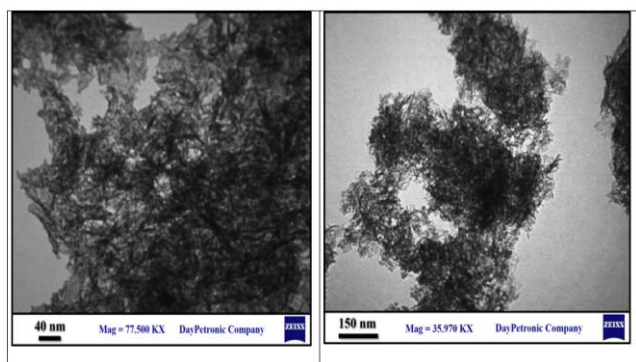
where L= size of crystalline (nm), K= constant dependent on crystallite shape (0.94-0.89),  $\lambda$  = x-ray wavelength (mostly for Cu), and B= FWHM (full width at half max) or integral breadth.



**Fig. 3.** X-Ray Diffraction pattern of  $\text{Al}_2\text{O}_3$  NPs

### 3.2. TEM Analysis of $\text{Al}_2\text{O}_3$ NPs

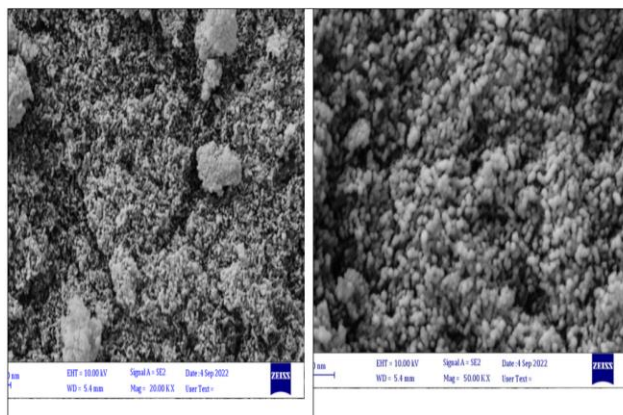
Figure 4 illustrates TEM micrographs of  $\text{Al}_2\text{O}_3$  NPs which were electrochemically prepared at room temperature. The TEM results indicate that the nanostructured shapes for  $\gamma$ - $\text{Al}_2\text{O}_3$  NPs electrochemical prepared have nanowire shape (Attia, et al., 2022).



**Fig. 4.** TEM images of  $\text{Al}_2\text{O}_3$  NPs

### 3.3. FESEM Analysis of $\text{Al}_2\text{O}_3$ NPs

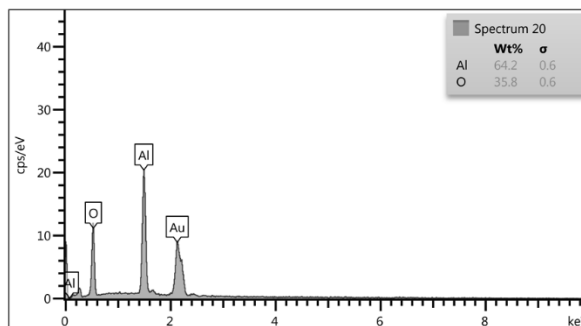
The SEM image in figure 5 was characterized as homogeneous surface morphology of a spherical shape for the  $\text{Al}_2\text{O}_3$  NPs.



**Fig. 5:** FESEM images of  $\text{Al}_2\text{O}_3$  NPs

### 3.4. EDX Analysis of $\text{Al}_2\text{O}_3$ NPs

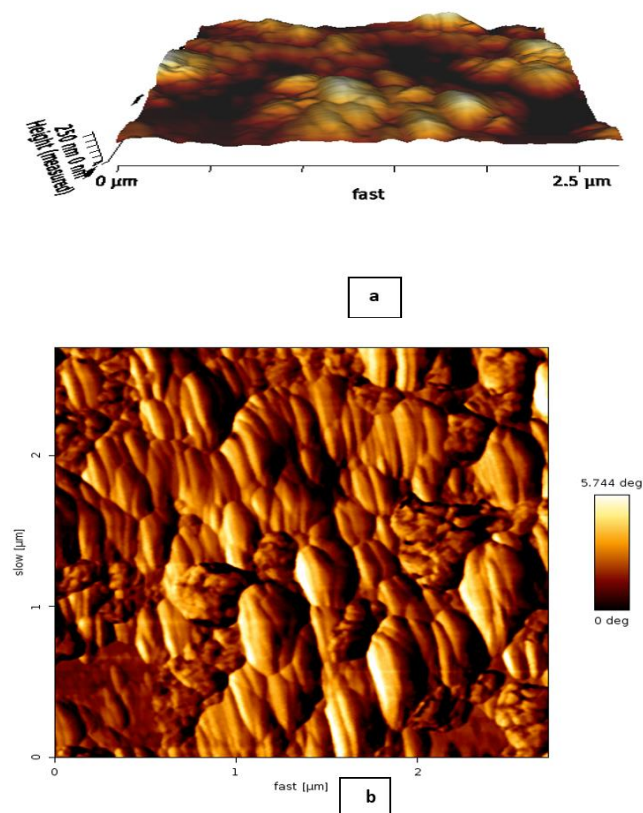
Energy dispersive X-ray spectroscopy was used to determine the purity and stoichiometry of  $\text{Al}_2\text{O}_3$  NPs that were produced electrochemically. Figure 6 illustrates the results, which reveal that the samples were highly pure due to the presence of only specific signals for oxygen and aluminum. Al and O make up 64.2% and 35.8% of the total weight percentages, respectively (Al-Fouadi & Hussain, 2020). In the chart appearance of gold due to the coverage of the sample by gold through the testing as seen in the chart EDX for  $\text{Al}_2\text{O}_3$  NPs.



**Fig. 6.** EDX -ray of  $\text{Al}_2\text{O}_3$  NPS

### 3.5. AFM Analysis of $\text{Al}_2\text{O}_3$ NPS

Morphology, topography, and texture of various surfaces can be thoroughly studied using an atomic force microscope (AFM) topography imaging technique (Resan & Essa, 2021). Due to the several directions that grain particles might go in AFM pictures, opaque colors represent feeble structures and bright colors represent soaring structures. This in-depth data was gathered using AFM measurements that included several significant characteristics, including roughness average and others. Figure 7 shows the production of the uniform dispersion of the electrochemically created  $\text{Al}_2\text{O}_3$  NPs in two and three dimensions (2D and 3D).



**Fig. 7.** (a) AFM 3D images of Al<sub>2</sub>O<sub>3</sub> NPs. (b) AFM 2D images of Al<sub>2</sub>O<sub>3</sub> NPs

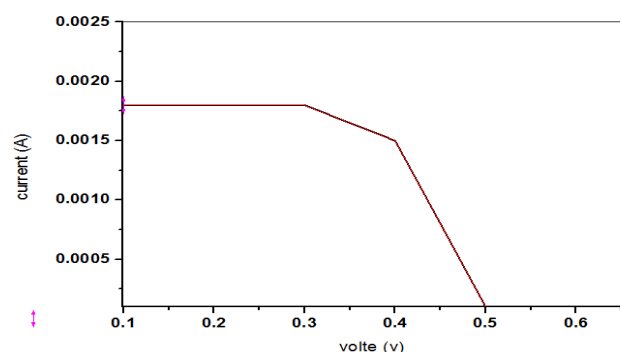
### 3.6. UV-Vis Analysis of Al<sub>2</sub>O<sub>3</sub> NPs

To evaluate the energy band gap of electrochemically prepared Al<sub>2</sub>O<sub>3</sub> NPs that were prepared under known conditions. By plotting  $(\alpha h\nu)^2$  against  $(h\nu)$  curves, the tauc's

**Table 1**

Photo-electrochemical parameters of the DSSCs, (A=1cm)and the intensity light (45.2Mw/cm<sup>2</sup>)

Catalyst/ dye	Isc(mA)	Voc(V)	Imax	Vmax	Pmax	F%	η%
Al2O3/methyl orange dye	1.6	0.5	1.5	0.38	0.455	66.5	1.17

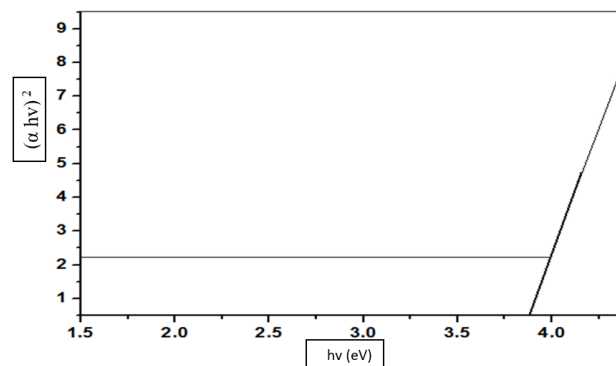


**Fig. 9.** I-V characteristics of prepared DSSCs Al<sub>2</sub>O<sub>3</sub> with methyl orange dye

## 4. Conclusion

Aluminum oxide nanoparticles was prepared by the electrochemical method, which is characterized by obtaining

approach is used to get the Eg values (Thakar, et al., 2022). The match Eg (eV) value is obtained by extrapolating from linear part of the figure at  $(\alpha h\nu)^2$ . A plot of  $(\alpha h\nu)^2$  against  $(h\nu)$  curves of electrochemically made Al<sub>2</sub>O<sub>3</sub> NPs that were prepared as shown in Figure 8 (Kaimonov, Safronova, Shatalova, & Lukina, 2022).



**Fig. 8.** The optical band gap of Al<sub>2</sub>O<sub>3</sub> NPs

### 3.7. Photo-electrochemical performances of DSSCs

The fill factor (FF) and the efficiency ( $\eta$ ) of solar cell calculated by the equations 2 and 3 (Srivastava, et al., 2021).

$$FF = \frac{J_m \cdot V_m}{J_{sc} \cdot V_{oc}} \dots \dots \dots (2)$$

$$\eta = \frac{J_{sc} \cdot V_{oc} \cdot FF}{P_{in}} \dots \dots \dots (3)$$

where Jsc, Voc, and Pin refer to short circuit current density, open circuit voltage, and incident light from the simulator respectively. Table 1 displays the I-V values of the synthetic cells based on methyl orange dye as shown in Figure 9.

a pure product free of impurities, as in the EDX analysis. The prepared aluminum phase has a high surface area, while the methyl orange dye has a simple chemical structure and a high electron density, and this led to an increase in the amount of adsorption, thus increasing the efficiency of the solar cell to reach 1.17%.

### Competing Interests

The authors have declared that no competing interests exist.

### References

- Al-Douri, Y. (2022). Renewable Energy: Analysis, Resources, Applications, Management, and Policy. [https://doi.org/10.1063/9780735424272\\_frontmatter](https://doi.org/10.1063/9780735424272_frontmatter)
- Alfaawaz, Y. F., Alamri, R., Almohsen, F., Shabab, S., Alhamdan, M. M., Al Ahdal, K., & Abduljabbar, T.

- (2022). Adhesive Bond Integrity of Experimental Zinc Oxide Nanoparticles Incorporated Dentin Adhesive: An SEM, EDX,  $\mu$ TBS, and Rheometric Analysis. Scanning, 2022. <https://doi.org/10.1155/2022/3477886>
- Al-Fouadi, A. H. A., & Hussain, R. K. (2020). Synthesis and characterize of porous aluminum oxide nanoparticles. NeuroQuantology, 18(1), 109. <https://doi.org/10.14704/nq.2020.18.1.NQ20115>
- Ansari, S. A., & Husain, Q. (2011). Immobilization of Kluyveromyces lactis  $\beta$  galactosidase on concanavalin A layered aluminium oxide nanoparticles—its future aspects in biosensor applications. Journal of Molecular Catalysis B: Enzymatic, 70(3-4), 119-126. <https://doi.org/10.1016/j.molcatb.2011.02.016>
- Attia, K. A., Abdel-Raouf, A. M., Serag, A., Eid, S. M., & Abbas, A. E. (2022). Innovative electrochemical electrode modified with Al<sub>2</sub>O<sub>3</sub> nanoparticle decorated MWCNTs for ultra-trace determination of tamsulosin and solifenacin in human plasma and urine samples and their pharmaceutical dosage form. RSC advances, 12(27), 17536-17549. <https://doi.org/10.1039/D2RA01962K>
- Eid, M. M. (2022). Characterization of Nanoparticles by FTIR and FTIR-Microscopy. In Handbook of Consumer Nanoproducts (pp. 1-30). Singapore: Springer Singapore [https://doi.org/10.1007/978-981-15-6453-6\\_89-1](https://doi.org/10.1007/978-981-15-6453-6_89-1)
- Isaifan, R. J., Samara, A., Suwaileh, W., Johnson, D., Yiming, W., Abdallah, A. A., & Aïssa, B. (2017). Improved self-cleaning properties of an efficient and easy to scale up TiO<sub>2</sub> thin films prepared by adsorptive self-assembly. Scientific reports, 7(1), 1-9. <https://doi.org/10.1038/s41598-017-07826-0>
- Janković, S., Mitić, M., Arsić, B., & Stankov-Jovanović, V. (2021). The kinetic and thermodynamic studies of solid-liquid extraction of apigenin-glycosides from parsley (Petroselinum crispum). Separation Science and Technology, 56(13), 2253-2265. <https://doi.org/10.1080/01496395.2020.1821219>
- Kaimonov, M., Safronova, T., Shatalova, & Lukina, Y. (2022). Composite Ceramics Based on Pastes Including Tricalcium Phosphate and an Aqueous Solution of Sodium Silicate. Journal of Composites Science, 6(9), 267. <https://doi.org/10.3390/jcs6090267>
- Lee, M. W., Kim, J. Y., Lee, H. G., Cha, H. G., Lee, D. H., & Ko, M. J. (2021). Effects of structure and electronic properties of D- $\pi$ -A organic dyes on photovoltaic performance of dye-sensitized solar cells. Journal of Energy Chemistry, 54, 208-216. <https://doi.org/10.1016/j.jechem.2020.05.060>
- Manou, L., Spyrtou, A., Hatzikraniotis, E., & Kariotoglou, P. (2022). What does “Nanoscience–Nanotechnology” mean to primary school teachers?. International Journal of Science and Mathematics Education, 20(6), 1269-1290. <https://doi.org/10.1007/s10763-021-10199-6>
- Micó-Vicent, B., Perales Romero, E., Jordán-Núñez, J., & Viqueira, V. (2021). Halloysite and Laponite Hybrid Pigments Synthesis with Copper Chlorophyll. Applied Sciences, 11(12), 5568. <https://doi.org/10.3390/app11125568>
- Ossai, A. N., Alabi, A. B., Ezike, S. C., & Aina, A. O. (2020). Zinc oxide-based dye-sensitized solar cells using natural and synthetic sensitizers. Current Research in Green and Sustainable Chemistry, 3, 100043. <https://doi.org/10.1016/j.crgsc.2020.100043>
- Pathania, D., Katwal, R., & Kaur, H. (2016). Enhanced photocatalytic activity of electrochemically synthesized aluminum oxide nanoparticles. International Journal of Minerals, Metallurgy, and Materials, 23(3), 358-371. <https://doi.org/10.1007/s12613-016-1245-9>
- Resan, S. A., & Essa, A. F. (2021). Preparation and study of the optical properties for polyaniline-Al<sub>2</sub>O<sub>3</sub> nanocomposite. Materials Today: Proceedings, 45, 5819-5822. <https://doi.org/10.1016/j.matpr.2021.03.182>
- Roslan, N., Ya'acob, M. E., Radzi, M. A. M., Hashimoto, Y., Jamaludin, D., & Chen, G. (2018). Dye Sensitized Solar Cell (DSSC) greenhouse shading: New insights for solar radiation manipulation. Renewable and Sustainable Energy Reviews, 92, 171-186. <https://doi.org/10.1016/j.rser.2018.04.095>
- Sahoo, M., Panigrahi, C., Vishwakarma, S., & Kumar, J. (2022). A Review on Nanotechnology: Applications in Food Industry, Future Opportunities, Challenges and Potential Risks. <https://doi.org/10.1109/SOI.1999.819873>
- Shelke, P. D., & Rajbhoj, A. S. (2017). Electrochemical synthesis and their photocatalytic application of mesoporous  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> nanoparticles. Der Chemica Sinica, 8, 482-6. <https://doi.org/10.1109/LEOSST.2000.869673>
- Srivastava, N., Srivastava, M., Mishra, P. K., & Gupta, V. K. (2021). Green Synthesis of Nanomaterials for Bioenergy Applications. <https://doi.org/10.1016/j.rser.2021.111206>
- Thakar, M. A., Jha, S. S., Phasinam, K., Manne, R., Qureshi, Y., & Babu, V. H. (2022). X ray diffraction (XRD) analysis and evaluation of antioxidant activity of copper oxide nanoparticles synthesized from leaf extract of Cissus vitiginea. Materials Today: Proceedings, 51, 319-324. <https://doi.org/10.1016/j.matpr.2021.05.410>
- Wang, D., Behura, S., Karim, F., Kazi, A., Wangila, G., & Wang, S. (2021). Nanoscience and nanotechnology for food and agroforestry. ES Food & Agroforestry, 3, 1-3. <https://doi.org/10.30919/esfaf/445>
- Wang, D., Liu, H., Li, Y., Zhou, G., Zhan, L., Zhu, H., ... & Li, C. Z. (2021). High-performance and eco-friendly semitransparent organic solar cells for greenhouse applications. Joule, 5(4), 945-957. <https://doi.org/10.1016/j.joule.2021.02.010>
- Yadav, S., Mittal, A., Sharma, S., Kumari, K., Chauhan, N. S., & Kumar, N. (2020). Low temperature synthesized ZnO/Al<sub>2</sub>O<sub>3</sub> nano-composites for photocatalytic and antibacterial applications. Semiconductor Science and Technology, 35(5), 055008. <https://doi.org/10.1088/1361-6641/ab7776>