RESEARCH ARTICLE

The Potential of Dye Synthesize Solar Cells for Mitigation Of Carbon (Iv) Oxide Emissions

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Abstract
World is experiencing rapid commercial growth and urbanization. Carbon (IV) oxide (CO_2) emissions into the atmosphere is increasing. As a result, a more effective energy policy is required. As a matter of fact, sustainable environmental quality has been identified as a critical component of long-term economic development success. Many studies have found that lower CO_2 emissions are an indicator of improved environmental quality. In the future, low-cost photoelectric technologies with superior sun-to-energy power conversion efficiency, extended lifetime, and low toxicity may replace conventional silicon-based solar panels and provide effective global illumination. Dye-sensitized solar cells (DSSCs) based on the zinc oxide nanorods are capable of all the aforementioned features. Zinc-oxide (ZnO) nanostructures are important for dye synthesis solar cells, and it is a leading semiconductor that researchers are interested in. The primary objective/purpose of this resarch is to highlight impact of carbon (IV) oxide and the potential of DSSC for reducing CO_2 discharges into the atmosphere. Method of ZnO NRs deposition on seed layer coated FTO Glass by Hydrothermal method was also expounded. The morphology of nanorods is presented, based on the available literature it concludes that the production of efficient DSSCs can reduce reliance on fossil fuels, which are the agent of ozone depletion layer due to green gas emissions.

Keywords: Carbon (IV) oxide emissions; Dye Synthesis Solar Cell; Deposition; Zinc oxide

Introduction

Energy plays a key role in a country's socioeconomic development. Economic growth and the betterment of people's living standards are all related either directly or indirectly to the increased use of energy, the most important of which is electricity (Nguyen, 2007). With a world population approaching eight billion, and a forecast of ten billion by the middle of the century, we must adequately answer the question of how humanity will meet its power needs in the coming years (Mariotti et al., 2020). The growing demand for energy and the worries about greenhouse gas emissions have fueled interest in this area and storage of efficient, renewable, and inexpensive energy and fuels (Rama Krishna & Kang, 2017). About 70% of energy production is dependent on fossil fuels. As a result of the combustion of fossil fuels, dangerous pollutants such as carbon monoxide, chlorofluorocarbon, sulfur dioxide, nitrogen dioxide, carbon dioxide, and nitrogen oxide, s, as well as other harmful chemicals, are produced. The use of fossil fuels in cities and land use in tropical zones as a result of industrialization and modernization account for nearly 70% of global CO_2 emissions. Cities consume approximately 75% of global power, which is predominantly generated by fossil fuels. GHG emissions, climate change, and global warming are all characteristics of fossil-fueled power generation (Ebhota & Jen, 2019). According to (B. Mehmood et al., 2021), (Zulkifili et al., 2015) Each year, the global temperature increases by 0.5 to 1.1 degrees Fahrenheit, which results in floods, global warming, and ozone layer loss. And hence, one of the most complex obstacles in this century is the production of clean and renewable energy (Hemmatzadeh & Mohammadi, 2013), (Mendizabal et al., 2015). As a result, the Environmental Protection Agency (EPA) has warned many countries to decrease their reliance on increasing their reliance on energy sources other than fossil fuels (Mehmood et al., 2017). This will reduce pollution caused by the combustion of fossil fuels and boost job opportunities. The best way to diversify the electricity supply is to develop accessible renewable energy productions (Rama Krishna & Kang, 2017), (Venkatachalam et al., 2017), (Choi et al., 2013). The Solar is an observable means of clean as well as less expensive energy that Nature already uses to sustain nearly most of life on Earth. As a result, embracing the Solar power through technologies of photovoltaic seems to be the one viable main solution to the challenge of energy. (Nazeeruddin et al., 2011). In today's world, technological and scientific advancements have elevated solar power to the top of the list of renewable and sustainable energy resources because it is a clean, dependable, readily available, environmentally friendly unlimited source of energy, has global availability, and is a cost-effective alternative energy source (Chou et al., 2012). As a result, establishing how to turn sunlight into usable energy efficiently is a significant challenge (Liu et al., 2016).

So, to ensure that energy production is sustainable and cost-effective for future generations, research into renewable energy sources must be conducted. In this regard, DSCs, a new generation of photovoltaic solar cells, offer one promising alternative (Ellis-Gibbings et al., 2012). DSSCs are critical devices because they address multiple environmental and energy issues (Aksoy et al., 2019). The device DSSCs continue to pique the public's interest due to a variety of factors including high light-to-energy conversion efficiencies, ease of processing, and distinct transparency and coloration, permitting the design of efficient lively devices (Grisorio et al., 2015). A DSSC is a photovoltaic device that effectively converts solar radiation into an electric current. The sensitization of wide bandgap semiconductors, photoelectrodes, redox electrolytes, and counter electrodes determines the progress of DSSC conversion from visible light to electricity (Abdin et al., 2013). This paper aims to bring together the lots of activities carried out by academics to strengthen the DSSC's efficiency. The suggested improvements and experiments are properly divided based on the various components of the DSSC. According to the review, zinc oxide nanorods of various sizes in the photoanode could help to improve the DSSC's efficiency.

Literature Review

There are numerous studies on DSSCs after work of O'Regan and Gratzel in 1991. In this section, we compiled some recent literature on DSSC research made from ZnO semiconductor due to very promising avenue in solar cell research. Hussein et al., (2018) studied Interconnected ZrO_2 doped ZnO/TiO_2 under simulated AM1.5 solar irradiation. A power conversion efficiency of approximately 6.97% is observed in DSSCs with ZrO_2 surface passivation, as demonstrated by the J-V characteristics. In their study, Kao et al. (2010) explored the impact of preannealing temperature of ZnO thin films on the performance of dye-sensitized solar cells. Their findings indicate that the ZnO film preannealed at 300°C resulted in the highest efficiency (η) of 2.5%, with Jsc and Voc values of 8.2 mA/cm^2 and 0.64 V, respectively. ZnO-NRs were synthesized using ZnO nanoparticles (ZnO-NPs) seed layer. Yuliasari et al. (2022) found that the power conversion efficiency of a solar cell utilizing hedgehog-like ZnO-NRs was about 2.35%, which is higher than the efficiency of a cell with all-vertically aligned ZnO-NRs (approximately 1.86%). In another study by Chou et al. (2019), a photoanode was created by combining nanorods with TiO_2, resulting in a short-circuit current density (Jsc) increase from 9.07 mA/cm^2 to 10.91 mA/cm^2, an open circuit voltage (Voc) increases from 0.68 V to 0.70 V, and an enhancement in PCE from 3.70% to 4.73%. Furthermore, Yang et al. (2014) reported the successful fabrication of a photoanode with ZnO nanotube arrays decorated with TiO_2 nanoparticles. The cell achieved an overall conversion efficiency of 3.94%, which represented an 86.7% improvement over pure ZnO nanotube cells. The researchers also investigated the impact of electrodeposited ZnO nanostructure on TiO_2 nanoparticles. Incorporating ZnO into the system led to a significant enhancement in short circuit current density, electron lifetime, and overall efficiency by more than 22%, 63%, and 1.8%, respectively. Chou et al. (2019) developed an innovative dye-sensitized solar cell featuring a ZnO nanorod-modified TiO_2

photoanode. The maximum efficiency of 4.87% was achieved.

Zatirostami (2021) produced dye-sensitized solar cells (DSSCs) utilizing a composite of TiO_2 nanoparticles and ZnO nanorods with various porosities. The most optimized cell exhibited an open circuit voltage of 704 mV, a short circuit current density of 14.2 mA/cm^2, a fill factor of 65%, and an efficiency of 6.5%. Ali et al. (2021) reported that the rod diameter decreased as the seed layer thickness increased, which demonstrated the effect of the seed layer on the system. Despite the extensive research and innovation in improving the efficiency of DSSCs, there are still many novel concepts being explored, indicating that the area of DSSCs is still attracting researchers. Figure 1 provides a visualization of the popularity of DSSCs, summarizing the number of publications by year from 2010 to 2020 (September). Figure 2 highlights the substantial research efforts made year after year to enhance the effectiveness of the solar cell in each subsystem.

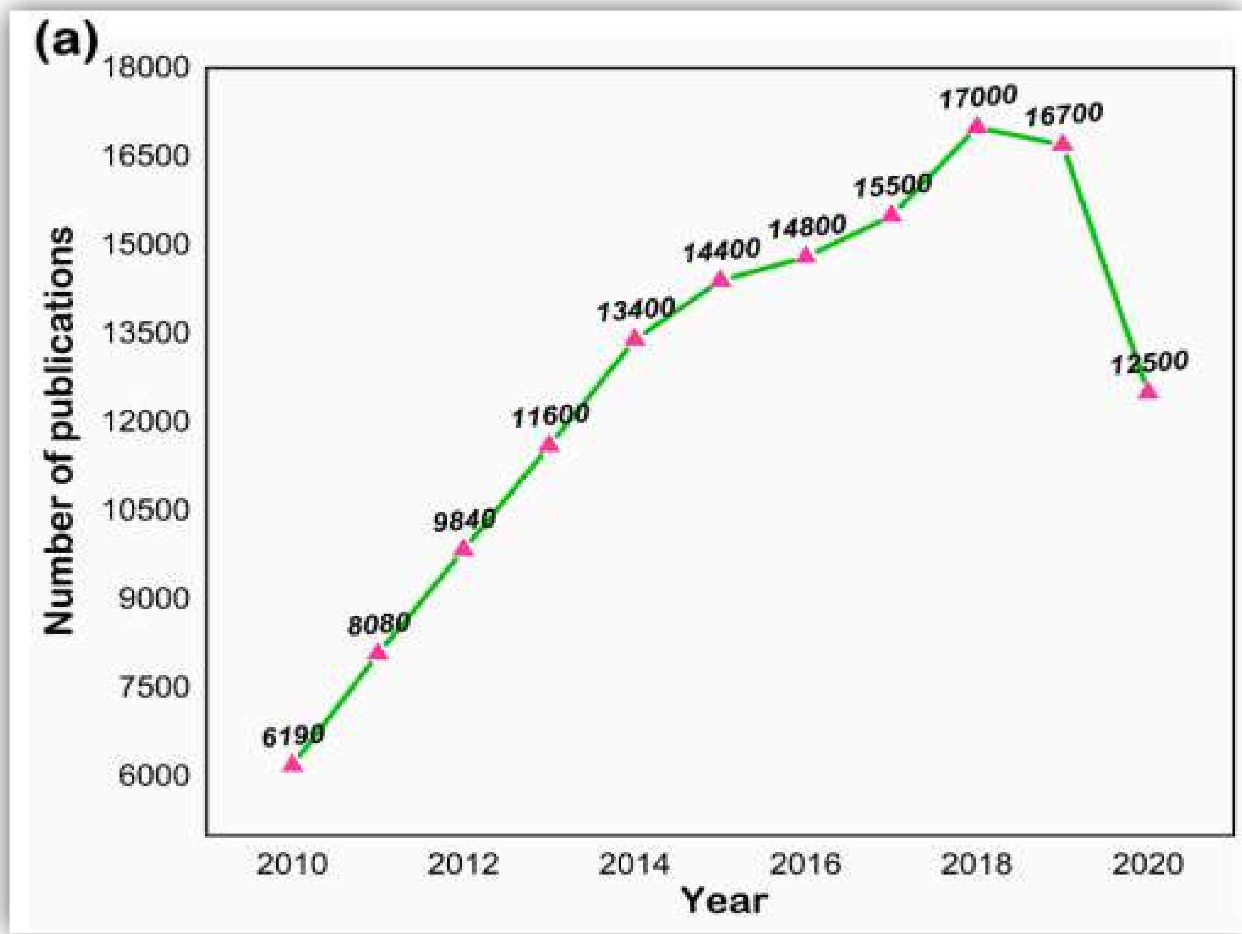

Figure 1. Research trend of DSSC publication growth year wise from 2010 to 2020 (Sept) (Nandan Arka et al., 2021)

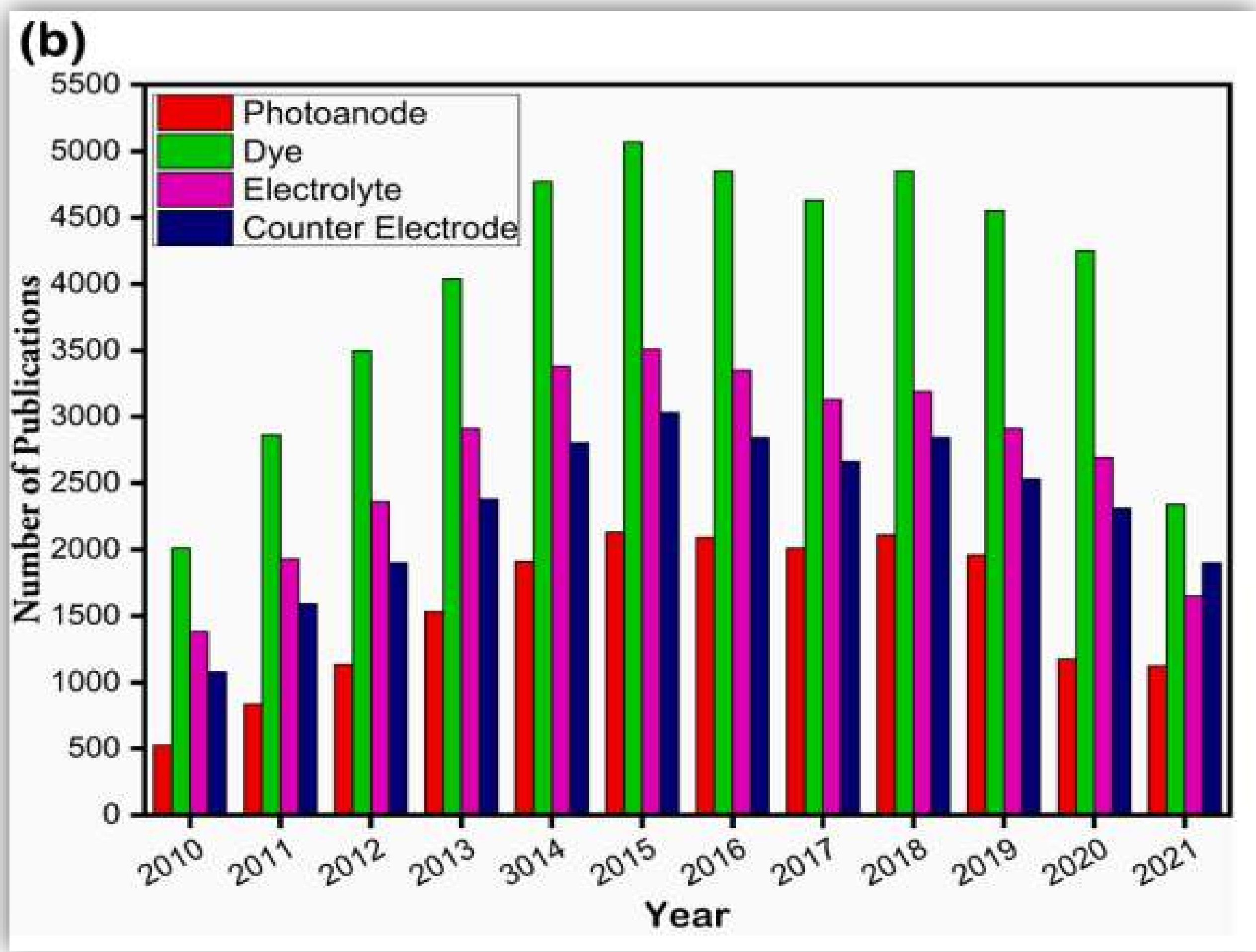

Figure 2. Research trend of DSSC subsystems publication year-wise from 2010 to 2021 (April) (Nandan Arka et al., 2021)

Zinc oxide (ZnO)

Semiconducting metal oxide nanoscale materials are the most promising targets for energy harvesters, as they possess wide bandgaps, high surface area, and high charge carrier mobility, which are essential for efficient dye-sensitization and light harvesting in DSCCs (Al-Kahlout, 2012). Zinc oxide (ZnO) and titanium oxide are examples of such materials (Qin et al., 2021). ZnO, in particular, has a direct optical energy band gap of 3.37 eV, which allows it to transmit most of the useful solar radiation (Singh & Vishwakarma, 2015). Due to its higher electron diffusivity and mobility (115-155 cm2) compared to other window layers such as TiO_2, ZnO is often used as a window layer in DSSC, which improves electron transport and reduces recombination rate (Ossai et al., 2020). The crystal structure of ZnO at ambient conditions is depicted in Figure 3.

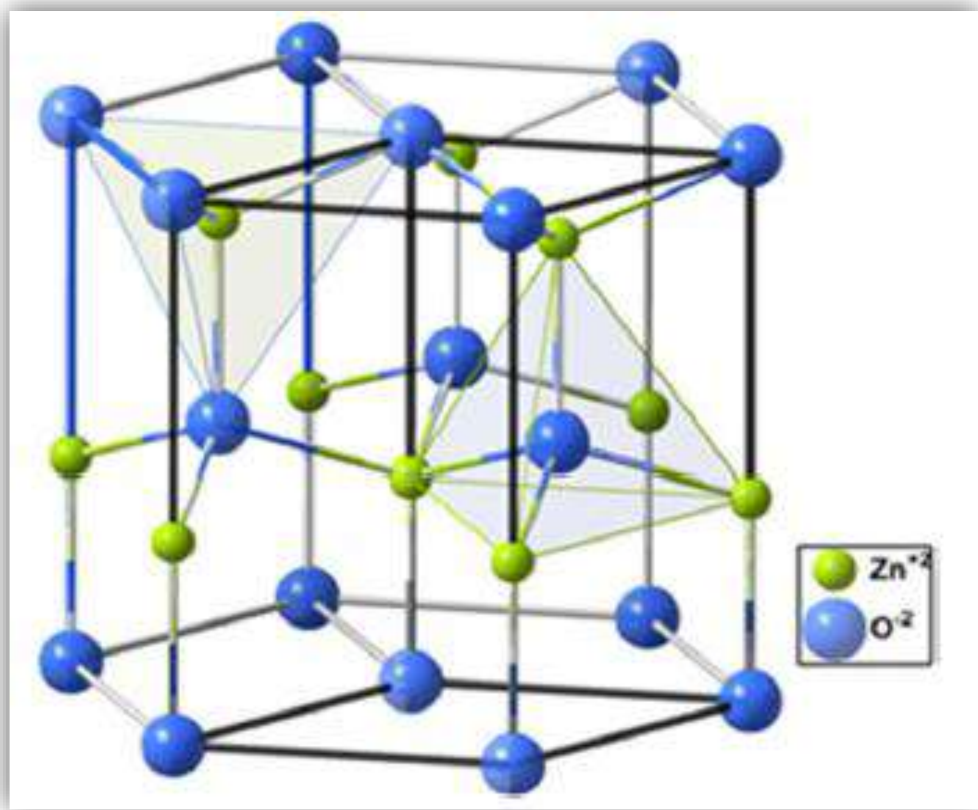

Figure 3. Wurtzite hexagonal crystalline structure of ZnO (Bhuiyan & Mamur, 2021)

Carbon (IV) oxide (CO_2)

Carbon dioxide (CO_2) is a gas that is colorless, odorless, incombustible, and non-toxic, and is generated during carbon combustion, organic compound decomposition, and living organisms' respiration (Hui et al., 2012). The release of carbon dioxide into the atmosphere occurs when it is exposed to the air over a particular area and time period through natural phenomena or human activities such as burning fossil fuels (Begum et al., 2020). Carbon dioxide is a chemical compound that consists of one carbon atom and two oxygen atoms. Due to its long lifespan in the atmosphere, along with other gases, it becomes almost impossible to remove them once they are released (Begum et al., 2020). In case humans fail to control the emission of CO_2, it could result in significant consequences such as climate change and global warming decomposition, and living organism respiration, resulting in a colorless, odorless, incombustible, and non-poisonous gas (Hui et al., 2012). The combustion of fossil fuels and other human activities contributes to the increase of CO_2 concentration in the atmosphere, which causes rising sea levels and loss of habitat due to Arctic ice melting (Rambeli-Ramli et al., 2018) and farmland destruction. The global average temperature has risen by 0.85 degrees Celsius from 1880 to 2012, leading to greater variation in temperature and severe weather, and an increase in the degree and frequency of hot days in most parts of the world. According to the Inter-governmental Panel on Climate Change (IPCC), global temperatures could rise by 1.1 to 6.4 degrees Celsius, and sea levels could increase by 16.5 to 53.8 cm by 2100 (Saboori et al., 2012). The concentration of atmospheric CO_2 was around 280 parts per million (ppm) during the industrial revolution in the 1880s, but it reached 399 and 403.9 ppm in 2015 and 2016, respectively, representing a thirty percent increase over the pre-industrial level (Saboori et al., 2012). To mitigate the spike in global warming, urgent action is needed to reduce CO_2 emissions and control the effects of climate change.

Numerous studies have suggested that lower carbon dioxide (CO_2) emissions indicate better environmental quality. The IPCC report recommends reducing greenhouse gas emissions, particularly CO_2, by 50-80% by 2050 (Rau et al., 2021). Therefore, a clear understanding of how to curb CO2 emissions is necessary. International organizations worldwide are striving to minimize the negative effects of global warming by formalizing various agreements, such as those proclaimed in the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). These organizations are committed to reducing the impact through initiatives such as the Green Climate Fund, the European Environment Agency, and the Partnerships in Environmental Management for East Asian Seas (Rambeli et al., 2021).

Figure 4 illustrates the global and Asian trends in carbon dioxide emissions per capita. From 1965 to 2015, carbon dioxide emissions per capita in the world increased at a 32.55 percent annual rate, while Asia increased at a 3.45 percent annual rate between those years. Developing countries, according to the report, are experiencing the fastest growth in carbon dioxide emissions per capita.

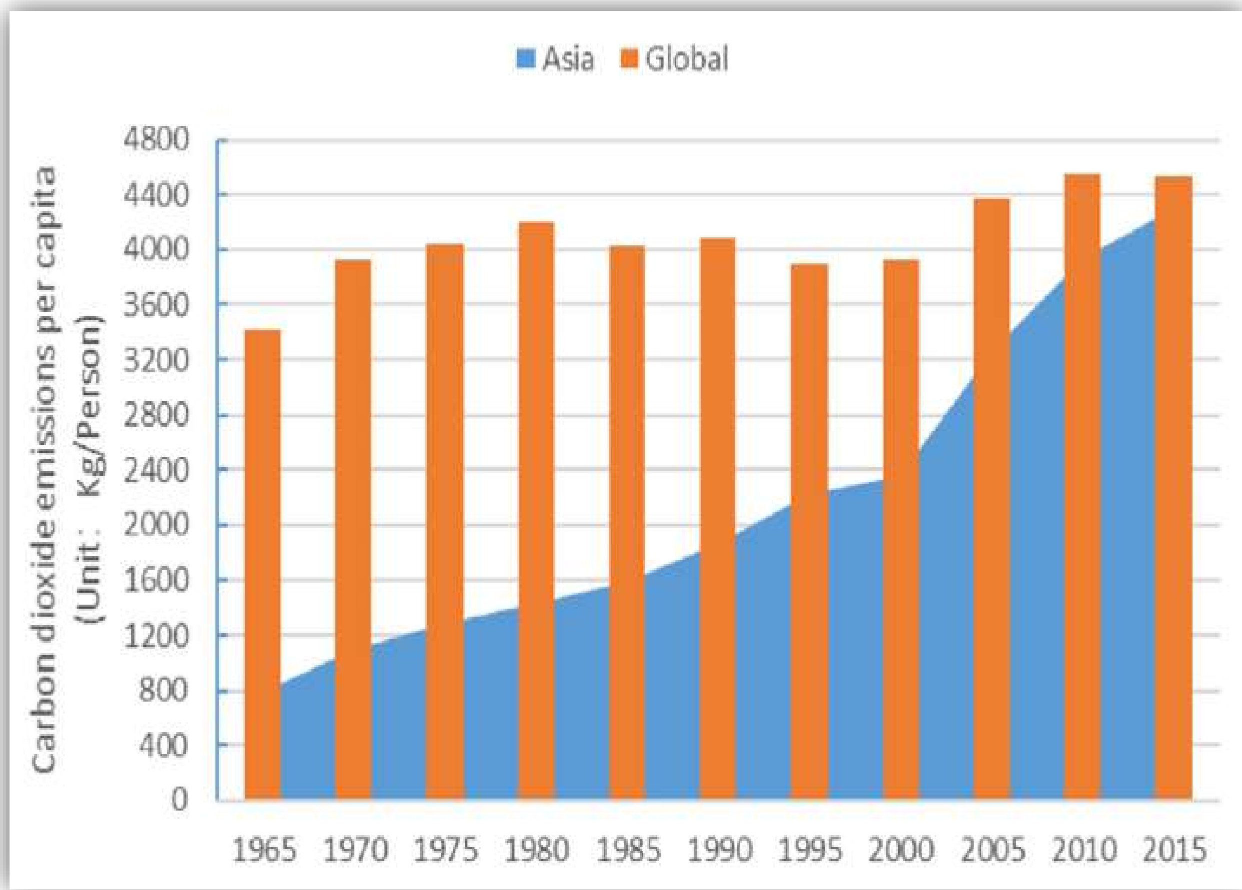

Figure 4. The pattern of per capita carbon dioxide emissions in Asia and worldwide, as reported by Song and Zhang (2019)

Development of Sustainable Energy Technology

Our humanity is reliant on electricity and diverse forms of energy. Sustainable energy production is regarded as one of the top ten problems facing society in the coming years (Ellis-Gibbings et al., 2012). Living, producing, and consuming in a way that meets the needs of the present without jeopardizing future generations' ability to meet their own needs is a broad definition of sustainable development. The goal of sustainable development is to improve people's quality of life, including raising living standards in developing countries while protecting the ecological processes on which livelihoods depend (Oyedepo, et al., 2018). Therefore in regard, sustainable energy technology (SET) refers to energy technology that is able to meet consumers' needs (demands) at an inexpensive price over time while not disrupting (compromising) ecosystems (Ali, 2011). This means that SET is both eco-friendly and cost-effective. Nevertheless, the survival of SET adoption in Malaysia is dependent on the socioeconomic and technical backgrounds of people in rural areas.

Power generation reliability is critical in all markets for lighting, heating, communications, industrial equipment, transportation, and so on.

To provide sustainable energy, the generation process, have to be more efficient. Improving the energy efficiencies of processes that use sustainable energy resources is critical to achieving sustainable development. The use of renewable energy provides numerous great benefits (Hao, et al., 2021). In addition, the development of renewable energy resources in Malaysia is essential for promoting economic growth, protecting ecosystems, and providing sustainable natural resources. Furthermore, the development of renewable energy resources in countries such as Malaysia will promote poverty alleviation, enhance education quality, prenatal care, gender equality, and combat child mortality, and other diseases, all of which are in connection with the Millennium Development Goals (Sovacool, 2012). Furthermore, because sustainable energy technologies frequently reduce or avoid greenhouse gas (GHG) emissions, such projects would also address the problem of climate change (Karakosta, et al., 2010). As such, there is a guarantee of sustainable national development in Malaysia with effective policy formulation by the government and private partnership involvement in renewable energy technologies.

Deposition methods

As illustrated in Figure 5, there are numerous identified, well-established, and recently discovered layer-deposition techniques. Each has advantages and disadvantages.

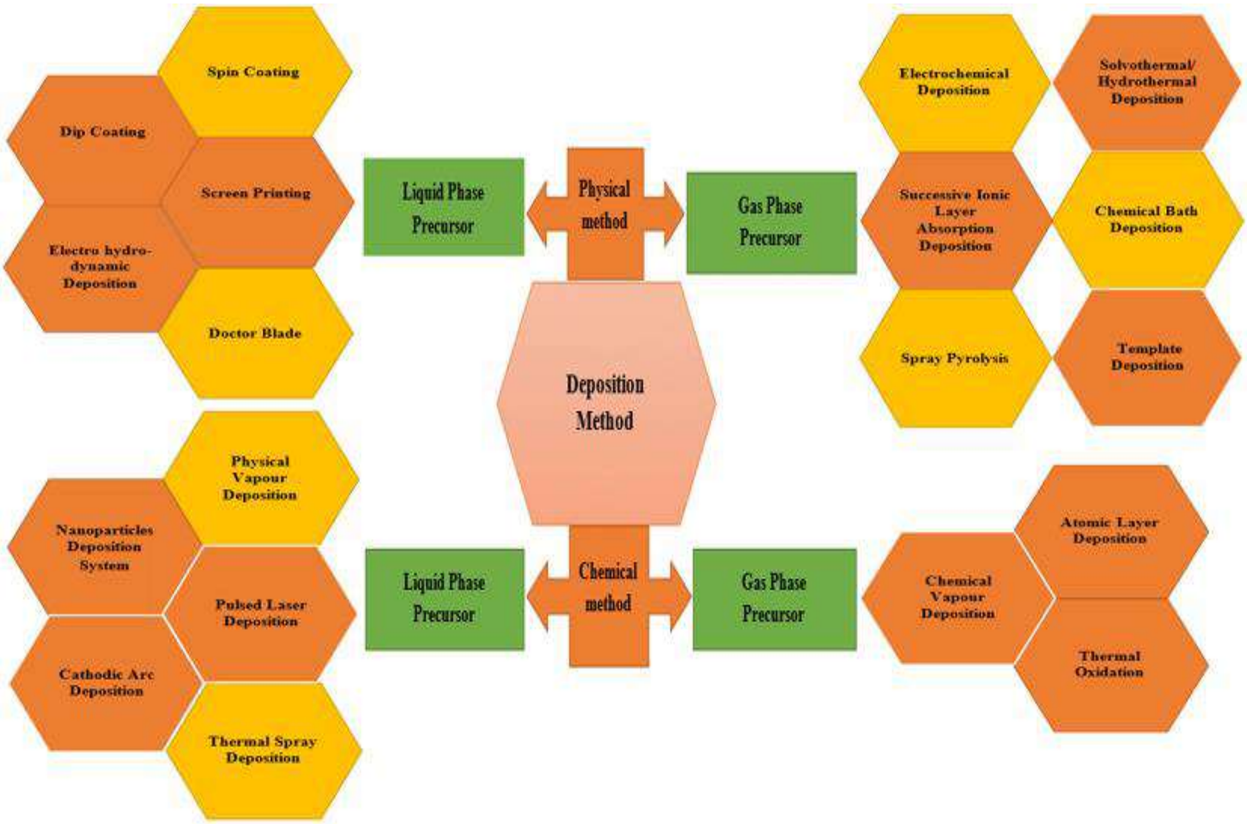

Figure 5. Deposition technics

Zinc oxide nanorods DSSC and Working principle

Improving the performance of DSSCs has been a subject of numerous attempts, and adjusting the photoanode is a crucial method to achieve this (Zatirostami, 2021). The dye-sensitized ZnO NR solar cell is an innovative photovoltaic device that utilizes a NR electrode as a structured geometry to increase the electron transport rate, thereby enhancing the quantum efficiency of DSSCs. The surface area can be increased to achieve higher dye loadings, which is a critical factor in increasing the efficiency of the PV cell. The working principle is described in figure 6 as follows: When photons strike the ZnO NRs photoanode, the dye absorbs them, becomes excited, and introduces an electron into the conduction band of the ZnO NRs electrode. The electron then flows through the external circuit from the TCO layer to the counter electrode. The dye is regenerated by accepting electrons from the redox mediator, and the redox mediators are regenerated by accepting electrons from the counter electrode. This process is repeated indefinitely to complete the circuit (Yusuf et al., 2022; Saboor et al., 2019).

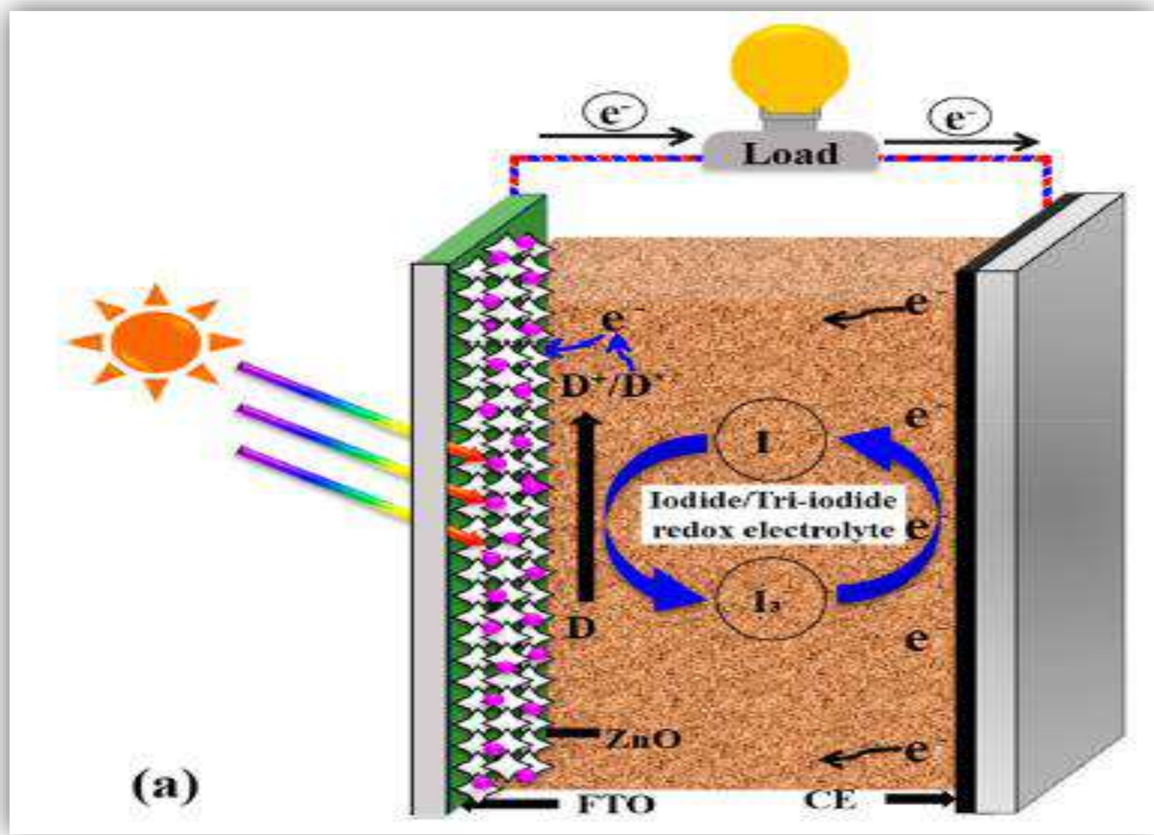

Figure 6. Dye synthesis solar cell structure

Hydrothermal synthesis of ZnO nanorods

To create ZnO nanorods on glass substrates, two primary procedures are involved is given in figure 7: (i) the formation of a seed layer utilizing spin coating techniques, and (ii) the growth of nanorods using the hydrothermal method.

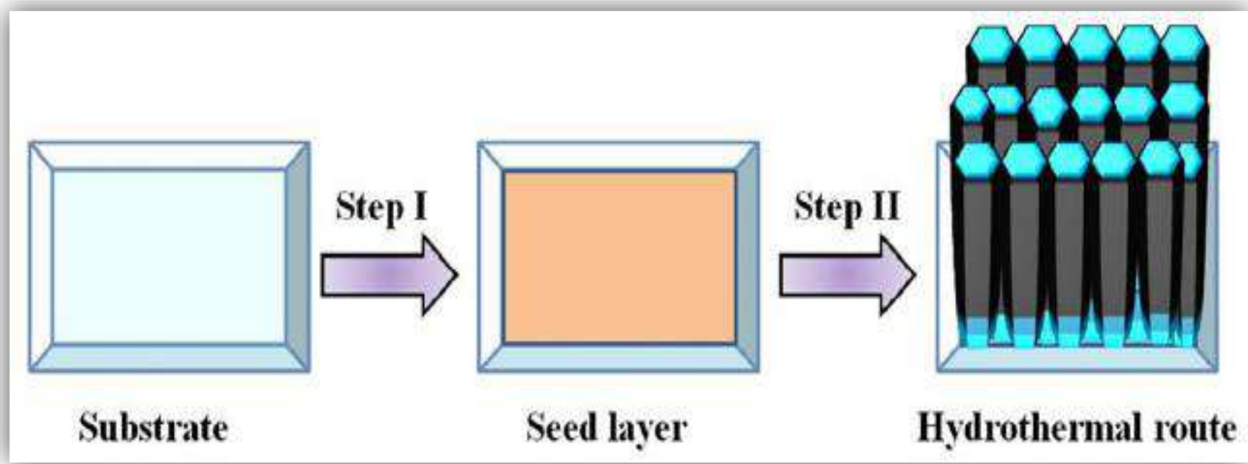

Figure 7. Schematic presentation of Zinc oxide nanorods formation

The ZnO NRs growth procedure is as presented in figure 8: Firstly, prepare a suitable concentration of growth mixture solution by dissolving zinc nitrate hexahydrate and hexamethylenetetramine in 100mL of deionized water in a beaker. The resulting solution is then stirred for 20 minutes to ensure a homogeneous mixture. Next, transfer the mixture into a blue cap bottle with a ZnO seed layer placed at a 45-degree angle to the wall. The bottle is subsequently placed in an oven and heated at 100°C for 4 hours. Lastly, the final product is taken out of the device and washed with deionized water before drying.

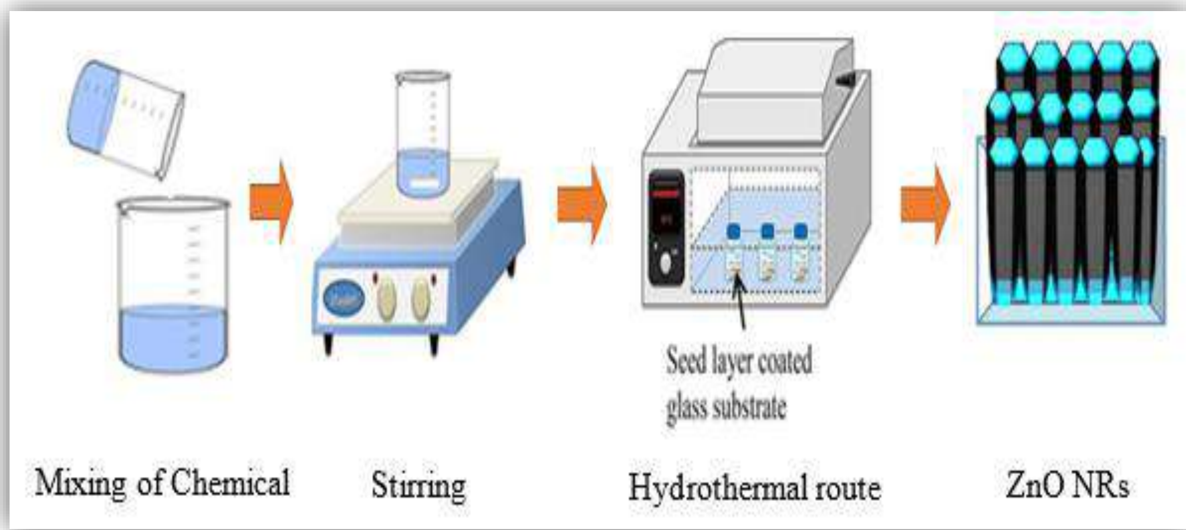

Figure 8. Steps of ZnO Nanorods formation

Yan et al. (2012) reported that the scanning electron microscopy top-view image of ZnO nanorods grown by hydrothermal techniques showed perfect hexagonal shapes and were well-oriented. Figure 9 presents the surface morphology of the films.

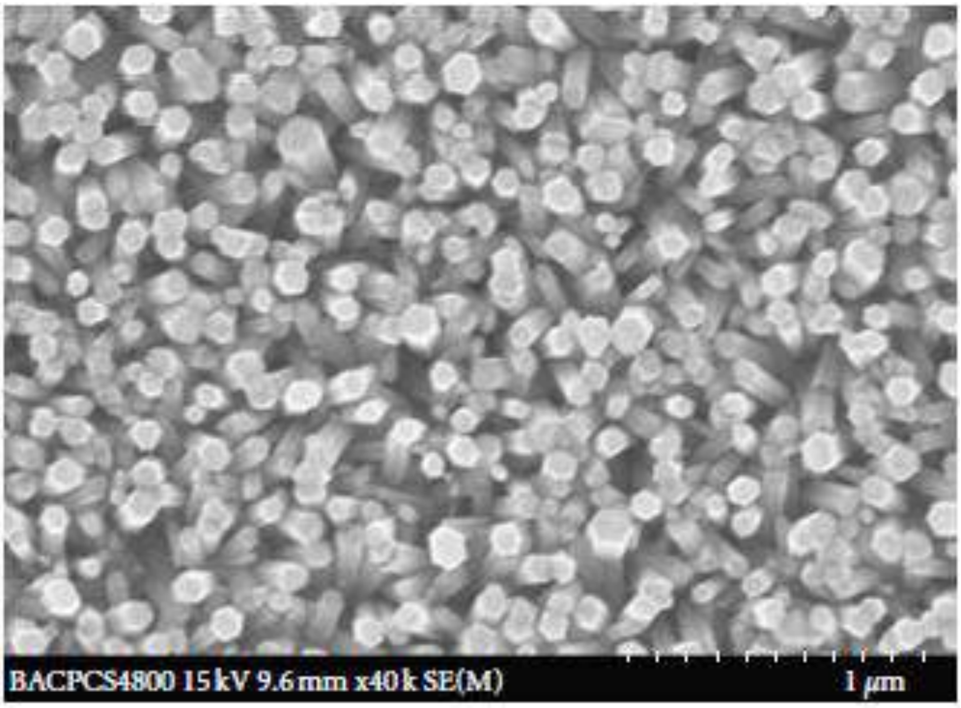

Figure 9. SEM top-view image of the ZnO nanorods (Yan, et al., 2012)

Conclusion

The advancement of sustainable energy and its effectiveness, along with the diverse technological options for energy sources, could enhance energy security. Given the significant potential and application of zinc oxide (ZnO) nanostructures in various practical areas, particularly in enhancing photovoltaic solar cells, this research aims to explore the potential of ZnO NRs DSSC in reducing CO2 emissions in Malaysia. The study details the deposition methods and reviews renewable energy technology and its benefits. An experimental demonstration of growing ZnO NRs on seed layer-coated FTO Glass was conducted. The research emphasizes the importance of developing efficient solar power devices to decrease dependence on fossil fuels, which are the primary contributors to ozone depletion.

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Conflict of Interest: The authors declare no conflict of interest

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