ISBN: 978-978-67-0285-8 **DOI:** https://doi.org/10.55455/acsnigeria.1.3.18-21

Effect of Temperature on the Adsorption of *Lonchocarpus cyanescens* Dye Extract on TiO_2 Semiconductor

John Moriamo O.[a,b] , Ogunbayo Taofeek B.[b], Olopade Mutteu A.[c], Isanbor Chukwuemeka [b], Babatunde Alice. I.[b], Alayande Samson O.[d], Msagati Titus A. M.[e]

[a]Department of Chemistry, Sikiru Adetona College of Education, Science and Technology, Omu-Ajose, Ogun state
[b]Department of Chemistry, University of Lagos, Lagos
[c]Department of Physics, University of Lagos, Lagos
[d]Department of Industrial Chemistry, Abiola Ajimobi Technical University, Ibadan, Oyo
[e]Institute of Nanotechnology and Water Sustainability (NanoWS), College of Science, Engineering and Technology, University of South Africa, Florida Park, South Africa
Corresponding Author's email: tbentos22@gmail.com
DOI: https://doi.org/10.55455/acsnigeria.1.3.18-21

ABSTRACT

The dye-sensitized solar cell (DSSC) has huge benefits with respect to competing technologies, but challenges remain in attaining a high power conversion efficiency and stability in the long term. In this study, we made an effort to optimize the DSSC by investigating the effect of dye- sensitizer temperature on the amount of dye adsorbed on the TiO_2 semiconductor during the fabrication process using different concentrations of a natural dye extracted from the leaves of *Lonchocarpus cyanescens*. The studied temperatures are 30 °C, 35 °C, 40 °C and 45 °C with concentrations 1.67g/L, 3.33 g/L, 5.00g/L, 6.67 g/L, 8.33 g/L and 10.00g/L. The results revealed that the percentage adsorption of dye increased from 30 °C to 35 °C to 40 °C and then decreased at 45 °C for all dye concentrations. This suggests that the optimal temperature for the adsorption of *Lonchocarpus cyanescens* dye extract on TiO_2 semiconductor is 40 °C, and adsorption is both physisorption and chemisorption. The information obtained in this study will aid in gaining access to clean and affordable energy, a key factor in the development of any nation.

KEYWORDS: *Lonchocarpus cyanescens*, semiconductor, optimize, DSSC, adsorption.

1. INTRODUCTION

The generation of electricity using solar cells is becoming more popular and it is high time the dye-sensitized solar cell (DSSC), became more functional as a viable alternative to the silicon solar cells. A major factor in determining the quality of a dye-sensitized solar cell is the adsorption process.The semiconductor surface adsorbs dye and gets sensitized to absorb visible light so as to initiate the flow of electrons which eventually get injected into the conduction band to generate electricity.The dye molecules are deposited by soaking the mesoporous semiconductor layer in a solution containing the dye.

The adsorption technology has been widely utilized due to its high efficiency, simple procedural process and cost effectiveness.[1] It is the transfer of organic substances from a liquid phase onto the surface of a solid phase. It can be either physical, caused by Van der Waals force or chemical, caused by chemical bonds such as covalent bond or ionic interaction. The efficiency of adsorption of dyes on the TiO_2 semiconductor material is important and carried out because the performance of DSSCs is known to be closely related to the equilibrium amount of adsorbed dye on TiO_2.[2] It is at the root of the four major processes (light absorption, electron injection, dye regeneration and charge transport) of the DSSC operation.

The interaction between TiO_2 nanoparticle and functional groups of the dye would then drive the electron transfer from the dye molecules to the conduction band of the semiconductor TiO_2.[3] This is very important in enhancing the photoelectric conversion efficiency of the DSSC. Although the operating principle of the DSSC is well understood, it is a complicated system involving four major parts and several working processes and so enhancing their performance is not an easy task since it is mutually influenced by many factors. Several variables, such as the solvent polarity, pH of sensitizer solution, thickness of film, annealing or sintering temperature of films, temperature of the dye solution, dye sensitisation time, co-sensitisation etc. may act independently or dependently to affect the efficiency of the DSSC and so can be carefully determined and/or manipulated to enhance its performance, by selecting the optimum values of parameters during the fabrication process to favor the performance of DSSCs.

Hence, there is a need to understand the effect of these factors/working parameters on the efficiency of DSSCs and various methods have been developed for exploring the knowledge of how to improve the performance of DSSCs.[4] For a breakthrough on the performance of DSSC and to preserve its durability, scientists and engineers need to optimize every material within the DSSC. The hope is very high that in the near future the DSSC is going to compete successfully with the silicon cells in terms of efficiency and its commercialisation will be realised within a few years with more efforts devoted to it.[5]

2. MATERIALS AND METHODS

Titanium (iv) oxide TiO_2, titanium (iv) chloride $TiCl_4$, ethanol (Sigma Aldrich), glass substrates, crude extract of *Lonchocarpus cyanescens* and analytical balance.

The synthesis of titanium (iv) oxide and the preparation of plant materials are as stated in our previous study.[6] TiO_2 colloidal paste was prepared by mixing TiO_2 nanoparticles with aqueous solution of $TiCl_4$ to achieve optimal crack-free mesoporous films and good adhesion to glass substrate. This involves dispersing the TiO_2 powder in the aqueous solution and then crushing and grinding with a mortar and pestle for about 1 hour until a uniform suspension is obtained. Different concentration of leaves extract of *Lonchocarpus cyanescens*, 1.67 g/L, 3.33 g/L, 5.00 g/L, 6.67 g/L, 8.33 g/L and 10.00g/L were prepared in ethanol solution. Films of TiO_2 on the glass plate spread by doctor blading method, [7] were soaked in the dye solutions for 16 hours 20 minutes in a small beaker. The experiment was carried out at four different temperatures, 45 °C, 40 °C, 35 °C and 30 °C and the mass of the adsorbed dye was determined gravimetrically using the analytical balance.

3. RESULTS AND DISCUSSION

The evaluation of the effect of temperature on the adsorption of dye in the DSSC is critical in its optimization. The Figure below shows the variation of the adsorption of Lonchocarpus cyanescens using different concentrations on the TiO_2 at different temperatures.

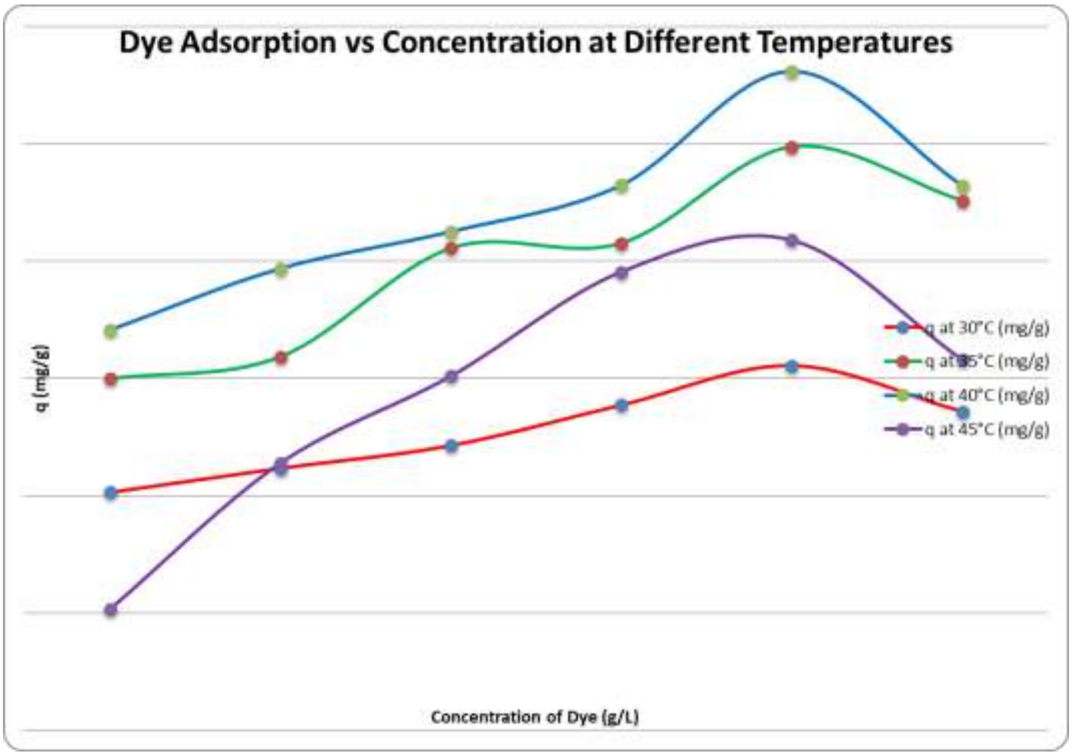

Figure 1: Graph of the amount of adsorbed dye (q) versus concentration at different temperatures

The effect of temperature was studied at 30 °C, 35 °C, 40° C and 45 °C. As displayed on the graph above, result shows that the adsorption of dye was found to increase from 30 °C to 35 °C to 40 °C and then decreased at 45 °C (Figure 1), This was observed at all concentrations, suggesting that adsorption is both physisorption and chemisorption. This has been reported by Hirose et al.[8] The result also shows that adsorption of LC is not favoured at high temperature as it was found to decrease at the highest studied temperature (45 °C). Similar study by Rahman et al. showed the effect of dye temperature on the efficiency of cells at temperature of 30 °C, 50 °C, 60 °C, 70 °C and 80 °C.[9] The result from their study, reveals that optimum dye loading and efficiency were obtained at 50 °C.

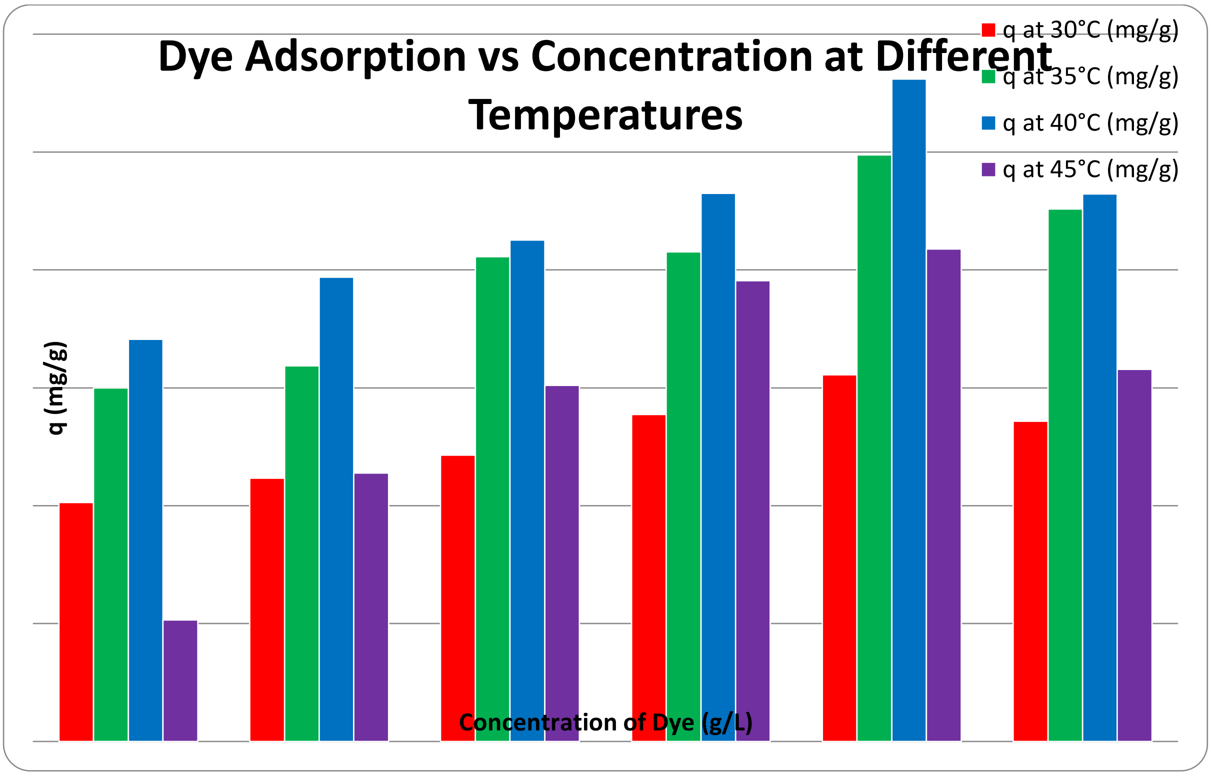

Figure 2: Bar chat displayof the amount of adsorbed dye (q) versus concentration at different temperatures

Adsorption of LC is generally observed to increase with increasing concentration as shown in Figure 2. However, there appear to be a critical adsorption at the fifth concentration (8.33 g/L), at this concentration, adsorption of crude extract of *Lonchocarpus cyanescens* was found to be the highest at all studied temperatures. A decrease in the amount of dye adsorbed was observed at the highest studied concentration in this work after the critical concentration for all temperatures. The reason for this is that the surface of TiO_2 may no longer adsorb after a particular concentration, and dye may have a maximum adsorption concentration. This result is in agreement with the study on effect of concentration of chlorophyll extract from binahong leaves, *Anredera cordifolia* on TiO_2 as adsorbents.[10]

Their result, showed an increase in efficiency as concentration increases until it got to a threshold concentration after which it decreased. Also, Chang et al. in their study demonstrated that dye layer increases with increasing dye adsorption time;[11] however, beyond an optimum concentration, the dye layer obstructs the charge transfer from the conduction band of the TiO_2 surface to the electrolyte.[12] In this study, the optimal adsorption temperature for crude *Lonchocarpus cyanescens* on the TiO_2 semiconductor is at 40 °C and a dye uptake of 112.360mg/g was possible and adsorption is both physisorption and chemisorption as a decrease was observed at a higher temperature. Both physical and chemical adsorption may occur on a surface at the same time. A layer of molecules may be physically adsorbed on top of an underlying chemisorbed layer and on the same surface can display physiosortion at one temperature and chemisorption at a higher temperature.[13] The basic knowledge of adsorption equilibrium and kinetics is a fundamental to design an adsorption system, [14] of which the DSSC is one.

4. CONCLUSION

It is important to obtain the maximum amount of dye adsorbed by the TiO_2 semiconductor during the fabrication process of the dye sensitized solar cell as the efficiency of the cell most of the time is directly dependent on it. This study revealed that there is a particular temperature to attain the highest dye uptake for every dye that will be used as a sensitizer in the DSSC. There is therefore the need to carefully optimize all varying parameters of the DSSC especially the temperature of the sensitizer solution.

REFERENCES

1. Siyal, A.; Shamsuddin, M. R.; Khan, M.; Rabat, N. E.; Zulfiqar, M.; Man, Z.; Siame, J.; Azizli, K. A. A. Review on geopolymers as emerging materials for the adsorption of heavy metals and dyes. *J. Environ. Manag,* **2018,** 224, 327-339.
2. Perez, C.; Kador, L.; Peng, B.; Thelakat, M. Characterization of the Adsorption of Rubpy Dyes on Mesoporous TiO_2 Films with UV-Vis, Raman, and FTIR Spectroscopies. *J. Phys. Chem. B*, **2006**, 110, 8723-8730.
3. Narayan, M. N. Review: Dye sensitized Solar Cells based on Natural photosensitizers. *Renew. Sustain. Energy Rev.,* **2012,** 16:208-215.
4. Arifin, Z.; Soeparman, S.; Widhiyanuriyawan, D.; Agus, P. A.; Dharmanto, D. Synthesis, characterization, and fabrication of hollow fibers of Zn-doped TiO_2 for dye sensitized solar cells. *J.Eng. Sci. and Technol.*, **2017,** 12(5), 1227-1239.
5. Lee, C.; Li, C.; Ho, K. Use of organic materials in dye-sensitized solar cells. *Mater. Today*, **2017**, 20(5), 267-283.
6. John, M. O.; Ogunbayo, T. B.; Ikechukwu, P. E.; Chukwuemeka, I.; Olopade, M. A.; Babatunde, A. I.; Olaleru, S. A.; Olugbuyiro, J. A. O.; Alayande, S. O.; Msagati, T. A. M. Enhanced photoelectrochemical activity of green-capped TiO_2 photoelectrodes for DSSC application. *ChemistrySelect*, **2025,** 10, e02349, 1-8.
7. Onah, E. O.; Offiah, S. U.; Chime, U. K.; Whyte, G. M.; Raphael. M.; Obodo, R. M.; Ekechukwu, O. V.; Ahmad, I.; Ugwuoke, P. E.; Ezema, F. I. Comparative photo-response performances of dye sensitized solar cells using dyes from selected plants. *Surf. and Interfaces,* **2020**, 20(100619), 1-12.
8. Hirose, F.; Shikaku, M.; Kimura, Y.; Niwano, M. IR Study on N719 Dye Adsorption with High Temperature Dye Solution for Highly Efficient Dye-Sensitized Solar Cells. *J. Electrochem. Soc.*, **2010,** 157, B1578-B1581.
9. Rahman, M. Y.; Rozab, L.; Samsuric, S. A.; Umar, A. A. Effect of N719 Dye Dipping Temperature on the Performance of Dye-Sensitized Solar Cell. *Russ. J. Electrochem*, **2017,** 54(10), 863-868.
10. Muryani, B. Y.; Sarifah, N.; Kusumawardani, D. R.; Nurosyid, F. Effect Concentration of dye solution Binahong Leaves to the Efficiency of Dye-Sensitized Solar Cell (DSSC). *AIP Conf. Proc.*, **2019**, 1-5.
11. Chang, W.; Lee, C.; Yu, W.; Lin, C. Optimization of dye adsorption time and film thickness for efficient ZnO dye-sensitized solar cells with high at-rest stability. *Nanoscale Res. Lett.*, **2012,** *7,* 1-10.
12. Faqir, P.; Aini, N. A.; Mardhiyah, Z.; Nurosyid, F. Effect of concentration of red dragon fruit (*Hylocereus costaricensis*) peels extract as a dye of Dye-Sensitized Solar Cell (DSSC) on DSSC efficiency. *AIP Conf. Proc*., **2019,** 2202, 2-7.
13. Webb, P. A. Introduction to Chemical Adsorption Analytical Techniques and their Application to catalysis MIC Technical Publications Micromeritics Instrument Corp., Norcross, Georgia 30093, **2003,** 1-12.
14. Azizian, S.; Eris, S. Adsorption isotherms and kinetics. *Interface Sci. Technol.*, **2021**, 33, 445-509.