International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2633-2639


# Spectral Filtering of Photovoltaic Cells using Novel Bio-filter

**Emetere Moses E.[1,2] & Gabe-Oji Testimony[1]**

[1] *Department of Physics, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria.*
[2] *Department of Mechanical Engineering Science, University of Johannesburg, South Africa.*

**Abstract**

The reality of global climate change is evident in the solar radiation signatures in the tropics. The performance of the photovoltaic (PV) cells is mitigated significantly as mere observation has shown that the performance of PV panels drops below 50% the first year of purchase. This challenge has raised the cost of maintenance for PV users in some tropical belt of the universe. This research proposed the use of bio-filter to undertake the solar spectra filtering process to boost the performance of the PV cells. The bio-filter is made up of a copper-coated Ixora extract in butanol solution. It has been observed that the bio-filter has novel optical properties that could stabilize excess fluctuations of measured parameters from a mono- and polycrystalline PV panels.

**Keywords**: Solar energy, solar, spectral filtering, photovoltaic, bio-filter

## INTRODUCTION

Renewable energy sources have been available through human existence, the problem of how to harness this energy more efficiently still exist (Emetere et al., 2019). The failure of evolving technologies has given researchers new ways of overcoming unforeseen challenges (Kabir et al., 2018; Ogunmodimu and Okoroigwe, 2018; Ma et al., 2014; Zalba et al., 2003). For example, the solar energy option has witnessed tremendous scientific improvement. First, it started with heat-trapping device to dry food, fruits or cloth. Then it went unto building of solar collectors and then towards the emergence of thermovoltaic (Wei and Bao, 2013) and photovoltaic (Emetere et al., 2016) devises. Later, research went unto solar storage systems (Ma et al., 2014). The research on solar storage system gave recourse to advancing solar collectors into a new technology referred to as concentrated solar power (CSP) (Cavallaro, 2010; NREL, 2012). CSP is powered by two technologies i.e. concentrated solar pillar (CSP) and concentrated solar tower (CST).

Basically, the sun is referred to as the source of solar energy. When describing solar energy, two terms are used i.e. solar radiation and solar irradiance. Solar radiation is all the radiant energy emitted by the sun. Solar irradiance is the power per unit area received from the Sun in the form of electromagnetic radiation measured in space or at the Earth's surface. Solar radiation classified between three major spectrums; infrared, visible light and ultraviolet spectrum (Johan, 2019). Solar cells only make use of visible light, the infrared region is largely responsible for heat and this would result in the rise in temperature of the panel. The understanding of the effect of solar radiation spectrum on solar panels can be best explained by the malfunctioning of solar photovoltaic (PV) panels in some tropical regions of the world (Walsh et al., 2012). It is easy to understand this challenge from the concept of climate change (Lean and Rind, 1998). This event has lead to the release of harsh solar radiation that has defied the principles of PV. Hence, just as solar panel output decreases with an increase in temperature, its performance also decreases based on the harsh solar radiation heating the PV panel.

The above research problem has made the adoption of solar module in developing countries less fashionable despite the price reduction of PV devices in the solar market. Hence, while the initial challenge of high cost of solar PV panel has been resolved, the maintenance cost of changing module in less than a year or two is more frustrating. A typical example is the solar grid generation in South Africa. According to Schmela et al. (2019), the solar grid production of South Africa has dropped since 2017. In Nigeria, the adoption of solar PV panels for standalone users is gradually failing since its cost of maintenance has arisen due to low performance of solar PV panels. It is generally observed that the output of the PV panel begins to drop from the time of purchase and may likely be at its lowest energy generating before the end of the year. This observation cuts across the different brands of solar panel.

Based on the above, this research aims to improve on the sustainable energy output of monocrystalline and polycrystalline panels, thereby elongating its life span by introducing bio-filter. The bio-filter is made-up of copper coated plant extracts. In this research, Ixora coccinea Linn (Rubiaceae) extract was used as the bio-optical filter. Ixora is known in different regions of the earth with many names such as: Jungle of Geranium, West Indian Jasmine, Ponna,Flame of the woods, vetchi in Ayurveda, Rangan, Kheme etc. Ixora coccinea Linn is a flowering plant that belongs to the Rubiaceae family. This plant is common in Africa, Southern Asia and some parts of India. The Ixora plant possesses high medicinal value (Dontha et al. 2015). The Ixora plant is one of the most research plants (Nayak et al., 1999; Faten et al., 2003; Yasmeen and Prabu, 2011). The ixora extract was synthesized with copper to alter the optical properties of the extract to act as bio-filter. If the outcome of this experiment is successful, it implies an increase in output energy given by solar panels. Also, the preservation of the lifespan of PV panels can be ensured.

## MATERIALS AND METHODS

The Ixora coccinea Linn flower was blended with butanol and filtered. The filtrate collected into a beaker. The 10 ml of the filtrate was mixed with 0.0045 moles of $Cu(NO_3)_2.3H_2O$ and left a day to enable the proper dissolution of copper. Ixora coccinea flower is of ursolic acid chemotype (Elumalai et al., 2012) with the stoichiometry composition as $C_{30}H_{48}O_6$. The chemical structures of the active chemicals are presented in Figure 1 below. The computational chemical structure of the resultant product of the bio-filter is presented in Figure 2.

Four panels were attached to the data logger i.e. two monocrystalline and two polycrystalline panel. One monocrystalline and polycrystalline panels was unsprayed and the other two panels (monocrystalline and polycrystalline) were sprayed with the liquid bio-filter (Figure 2). The unsprayed panels were used as control mechanism to monitor the sprayed panels.

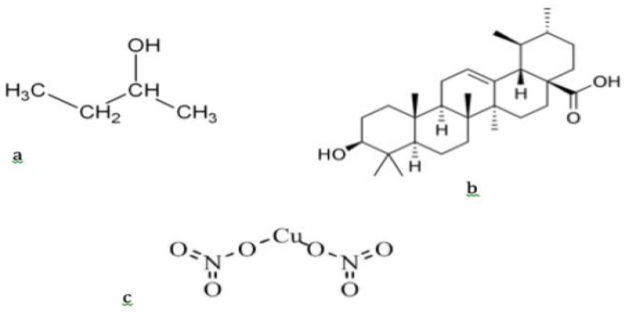

**Figure 1:** Structures of reacting chemicals (a) Butanol (b) Ursolic acid in ixora (c) copper nitrate trihydrate

Before the panels were sprayed, it was cleaned with distilled water. The panels were afterward put under the sun and the readings from the panels were recorded on the logger and stored in an SD card.

**Figure 3:** Experimental set-up of sprayed and unsprayed PV panel

The rating of the monocrystalline solar panel is: nominal peak power (+-3%)(pmax) = 3w; open circuit voltage (voc) =10.8v; short circuit current(isc) = 418mA; maximum power voltage(vmp) = 8.2v; maximum power current (imp) = 366mA; and standard test conditions = 1000W/M2. 25c AM1.5. The rating of the polycrystalline solar panel is: nominal peak power (+-3%) (pmax) = 4W; open circuit voltage (Voc) = 22.466V; short circuit current (Isc) = 0.235A; maximum power voltage (Vmp) = 18.436V; maximum power current (Imp) = 0.220A; standard test conditions = 1000W/m2. 250C AM1.5. Lastly, the optical properties of the bio-filter was analysed using XRD at $\lambda = 1.54054$ Å.

## RESULTS AND DISCUSSION

The chemical structure of the bio-filter is presented in Figure 2 below. Along the a-c axes, the cyclic bonds appear in six units known as the lattices of the bio-filter (Figure 2a). The non-cyclic bond was found to accommodate the copper element. This is evidence that the plant extract has been coated. The a-b-c axes supports the above inference (Figure 2b). The implication is that the optical properties of the bio-filter are also determined by the inherent properties of the copper element. Along a-b axes, it is clear that the bio-filter has four intra and one inter plane (Figure 2c). The inter-plane is dominated by the copper and hydrogen element. It is proposed that the intra bond enables the filter to curtail heat, the inter plane shield filters out the harmful UV radiation.

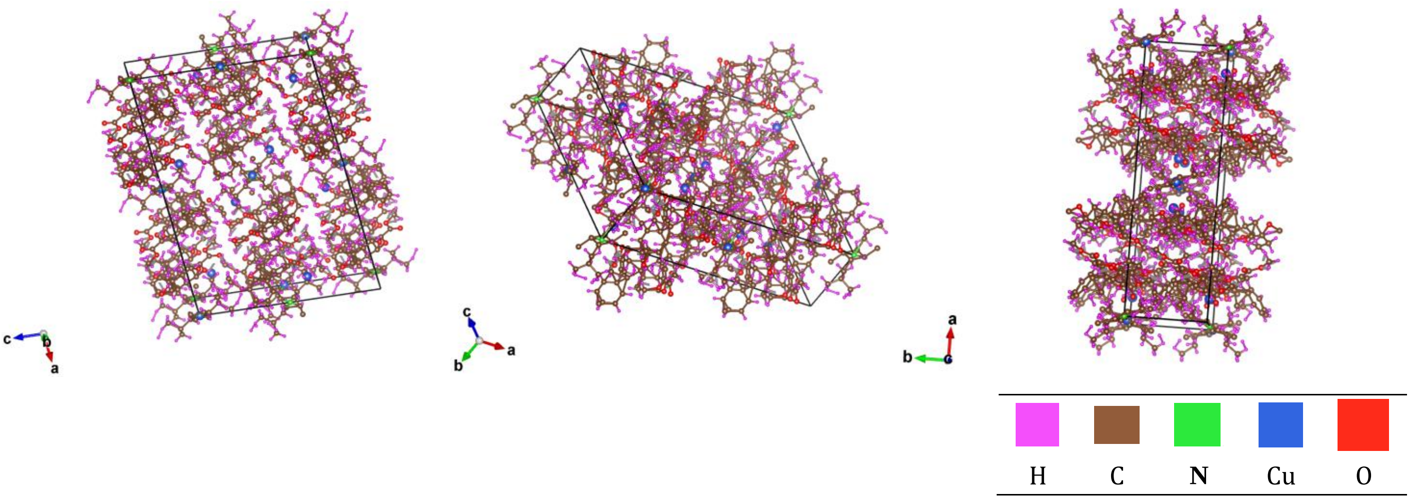


**Figure 2:** Structures of copper coated Ixora extract

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2633-2639


The XRD plot shows that the bio-filter has many planes that make an optical device. Secondly, the main planes in the bio-filter can be traced via the peaks as shown in Figure 3. The main peaks were located within 4 and 20º of 2θ. From the structural analysis, it can be inferred that this region was the interplane resides. The intra planes are the region with oxides i.e. 24 and 50º of 2θ. The refinement of the XRD data is presented in Figure 4. The intra planes section is made clearer with fewer oxides.

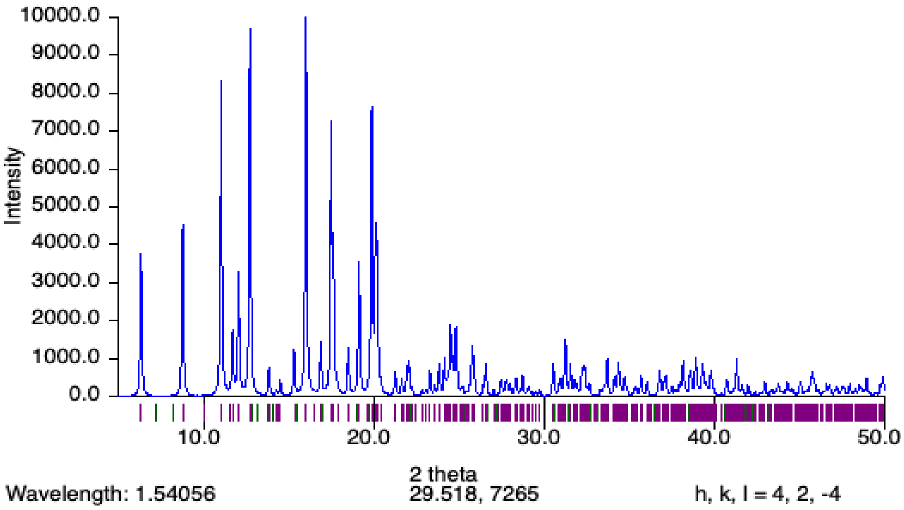


**Figure 3:** XRD of copper coated Ixora extract

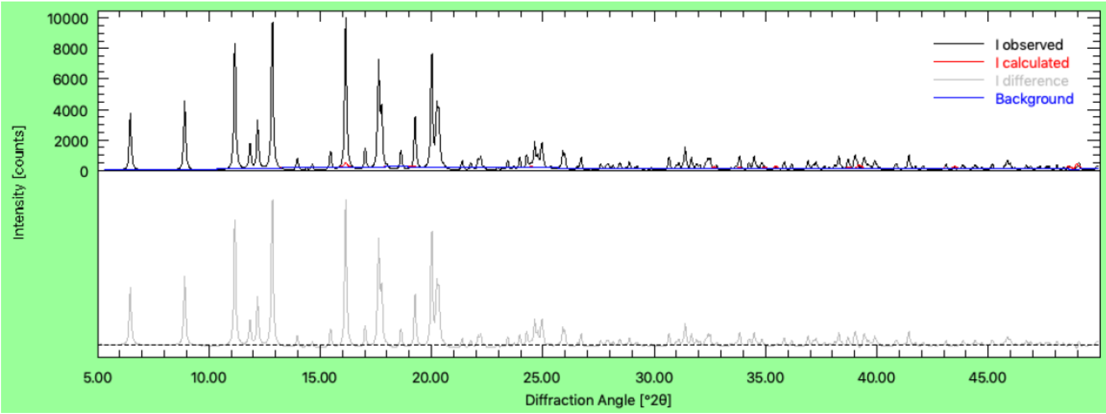


**Figure 4:** XRD refinement of copper coated Ixora extract

The monocrystalline and polycrystalline PV panels were tested in the darkroom using five types of filters i.e. blue, green, yellow, white and red. The monocrystalline PV panel voltage outputs of the experiments are presented in Figure 5. The yellow filter produced the highest voltage. The green and white filter produced almost the same result while the blue filter had the lowest voltage generation. The red filter had a second higher voltage generation. The auto-correlation for all the voltage production is presented in Figure 6. It is revealed that all pattern of voltage generation was directly proportional to the irradiance received as all of the auto-correlation of the voltage generated fell within a 95% confidence interval (i.e. the cone-like shape). The implication of this result affirms that the monocrystalline panel has a fundamental pattern of converting irradiance to voltage.

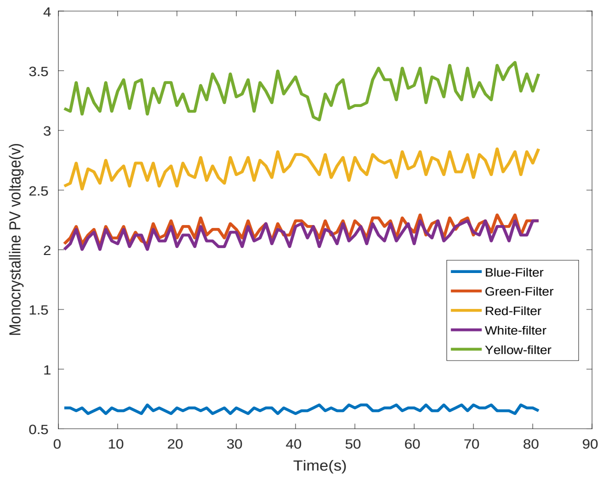


**Figure 5:** Darkroom experimentation of monocrystalline PV panel.

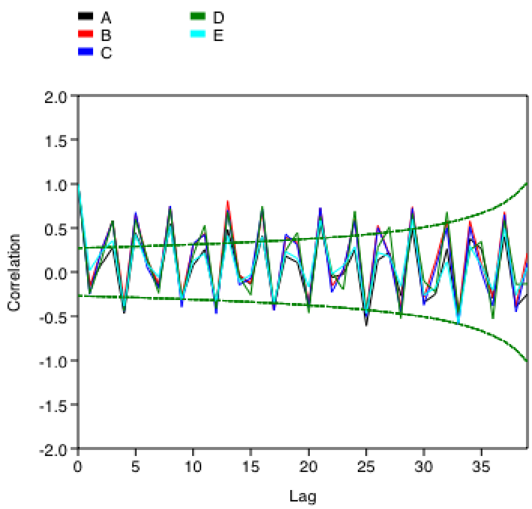


**Figure 6:** Auto-correlation analysis of monocrystalline PV panel performance.

The darkroom testing of the polycrystalline PV panel is presented in Figure 7. Like the monocrystalline panel, the yellow filter had the highest output. However, after 39 secs, the data-logger stopped recording the measurement. This scenario occurred for other filters except for the white filter. Since the challenge was not an electrical fault, it could be inferred that the polycrystalline PV panel stopped the conversion of irradiance because it could no longer assimilate the irradiance. Unlike the monocrystalline PV panel, white and red had almost the same type of voltage generation. The auto correlation of the voltage generation was performed as presented in Figure 8. The results show that irradiance is not proportional to the voltage generation as all of the auto-correlation of the voltage generated fell within a 95% confidence interval (i.e. the cone-like shape). This experiment technically shows the operational disposition of the polycrystalline panel to harsh solar radiation.

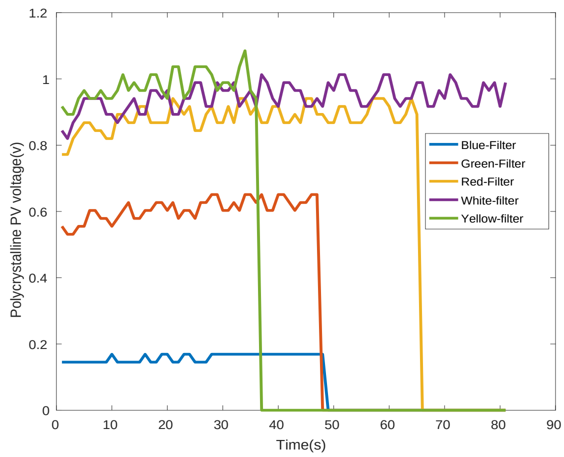


**Figure 7:** Darkroom experimentation of polycrystalline PV panel.

After testing the panels in the darkroom, the panels were sprayed as shown in Figure 3. One of each type of the panels was not sprayed. The unsprayed panel is referred to like the control of the experiment. Therefore the results that would be discussed hereafter are live experiments in the open sunlight. All the measurements were obtained same the time on the data logger.

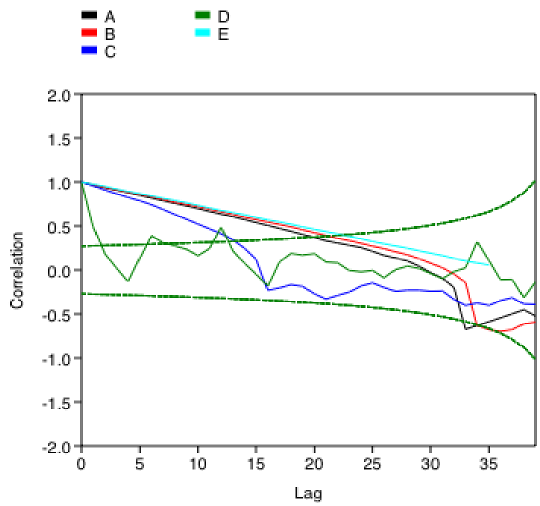


**Figure 8:** Auto-correlation analysis of polycrystalline PV panel performance.

Figure 9 below represents radiation against time on the monocrystalline PV panel. It showed significant solar radiation fluctuations before it assumed a stable state. Hence, at the transient state of the solar radiation, the fluctuation patterns may signify the harsh radiation signatures. The temperature distribution on the PV panel during the transient state of solar radiation is presented in Figure 10. It is observed that it affected the temperature distribution on the solar panel to a maximum of 52 ºC. This clearly shows that the working condition of the PV panel in the tropical zones would not enable a sustainable optimal performance.

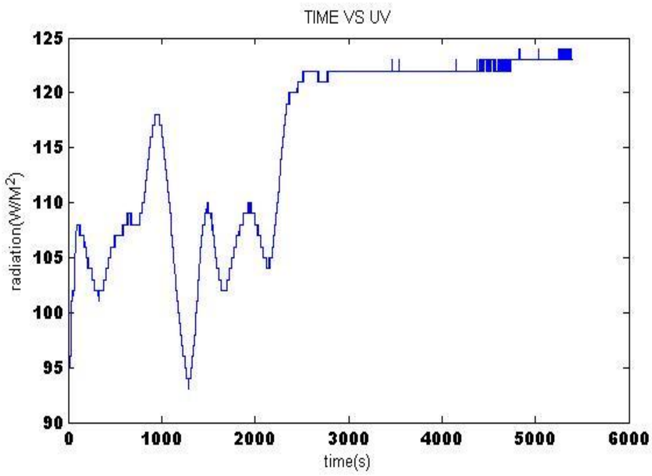


**Figure 9:** Solar radiation measurement on the monocrystalline panel

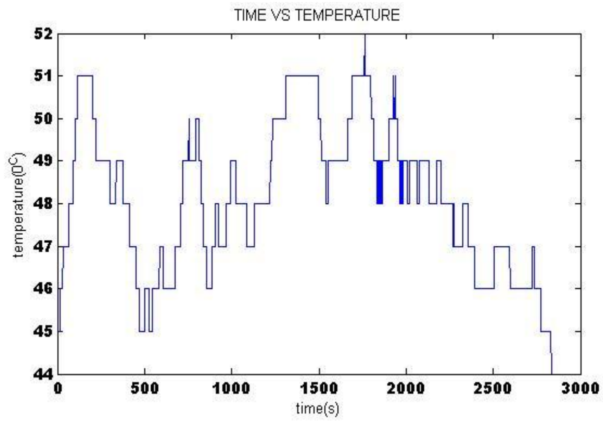


**Figure 10:** Temperature distribution on the monocrystalline panel

Figure 11 presents the current against time measurement on the sprayed and unsprayed monocrystalline PV panel. The current of the sprayed panel (current2) is higher than that of the unsprayed panel at all points of current. It is therefore salient to note that Figure 11 takes the same form as radiation pattern (Figure 9), inferring the amount of solar radiation is directly proportional to current. The results showed that the bio-filter could cushion the harsh solar radiation

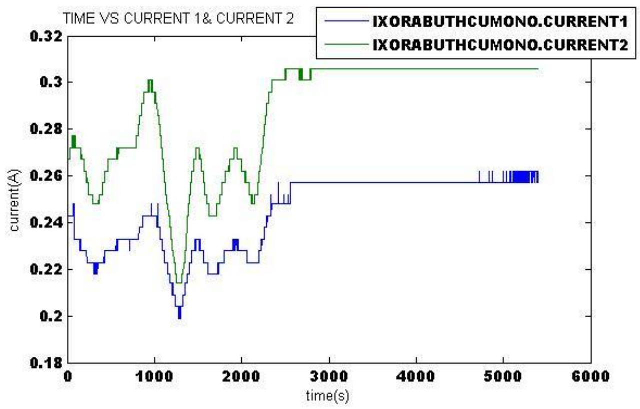


**Figure 11:** Current generation per time for monocrystalline panel

The voltage generation per time for the sprayed and unsprayed monocrystalline PV panel is presented in Figure 12. In this case, the voltage of the unsprayed panel (Voltage1) is higher than the voltage of the sprayed panel. It was observed that the unsprayed panel produced a stabilized voltage. In this case, the bio-filter acted like a stabilizer. It is worthy to also note that Figure 12 takes the same form as the radiation pattern (Figure 9), inferring the amount of solar radiation is directly proportional to voltage.

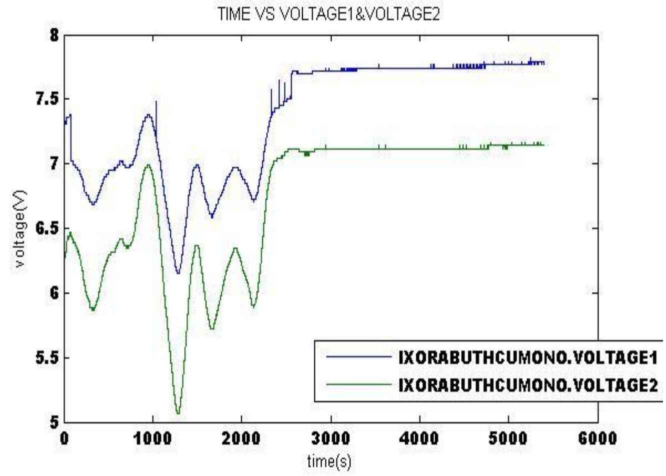


**Figure 12:** Voltage generation per time for monocrystalline panel

Figure 13 illustrates the graph of power against time in the sprayed and unsprayed monocrystalline PV panel. The power of the sprayed panel (power2) is higher than that of the unsprayed panel (power1). Like other parameters discussed earlier, the power generation takes the same form as radiation pattern, inferring the amount of solar radiation is directly proportional to the power of a solar panel. Also, it can be observed that the bio-filter stabilized the power output i.e. compared to the output from the unsprayed panel.

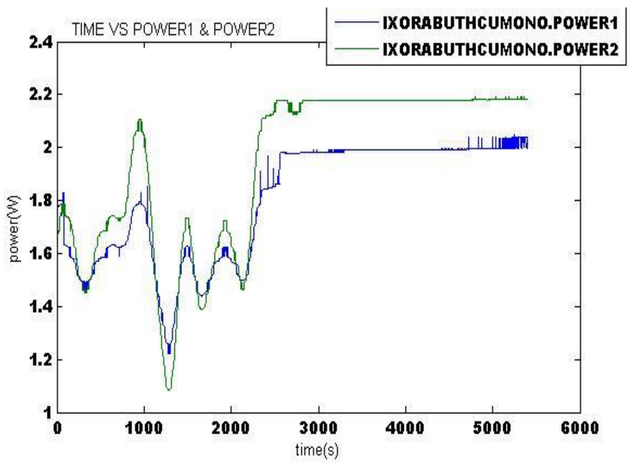


**Figure 13:** Power generation per time for monocrystalline panel

Figure 14 shows the solar radiation against time in the polycrystalline PV panel. Like the output discussed in the monocrystalline, There was a high transient state that is characterized by fluctuations that describes a sinusoidal pattern. In the later part of the day, solar radiation was found to be in a stable state. It was observed that the temperature distribution during the radiation transient state rose to 43 ºC and later decreased almost linearly (Figure 15).

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2633-2639


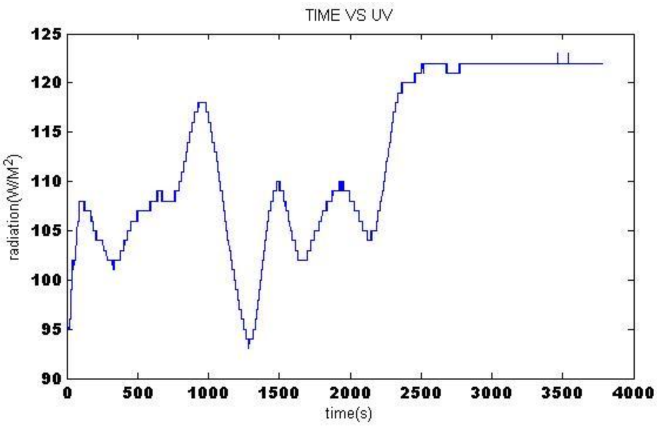


**Figure 14:** Solar radiation in the polycrystalline panel

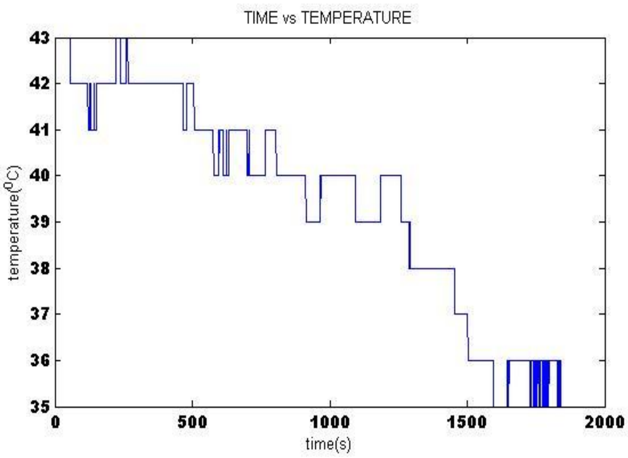


**Figure 15:** Temperature distribution on the polycrystalline panel

Figure 16 below shows the pattern of the current generation in the sprayed and unsprayed panel. It is clear that the bio-filter was able to extend the duration of the current (Figure 16) and power (Figure 18) production. Hence, the bio-filter has shown tremendous qualities to improve, stabilize and sustain current production in polycrystalline PV panels. The same stabilizing trend can be seen in the voltage generated as presented in Figure 17.

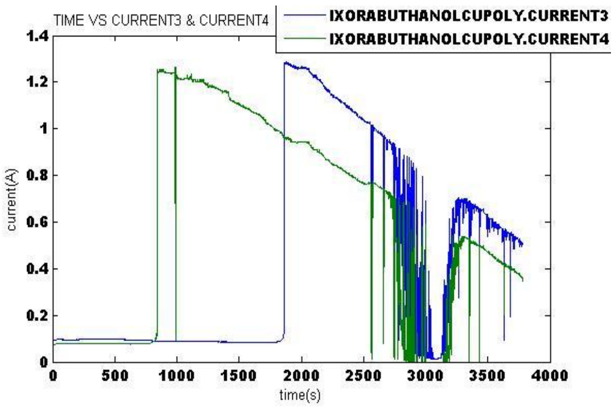


**Figure 16:** Current generation in polycrystalline panel

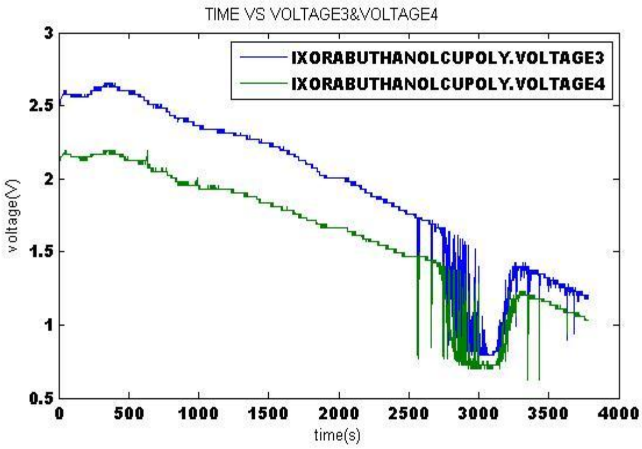


**Figure 17:** Voltage generation in polycrystalline panel

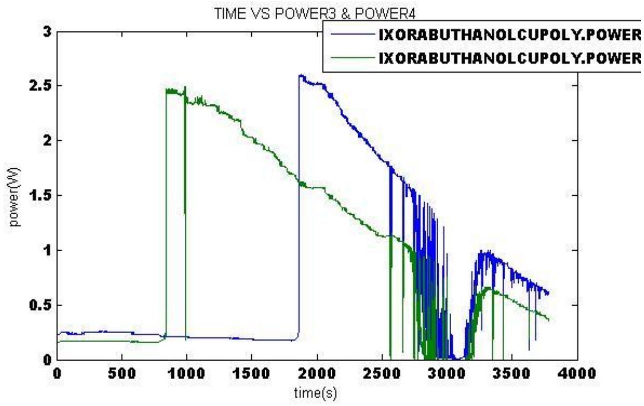


**Figure 18:** Power generation in polycrystalline panel

## CONCLUSION

From the chemical and XRD analysis of the bio-filter, it is clear that it has four intra and one inter plane. The inter-plane is dominated by the copper and hydrogen element. It is proposed that the intra bond enables the filter to curtail heat, while the interplane shield filters out the harmful UV radiation. From the darkroom test of the PV panels, it can be concluded that the monocrystalline panel has a fundamental pattern of converting irradiance to voltage while the polycrystalline panel does not directly convert irradiance to voltage. From the experiments on the bio-filter it can be concluded that the bio-filter is a novel material that can improve, stabilize and sustain salient parameters in the PV panels.

**Appreciation**
The author wishes to appreciate Covenant University for their partial contribution to the research.

## REFERENCES

[1] Cavallaro F., (2010), Fuzzy TOPSIS approach for assessing thermal-energy storage in concentrated

solar power (CSP) systems. Appl. Energy, 87: 496–503

[2] Dontha S, Kamurthy H and Manthripragada B: Phytochemical and Pharmacological Profile of Ixora: A Review. Int J Pharm Sci Res 2015; 6(2): 567-84

[3] Emetere M, S Sanni, O Dauda, A Akinsiku, O Osunlola, A Adejumo, (2019). Operational Trends of a mini parabolic solar collector for agricultural purposes in a non-active solar environment, Journal of Computational & Applied Research in Mechanical Engineering 15:4

[4] Emetere Moses E., Marvel L. Akinyemi, and Etimbuk B. Edeghe, (2016). A Simple Technique for Sustaining Solar Energy Production in Active Convective Coastal Regions, International Journal of Photoenergy 2016, 3567502, 1-11,

[5] Elumalai A., Chinna Eswaraiah, Yetcharla Venkatesh, Burle Shiva kumar and Chava Narendar, Phytochemical and pharmacological profile of Ixora coccinea Linn, International Journal of Pharmacy & Life Sciences, 3(3): 1563-1567

[6] Faten MM Darwish and Zedan Z Ibraheim: Phytochemical Study of Ixora finlaysoniana Ex. G. Don growing in Egypt. Bull. Pharm. Sci. 2003; 26(1): 91-96

[7] Johan Moan, Visible Light and UV Radiation, https://pdfs.semanticscholar.org/2273/1179c3806fdabb809e1277a6d1a3cb2e6974.pdf (25/07/2019)

[8] Kabir E., Kumar P., Kumar S., Adelodun A.A., Kim K.H. (2018).Solar energy: Potential and future prospects. Renew. Sustain. Energy Rev., 82: 894–900

[9] Lean J., and Rind D., (1998). Climate forcing by changing solar radiation. J. Climate, 11: 3069–3094.

[10] Ogunmodimu O. and Okoroigwe E.C. (2018), Concentrating solar power technologies for solar thermal grid electricity in Nigeria: A review. Renew. Sustain. Energy Rev., 90: 104–119

[11] Ma T., Yang H., Lu L., (2014), Feasibility study and economic analysis of pumped hydro storage and battery storage for a renewable energy powered island. Energy Convers. Manag., 79:387–397

[12] Nayak B.S, Udupa A.L, Udupa S.L. (1999). Effect of Ixora coccinea flowers on dead space wound healing in rats, Fitoterapia, 70(3): 33-236

[13] NREL (2012), Concentrating Solar Power Projects Database, US Department of Energy, Available at: http://www.nrel.gov/csp/solarpaces/by_country.cfm. (accessed 25/07/2019)

[14] Schmela Michael, Aurélie beauvais, Naomi Chevillard, Mariano Guillén Paredes, Máté Heisz, Raffaele Rossi, Michael Schmela, SolarPower Europe et al. (2019). Global Market Outlook For Solar Power / 2018 – 2022, http://www.solarpowereurope.org/wp-content/uploads/2018/09/Global-Market-Outlook-2018-2022.pdf (Accessed 19th July, 2019).

[15] Walsha Timothy M., Zhengpeng Xionga, Yong Sheng Khooa, Andrew A.O. Tayb and Armin G. Aberl, (2012). Singapore Modules - Optimised PV Modules for the Tropics, Energy Procedia, 15:388 – 395

[16] Wei C. G., and Bao Y. W., (2013), Performance Research on Photovoltaic/Thermovoltaic Solar System in Building Integrated Photovoltaic (BIPV), Key Engineering Materials, 544: 401-404

[17] Zalba B., Marın J.M., Cabeza L.F., Mehling H., (2003). Review on thermal energy storage with phase change: Materials, heat transfer analysis and applications. Appl. Therm. Eng., 23: 251–283