Spectral filtering of photovoltaic cells using novel bio-filter: silver-coated Ixora extract using water as a solution

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Abstract

Over the years, it has been noticed that there is a rising interest in spectral filtering to increase the overall efficiency or output of photovoltaic solar systems. Meanwhile methods for comparing the performance of spectral filtering and the effects of optical spectral filter design on system performance are not well developed. This research emphasizes on two areas, that is, to screen plant extract to serve as a coating to elongate the life span or improve the efficiency of solar cells, to test for the different spectral incident on solar cells and to apply silver-coated plant extract to filter spectral hitting the PV cells. The parameters (voltage, current, and radiation) obtained during the experiment indicate the benefit of using plant extract to coat the PV cells’ surface. Data are obtained to assess the performance of experimental spectral filters in different spectral filtering configurations. The result shows that the efficiency of the PV cell increased by 8%. This research has shown that these spectra filtering method is viable. Hence, it is recommended that solar companies concentrate on the protective layer to improve solar cell efficiency.

Keywords

The role energy plays are vital in any country’s economy, playing a vital role in its advancement and development and alleviating poverty, under-employment, and security. Uninterrupted supply of energy is a crucial problem today for many countries. Future economic growth is crucial as it depends on energy sources that are affordable, accessible, and environmentally friendly. There is a close link between climate change, the standard of living, state of the public health sector and security of the nation, and the level of energy production (Chua et al., 2005; Bakulin et al., 2012; Henson et al., 2012). A country’s standard of living is directly linked to the usage of per capita energy. The recent energy crisis in the world is caused by two factors: the fast growth of the population and the growth of the country’s standard of living. The consumption of per capita energy is a measure of the per capita income and a measure of a nation’s economic success (Mumford, 2016; Sugiawan and Managi, 2019).

Basically, the challenges facing renewable energy in developing countries include policy formation, regulation of energy, technical capacity, and finance. Governmental regulations and policies on renewable energy are salient to create a better environment for industrial and private sectors to work efficiently and effectively (Kostka and Hobbs, 2012; Wang, 2013). For example, Nigeria, Kenya, and Zimbabwe have adopted unworkable renewable energy policies such as granting incentives or abolishing the excise duty on importing components of the PV system (Karekezi and Kithyoma, 2003). Some countries have recently implemented some informal renewable energy policies, for example, Kenya and Zimbabwe have removed excise tax on photovoltaic systems. The working modalities of the PV module depend on
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The make-up of the module (Janos and Elza, 2008; Brennan et al., 2014; Eduardo et al., 2014; Arnulf et al., 2015; Hugo et al., 2015). At the moment, the challenge of the PV is not tied to cost but to the high cost of maintenance, i.e., changing PV modules two years after purchase. The performances of the PV used in the tropical Africa zone are found (i.e., by observation) to drop 50% of the performance in the first year of purchase.

Solar cells were developed to reduce the hazardous effect of fossil fuels on the environment, like the greenhouse effect, carbon footprints in the environment, acid rain, and global warming. The problem is that solar cells are most times not durable for a long time, especially here in Nigeria due to harsh weather conditions and they are also unable to produce maximum output due to different spectral of light hitting the surface of the PV cells (Emetere and Akinyemi, 2015; Emetere et al., 2016, 2019). In this research, the use of bio-filters was suggested to prolong PV lifespan and efficiency. These bio-filters are expected to perform spectra filtering to screen-out harmful radiation from hitting the PV module (Hussein and Miqdam, 2011; Daniela et al., 2014).

Materials and method

The materials used for the experiment include two monocrystalline modules (3 watt each), solarimeter, silver oxide (Ag₂O), color filters, polycrystalline module (4 watt), halogen lamp, methanol solution, ethanol solution, butanol solution, multimeter, weighing balance, beaker, and data logger.

The darkroom experiment was carried using a different color filter, as shown in Figure 1. Different color filter was used to filter the spectra of light hitting the solar module.

The data logger was used to measure desired parameters such as radiation, current, voltage, and power for two types of PV modules i.e., monocrystalline and polycrystalline. A data logger records and saves all readings obtained from the PV modules in an SD card. The darkroom experiment is to help understand the result obtained from the darkroom when compared with the data or result obtained from the silver-coated plant extract. The colors of the filters used for the experiment are yellow, white, blue, orange, green, yellow, and red.

The Ixora flower were plucked from the host institution (Figure 2) and was divided into four parts. Each portion of the flower was grinded (using an electronic blender) in 25 ml of water (H₂O), methanol (CH₃OH), ethanol (C₂H₅OH), and butanol (C₄H₉OH). After blending, extracts were filtered out and mixed with 1.84 g/mole of silver oxide (Ag₂O) and then left for a day so that the silver oxide can dissolve with the mixture. The filtrate was not heated to conserve vital chemical components. The two-polycrystalline PV modules (i.e., one module sprayed with the bio-

Figure 1: Spectral filtering using color filter in the darkroom.

Figure 2: Ixora flower.
filter and the second module not sprayed) and four monocrystalline modules (i.e., two sprayed with the bio-filter and the other two modules not sprayed) were connected to the data logger as shown in Figure 3.

Results and discussion

The simulation of the different color filter outputs is presented in Figure 4. It was observed that orange, red, yellow, and white filters had the highest power generation. Among these color filters, only the white and yellow color filters had a normal trend. Blue and red filters had the same unique trend. This result means that the PV module can accommodate the orange, red, yellow, and white color filters. This result gave a vivid idea on the type of bio-filter that must be synthesized to mimic the same results.

The graph below (Figure 5) shows the UV radiation (w/m²) against time (sec) plot of the silver-coated Ixora extract in water solution on the polycrystalline module. The trend of the graph is sinusoidal. The UV radiation at the period of measurement was averagely 82 W/m². This radiation pattern shows that the unpredictability of radiation coming from the sun over the research area. This challenge extends to the tropical belt of West Africa.

The graph below (Figure 6) shows the current (A) against time (sec) plot of the silver-coated Ixora extract in water solution for both the sprayed/coated and uncoated/unsprayed module. Generally, the graph shows a fluctuating pattern and it can be said to be transient in nature. The blue color shows the coated module, while the green shows the uncoated module for the polycrystalline module. From the graph, it can be observed that there is an increase in the current output of the coated polycrystalline module. The
peak signifies where the current is highest in relation to the UV radiation explained in Figure 5 (Figure 6).

The graph below (Figure 7) shows the voltage (V) against time (sec) plot of the silver-coated Ixora extract in water solution for both the coated and uncoated module. This graph also shows a fluctuating pattern in the voltages of both module. The blue color shows the coated module, while the green shows the uncoated module for the polycrystalline module. From the graph, it can be observed that there is an increase in the voltage output of the polycrystalline module when coated with silver-coated Ixora extract in water solution. Like the current generation, the peak signifies where the voltage is highest, as shown in the UV radiation. This result affirms the performance of the PV module is dependent on the solar irradiance.

The graph below (Figure 8) shows the power (W) against time (sec) plot of the silver-coated Ixora extract in water solution for both the coated and uncoated polycrystalline module. The blue color shows the coated module, while the green shows the uncoated module. From the graph, it can be observed that there is an increase in the power output of the polycrystalline module when coated with Ixora water silver plant extract, this is because there has already been an increase in the currents and voltages as explained above. The graph is transient in nature because it is unstable as the solar irradiance. From the above experiment, it is clear that bio-filter is very effective.
The graph below (Figure 9) shows the UV radiation (w/m²) against time (sec) plot of the Ixora water silver oxide extract for the monocrystalline module. The graph showed a stepwise increase in the UV and fluctuations at certain time. The UV over the period was averagely measured as 34 W/m². It is observed that there were positive fluctuations at time between 1,000 and 1,700 sec. Also, there were negative fluctuations of UV between 3,000 and 4,500 sec. This event is common to tropic region where solar irradiance is interfered by cloud movement or modulating corrective weather system.

The graph below (Figure 10) shows the voltage (V) against time (sec) plot of the silver-coated Ixora extract in water solution for the monocrystalline module. At 1,000 to 3,000 sec, the voltage in relation with time was stable and there was a sharp change between 3,000 and 3,500 sec. The trend of the graph is both stable and transient. The blue color shows the coated module, while the green shows the uncoated module for the monocrystalline module. From the graph, it can be observed that there is an increase in the voltage output of the coated monocrystalline module. The voltage trend is almost the same as the UV radiation.

The graph below (Figure 11) shows the current (A) against time (sec) plot of the silver-coated Ixora extract in water solution for the monocrystalline module. The blue color shows the coated module, while the green shows the uncoated module for the monocrystalline module. From the graph, it can be observed that there is an increase in the current output of the coated monocrystalline module. This result shows that the bio-filter was perfect in filtering solar spectrum.
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Figure 9: Voltage (V) against time (sec) of the silver-coated Ixora extract in water solution for the monocrystalline module.

Figure 10: Current (A) against time (sec) of the silver-coated Ixora extract in water solution extract for the monocrystalline module.

Figure 11: Power (W) against time (sec) of the silver-coated Ixora extract in water solution for the monocrystalline module.

The graph below (Figure 5) shows the power (W) against time (sec) plot of the silver-coated Ixora extract in water solution for both the coated and uncoated monocrystalline modules. The blue color shows the coated module, while the green shows the uncoated module. From the graph, it can be observed that there is an increase in the power output of the coated monocrystalline module. The following results show that the bio-filter was effective for both monocrystalline and polycrystalline PV modules.

Conclusion

The main aim of this research was to investigate plants extract that can protect the solar module from UV radiation, thereby elongating the life span of
improve the efficiency of solar cells. The plant extract acts as an optical filter that screens-out unwanted wavelength of light incident on the PV module. The silver-coated plant extract is expected to reflect heat from the cells and allow wavelengths that are not in the range of the UV radiation to pass through it. From the results obtained, it was observed that the silver-coated Ixora coccinea extracts optimized the output of the PV cell. The result shows that the efficiency of the PV cell increased by 8%.

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Literature Cited


