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EFFECT OF CHITOSAN COATING ON THE EFFICIENCY AND DEGRADATION OF SOLAR PANELS

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Abstract

The effect of an optically optimized chitosan coating on the performance of solar panels was intensively investigated. precisely, the extent to which the efficiency and the degradation of solar panels were influenced by the chitosan coating, has been discussed. The solar panels were coated with the chitosan thin films under optically optimized conditions i.e spin coating speed of 4000rpm, 1% w/v concentration and annealing temperature of 200C. The samples were exposed outside and their degradation investigated as a function of time for a period of six months. Chitosan improved the efficiency of solar panels by 4.5% just after coating and lowered their degradation rate by 0.56% p.a

Introduction

In the quest for an eco-friendly, coast effective and a sustainable source of energy, technology has focused on ways of improving the performance of photovoltaic cells OSEMBA (2019). Solar energy is renewable, more sustainable and hence can substitute fossil fuels which are depleting with time. Solar panels degrade with time when in use (Cheng et al., 2020) due to weather conditions, chemical corrosion, UV exposure, and mechanical damage (Rajput et al., 2017). Apparently, the efficiency and degradation of PV cells are about 24% %,(Köhler et al., 2021)and 1% (Dubey et al., 2017), respectively. PV cells are delicate and have been protected with a layer of a special glass with additional anti-reflective coatings to enhance its functionality. Huafei Guo et.al. in 2017 conducted a study on ITO film deposition with varied substrate temperatures for solar

Low temperatures. The structures became more polycrystalline with increase in temperature. An examination of the FE-SEM images show that rough and irregular surfaces were formed when the deposition was done at room temperature with their irregularity in both shape and size increasing with increases temperature (M. Osemba et al., 2024). Optical transmittance measurements showed that the transmittance was affected by the crystallinity, with the highest transmission registered at 200^0C and the lowest at room temperature. Lastly, an examination on the effect of the ITO structure when different amounts of oxygen were introduced to the sputtering environment was carried out (M. O. Osemba, Ojwang, et al., 2024). The optical transmittance results showed that there was low transmittance when no oxygen was added and grain size decreased at higher oxygen rates. It was clear that the optical properties of the substrates were best (90%) when the grains had good morphology, (Guo et al., 2017). Jeong and his team used Tin Oxide which is antireflective and of low refractive index under various O_2 ratios to coat solar panels by sol-gel process and improved their efficiency by 3%, (Zambrano et al., 2021). They noted that the deposited layers had smooth surfaces which was resistant to moisture absorption. Li et al., in the pursuit to establish an antireflective coating material for solar panels prepared polystyrene films and coated on both sides of a silicon substrate. Polystyrene is a synthetic polymer with good thermal stability and fluidity. The films showed a transmittance of about 75% and solar cell efficiency improved by 3.5 %. No much information was provided on the effect of the efficiency or degradation of the panels, (Shanmugam et al., 2020). Jabbar, with an objective of studying the effect of polymer thin layer on the performance of PV cells used polystyrene on crystalline solar cell. The solar cells were designed using the PCID modeling simulation software and achieved a 3.5% efficiency improvement (Osemba et al., 2024) . Chundi and friends used Magnesium carbonate precursor to develop hollow magnesium fluoride nanoparticle-based omnidirectional broad band antireflective films. The MgF^2 films for PV cells application recorded a reflectance of lower than 1%, (Chundi et al., 2020). Much on the effect of the MgF^2 films on the direct performance of the solar cells was not reported.

From the above reviews, reflective coatings used on glass are toxic and pose direct harm to both human and animals. For instance, for the case of tin oxide, the uptake of tin particles causes liver and brain damage and it is also toxic to aquatic life, (Ferraz da Silva et al., 2018), (Sharma et al., 2021). For polystyrene, when the micro-particles are ingested or accumulated by animals may cause elicit inflammatory response to heterogenic substances or physical tearing of organs, (Messinetti et al., 2018). Magnesium fluoride on the other hand causes brain and kidney damage, with chronic fluoride leading to significant bone changes. (Ciosek et al., 2021). There is hence a need for a more sustainable, cost-effective, nontoxic, and biodegradable material to be used as a coating on solar panels to reduce their degradation. Chitosan is a biopolymer from crustaceans, with good optical properties, (Han *et al*., 2018), and this paper investigates its potential in addressing the degradation of solar panels.

Experimental

Solar Panel Coating

Three miniature solar modules of dimensions 5cm by 5cm were obtained by subdividing a 10cm by 20cm monocrystalline panel using a grinder. Two of the three solar modules were spin coated with chitosan solution by placing 5 ml of 1% chitosan solution on each module placed on the rotating table of the spin coater one at a time. The spin coater was then run at 4000 rpm for 50 seconds and the spin coated samples were labelled B and C. The uncoated sample was labelled A.

(a) (b)

Fgure 1. (a) A schematic diagram of spin coating process and (b) a real photo of the solar modules being spin coated alongside

Measurements

The I_{sc}, the V_{oc}, the V_{max}, the $I_{max,}$ the power output, the conversion efficiency and the normalized output power efficiency, were the parameters whose values were the evaluating aspects of the panels. The Isc and the V_{oc} of each panel were measured and recorded using the digital multimeter, configured to DC mode. Additionally, the current and voltage at maximum power output with the help of resistors, were measured using the multimeter too.

Results and analysis

The initial efficiency of panel C, B and A before coating was computed as follows.

$$\eta = \frac{Isc * Voc}{power\ Input} * 100\%$$

$$= \frac{0.39 * 1.24}{2.125} * 100\%$$

=22.7%

The final efficiency of panel C and B after coating were achieved as follows

$$\eta = \frac{Isc * Voc}{power\ Input} * 100\%$$

$$= \frac{0.4 * 1.45}{2.125} * 100\%$$

=27.2%

P-V Curve Analysis.

For easy interpretation, the maximum power of a solar cell (P_{max}) is shown by plotting a power voltage curve. The Power-voltage curve characteristic of a PV cell shows the relationship between the voltage across the terminals of the solar cell and the corresponding power output. The power output of each panel was calculated using the product of the Isc and V_{oc} results. A graph of power output against the short circuit voltage was generated as shown in Figure 2.

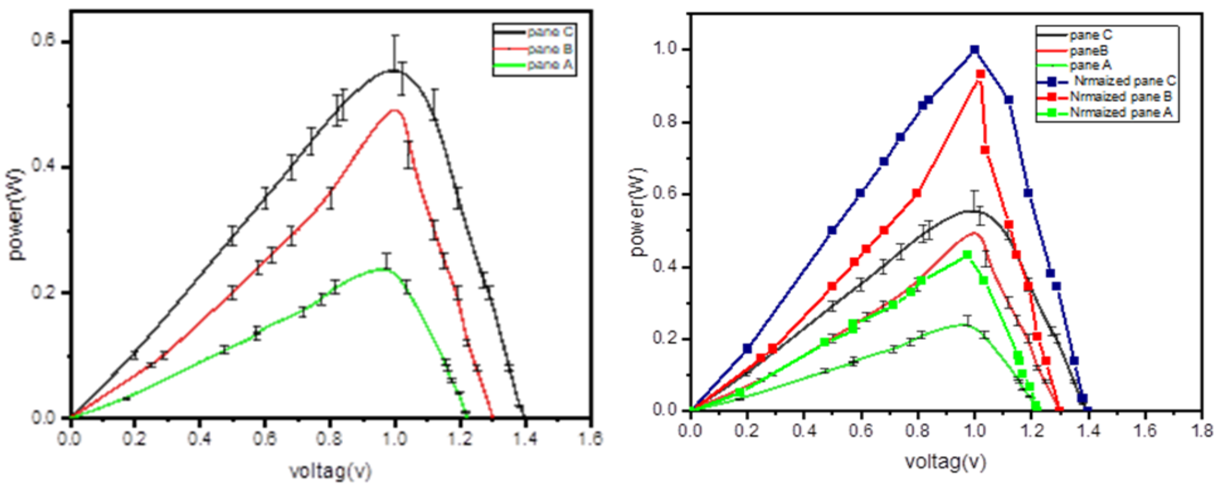

Figure 2: A graph of power against voltage of panels A, B and C after the six months' exposure period.

At zero voltage, the power output of the panels was also zero. An increase in the voltage implies that the potential difference in terms of electric charge between the terminals of the solar cell rises. Consequently, according to P=IV the power output increases too. When the maximum power output of the panels was attained, the voltage approached terminal voltage and there was a drastic drop in the power. Near the V_{oc}, electrons cannot flow because it represents an open circuit and the terminals of the solar cell are externally disconnected. The significance of this scenario is a resistance R= ∞. The current is hence reduced and reaches zero at the V_{oc}, reducing the power to zero too.

Panel B and C maintained high power output compared to A due to increased light transmittance that was made possible by the thin layer of chitosan coating, which increased the output currents. However, the power output for panel C was higher than that of B since it was not exposed to degradation agents.

Power-Time Curve Analysis

The performance of the PV module specifically its output over a certain period of time is important to manufactures technologists. This information helps technologists in understanding to what extend the solar cell is able to withstand the harsh environment and hence determine the degradation rate of the device. The rate of degradation of the PV modules dictates the direction which the technoligst have to take to inovatively and creatively come up with sustainable solutions to solve this problem. The manufacturers sleep over the solutions recommended and implement the workable ones in pursuit of improving the performance and life of solar cells. The power-time curve in figure 3 shows clearly how the maximum power output of the three panels varied throughout the six months' study period

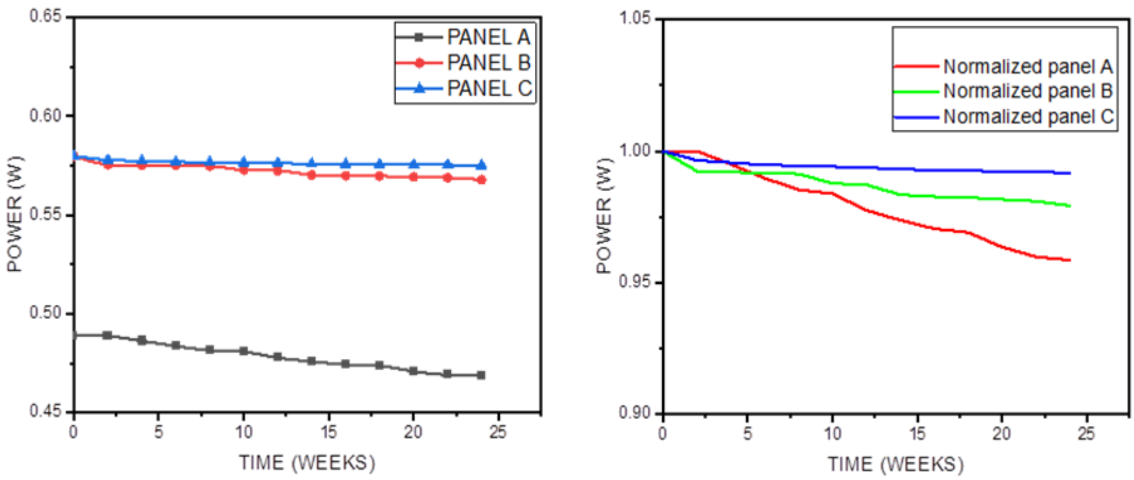

Figure 3: A graph of power output against time for panel A which was not coated with chitosan, panel B which was coated with chitosan and exposed, and panel C which was coated with chitosan and kept indoors, during the six months' study period.

The initial power output for panels B and C were similar and higher than that of A because they had been coated with chitosan which proved to improve their optical characteristics (Zoungrana *et al*., 2017). A noticeable slight drop in the power output for panel B and a radical drop of power output for panel A during the first few weeks of outdoor exposure was observed. This was attributed to the degradation agents i.e UV rays, high salty humidity, and dust exposure. During the research period up to the 10^{th} week, the power output for panel A dropped gradually but afterwards, a slight decrease in the power drop was noticed. Panel B maintained a petite power drop over the six months confirming that the chitosan coating lowered its degradation rate. Chitosan which is self-adhesive ensured a smooth surface that reduced light scattering throughout. In addition, the self-cleaning property of chitosan guaranteed a reduction of dust particles especially after the rains. Panel C maintained almost the same power all through ascertaining that the agents of degradation were present but since it was only exposed during the data collection period, the effects of these agents were minimized. Figure 3 indicates clearly that chitosan coating increases the light transmittance of glass on the solar panels and thus it improves the power output of solar panels as well as reducing the panel's degradation over time.

Conclusion

Chitosan improved the solar panels efficiency by 4.5% and lowered the degradation of solar panels by 0.56% p.a

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