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Original Article

Hydrophobic Nano Coating on Photovoltaic at Telecommunications Sites for Enhancing Efficiency and Cleaning

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Abstract - *Nano coating on PV modules has tremendous potential to improve efficiency, maintain energy production continuity, and minimize environmental impact on solar energy systems as the demand for renewable energy continues to rise. Nano coating technology's feasibility is explicitly demonstrated by the wide range of products made of different new coating technologies, which serve as a solid foundation for further research and development in this field. The article aims to discuss a case study of hydrophobic nano coating applications on PV modules at three sandy and dusty telecommunications sites. The case study examines hydrophobic nano coating application feasibility on PV systems at three remote Saudi Aramco telecommunications sites. The results were observed over a year under different weather conditions, indicating performance enhancement and less frequent maintenance.*

Keywords - *Energy, Production, Coating, Solar panels, Photovoltaic.*

1. Introduction

PV modules are a prevalently tempting renewable energy source with many environmental and economic advantages. However, several environmental factors may compromise their performance and efficiency. Many manufacturers are developing several technologies to improve PVs' efficiency and self-cleaning. Nano coating is the leading technology to improve their performance. This case study examined hydrophobicity nano coating technology for increasing efficiency by lowering light reflection, improving light absorption, and allowing self-cleaning processes.

2. Technology Background

Research on this technology and its effect on solar panels has been massive. Below is a summary of the research results:

Research showed that nano coating increases hydrophobicity and contact angle by producing nano and micro-sized surface discomfort, as observed by Scanning Electron Microscope (SEM). "Metal oxide nano particles are dispersed throughout Polydimethylsiloxane (PDMS). Research showed that nano coating increases hydrophobicity and contact angle by producing nano and micro-sized surface discomfort, as observed by Scanning Electron Microscope (SEM). "Metal oxide nano particles are dispersed throughout Polydimethylsiloxane (PDMS) polymer," the scientists realized. Clusters of varying sizes and micro nano structures are formed when PDMS-SiO_2 nano particles crosslink among themselves via the hydrophobic PDMS chain. The academics double-checked that the coating is regular transport by measuring its transparency to 91% of the visible spectrum using an Ultraviolet-Visible spectrophotometer (UV-Vis) [5].

It is pretty well known in the glass industry that applying nano coatings to glass has various beneficial effects. The coating can increase the glass's hydrophobic and residue-repellent, making cleaning more straightforward. In dusty and sandy areas, PV modules are more prone to dirt accumulation than other areas. However, this could differ from one area to another depending on different factors such as weather conditions, panel tilt and orientation, and proximity to roads. To avoid dirt accumulation, cleaning PV modules regularly and applying preventive measures before and after installation is necessary. While PV modules have a lifespan of 25 to 30 years lifespan, their efficiency starts decreasing after six years of operation in optimum condition. This signifies the importance of maximizing PV performance and efficiency [1].

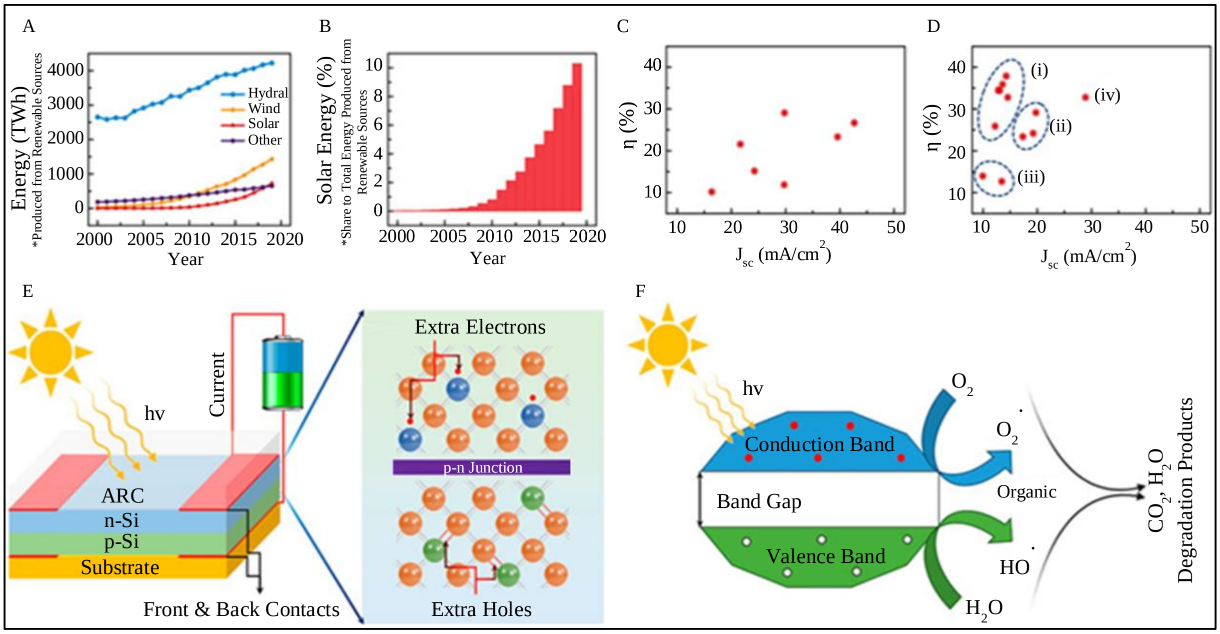

Fig. 1 Measurement before and after coating [1]

Significant progress has been made in the solar panel nano coating technology field, leading to patents and products on the market. A method for applying a special hydrophobic nano coating to solar panels is described in one significant patent. Dust accumulation is reduced by this coating type, making it simpler to clean and improving overall performance. Nano coatings enhancing energy generation capabilities and self-cleaning properties are used in some well-known products industry-wide.

Worldwide energy production from renewable sources like hydropower, wind, solar, biofuels, and biomass has significantly increased over the past two decades. The proportion of solar energy among these renewable sources has also increased, contributing to the overall energy mix. It verifies the efficiency and current density of various materials-based single-junction terrestrial solar cells. Furthermore, they have likewise concentrated on presenting multi-intersection earthbound sun-oriented cells in light of materials like GaInP, perovskite, GaAsP, a-Si/nc-Si, and precisely stacked GaAs/c-Si.

To evaluate the efficiency of solar cells, these studies have looked at factors like the short-circuit current density (Jsc, mA/cm2) and the Incident Photon-to-Current Conversion Efficiency (IPCE, %).

Furthermore, a typical design of a single p-n junction silicon solar cell includes an anti-reflective coating on top to enhance efficiency. Also involved is a self-cleaning process in which organic contaminants are broken down through photooxidation when exposed to sunlight. This cycle uses the retention of photons to create sets of electrons (e-) and openings (h+), which start oxidative and reductive pathways in the photocatalytic debasement of foreign substances.

2.1. PV Challenges in Dusty and Dry Areas

Solar Photovoltaic (PV) generation is expected to expand by 23% by 2020 [7], making it the renewable technology with the second quickest growth rate. PV is currently the third largest sustainable power plant thanks to substantial growth in established limits and significant research into further development of efficiency modifications.

2.2. Challenges of Solar in Dusty and Dry Areas

The remaining incident energy is converted into heat, which causes the temperatures of the solar cells to rise. The effectiveness of the transformation and the useful life of the board are negatively impacted by external factors such as pollution, the deposition of dust on photovoltaic panels, higher operating temperatures of the cells, and other similar factors.

According to the findings of a meta-review inquiry, the prolonged corruption rate of mono-translucent silicone sheets that are routinely used is close to 0.4% each year, even when the sheets are employed in apparent working conditions [3]. According to some estimates, the lifespan of the module can be increased by over two years if the operating temperature is lowered by just one degree Celsius.

Solar power plants can lose up to half of their annual output due to surface pollution, which directly impacts the plant's power generation capabilities. In addition, it causes the creation of local hotspots in solar cells, which leads to an increase in temperature within the cells and an acceleration of the breakdown of the cells. In research efforts aimed at mitigating the harmful effects that high temperatures can have on Photovoltaic (PV) cells, a wide variety of techniques for temperature control, including air cooling, water cooling, the use of heat pipes, phase change materials, and thermoelectric cooling, have been investigated. These techniques involve considerable capital expenditures and physical adjustments to the plant installation, such as pipes, fittings, mountings, and other similar things. Despite their effectiveness in preventing a rise in the temperature of PV cells, they do so at a cost. These technologies will have a protracted payback period, making them less practicable financially.

3. Case Study

This study aims to assess PV system performance, measure preventative maintenance frequency, and set a baseline for current system performance measurement. These sites were selected due to the massive amount of dust accumulation.

3.1. Performance before Hydrophobic Nano Coating Application

The three telecommunications sites are repeaters meant to house some signal processing and radio system components. Each site has an off-grid PV system with a five-day battery backup time. The solar system comprises eight arrays with 240 PV modules, four connected in series to constitute a string. Each array is a combination of multiple strings attached in parallel. The epidemic performance measures are the absolute maximum power and maximum generated current. The measurement was taken over a year for all three telecommunications sites. The system performance was observed and examined on an IV curve basis. As a result, all three telecommunications site measurements are pretty typical, showing poor performance due to soiling and ageing.

Table 1. PV module specification used in this case study

PV Module Details	
Module Manufacturer	BP Solar
Module Power (W)	85 W
Technology	Monocrystalline
Total Quantity	240
System Capacity (kW)	20 kW
Installation Date	2009

Table 2. PV modules performance

Location	System	Performance
Abqaiq	Repeater-102	Poor
Shaybah	Repeater-108	Poor
Shaybah	Repeater-109	poor

Fig. 2 Sand accumulation in one of the telecommunications repeaters

Fig. 3 Soiling and discoloration on the outside layer of modules

These can be attributed to improper maintenance and cleaning. Despite the continuous and laborious solar panel cleaning process, the nano coating was harnessed in this case to assess its effectiveness in easing the cleaning process.

3.2. Performance after Hydrophobic Nano Coating Application

Nano coating was applied on all the PV arrays, but a few were left as a comparison reference. Then, performance and efficiency were observed and recorded over a year. It was noticed that the coated surface can be cleaned by merely blowing air over it and that it continues to be clean even after it has rained, unlike the uncoated surface, which retains water spots. Buildup of particulate matter, soil, and water: with an air blower, the surface of the treated panels' protective lens was brought to a higher level of cleanliness than that of the uncoated ones. In addition, the surface of the protective lens was cleaned using an absorbent cloth after it had been dried, resulting in a smoother surface free of any noticeable watermarks. Uncoated panels, after being cleaned with an absorbent material, the surface of the protective lens still had water spots with a clear, uneven surface. The solar panel has a protective lens with a nano coating applied. This results in the surface of the lens being smoother and cleaner, and it also repels water and prevents water stains, which makes the panel much simpler to clean.

On the efficiency level, applying nano coating to solar panels resulted in several notable efficiency and cleaning enhancements. First and foremost, the coated panels displayed a substantial increase in an overall efficiency of 10%, considered a massive step due to the solar panel age and installation condition. This increase can be attributed to the hydrophobic nature of the nano coating, reduced light reflection, water droplet formation, and energy absorption losses.

Table 3. Measurement taken to compare between nano coated and non-nano coated string

	String 1 (Nano Coated)	String 2 (Non-Nano Coated)
Measurements		
Date	3/21/2023	3/21/2023
Time	11:38:49 AM	11:33:41 AM
Pmax	228.78	218.69
Vmpp	60.03	50.72
Impp	3.81	4.31
Voc	77.78	67.09
Isc	4.34	4.86
Target Estimation		
Pmax	298.40	321.53
Vmpp	67.84	68.45
Impp	4.80	5.14
Voc	86.14	86.64
Isc	4.33	4.93
SolSensor Measurements		
Irradiance (W/m^2)	1012.30	1022.76
Ambient Temperature (Deg C)	34.48	35.20
Cell Temperature (Deg C)	46.69	49.92
Pitch (Deg)	29.26	28.95
Roll (Deg)	-0.98	-0.72
Tilt (from pitch and roll above) (Deg)	29.27	28.95
Results		
Performance Factor (%)	**76.7**	**62.2**
Latitude	25.7	25.7
Longitude	-50.1	-50.1
Time Zone	3	3
Module Mfr	BP Solar	BP Solar
Module Model	BP275	BP275
# of Modules in String	4	4
# of Strings in Parallel	1	1

The nano coating's self-cleaning properties prevent dust accumulation on the panels. 30% reduction in dust accumulation was attested. This reduced the need for manual cleaning regularly, saving time, reducing resources for maintenance, and improving the solar panel lifespan.

4. Conclusion

By leveraging advancements in nano technology and continuously improving solar PV cell efficiency, we can unlock the full potential of solar energy and pave the way towards a cleaner and more sustainable future. In terms of enhancing efficiency and making cleaning solar panels simpler, nano coatings offer significant advantages. The hydrophobic properties of the coatings limit water drop arrangement, upgrade light transmission, and increase energy age. Furthermore, self-cleaning properties effectively decrease dust aggregation, prompting diminished maintenance requirements and improved long-term performance.

Future examinations ought to focus on upgrading the piece of nano coatings, investigating extra functionalities like anti-reflective properties, and directing long-term durability tests to evaluate the coating's presentation under different natural circumstances. By advancing nano coating technologies, we can make solar panels more effective, long-lasting, and environmentally friendly. This will allow us to realize their full potential.

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