Beneficial effects of Nano hydrophobic coatings for Solar photovoltaic modules in dusty environment

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Abstract. In this paper, we propose and experiment the application of self-cleaning Nano coating on solar panels. We have measured an important increase of water droplet contact angle on Nano coated surface. We found beneficial effects on light transmittance and Open Circuit Voltage (Voc) for the photovoltaic modules. Experimentally, we have shown a higher Transmission coefficient (T) in case of treated glass. In addition, from Thermal Camera analysis, we have shown that the Nano coated Photovoltaic module became cooler and cleaner comparatively to untreated module.

Introduction

Through ongoing advances in materials technology, thin films and nanomaterials are a potential alternative to significantly reducing the costs of solar energy systems; they have the potential to use high-performance materials that offer high energy conversion efficiency and functionalized properties [1]. In this study, the sensitivity of solar modules to the dust deposition and the temperature variations are experimented and allowed us to optimize energy production for solar plants to be implemented in our dusty sites (desert region, close to the sea side, arid and semi-arid) [2, 3]. To fulfill this requirement, we propose and experiment in this paper the application of self-cleaning Nano coating on solar panels.

In order to avoid the soiling on PV modules glass, we have conducted several trails by applying a hydrophobic Nano coating material. As shown in previous studies for desert and semi-arid regions, the cleaning cost is very important and implies increases in the maintenance and operating costs (M&O) of PV power plants and then energy price [4]. That supports our interest in proposing solutions to the use of solar panels in dusty or polluted environment.

Experimental of surfaces treatment by hydrophobic coating

In order to avoid the soiling on PV modules Glass, we have conducted several trails by using a hydrophobic coating material based on mixture of polymers and essential natural oils. Its exact formulation is under patent and commercialized by nanotol® brand name [5]. Several trails have been conducted on free glass samples and PV modules. The glass samples are destined to study the water repellant propriety (Hydrophobicity) that we create and the measurement of droplet water contact angle. Then, the glass samples permitted us to study light transmission evolution. The coated PV modules by the hydrophobic layers go to electrical and thermal analyses to determine their performances and behavior presented in the next section. The Fig. 1 summarizes the main steps for glass and PV module Coating. The Deposition process of the Hydrophobic Nano - coating are start by Cleaning of glass or PV module with distilled water and detergents. Then, in case of residual dirt, cleaning by using concentrated nanotol® Primer solution [5]. Otherwise, we go directly to final step of cleaning by diluted nanotol® Primer solution in distilled water (15 ml /1 litre). After drying by using microfiber weeper, we obtain a perfect clean surface ready to seal by the hydrophobic Nano coating. Finally, we spray a thin film of nanotol® Sealant solution [5] of on the cleaned glass which is keep 10 minutes before polishing by a specific microfiber weeper. The treated glass and PV module are kept in clean place for 48hours before exposure to outdoor conditions.

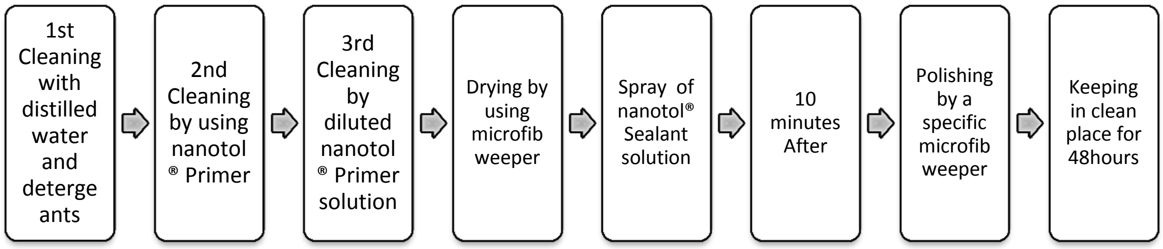
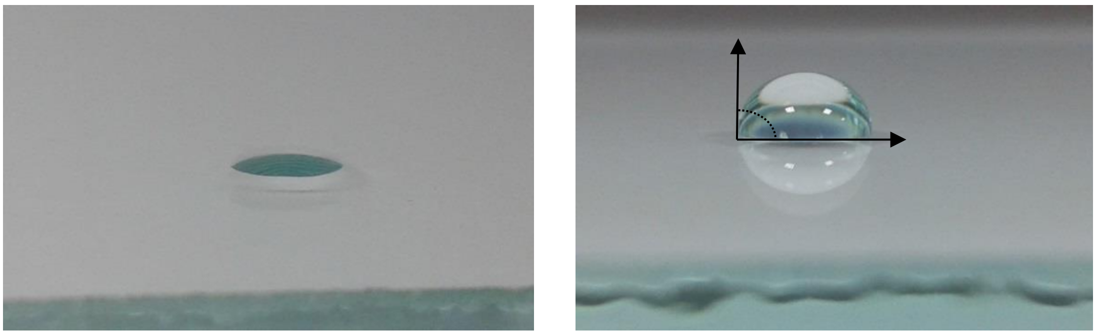


Figure 1. *Nano-Coating Process flow chart for glass samples and PV modules*

Results and discussions

To verify the hydrophobicity behavior of our coating, we have measured the contact angle. For this subject, we have applied a high resolution camera for image capture of water droplet on glass surface. We have seen from Fig 2. a and b) an important increase of water droplet contact angle reaching around 90° (Fig 2.b). Also, we can see the beneficial effect in cleaning dusty surfaces on the Fig.3 where we can observe the clean wake of the water.



a) b)

Figure 2. *Droplet water angle contact increase by Nano coating.*
a) Untreated Glass, b) Nano coated glass.

We have successfully shown a higher Transmission coefficient in case of treated glass. Tis improvement is shown experimentally on Fig. 4, where an average gap of 3.73% between treated and untreated clean glass was measured. On the other hand, this gap of transmission is widened in case of dusty glass and became 8.78% in our conditions of dust deposition (4.6 g/m^2).

a) b)

Figure 3. Water effect on dusty glass surface, a) untreated, b) treated

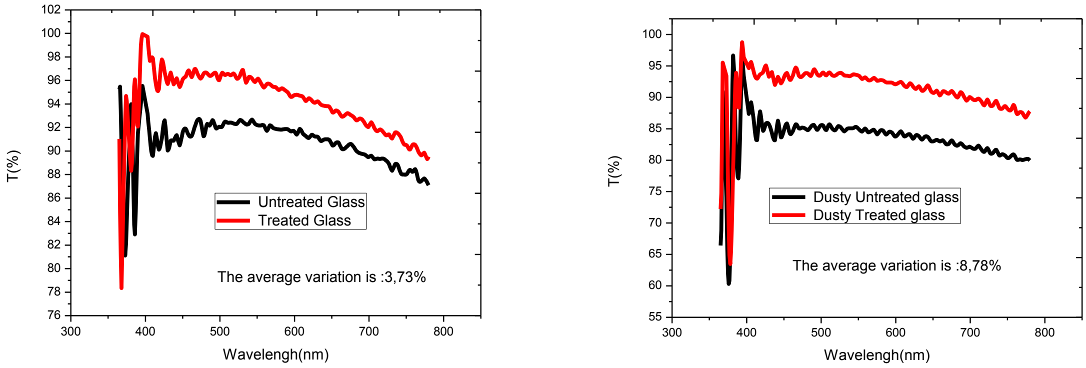


Figure 4. *Experimental results for light Transmission coefficient (T)*

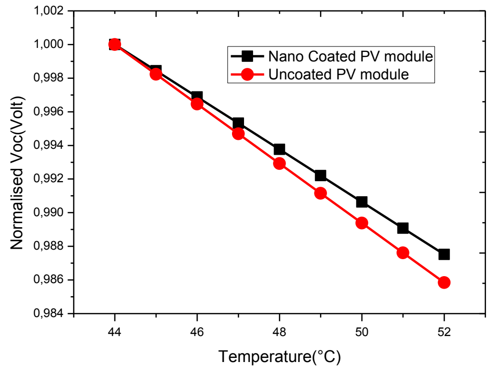
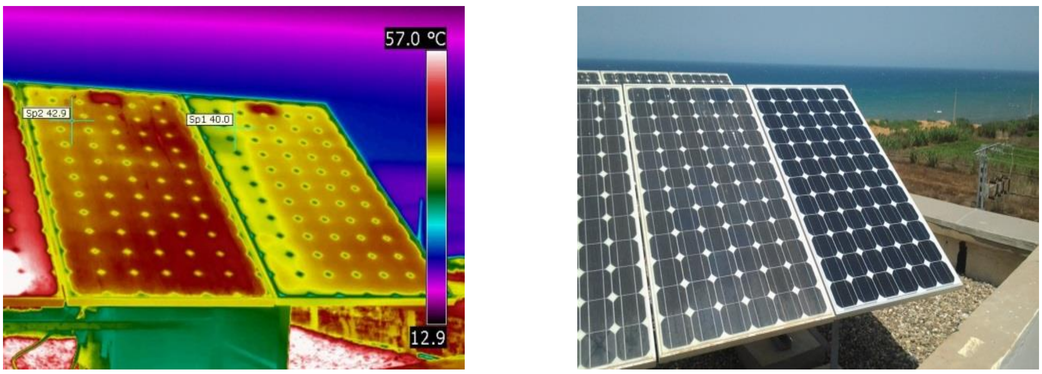


Figure 5. *Dusty PV module backside Temperature versus Open Circuit Voltage (Voc)*

By using a data logger Hydra Fluke-series II in an outdoor experimental bench, the PV module backside Temperature versus Open Circuit Voltage (Voc) has been studied. We have plotted our measurement results on Fig. 5. Then, we calculted the losses coefficient of Voc voltage versus Temperature (ΔVoc/ΔT) for Nano Coated and Uncoated PV module. We found that lower losses for Nono Coated PV modules (ΔVoc/ΔT= -15.6mv/°C for Nono Cated PV, ΔVoc/ΔT = -17.7mv/°C for Uncoated PV). This will improve their behavior for our high temperature conditions in our sites (North Africa). The application of a thermal camera has confirm this previous results by showing a profile color (Fig. 6-a) indicating lower temperature for treated module this is explained by dust hot spot effect [6]; Indeed, the dust accumulation conducts to an increase of the shadowed area in PV cells, which generate more higher hot spot and then higher temperature in PV module. Meanwhile, we observe a cleaner surface module in case of treated surface by hydrophobic Nano coats.



a) b)

Figure 6. *Nano coated PV module is cooler and cleaner.*
(a) Thermal Camera view, (b) Optical Camera view.

Cost Analysis of hydrophobic coating

In order to prove the added value of our proposal of coating for PV modules technology Operating and Maintenance (O&M), we have estimated the cost of surface treatment by the hydrophobic coating from nanotol® including its application labor, for a total price of about 0.72Euros/m2/2 years, where the treatment is valid for two years at least [7]. Thus, it is 0.36Euros/m^2/year. From reference 4, where climatic condition is matched with our region (North Africa), we calculated the cost for cleaning one square meter by conventional method in large scale PV plants (>1 MW); it is 2.25 Euros/m^2/year. Therefore, by using Nano coating proposal, we win 1.89 Euros/m^2/Year, it is equivalent to 18.900 Euros/1MW/ Year.

Conclusion

We have shown that Nano coated glass have higher transmission which is translated by enhanced electrical performance of PV modules. The experimental studies of thermal and electrical behavior of PV modules showed a significant decrease of losses in Open Circuit voltage versus temperature coefficient. In addition, the cost analysis estimated an interesting gain about 1.78 Euros/m2/Year when we compare to conventional technic of cleaning. Also, this supports the sustainability of PV technology in our region where water reserve is limited. In perspective of this paper, we are collecting experimental data to measure how much the gain of efficiency (%) and energy output (W) would be per square meter over a period of two year of a nanotoled PV panel compared to a uncoated one.

References

[1] Suresh Sagadevan, Recent trends on nanostructures based solar energy applications: a review, Rev. Adv. Mater. Sci. 34 (2013) 44-61

[2] S. Bhrath Raghav, V. Dinesh, Recent Developments on Nanotechnology In Solar Energy, International Journal Of Engineering And Computer Science ISSN:2319-7242 ,Volume – 5 Issue -02 February, 2016 Page No. 15829-15834

[3] J.K. Kaldellis, M. Kapsali , Simulating the dust effect on the energy performance of photovoltaic generators based on experimental measurements, Elsevier, Energy 36 (2011) 5154-5161, doi:10.1016/j.energy.2011.06.018

[4] Tamer Shahin, New Energy Oasis (NEO)-Desert Solar at KAUST King Abdullah University, http://saudi-sia.com/wp-content/uploads/2013/05/7-Tamer-Sahin-NEO-Presentatin_SolarPlaza.pdf

[5] Information on: http://www.cenano.co.uk/nanotechnology-products/our-products/nanotol-the-universal-nano-product/

[6] Yuzuru UEDA et al, “Performance degradation analysis of different kinds of PV technologies in HOKUTO solar project”, 26th EPVSEC, 05-09 Sep. 2011, Hamburg

[7] Information on: https://www.nanotol.de/en/online-shop/nano-coating-for-glass/

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