SUSTAINABLE TECHNOLOGY OF HYDROPHOBIC THIN FILMS DEPOSITED WITH PLASMA TO REPLACE THE USE OF WATER IN THE MAINTENANCE OF PHOTOVOLTAIC SOLAR CELLS

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INTRODUCTION

Photovoltaic solar cells can be installed in different environmental conditions, where exposure to superficial dirt material varies, such as: sand[1] industrial smut[2] and organic material[3]. The reduction in efficiency can reach up to 12.7% depending on the level of accumulated superficial dirt[4]. In order to mitigate the effects of dirt deposition, surface washing processes are recommended by manufacturers, which demand time, specialized workers and potable water consumption, all of which are subjected to unavailability in certain regions[1,5].

Thin films based on aluminum oxides and nitrides have optical, electrical and morphological characteristics of interest in the area: being transparent to visible light, resistant to corrosion and thermally stable[6]. The magnetron sputtering DC plasma technology (PDMS) is widely used to grow nanometric films with low energy consumption, without generation of toxic wastes, and to deposit continuous thin films over the sample surface[7].

In this work, the deposition of aluminum nitride (AlN) thin films, produced by PDMS on glass surfaces, were characterized regarding optical, morphological and wettability properties aiming the manufacture of self-cleaning photovoltaic solar cells.

MATERIALS AND METHODS

The plasma reactor consisted of a Pyrex cylinder (Fig. 1a) with aluminum walls. The cathode is the magnetron (Fig. 1b) where the 99.99% purity aluminum target was positioned (Fig. 1c). Precision branded cover slip samples (22 x 22 x 0.13 mm) were cleaned in isopropyl alcohol and acetone, dried and placed in the sample holder (Fig. 1d) at a distance of 140 mm from the plasma source. A pre-vacuum was carried out with a mechanical pump and final pressure of 10^{-5} mbar was achieved with a diffusion pump (Fig. 1e). N_2 (99.99% purity) working gas was inserted with a needle valve (Fig. 1f) up to the working pressure of 3.10^{-3} mbar, monitored by an Edwards interface (Fig. 1g). The pulsed voltage source (Fig. 1h) was activated to generate the plasma (Fig. 1i) with a 50% cycle, 500 V, electric current of 1.3 A and 20 kHz. The thin film deposition time varied from 10 to 60 s, with an increment of 10 s, and from 60 to 300 s, with an increment of 60 s. The morphology of the films and the deposition rate were investigated by scanning electron microscopy (Field Emission Gun, FEG

– SEM, Tescan). Wettability tests were performed using the sessile drop technique, in accordance with the ASTM[8] standard, using an Image software. The optical characteristics of films were investigated by UV-Vis (Varian, Cary 50) in transmittance mode, ignoring the interference of the glass substrate.

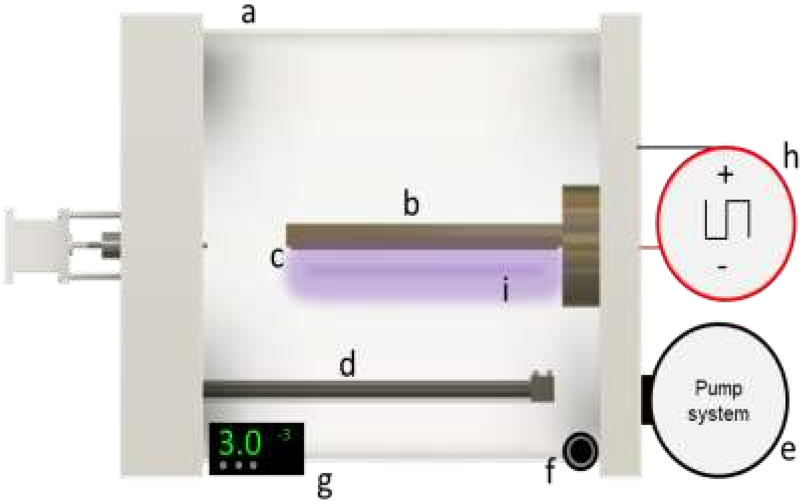

Figure 1. Plasma reactor and its main parts.

RESULTS AND DISCUSSION

Micrographs of the thin films with deposition times from 120 to 300 s showed surfaces with a smooth texture and without defects, as shown in Fig. 2a. In Fig. 2b it is possible to observe a region that was purposely damaged for the analysis. For the deposition time of 300 s, the thickness obtained was of approximately 39 nm. Thus, the average deposition rate under the proposed conditions was 7.8 nm.min^{-1}.

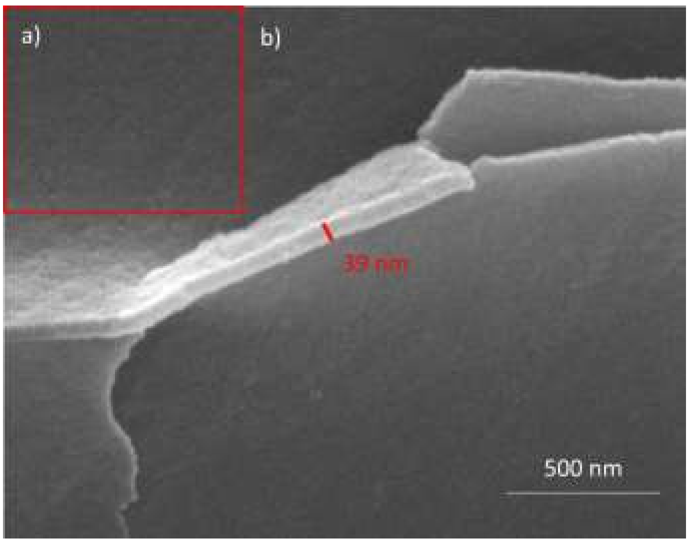

Figure 2. Morphology and thickness for 300 s films.

In Fig. 3, the samples' surface spectra are presented as a function of the changes in transmittance and exposure time in the plasma.

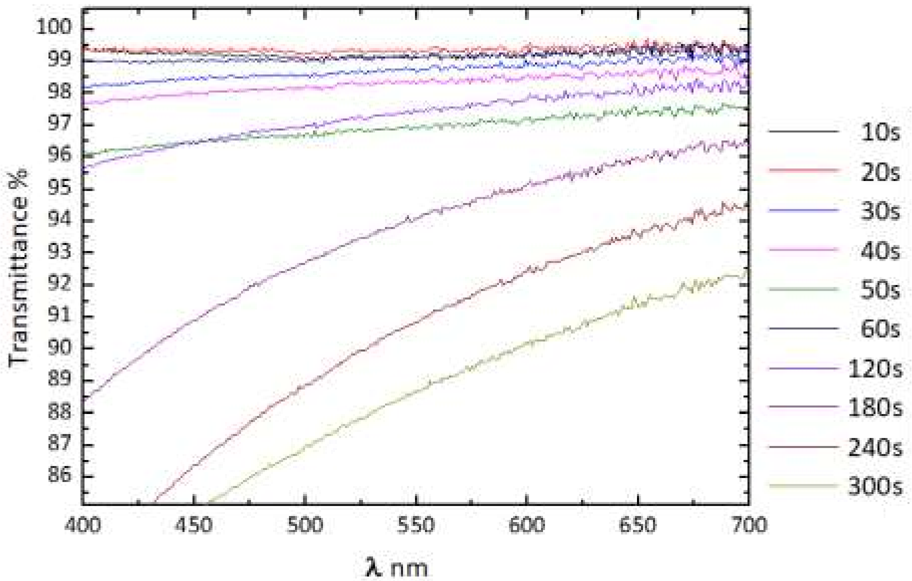

Figure 3. Transmittance % results for AlN thin films.

Fig. 4 shows the wettability results. The substrate surface presented contact angles (θ) of 33°, typical of hydrophilic surfaces[9]. However, the thin films increased the θ to 100°, being classified as hydrophobic[9] in all depositing conditions.

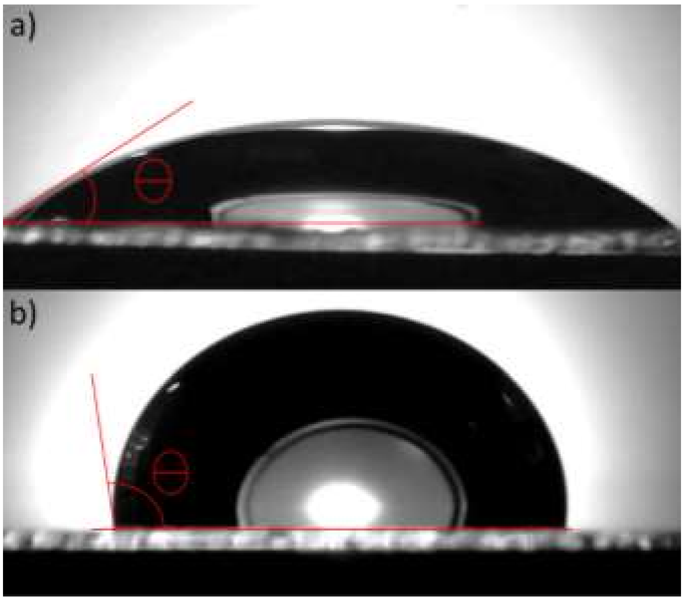

Figure 4. θ angle for glass samples (a) and coated with AlN (b).

The film deposition rate in this study allowed for the complete coating of the substrate surface. According to the results obtained by UV-Vis, there was a decrease in transmittance due to the increase in film thickness. Deposition conditions using 100% N_2 produced transparent films. However, differences in morphology and roughness can generate absorption and reflectance[9]. For all cases, the deposited thin films were hydrophobic with θ angle above 100°, allowing self-cleaning properties for applications in photovoltaic solar cells.

CONCLUSION

Thin films of aluminum nitride of nanoscale materials, produced by PDMS, changed the optical characteristics of the substrate glass, showing a gradual reduction in transmittance as a function of the thin film thickness.

Samples produced with deposition times between 10 to 30 s are promising to *in situ* applications, due to their high transmittance—in the order of 99%—which can be beneficial to commercial solar panel surfaces, mainly due to the self-cleaning features added to the panels' surface. The premise of this application is to increase long-term efficiency and mitigate the use of water resources in the cleaning processes, increasing sustainability of energy production in photovoltaic solar cells.

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REFERENCES

Al-Dousari, A., Al-Nassar, W., Al-Hemoud, A., Alsaleh, A., Ramadan, A., Al-Dousari, N., & Ahmed, M. (2019). Solar and wind energy: Challenges and solutions in desert regions. Energy, 176, 184–194. https://doi.org/10.1016/j.energy.2019.03.180

ASTM International - ASTM D7334-08. (2008). *Standard Practice for Surface Wettability of Coatings, Substrates and Pigments by Advancing Contact Angle Measurement*. https://www.astm.org/

Deb, D., & Brahmbhatt, N. L. (2018). Review of yield increase of solar panels through soiling prevention, and a proposed water-free automated cleaning solution. Renewable and Sustainable Energy Reviews, 82, 3306–3313. https://doi.org/10.1016/j.rser.2017.10.014

Hachicha, A. A., Al-Sawafta, I., & Said, Z. (2019). Impact of Dust on the Performance of Solar Photovoltaic (PV) Systems under United Arab Emirates Weather Conditions. Renewable Energy. https://doi.org/10.1016/j.renene.2019.04.004

Joshi, A., Chiranjeevi, C., Srinivas, T., Raja Sekhar, Y., Natarajan, M., & San, N. A. (2020). Experimental investigations on the performance of solar photovoltaic system for different industrial weather conditions with dust accumulation. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2020.08.637

Mwema, F. M., Akinlabi, E. T., & Oladijo, O. P. (2020). A systematic review of magnetron sputtering of AlN thin films for extreme condition sensing. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2020.02.317

Rosa-Clot, P. (2020). FPV and Environmental Compatibility. Floating PV Plants, 101–118. https://doi.org/10.1016/b978-0-12-817061-8.00009-9

Swann, S. (1988). Magnetron sputtering. *Physics in Technology*, 19(2), 67–75. https://doi.org/10.1088/0305-4624/19/2/304

Dimitrova, V., Manova, D., & Valcheva, E. (1999). Optical and dielectric properties of dc magnetron sputtered AlN thin films correlated with deposition conditions. Materials Science and Engineering: B, 68(1), 1–4. https://doi.org/10.1016/s0921-5107(99)00221-4