eNergetics 2020

Effect of Surface Treatment of Substrates on Optical and Morphological Properties of Multilayer Selective Solar Surfaces (Cr/Si)

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I. Introduction

In the midst of the search for sustainable development, solar energy is an important energy alternative. One of the simplest ways to use this energy is through its thermal conversion in solar collectors [1][2]. To increase the efficiency of these collectors, coatings called selective solar surfaces (SSS) are applied, which aim to increase the absorption of incident solar radiation and reduce thermal losses by emission in the infrared region [2][3]. The optical and morphological properties of the SSS are influenced both by the material and the deposition technique used in its construction [3].

Therefore, the objective of this work is to obtain selective surfaces with a single layer of chromium (*Cr*) and multilayer of chromium (*Cr*) and silicon (*Si*) through the Magnetron Sputtering technique with different deposition times and using substrates subjected to different surface treatments (cleaning with hexane and electropolishing).

II. Materials and Methods

The methodological procedures followed the order presented in the flowchart of Fig. 1.

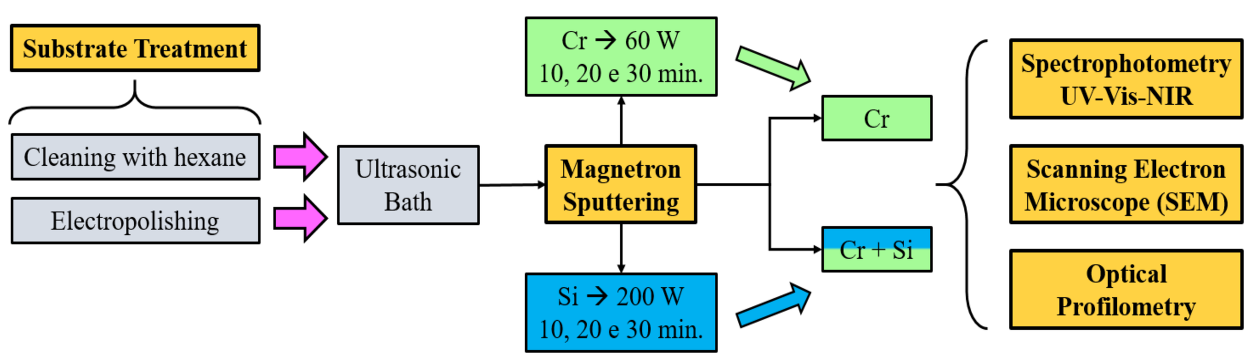

Figure 1. Flowchart of methodological procedures

Based on the different surface treatments and the parameters adopted in the depositions, 12 conditions were obtained, according to Table 1.

TABLE 1 SAMPLES NOMENCLATURE

Sample	Composition	Surface Treatment	Deposition time
C1	*Cr*	Hexane	10 min
C2			20 min
C3			30 min
C4		Electropolishing	10 min
C5			20 min
C6			30 min
CS1	*Cr/Si*	Hexane	10 min/10 min
CS2			20 min/20 min
CS3			30 min/30 min
CS4		Electropolishing	10 min/10 min
CS5			20 min/20 min
CS6			30 min/30 min

III. Results and Discussion

A. UV-Vis-NIR Spectrophotometry

To facilitate the comparison between the different films, the solar absorptivity and the standard deviation for each condition were calculated. These values are shown in Fig. 2, which shows that the electropolished samples presented the highest values of solar absorptivity, greater than 95 %, associated with standard deviations between ±0.21 % and ±3.77 %. Furthermore, it is observed that, in most samples, the addition of the Si layer contributed to an increase in the absorption. And 20 minutes of deposition per layer prove to be the ideal deposition time for most conditions.

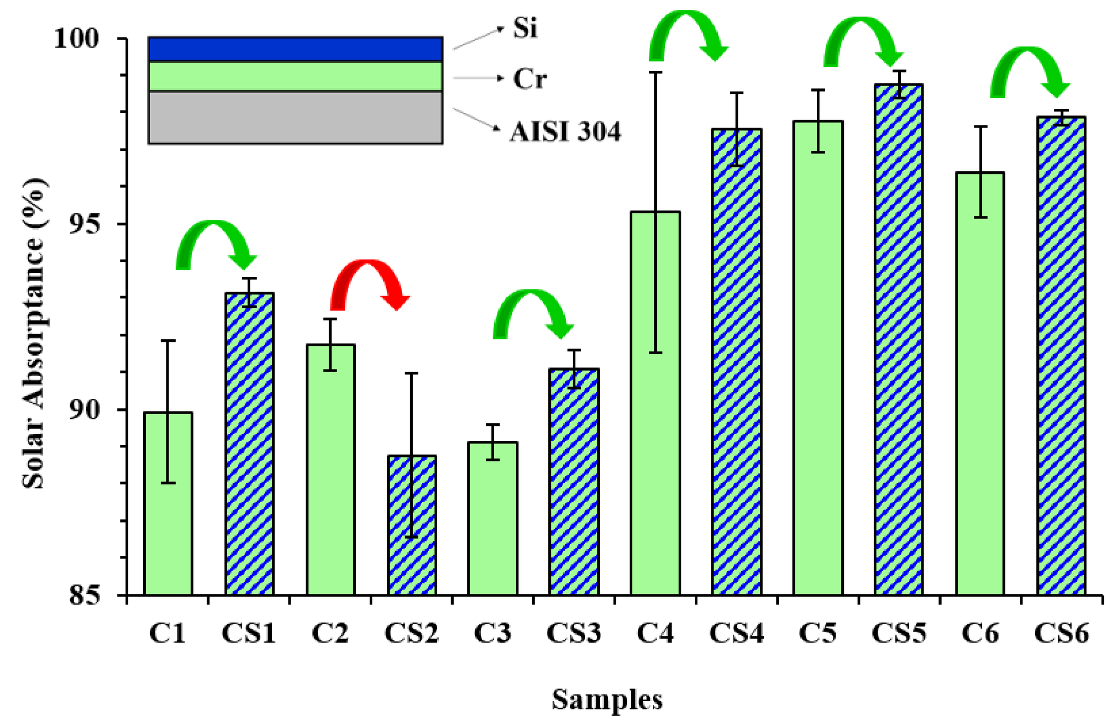

Figure 2. Solar absorptivity and standard deviation

When comparing the selective surfaces obtained in this research with the commercially available films and in the literature (Fig. 3), it is clear to observe that the best chromium films that were produced, C5 and CS5, present very satisfactory results. They obtained better results than so many SSS produced via Sputtering (●) and reached a level above the recommended (90%) to be considered commercial absorber surfaces.

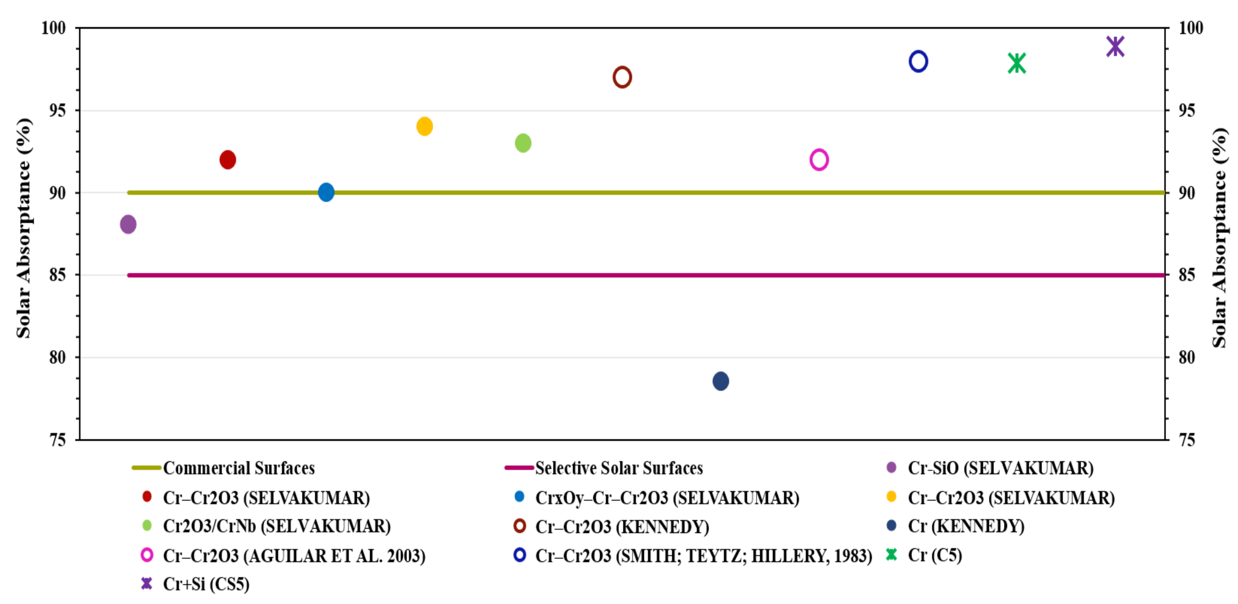

Figure 3. Results in literature and commercial surfaces

B. Optical Profilometry

From the optical profilometry analysis, the roughness parameters and the thicknesses of the films were obtained. The results shown that, in coatings deposited on substrates cleaned with hexane, the highest levels of absorption are associated with higher values of Ra (arithmetic roughness). On the other hand, the opposite behavior was observed in the films deposited on electropolished substrates: the reduction in Ra contributed to an increase in the solar absorptivity of the *Cr* surfaces and the *Cr/Si* multilayer surfaces.

Moreover, the films obtained nanometric thicknesses, except CS3. And the thickness values increased after the application of the silicon layer and with the increase in the deposition time.

Fig. 4 shows the 3D microstructures of the *Cr* and *Cr/Si* films that presented the best solar absorptivity considering both surface treatments. It shows that the films that have a more homogeneous surface and with lower values of roughness, notably those deposited on electropolished substrates, presented better performance in terms of absorption.

C. Scanning Electron Microscopy (SEM)

The micrographs with magnitudes of 10000 times for the *Cr* films deposited on substrates subjected to cleaning with hexane are shown in Fig. 5.

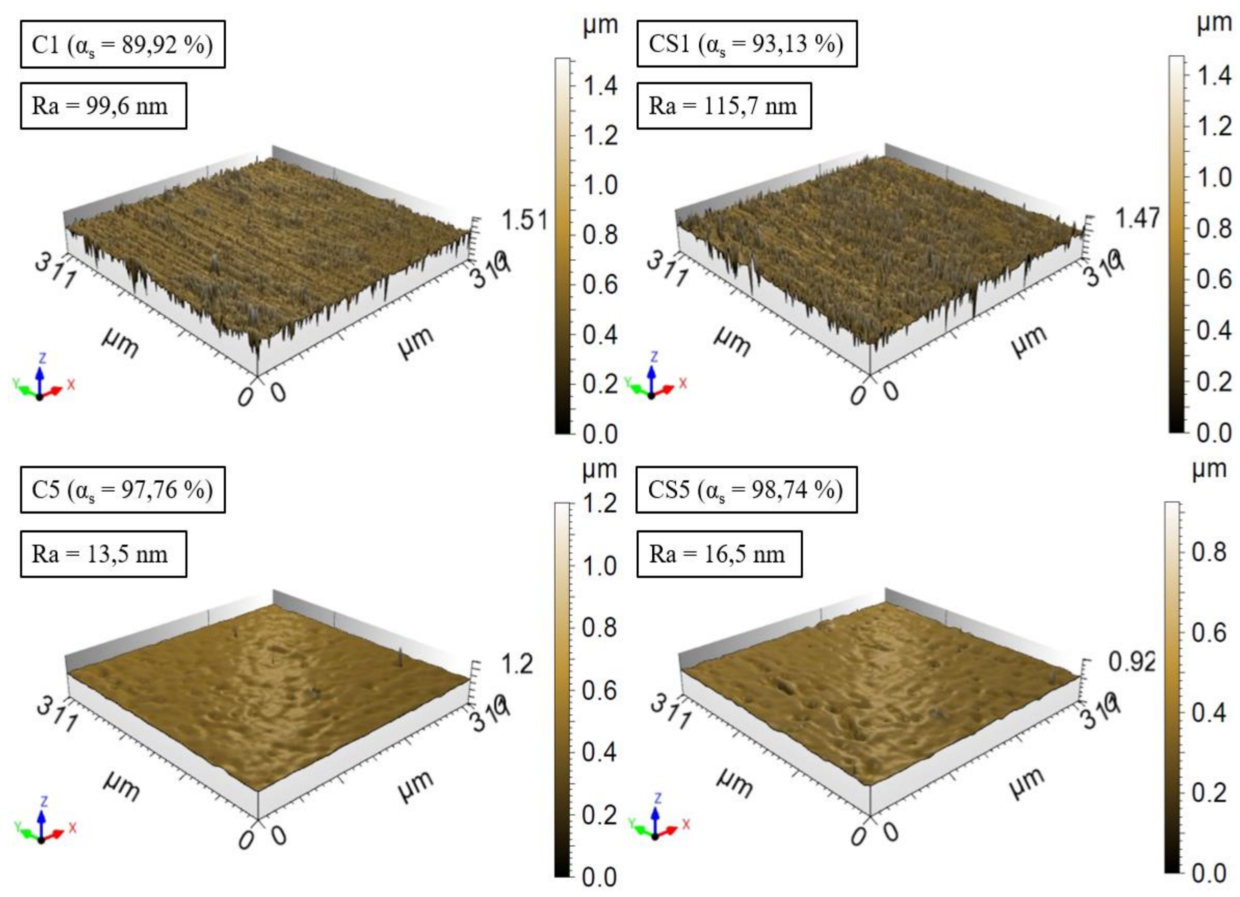

Figure 4. 3D microstructures of the best films

It can be seen that the films which had longer deposition times (C2 and C3) presented a rougher surface and the highest levels of absorption, indicating that the increase in the roughness of the surfaces favored the increase in the solar absorptivity for the *Cr* films treated with hexane.

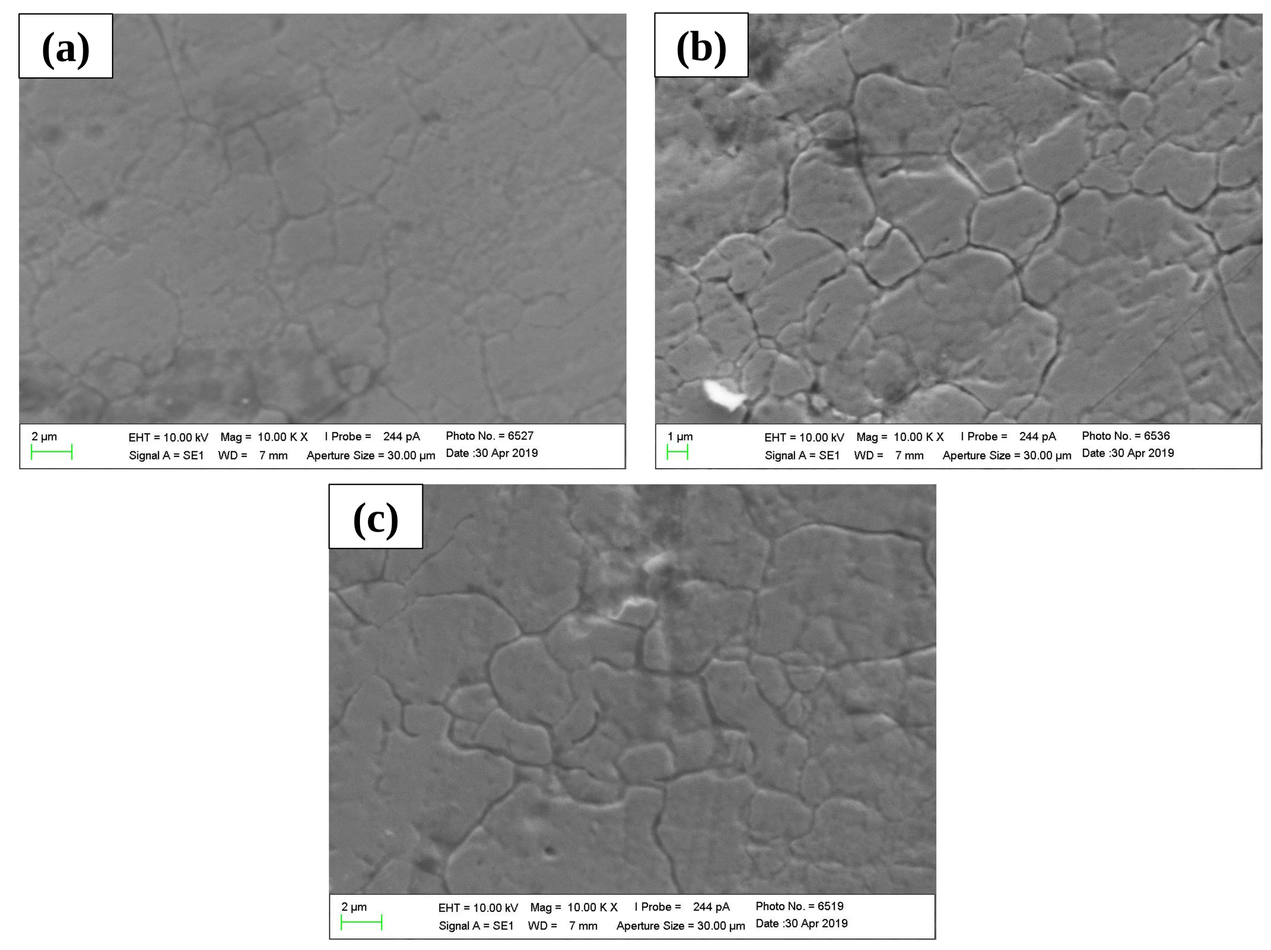

Figure 5. Micrographs of the films: (a) C1, (b) C2 and (c) C3

IV. Conclusion

The surface treatment influences the optical and microstructural characteristics of the films. Among the surface treatments used, electropolishing proved to be more efficient and contributed to the achievement of better performances, because the films deposited on electropolished substrates showed the highest solar absorptances (≥ 95%). These films also had the lowest roughness parameters.

Furthermore, the application of the silicon layer and the time of 20 minutes of deposition per layer provided an increase in the level of absorption in most samples.

References

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