Artificial Bee Colony algorithm: a novel strategy for optical constants and thin film thickness extraction using only optical transmittance spectra for photovoltaic applications

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Abstract

An effective approach to determine thin film thickness (d) and optical constants (n, k, α) from transmittance spectrum with interference fringes is proposed. The developed strategy is based on applying the artificial bee colony (ABC) algorithm and Cauchy dispersion model. The accuracy test of this method has been assessed by using simulated and real tests. Simulated test is used to check the ability of ABC algorithm to determine the parameters of simulated transmittance spectra. Real test deals with the investigation of the determination approach on experimental measured transmittance spectra. Those spectra were measured from six elaborated samples of amorphous hydrogenated silicon (a-Si:H) thin films with different thicknesses, which will be used as an eco-friendly layer for solar cell applications. The obtained results noticeably show the high effectiveness of the developed strategy to accurately determine the thin film thickness and optical constants.

Keywords: ABC algorithm, a-hydrogenated silicon, Cauchy dispersion model, optical properties determination, solar cell, transmittance spectrum.

1. Introduction

Traditional energy sources, such as oil, coal and natural gas provide huge amounts of greenhouse gas emission that result in global warming and climate change [1]. Nowadays, renewable energy sources are the best solution to protect environment and satisfy human demands of energy. There are several types of renewable energy sources in which solar energy is considered as very prominent sources. It is a free, sustainable and completely inexhaustible source of energy. Photovoltaic (PV) system is one of the most commonly used types of solar energy sources [2]. The main idea behind this technology is the conversion of sunlight beams into electricity through the photovoltaic effect. In other term, the semiconductor material that compose the PV cells absorbs the sunlight beams, which causes a reaction and generate electricity [3]. However, the collection of important amounts of sunlight beams by PV cells is a serious challenge for the researchers [4].

Optical thin films have been considered as good candidate in the fabrication of solar cells due to their good optical properties. Indeed, lots of works have been proposed as use of optical thin films in PV cells fabrication [5, 6]. The amorphous hydrogenated silicon (a-Si:H) thin films is widely utilized in the process fabrication of solar cells [7]. The determination of its optical properties is important to enhance the conversion efficiency and performance of a-Si:H based solar cells.

The study of thin films optical properties consists of determining the film optical constants (refractive index n, extinction coefficient k and absorption coefficient α) and film thickness d. Optical transmittance and reflectance spectra are frequently used to deal with this concern. In the literature, several works have been proposed to identify the optical parameters using the transmittance spectrum. Manifacier et al [8] proposed an efficient traditional method to compute optical properties and film thickness by using transmittance spectrum of non-absorbing substrate-based optical thin film. In addition, Swanepoel [9, 10] suggested an analytical method to determine n, k and d for a-Si:H films. This method, which is based on computing upper and lower tangent envelops, allows the calculation of the optical constants following many approximation steps. Several researchers have adopted this technique in order to analyze the optical properties and thickness of thin films [11-13]. However, some difficulties can be remarked when using this method [9], for instance the need to manually reject abnormal values of film thickness during the first approximation of d. A Levenberg–Marquardt algorithm-based approach was suggested in [14] to determine the film thickness and optical constants of TiO_2 nanotube array thin films.

To facilitate the extraction stage, a special attention has been given to another type method, referred to as fitting method [15-17]. Its main principle is the use of efficient algorithms to determine the aforementioned parameters in such a manner that the calculated spectrum show a good fit with the measured one.

In the present work, a novel efficient fitting-based strategy is proposed. It uses the Artificial Bee Colony (ABC) algorithm [18] and Cauchy dispersion model [19] to deal with the aforementioned limitation. This method consists of subdividing the transmittance spectrum into two main parts. The first part corresponds to the medium and weak absorption zone of transmittance (interference fringe region). The thin film thickness (d) and refractive index (n) values are determined by using this part of transmittance. The second part corresponds to the remaining zone of transmittance (strong absorption region). Absorption and extinction coefficients (α, k) values are determined based on the transmittance data of this region. The efficiency test of this approach was elaborated by using simulated and experimental transmittance spectra of six elaborated a-Si:H samples.

Experimental details

During this work, a-Si:H thin films have been fabricated from (SiH_4+Ar) by using a standard capacitive radio frequency (13.56 MHZ) PECVD system. The electrode diameter and separation between electrodes were set as 10 and 2 cm, respectively. The thin layers have been deposited on glass substrates after rinsing them with acetone and then ethyl alcohol for 30 min using ultrasonic syringes.

In order to perform the deposition, the following experimental conditions have been adopted:

- Substrate temperature (T_s) was set to 200°C
- Reactor pressure was in the range of 400-1000 mTorr
- RF power varied between 100 and -200 W
- Deposition time was fixed at 15 min

Once the deposition was performed, the optical properties of all samples were investigated using the transmittance spectra obtained by a double beam UV–Vis-NIR spectrophotometer (Jasco V-570). The film thicknesses were measured by using TENCOR P12 profilometer to verify the accuracy of the estimated optical thicknesses.

2. Developed approach

The following sections give a detailed explanation of the developed strategy for the determination of the optical constants and film thickness. The problem formulation, theoretical background, and the ABC algorithm will be presented.

2.1. Problem formulation

The optical transmittance, T, of a deposited thin film on a transparent substrate for a normal irradiance is given by Eq. (1) [9, 15].

$$T = \frac{Ax}{B - Cx + Dx^2} \qquad (1)$$

where

$$A = 16\, n_s(n^2 + k^2) \qquad (2)$$

$$B = [(n+1)^2 + k^2]\,[(n+1)(n+n_s{}^2) + k^2] \qquad (3)$$

$$C = [(n^2 - 1 + k^2)(n^2 - n_s{}^2 + k^2) - 2k^2(n_s{}^2 + 1)]2\cos\varphi - k[2(n^2 - n_s{}^2 + k^2) + (n_s{}^2 + 1)(n^2 - 1 + k^2)]\,2\sin\varphi \qquad (4)$$

$$D = [(n-1)^2 + k^2][(n-1)(n-{n_s}^2) + k^2] \quad (5)$$

$$\varphi = \frac{4\pi n d}{\lambda} \quad (6)$$

$$x = \exp(-\alpha\, d) \quad (7)$$

$$\alpha = \frac{4\pi k}{\lambda} \quad (8)$$

In Eqs. (1)-(8),

n_s is the substrate refractive index (its value is assumed to be known),
d is the film thickness,
n represents the film refractive index,
k is the film extinction coefficient,
α is the film absorption coefficient,
λ is the wavelength,
φ is the phase, and
x is the absorbance

Moreover, the dispersion is defined as the refractive index variation of transparent substance as function of light wavelength. In this case the film refractive index increases with decreasing light wavelength. Several formulas have been proposed to describe the dispersion relationship. However, the most commonly used one is Cauchy dispersion model. It is given as follows [19]:

$$n(\lambda) = A_1 + \frac{B_1}{\lambda^2} \quad (9)$$

$$k(\lambda) = A_2 + \frac{B_2}{\lambda^2} \quad (10)$$

Where A_1, B_1, A_2 and B_2 are four fitting parameters.

The determination of thin film thickness (d) and optical constants (n, k, α) investigated in this work involves solving complex and nonlinear equations (Eqs. (1)-(10)). In this approach, the crucial strategy is to consider the identification issue as an optimization (minimization) problem, for which the cost function F to be minimized will be defined as the Root Mean Square Error (RMSE) between the measured and estimated transmittance spectra, in the following manner:

$$RMSE = Min\,(F) \quad (11)$$

where

$$F = \sqrt{\sum_{i=1}^{n} \left[T_{exp}(i) - T_{est}\,(i,\mu)\right]^2 / L} \qquad (12)$$

In Eq. (12), T_{exp} and T_{est} are experimental and estimated transmittance spectra, respectively. μ is a vector that contains the list of parameters to be determined ($\mu = [A_1, B_1, A_2, B_2, d]$). L is the length of transmittance vector. This step aims to find the optimal values ($A_1{}^*, A_2{}^*, B_1{}^*, B_2{}^*\ and\ d^*$) such that the RMSE reach the smallest possible value. Towards this end, an efficient heuristic method, named ABC algorithm [18, 20] is used.

It should be mentioned that this strategy gives accurate results by dividing the transmittance spectrum into two parts.

The first one deals with the region of weak and medium absorption (area with interference fringes) and it is used to compute the thin film thickness (d). Also, based on the obtained values of $A_1$and B_1in this region, the refractive index variation $n(\lambda)$ is computed by replacing them into Eq. (9) for the complete wavelength range.

In the other hand, the second part of the spectrum deals with the strong absorption region. It will be used to compute the absorption coefficient variation $\alpha(\lambda)$ on the basis of Swanepoel approximation [9] after having replaced the obtained values of n and d (obtained from the region with interference fringes) as follows [9]:

$$T_\alpha = \sqrt{T_M T_m} \qquad (13)$$

$$G = \frac{128 n^4 {n_s}^2}{T_\alpha^2} + n^2(n^2-1)^2({n_s}^2-1)^2 + (n^2-1)^2(n^2-{n_s}^2)^2 \qquad (14)$$

$$x = \frac{\left\{G - [G^2 - (n^2-1)^6(n^2-{n_s}^4)^2]^{1/2}\right\}^{1/2}}{(n-1)^3(n-{n_s}^2)} \qquad (15)$$

$$\alpha = \frac{-\log(x)}{d} \qquad (16)$$

In Eq.(13)-(16), T_M and T_m are upper and lower tangent envelops, respectively (gotten from the transmittance spectrum). n_s is the substrate refractive index.

An extrapolation stage will be then elaborated to determine the variation of $\alpha(\lambda)$ for the complete wavelength range. Finally, the extinction coefficient values $k(\lambda)$ is computed by using Eq. (8).

The proposed approach is described in the flowchart shown in Fig. 1.

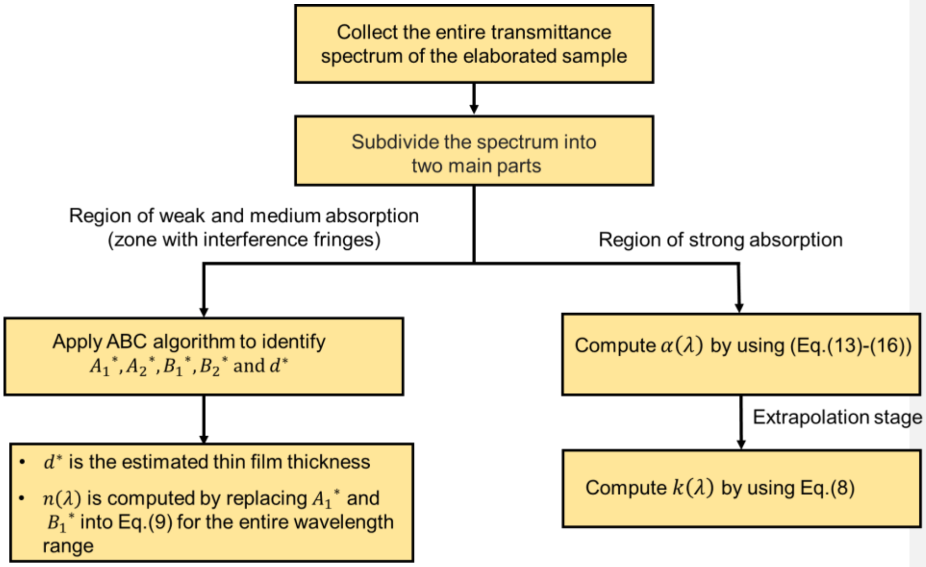

Fig. 1. Flowchart of the proposed approach for the determination of the optical constants and film thickness.

2.2. Artificial Bee Colony Algorithm

In the ABC algorithm, the colony of bees contains three different groups of artificial bees (named as employed, onlooker and scout bees). The main goal of the first category of bees (employed bees) deals with exploiting the food sources (nectar) that were previously explored. Then, they share different information about these sources of food (nectar position and quantity) with the waiting bees in the hive (onlooker bees). By using this information, the onlooker bees that are inside the hive will select the food source to be exploited. Finally, the scout bees aim to search randomly around the hive to find a novel food source site. In fact, when reaching an abundant food source, the scout bees will return to the hive and make their dance to direct other bees to a new food source site [18, 20, 21]. The main stages of ABC algorithm are given bellow:

a. Initialization stage

- Set the value of the subsequent parameters:
  - ✓ Number of employed (SN) and onlooker (LN) bees
  - ✓ Maximum number of cycle (MNC)
  - ✓ Solution dimension (Dim) (which is defined as the number of parameters to be determined).
  - ✓ Limit (number of failed trials to find a better food source)
- Generate in a random manner the initial positions of food sources (initial solutions) by using Eq. (17):

$$x_{ij} = x_j^{min} + rand[0,1](x_j^{max} - x_j^{min}) \quad (17)$$

where x_j^{min} and x_j^{max} are the values of lower and upper boundaries of solution x in dimension j, respectively. $rand$ [0,1] defines a randomly generated number in the range of [0-1], $i = 1,2, \dots, SN$ and $j = 1,2, \dots, Dim$.

- Compute the generated positions fitness by computing the cost function value of the initially generated positions x_{ij}.
- Cycle = 1
- while (cycle $\leq$ Maximum number of cycle (MNC)) do:

b. Employed bees' stage

- For the entire employed bees do:

  - Generate new food sources by using Eq. (18):

$$V_{ij} = X_{ij} + \Phi_{ij}(X_{ij} - X_{kj}) \quad (18)$$

where V_{ij} and X_{ij} represent the novel and previous solutions, respectively. Φ_{ij} is a random number in the range of [-1,1], k and j are randomly designated indexes, in the intervals $[1, SN]$ and $[1, Dim]$, respectively, so that $(k \neq i)$.

  - Compute the value of fitness (cost function) that corresponds to the generated positions V_{ij}. Next, compare the old and novel solutions with the aim of selecting the best one.

c. Onlooker bees' stage

- For all onlookers do:

  - Calculate the value of probability p_i, as follows:

$$p_i = \frac{fit(x_i)}{\sum_{n=1}^{SN} fit(x_n)} \quad (19)$$

where $fit(x_i)$ denotes the value of fitness that corresponds to the position x_i.

  - Allocate for each onlooker bee a food source by using the roulette wheel and the value of probability p_i.
  - Generate a new food source for each onlooker bee by using Eq. (20):

$$V_{ij} = X_{ij} + \Phi_{ij}(X_{ij} - X_{kj}) \quad (20)$$

where V_{ij} and X_{ij} are the novel and previous solutions, respectively. Φ_{ij} defines a random number in the range [-1,1].

- Compute the value of fitness that corresponds to the latest generated positions, then compare the old and new solutions and finally select the best one.

d. Scout bees' stage

- For the whole onlooker bees that could not enhance their quality of food sources, in predetermined number of cycles (defined by the parameter *limit*), do:
    - Abandon those food sources and transform the onlookers into scout bees in order to randomly generate new food source positions, according to Eq. (21).

$$x_{ij} = x_j^{min} + rand[0,1](x_j^{max} - x_j^{min}) \quad (21)$$

- Calculate the fitness function of the latest generated positions.
- Save the best solution as the new solution.
- Increment the number of cycle (cycle =cycle+1).

End while.

A descriptive flowchart of ABC algorithm is depicted in Fig. 2. More information about this algorithm can be found in [18, 20, 21].

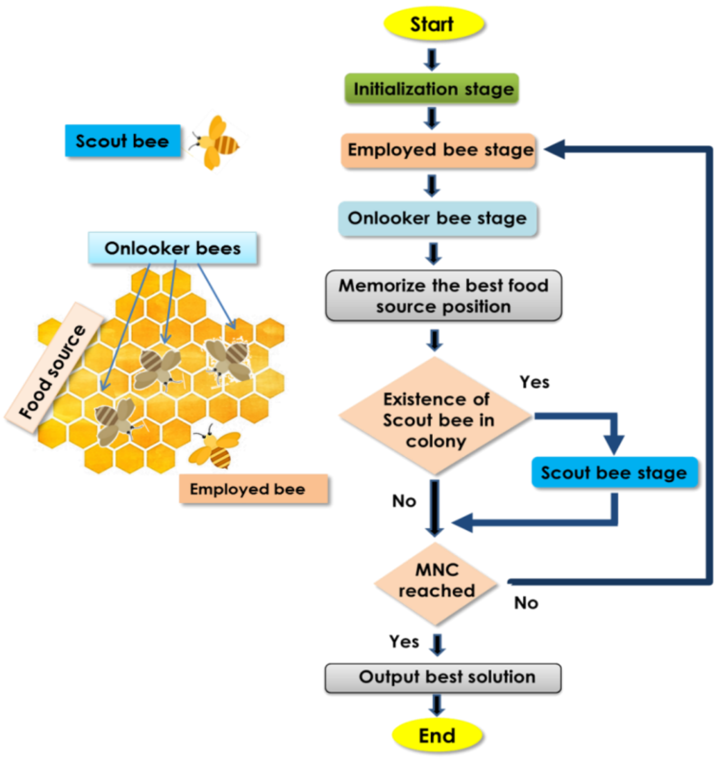

Fig. 2. Flowchart of ABC algorithm.

3. Results and discussions

To evaluate the performance of the proposed strategy, two types of evaluation test are proposed, namely simulated and real measured tests.

The simulated test is used to prove the efficiency of ABC algorithm to determine the thin film thickness and optical constants, despite the high complexity and nonlinearity of the mathematical model of the transmittance spectrum. During this test, the transmittance spectra are analytically generated by introducing predefined values of n_s, d, A_1, B_1, A_2 and B_2 in Eqs. (1)-(10) for a given range of wavelength λ. Here, the simulated transmittance spectra will be considered as real data. This data is then introduced into the implemented ABC algorithm to assess its performance. In other words, the earlier predefined values of d, A_1, B_1, A_2 and B_2 will be compared with the determined ones based on ABC algorithm. RMSE value between simulated and estimated transmittance spectra will prove the efficiency of the proposed strategy.

Commented [MH1]: determined ?

The real measured test aims to evaluate the performance of the suggested method on real experimental transmittance spectra. The evaluation test can be achieved, on one hand, in a graphical manner by depicting the fitting curve (compare the real measured and estimated spectra) and in analytical manner on the other hand by computing the RMSE value.

It should also be noted that values of ABC algorithm parameters, which will be used in the following subsections, have been set after having tested the algorithm several times and select the best values of *SN*, *LN*, *MNC*, *Dim* and *limit*.

A. Simulated tests

For the entire simulated tests, the thin films investigated here were considered as deposited on a glass substrate, where its refractive index n_s is equal to 1.51. Here, two simulated tests have been performed. The variation range for each predefined parameter for the two elaborated tests is presented in Table 1.

Table 1
Variation range of parameters predefined in the two simulated tests.

Parameters	Variation range of the 1st test	Variation range of the 2nd test
A_1	$[1 - 10]$	$[1 - 10]$
B_1	$[10^{+4} - 10^{+6}]$	$[10^{+1} - 10^{+3}]$
A_2	$[10^{-7} - 10^{-5}]$	$[10^{-4} - 10^{-2}]$
B_2	$[10^{+3} - 10^{+5}]$	$[10^{+2} - 10^{+4}]$
d (nm)	$[50 - 500]$	$[50 - 500]$

First simulated test

In the first case, the predefined parameters are set as follows: $A_1 = 3.6$, $A_2 = 15 \times 10^{-6}$, $B_1 = 2 \times 10^{+5}$, $B_2 = 3 \times 10^{+4}$ and $d = 100$ nm. Then, these parameters are introduced into Cauchy dispersion model (Eqs. (9) and (10)) in order to generate the simulated transmittance spectrum according to Eqs. ((1)-(8)) in the wavelength range $[300 - 900]$ nm. The obtained simulated spectrum of transmittance is depicted in Figure (3.a), and it is considered as the real data.

The used ABC algorithm parameters are: $SN = 100$, $LN = 100$, $Dim = 5$, $limit = 500$ and $MNC = 2000$. The obtained results are summarized in Table 2, while the variation of fitness function against wavelength is depicted in Fig. (3.b).

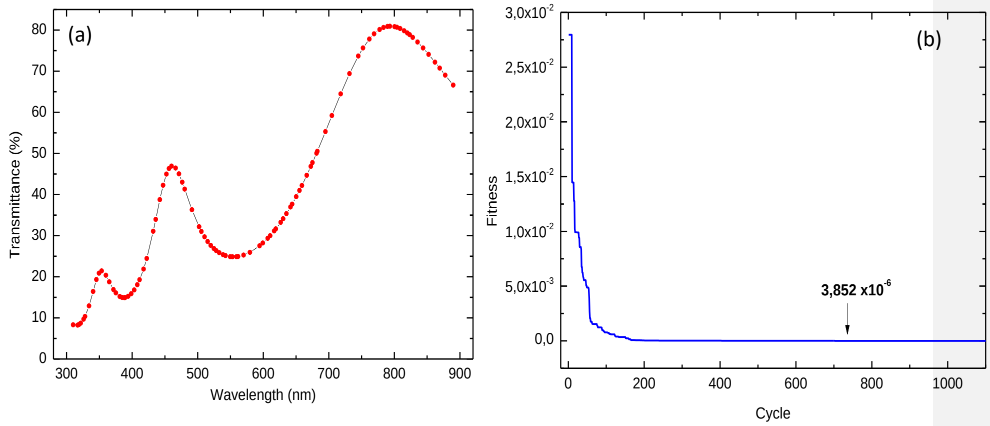

Figure 3. Results of the 1st simulated test in terms of a) simulated transmittance spectrum and b) fitness function variation during the convergence process.

Table 2
Parameters determination results of the1st simulated test.

Parameters	Predefined value	determined value	RMSE
A_1	3.6	3.6	
B_1	$2\times10^{+5}$	$1.988\times10^{+5}$	
A_2	15×10^{-6}	13.54×10^{-6}	3.852×10^{-6}
B_2	$3\times10^{+4}$	$3.001\times10^{+4}$	
d (nm)	100	99.97	

By analyzing the obtained results in Table 2, we can clearly observe the great similarity between the predetermined parameters and those determined by ABC algorithm. Moreover, the accuracy of the determined parameters can be confirmed according to the smallest value of RMSE (3.852×10^{-6}). In Addition, Fig. (2.b) displays both convergence speed and efficiency of the proposed method. Indeed, the algorithm has converged to the smallest RMSE value from cycle #200 at which it remains constant till reaching the *MNC*.

Second simulated test

The 2nd test consists of setting the predefined parameters values as: $A_1 = 6$, $A_2 = 2 \times 10^{-3}$, $B_1 = 5 \times 10^{+1}$, $B_2 = 3 \times 10^{+3}$ and d=200 nm.

Following the same strategy as the 1st simulated test, and taking into account the following ABC parameters: $LN = 150$, $SN = 150$, $Dim = 5$, $limit = 750$ and $MNC = 2000$, the obtained transmittance spectrum of the 2nd test is presented in Fig. (4.a). Moreover, the convergence rate of ABC algorithm is shown in Fig. (4.b). Finally, the identification results are given in Table 3.

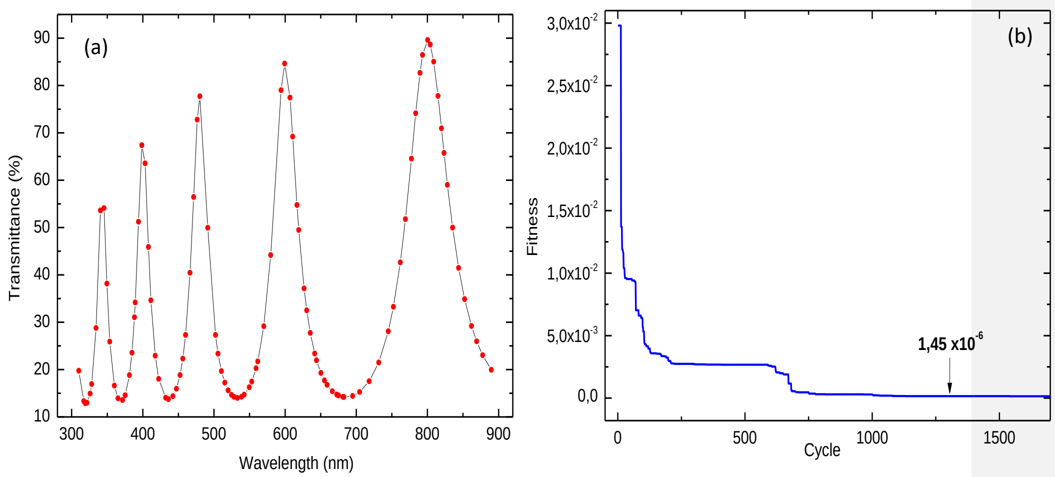

Fig. 4. Results of the 2nd test in terms of a) simulated transmittance spectrum and b) Fitness function variation during the convergence process.

Table3

Parameters determination results of the 2nd simulated test.

Parameters	Predefined value	determined value	RMSE
A_1	6	5.9993	
B_1	$5\times10^{+1}$	$5.3\times10^{+1}$	
A_2	2×10^{-3}	1.9×10^{-3}	1.45×10^{-6}
B_2	$3\times10^{+3}$	$3.01\times10^{+3}$	
d (nm)	200	200.02	

As shown from the aforementioned results, the suggested strategy to accurately identify the parameters is highly efficient. This is demonstrated by the parameter's high similarity (Table 3), smallest RMSE value and convergence speed (Fig. 4.b).

B. Real tests

In this section, the performance of the suggested strategy is tested when using real transmittance spectra obtained from six a-Si:H thin film-based samples. Those samples were fabricated by using different experimental conditions of reactor gas pressure and RF power, as summarized in Table 4. The transmittance spectra for the six samples are shown in Fig. 5.

Table 4:
The experimental conditions at which the samples were elaborated

Elaborated samples	Reactor gas pressure (mTorr)	RF power (w)
1st sample	400	100
2nd sample	600	100
3rd sample	600	200
4th sample	800	100
5th sample	800	200
6th sample	1000	200

The effectiveness assessment in this second type of test will be ensured by analyzing the obtained results. Indeed, the values of the determined parameters and RMSE will indicate the performance of the suggested method. Moreover, comparison between the measured and estimated curves will graphically demonstrate the suitability of the suggested method.

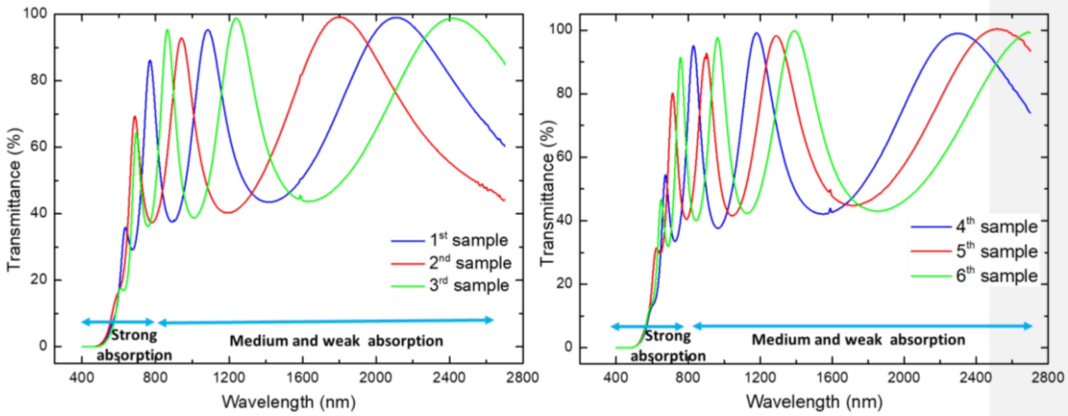

Fig. 5. The experimental transmittance spectra of the six elaborated samples

As mentioned before, the proposed approach consists of subdividing the spectrum characteristic of each elaborated sample into two main parts. The first one deals with the region of medium and weak absorption (zone with interference fringes). In this region, the thin film thickness (d) and refractive index (n) are determined by using ABC algorithm. In other words, the obtained values of $A_1$and B_1 (from ABC algorithm) are replaced into Eq. (9) to determine the refractive index variation for the entire wavelength, while the estimated value of d is considered as the thin film thickness.

In the other hand, the second part of the transmittance spectrum deals with the strong absorption region. In this region, the absorption coefficient variation $\alpha(\lambda)$ is determined by using Eq.s (13)-(16).Then, the extinction coefficient variation $k(\lambda)$ is computed by using Eq. (8).

For all elaborated samples, the variation range of the extracted parameters during the convergence process of ABC algorithm is presented in Table 5.

Table 5
Parameters variation range of the elaborated samples.

Parameters	variation range extracted parameters
A_1	$[1 - 10]$
B_1	$[10^{+3} - 10^{+6}]$
A_2	$[10^{-8} - 10^{-4}]$
B_2	$[10^{+2} - 10^{+5}]$
d (nm)	$[100 - 1000]$

During the identification process, the population size of ABC algorithm is assigned to be 160 and it is equally subdivided into employed and onlooker bees. The solution dimension is equal to 5. In Addition, *limit* of the scout bees is set as 400. Finally, the maximum number of cycles (*MNC*) is set as 1500.

Table 6 shows the obtained results. Values in this table are then introduced into Eqs.(1)-(10) to generate the estimated spectrum of transmission, which is depicted in addition to the experimental one in Fig. 6.

Finally, the variation of the determined refractive index for all the elaborated samples is computed by replacing values of ${A_1}^*$ and ${B_1}^*$ in Equ. (9) for the entire wavelength range. Refractive index variation of the all elaborated samples is depicted in Fig. 7.

Table 5
Obtained results for the zone with interference fringes for all the elaborated samples.

	${A_1}^*$	${B_1}^*$	${A_2}^*$	${B_2}^*$	d^*(nm)	$RMSE$
1st sample	2.81	$1.99 \times 10^{+05}$	10^{-04}	$8.025\times 10^{+03}$	315.06	1.4×10^{-03}
2nd sample	2.84	$1.97\times 10^{+05}$	10^{-05}	$9.301\times 10^{+03}$	375.02	1.18×10^{-03}
3rd sample	2.82	$1.78 \times 10^{+05}$	9.84×10^{-04}	$2.99 \times 10^{+03}$	422.31	9.23×10^{-03}
4th sample	2.87	$1.94 \times 10^{+05}$	10^{-04}	10^{+03}	392.09	1.24×10^{-03}
5th sample	2.85	$1.76 \times 10^{+05}$	1.03×10^{-04}	$6.58 \times 10^{+03}$	437	6.6×10^{-03}
6th sample	2.89	$1.83 \times 10^{+05}$	10^{-04}	$2.52 \times 10^{+03}$	495.15	3.6×10^{-03}

In the other hand, the second part of the transmittance spectrum is used to determine the absorption coefficient variation $\alpha(\lambda)$ by using Eqs. (13)-(16). The obtained results are depicted in Fig. 8 for all the elaborated samples. Finally, the extinction coefficient variation $k(\lambda)$, which is computed from Eq. (8), is presented in Fig. 9.

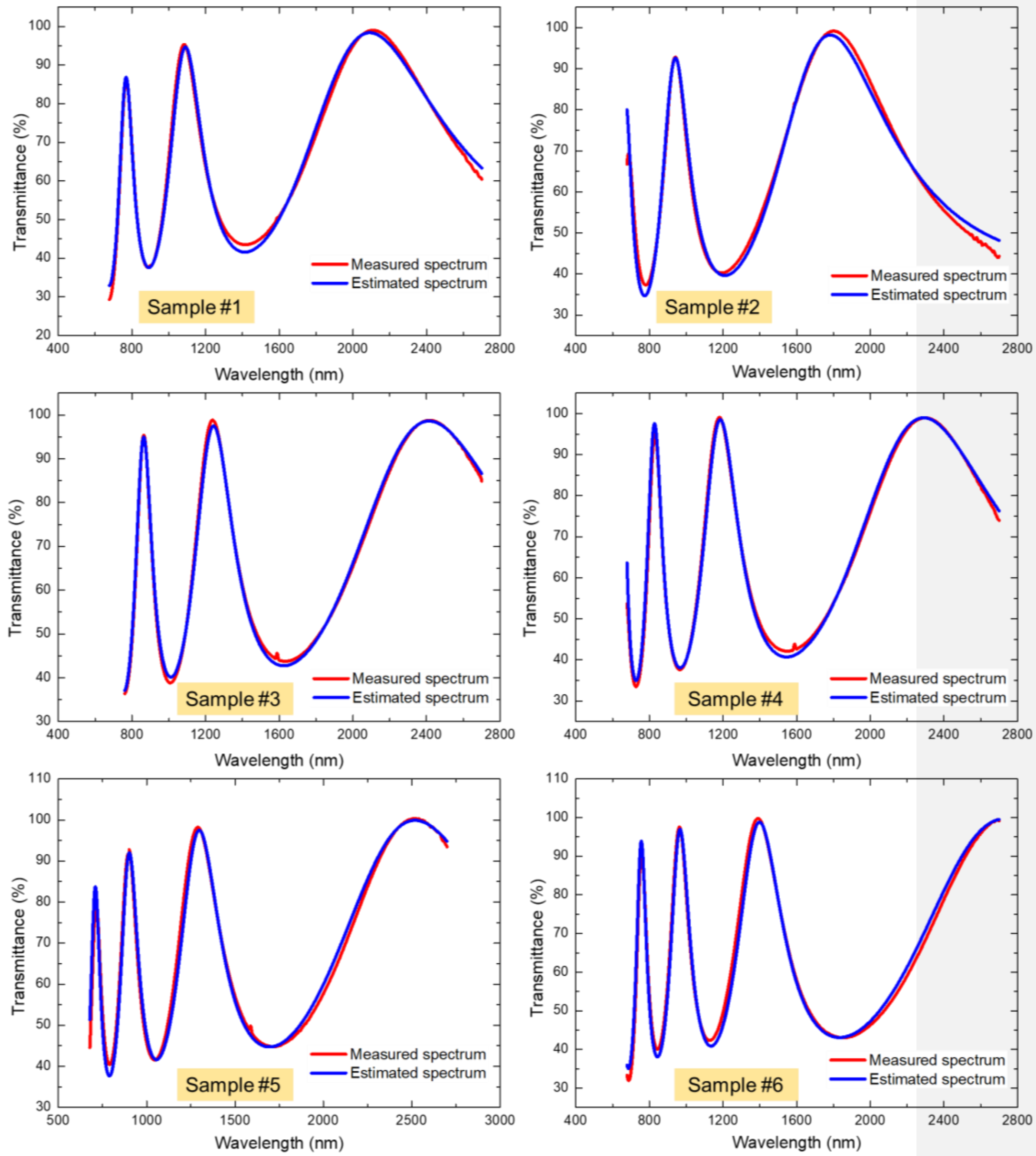

Fig. 6. Measured and estimated transmittance spectra for all elaborated samples in the zone with interference fringes.

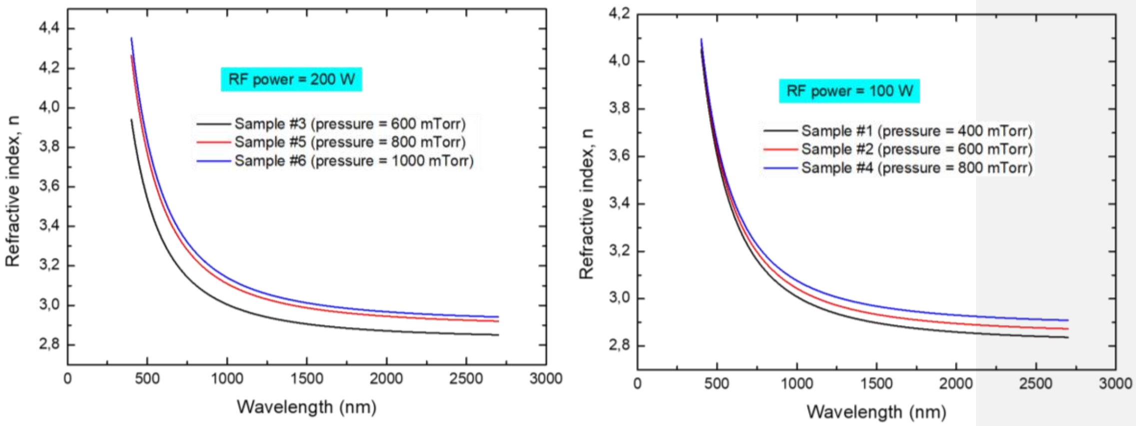

Fig. 7. Refractive index variation for all the elaborated samples

From the results shown in Table 5, one can clearly observe the low value of RMSE for all the elaborated samples, which provides evidence of the high accuracy of the calculated parameters. This can also be confirmed from the plot of Fig. 6, which shows a good fit between the measured and calculated transmittance curves for all samples.

The obtained results in Table 5 shows also that each experimental condition (process pressure and RF power) allows the deposition of specific thickness of a:Si-H thin film. Moreover, Table 5 shows that by increasing the process pressure, the layer thickness will increase, which prove the efficiency of the developed strategy in determining the thin layer thickness.

Besides, the obtained values of thickness (d) in Table 5 have been checked with the measured ones by using a profilometer. This test confirmed a good agreement.

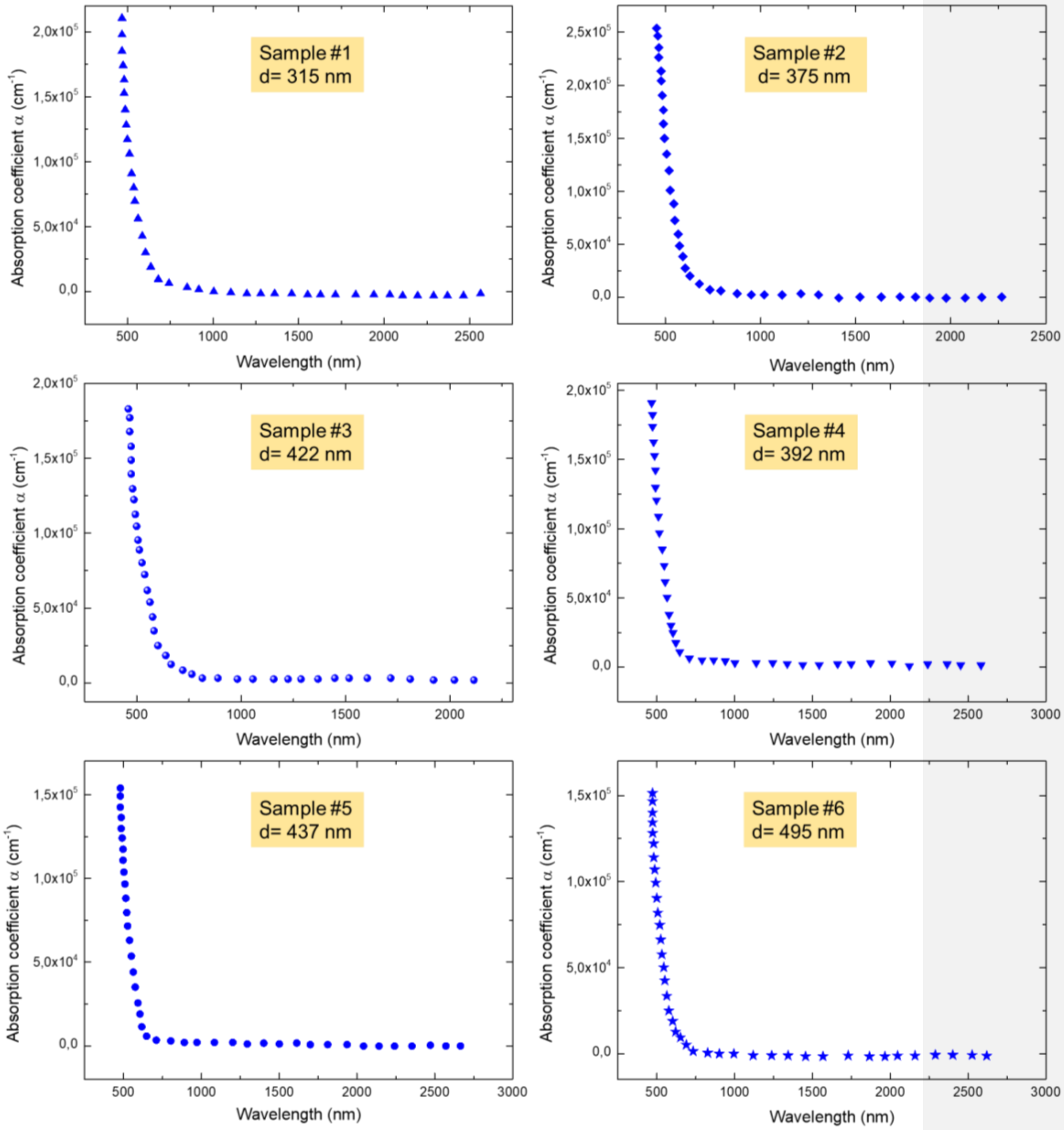

Fig. 8. Absorption coefficient variation for all the elaborated samples

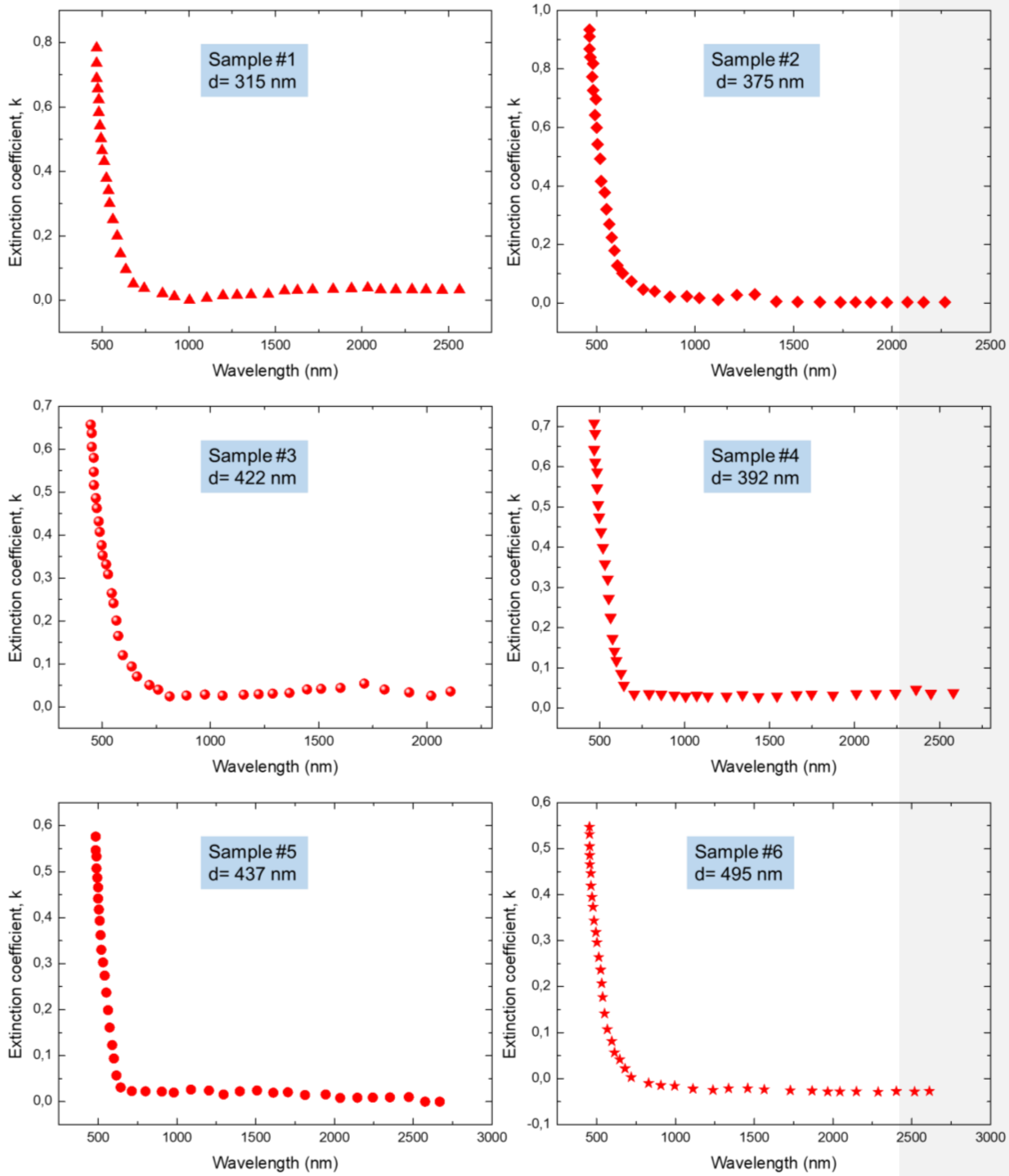

Fig. 9. Extinction coefficient variation for all the elaborated samples

Results in Figs. (7-9) show that the obtained optical properties (n, k and α) are in good agreement with those obtained by previous works [22, 23].

Moreover, by analyzing the refractive index variation for all the elaborated samples (Figure 7) one can see that the refractive index increases with increasing the process pressure at a specific RF power. This observation is in accordance with the obtained results in [23]. Fig. 10 shows the evolution of the refractive index and extinction value at 1100 nm for different deposition conditions and thicknesses.

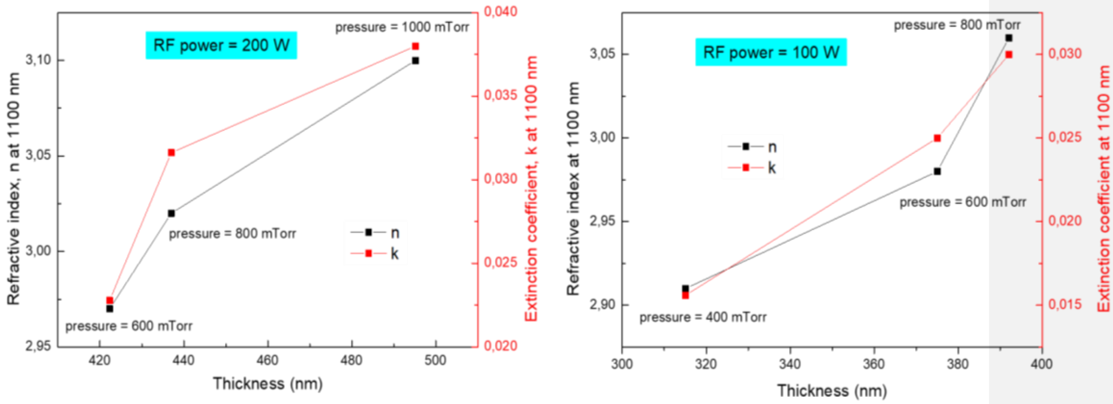

Fig. 10. Plot of the refractive index and extinction value at the band gap of silicon (1100 nm)

From Fig. 10 it can be seen that the values of optical constants (n, k) at 1100 nm of the elaborated samples are affected by the working pressure for each specific RF power. For instance, at low pressure of 400 mTorr the refractive index value was 2.91 and it reaches 3.06 at 800 mTorr. Also, it is clearly remarked that the extinction coefficient increases by increasing the working pressure.

4. Conclusion

An efficient approach to determine the optical constants and thickness of deposited thin films based on ABC algorithm and Cauchy dispersion model were presented. In this approach, the transmittance spectrum of the elaborated samples was measured first. Then, the data that corresponds to the interference fringes zone was introduced into the ABC algorithm in order to determine the thin layer thickness (d) and Cauchy model parameters (A_1, B_1, A_2 and B_2). This approach consists of dividing the spectrum into two main parts. The first part corresponds to zone with interference fringe. The thin film thickness and refractive index values are determined by using this part of the spectrum. The second part corresponds to the remaining zone of transmittance. Absorption and extinction coefficients values are determined based on the transmittance spectrum of this region. The efficiency of this method was tested by using simulated and real tests. Six elaborated samples based on a-Si:H thin films have been used to test the performance of this approach. Based on the obtained results, a highly efficient approach of thin film thickness and optical constants determination was presented, which could be invaluable to enhance the performance of solar cells and optoelectronic devices.

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