RESEARCH PAPER

The Effect of Temperature on Some of the Optical and Structure Properties of the $NiCl_2$:Al_2O_3 Thin Film

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ARTICLE INFO

Article History:
Received 11 October 2023
Accepted 24 December 2023
Published 01 January 2024

Keywords:
Doping
Thin film
Semiconductor
Thermal chemical spraying

ABSTRACT

In this research, pure nickel chloride films ($NiCl_2$) and doped with aluminum oxide (Al_2O_3) in proportions of (1,2,3)% . Using the method of thermal chemical spraying, where pure ($NiCl_2$) was prepared and sprayed on glass slides, then the smearing process was carried out at the above-mentioned proportions using a technique with a heating degree of the base $(150)^0C$, a thin film of a certain thickness was obtained Then the films were annealed in degree $(350)^0C$ for one hour for each degree, and by making optical measurements (UV visible spectrophotometer) and studying the surface on the prepared films (Atomic Force Microscope) and matching them. With what was prepared in advance, fine Results have been obtained.

How to cite this article
Khalil M K., Kadhim Hussein R G., Obaid Alshiaa S A Z. The Effect of Temperature on Some of the Optical and Structure Properties of the $NiCl_2$:Al_2O_3 Thin Film . J Nanostruct, 2024; 14(1):1-11. DOI: 10.22052/JNS.2024.01.001

INTRODUCTION

The study of matter in the form of a thin film is one of the important topics of solid-state physics, and thin-film technology has made a great contribution to the study of semiconductors, and many of its physical and chemical properties have been identified in order to determine its use in various practical applications [1,2]. The term thin film is used to describe one or more layers of atoms of matter, the thickness of which does not exceed one micron (1 µ) [3]. Thin-film technology has made a significant contribution to the study of semiconductors, in which interest began since the early nineteenth century [4].

Thermal chemical spraying method was used in our research current research. This technique is one of the chemical methods, and it was developed during the sixties of the last century due to the due to the necessary need for a less expensive technology to prepare large area devices in the photovoltaic industries. Thin films of inorganic sulfides and cyanides have been prepared by hydrolysis on a hot base. This method is distinguished from other methods of preparation by its simplicity and the low costs of the manufactured devices used to prepare the films compared to the costs of the devices used in other methods. thin films are prepared in normal weather conditions and at room temperature, so they do not give characteristics like those of films prepared under low pressure and the thin films with good homogeneity and large surface areas can be prepared [5-7]. Only chemical solutions are used, i.e. the powder of the substance cannot

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Table 1. Physical properties of nickel chloride [13]

Properties	Type
Color	Green
Density	1.92 g/cm^3
Melting point	140 ˚C

Table 2. Physical properties of Al_2O_3 [12]

Properties	Al_2O_3
Hardness (Mohs)	9
Young coefficient (GPa)	300-400
specific heat (J/kg.K)	900
melting temperature (°C)	2050

be precipitated directly or using alloys. This technique depends on spraying the material to be deposited in the form of a film on hot bases under a temperature (temperature Certain) depending on the type of material used, a thermochemical reaction takes place between the atoms of the hot base material, As a result of this reaction, a thin film is formed [8]. Nickel(II) chloride (or just nickel chloride) is one of the nickel salts used in this research is the chemical compound ($NiCl_2$). The anhydrous salt is yellow, but the more familiar hydrate $NiCl_2$•$6H_2O$ is green. Nickel(II) chloride, in various forms, is the most important source of nickel for chemical synthesis. The nickel chlorides are deliquescent, absorbing moisture from the air to form a solution [9]. Aluminum is the third element in the earth's crust, after oxygen and silicon. Aluminum turns into an intermediate or catalyst to spontaneously combine with oxygen, forming that thin film of oxide aluminum, which protects aluminum or allows it to be colored after anode oxidation, or forming aluminum metals such as) Bauxite), which gives, through the famous Bayer method , aluminum oxide (Al_2O_3), which ends either in aluminum metal and its alloys or in aluminum oxide ceramics, which appears in the form of a crystal single in a (ruby) gemstone, the first laser or polycrystalline ceramic material in which unique properties combine to attract diverse engineering applications [10-12].

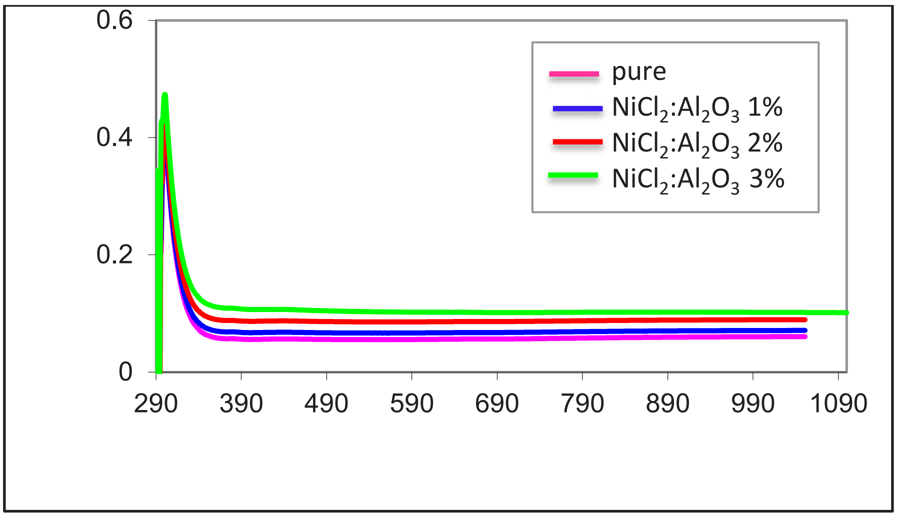

Fig. 1. The effect of doping on absorbance spectrum

MATERIALS AND METHODS

Experimental part

A nickel chloride solution was prepared by dissolving 0.9 g in 30 ml of distilled water and heating for 5 minutes at 70 ^{o}C. The mixture was mixed with a magnetic stirrer, and an aluminum oxide solution was also prepared, then it was filtered with filter paper.

RESULTS AND DISCUSSION

Optical Properties

Fig. 1 explain the absorption spectrum is shown as a function of changing the wavelength of the range from 290 to 1100 nm for pure $NiCl_2$ thin films doped with (Al_2O_3) with different doping ratios (1,2,3)% deposited on glass substrates , where It was observed that the absorbance value increased with increasing doping ratios because the particle size increases, also due to the decrease in the optical energy gap to form levels of aluminum oxide (Al_2O_3) impurities within the energy gap .

When annealing 350 ^{o}C, noticed that the absorbance decreases with the increase in the degree of annealing because the increase in the transmittance and porosity of the films, as shown in the Fig. 2 below.

this results means that incident photons is not able to excite the electron and transfer it from valence band because the energy of incident photon is less than the value of the energy gap value of the semiconductor . This lead to to the absorbance decrease with increasing of

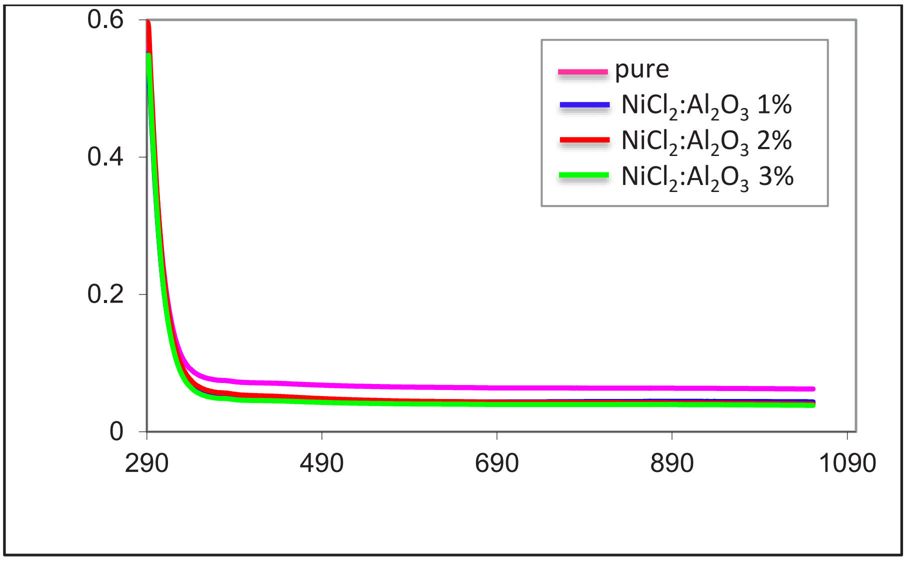

Fig. 2. The Effect of annealing 350 ^{o}C on absorbance spectrum

Table 3. The effect of doping on absorbance

Doping	Absorbance
Pure	0.0579
1%	0.0706
2%	0.0860
3%	0.0970

Table 4. The effect of annealing on absorbance

Annealing 350 ^{o}C	Absorbance
Pure	0.0483
1%	0.0537
2%	0.0479
3%	0.0464

wavelength. While increasing absorbance when increasing the doping Al_2O_3 this agree with refer [14]

Fig. 3 explain the transmittance spectrum as a function of wavelength variation of the range From 290 to 1100 nm for thin films ($NiCl_2$) pure and doped with aluminum oxide (Al_2O_3), where it was observed that the transmittance decreases with the increase in the doping percentage, this agree with refers [15,16] and the largest permeability is for the pure film and the least permeability is for the doping percentage (3)% , and the reason for this may be attributed to the formation of levels of (Al_2O_3) impurities within the energy gap that leads to an increase in reflectivity and thus a decrease in transmittance according to for the following relation

$T = 10^{-A}$

Where:
T: transmittance and A: absorbance

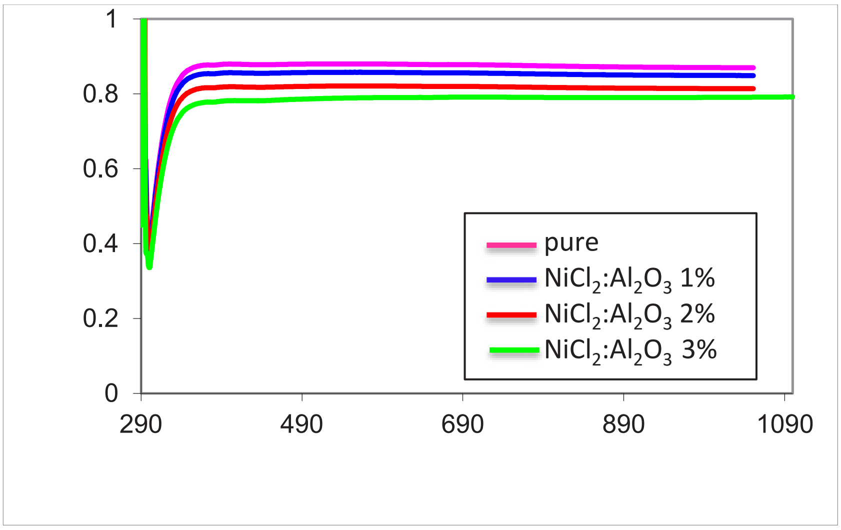

Fig. 3. The effect of doping on transmittance spectrum

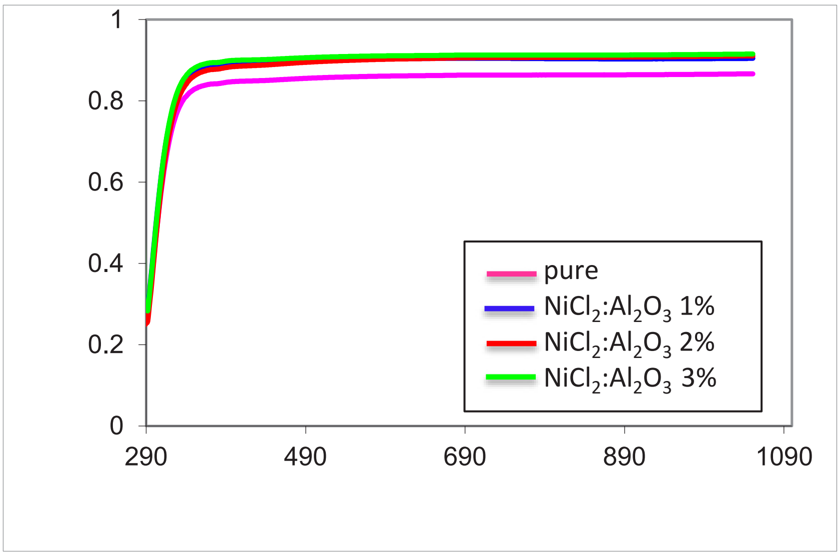

Fig. 4. The effect of annealing 350 °C on transmittance spectrum

Table 5. The effect of doping on transmittance

Doping	Transmittance
Pure	0.0970
1%	0.0860
2%	0.0706
3%	0.0579

Table 6. The effect of annealing on transmittance

Annealing 350°C	Transmittance
Pure	0.0464
1%	0.0479
2%	0.0537
3%	0.0483

Transmittance demonstrated behavior opposite of absorbance as shown transmittance of prepared films decreases with increasing of doping. As for when annealing the transmittance of the pure and doped films increases with the increase in temperature (annealing), this agree with refers [17,18] because the porosity of the membrane increases with this increase as shown in the Fig. 4.

Fig. 5 explain the absorption coefficient as a function of the incident wavelength of ($NiCl_2$:Al_2O_3) films deposited on glass substrates as a function of wavelength, where it is noted that the absorption coefficient increases with the increase in the doping ratio it increases with increasing inoculation rates to be levels of impurities added within the energy gap. This agree with refer [19].

When annealing, the absorption coefficient decreases with the increase in the degree of annealing 350 °C, as shown in the Fig. 6.This is due to the increase in crystallization of the material, which in turn reduces crystalline defects. This agree with refer [20].

The energy gap is one of the most important constants in semiconductor physics, as it depends on the value of this constant usesof semiconductors in optical and electronic applications calculated

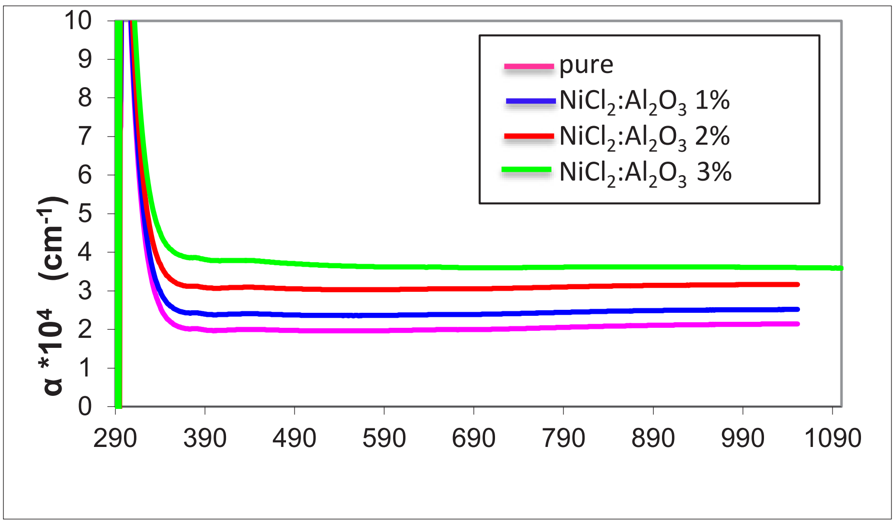

Fig. 5. The effect of doping on absorption coefficient

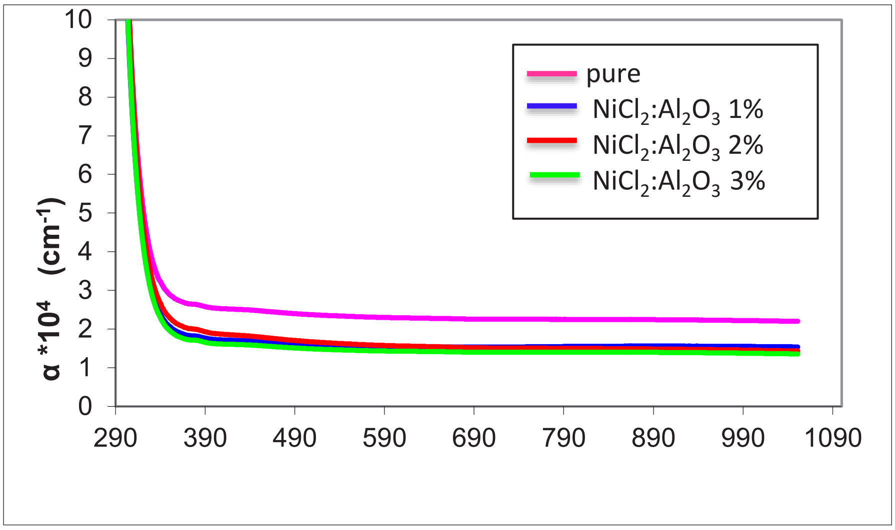

Fig. 6. The effect of annealing 350 ^oC on absorption coefficient

through equation.

$$\alpha h\upsilon = \beta (h\nu - Eg^{opt})^r \quad (2)$$

Fig .7 show the energy gap value of the pure ($NiCl_2$) thin film doped with different degrees (1,2,3)% of aluminum oxide (Al_2O_3) before the annealing process. This decrease in the values of the energy gap leads to the formation of levels impurities (Al_2O_3) within the energy gap, and the width of these levels increases with the increase in the inoculation ratios, which leads to a decrease in the width of the gap. This agree with refer [21].

Fig. 8 show the increase in the degree of annealing increases the values of the direct energy gap, and that the reason for this increase in the energy gap is attributed to the improvement of the structural properties of the films. This agree with refer [22,23].

Atomic Force Microscope (AFM)

The imaging of the prepared films using the atomic force microscope (AFM), which has the ability to photograph and analyze the deposited surfaces, was to give measurements of the values of the surface roughness (Root Mean Square -RMS), showing the topography of the surfaces of the pure films (Root Mean Square -RMS) for the mean square of the roughness and the impurity and the

Table 7. The effect of doping on absorption coefficient

Doping	Absorption coefficient(m^{-1})
Pure	2.6701
1%	3.2536
2%	3.5816
3%	3.6913

Table 8. The effect of doping on transmittance

Annealing 350^oC	Absorption coefficient (m^{-1})
Pure	2.2071
1%	2.2271
2%	2.4755
3%	2.6464

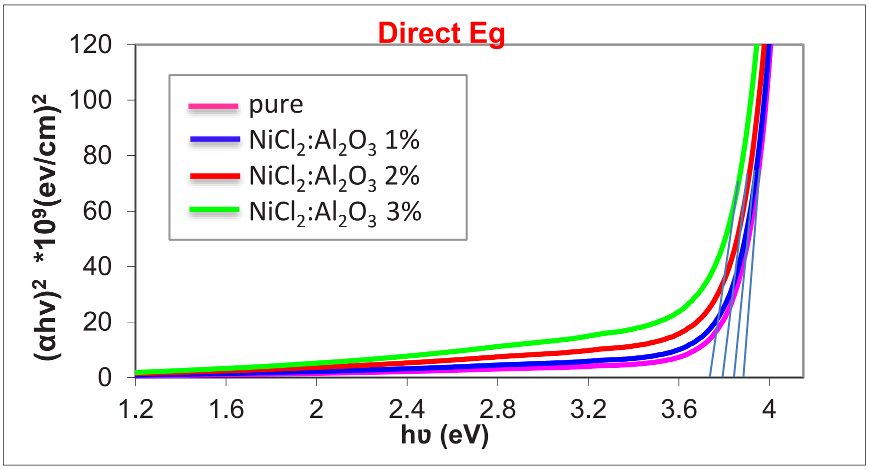

Fig. 7. The effect of doping on the energy gap

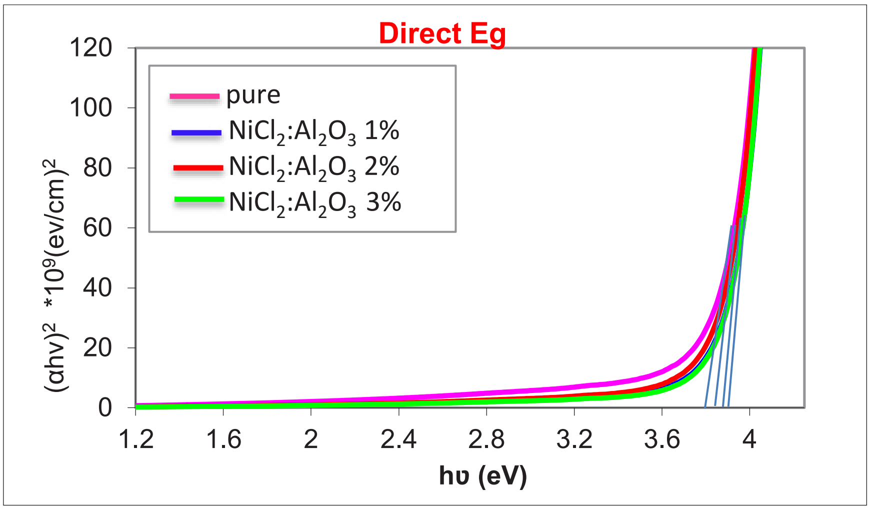

Fig. 8. The effect of annealing 350 °C on energy gap

Table 9. The effect of doping on energy gap

Doping	Energy gap (eV)
Pure	3.8
1%	3.7
2%	3.6
3%	3.5

Table 10. The effect of annealing on energy gap

Annealing 350 °C	Energy gap (eV)
Pure	3.81
1%	3.75
2%	3.7
3%	3.79

extent of the spread of the doped aluminum oxide material throughout the unit area and the extent of its homogeneity, inferring this from the average size of the grains and their distribution shown in the attached Figs. 9-16 form a film of pure nickel chloride doped with aluminum oxide, and the images show the effect of doping in the formation of the surface, where an increase in the size of the grains appears, and this is shown by the results of the roughness rate values (RMS) showing that the

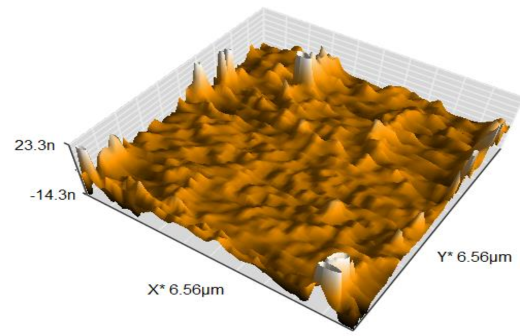

Fig. 9. show of ($NiCl_2$) pure

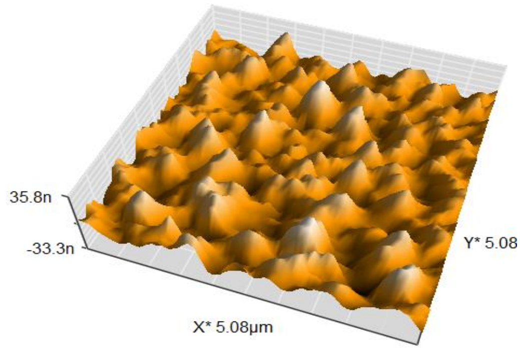

Fig. 10. show ($NiCl_2$:Al_2O_3) at 1%

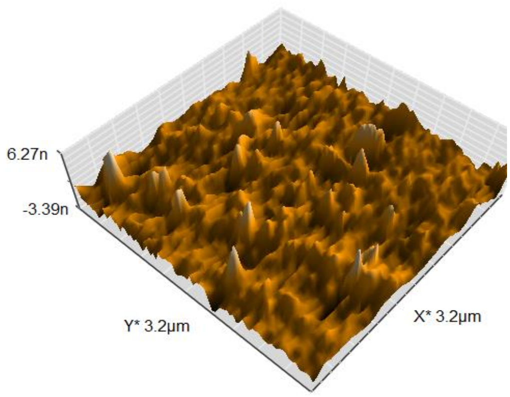

Fig. 11. show ($NiCl_2$:Al_2O_3) at 2%

ratio of doping with (Al_2O_3) increases the rate of surface roughness, Which indicates an increase in grain size and a decrease in grain boundaries[24].

When annealing increasing the temperature, noticed that the roughness decreases because the particle size decreases, and this is due to the decrease in the homogeneity of the membrane, as the increase in temperature reduces the aggregation of atoms with each other.

CONCLUSION

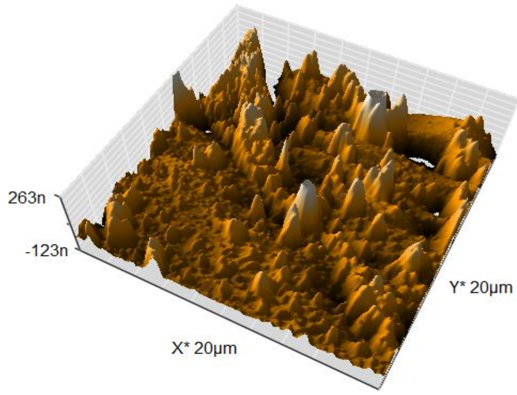

Fig. 12. show ($NiCl_2$:Al_2O_3) at 3%

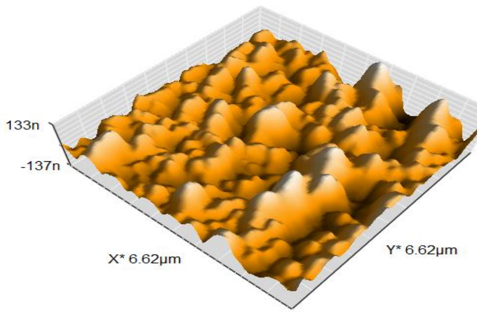

Fig. 13. show ($NiCl_2$) thin film at 350 °C

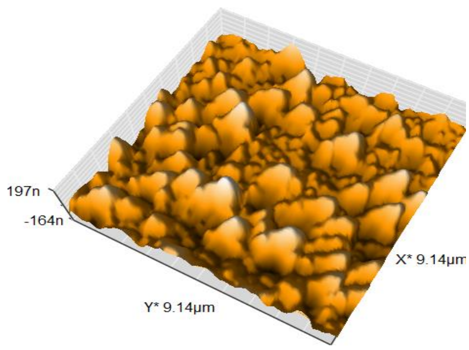

Fig. 14. show ($NiCl_2$:Al_2O_3) thin film 1% at 350 °C

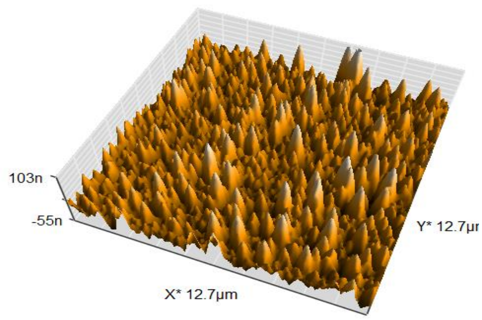

Fig. 15. show ($NiCl_2$:Al_2O_3) thin film 2% at 350 ^oC

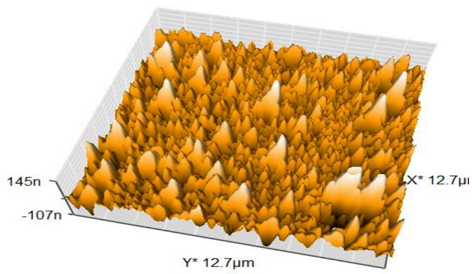

Fig. 16. show ($NiCl_2$:Al_2O_3) thin film 3% at 350 ^oC

Table 11. The effect of doping on roughness

Doping	RMS (nm)
Pure	18.03
1%	38.17
2%	52.68
3%	70.54

Table 12. The effect of annealing on roughness

Annealing 350 ^oC	RMS (nm)
Pure	15.55
1%	37.17
2%	44.58
3%	56.99

Through the results obtained in this research, the following was concluded:

It was conclude that the possibility of doping nickel chloride ($NiCl_2$) with aluminum oxide (Al_2O_3) using the thermal chemical spraying technique, and we found that the absorbance of the membranes increased with increasing the doping rates and decreased with annealing, and the best absorption was at the doping percentage (3%) , and the best transmittance at the doping ratio (3%) 350 ^oC , as the temperature increases the absorption coefficient decreases and increases with the increase in doping, and the highest value of the absorption coefficient was at the ratio (3%) . The pure and doped ($NiCl_2$) films has an optical energy gap for direct transitions only, and the energy gap value for the pure ($NiCl_2$) film is (3.8 eV) this value decreases when the doping ratios are increased, and it reaches (3.5 eV) when the doping ratio is (3%), the energy gap increases with annealing, reaching (3.79 eV) , when annealing at 350 ^oC when the doping ratio is (3%) .

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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