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RESEARCH ARTICLE

Effect of Thickness on the Optical Properties of Al-Ni-Cr Thin Films Prepared by Thermal Evaporation Technique

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Abstract

Al-Ni-Cr thin films with different thickness (18, 26, and 30 nm) were prepared by thermal evaporation technique on glass substrates under vacuum of 10^{-7} mbar. The influences of the thickness on the optical properties of Al-Ni-Cr thin films were mainly investigated from recording the absorbance and transmittance spectra by UV-Visible spectrophotometer in the range of 200-1100 nm. From these spectra, the transmittance decreased with increasing of thickness, while the absorbance increased with increasing of thickness. The values of optical energy gap decreases from 1.8 to 0.73 eV when thickness increased from 18 to 30 nm. The optical conductivity increased with increasing thickness.

INTRODUCTION

Alloys of the aluminum-nickel-chromium (Al-Ni-Cr) attract great attention in the modern metallography, because of its high mechanical properties at high temperature especially yielding, stiffness and combine high hardness with high resistance for corrosion [1]. Coating used aluminum alloys have wider applications connection with the formation on surface oxide film of aluminum and chromium. This film provides protective coating properties able to regenerate after mechanical damages [2].

Although the low-Al part of the Al–Cr–Ni alloy system has been studied since the 1950s, only a few recent publications have been devoted to its high-Al part. The Al-Ni-Cr layers which are used as an interconnect within a semiconductor device are disclosed, usually, the nickel or chromium concentrations are no greater than 0.5 weight percent. The layer is resistant to electro migration and corrosion. The low nickel and chromium concentrations allow the layer to be deposited and patterned similar to most aluminum-based layers [3]. The interest in thin films raised from the wide range of use and applications in electronic equipments and devices such as transistors, detectors, solar cells, etc. This leads to the study of electronic and optical properties of thin films [4].

Any thin film deposition process involves three main steps a- production of the appropriate atomic or molecular ionic species, b- their transport to the substrate through a medium and c- condensation on the substrate, either directly or via a chemical and or electrochemical reaction, to form a solid deposit. Formation of a thin film take place via nucleation and growth processes [5].

In this work, we study the effect of thickness on the optical properties of Al-Ni-Cr thin film deposited by thermal evaporation technique.

2. EXPERIMENTAL METHODE

Al-Ni-Cr thin films with different thickness (18, 26, and 30) nm prepared by thermal evaporation technique under lower pressure (10^{-7} mbar) onto glass substrate at room temperature by using Edwards-c coating system. For film deposition, all substrates (the glass substrates 8×2.5 cm^2 with 1 mm thickness) were cleaned in acetone and methanol solutions in an ultrasonic bath for 30 minutes. Optical properties of the films were studied by recording the absorption and transmittance spectra from UV-VIS spectrophotometer at room temperature in the wavelength range of 200-1100 nm.

3. RESULTS AND DISCUSSION

Fig.1 show the optical transmission as a function of wavelength in the range 200-1100 nm for Al-Ni-Cr thin films with different thicknesses. From this figure, it can notice that the transmittance decreases with increasing thickness. The maximum transmittance observed for thin film with thickens 18 nm approximately (85%), while for the thin film with thickens 30 nm the minimum transmittance equal approximately (80%). In general, the figure shows that the transmittance decreases slightly with the increasing of film thickness. This behavior is attributed to the increase the number of atoms with thickness, which leads to the increase the number of collisions between incident photon and atoms that lead to the increasing of absorbance and decreasing transmittance [6].
This behavior of transmittance is in contrast with the behavior of the absorbance. Similar behavior of transmittance is reported by [7].

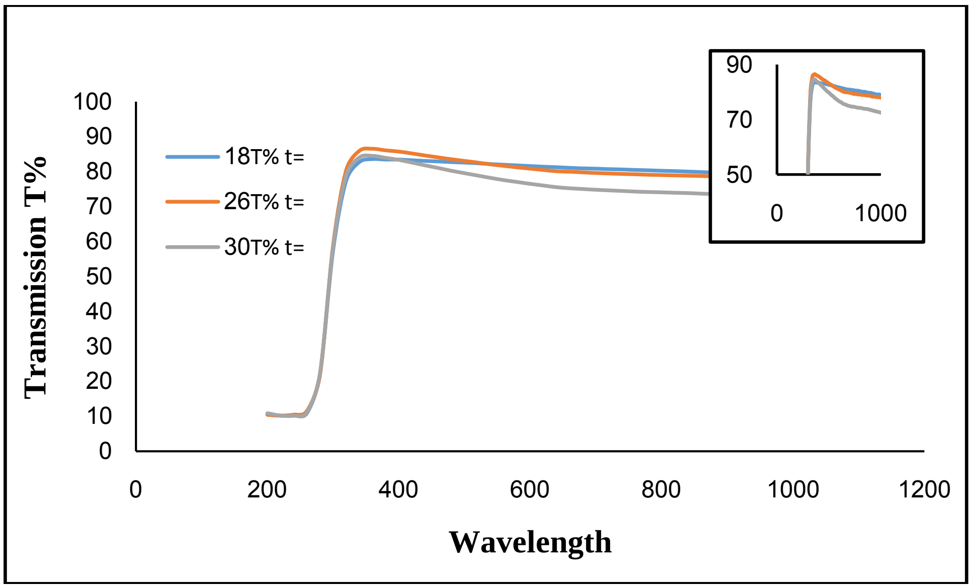

Fig. 1: Variation of transmission with wavelength of Al-Ni-Cr thin film for different thicknesses.

Fig.2 shows the influence thickness on absorbance. The absorbance increased with increasing film thickness, this is due to increasing in the thickness of deposited films. Usually increases the number of collisions between atoms with increasing thickness and thus lead to an increase in absorbance. All films show low absorbance in the visible range. This behavior can be explained as follows: at high wavelength the incident photon do not have enough energy to interact with atoms, thus the photon will transmitted, when the wavelength decreases (at the neighborhood of the fundamental absorption edge), the interaction between incident photon and material will occur, and the photon will absorbed [8].

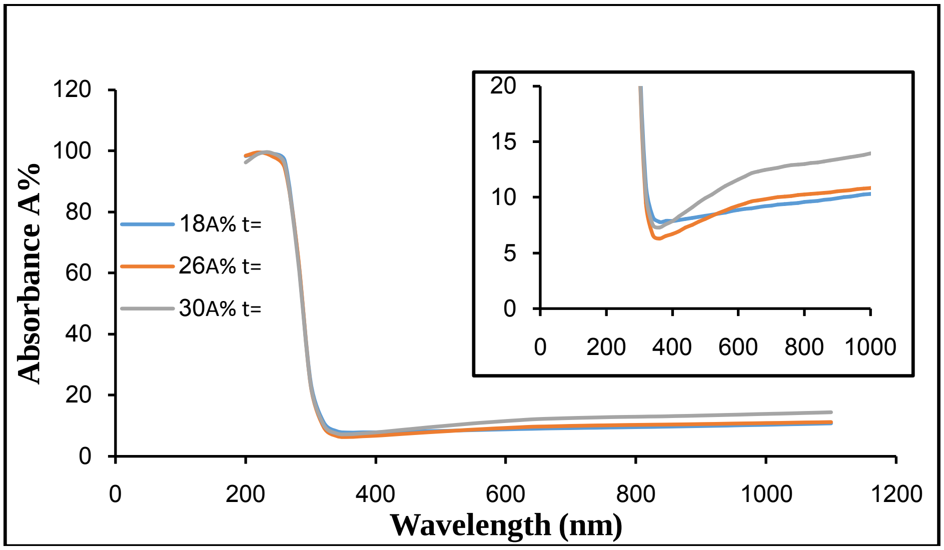

Fig. 2: Variation of absorbance with wavelength of Al-Ni-Cr thin film for different thicknesses.

The reflectance of the film was calculated from the following relation [9]:

$$R + \mathrm{T} + \mathrm{A} = 1 \qquad (1)$$

The change of reflectance as a function of wavelength in the range 200-1100 nm is shown in Fig. 3. It is clearly seen from the figure that the reflectance increases slightly with the increasing of film thickness. The behavior of reflectance is in agreement with the behavior of transmittance and absorbance according to above relation.

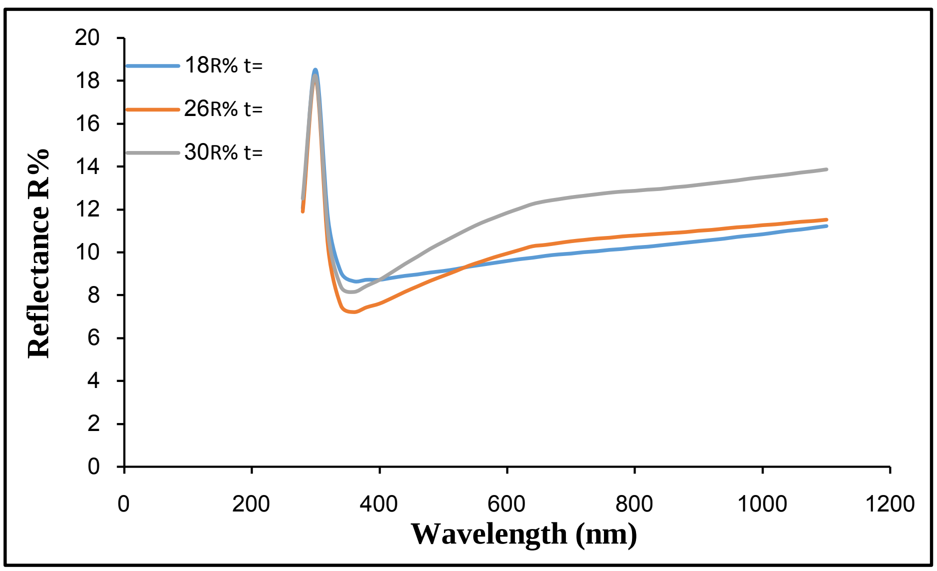

Fig. 3: Variation of reflectance with wavelength of Al-Ni-Cr thin film for different thicknesses.

To determine direct allowed band gap, a graph between $(\alpha h\nu)^2$ and hν (photon energy) is plotted for (Al-Ni-Cr) thin films with different thicknesses, and the straight portion of the graph is extrapolated to energy axis to give optical band gap. Figs. 4, 5, and 6 shows the energy gap which can be well fitted by the following expression:

$$y = ae^{bx} \qquad (2)$$

Where *a* and *b* are fitting parameters given in Table 1, *y* represent the value $(\alpha h\nu)^2$, and *x* represent the value *(hν)*. We noted from the Figs. (4-6) that the values of the optical energy gap of thin films decreases with increasing of film thickness. Where the energy gap for 18 nm is 1.8 eV and gradually decreases with thickness increasing to 0.73 eV at thickness 30 nm. The values of energy gap and fitting parameters are listed in Table 1. In addition, we conclude increase absorbance lead to a decrease in the energy gap, where increase the number of atoms lead to increased absorbance of photons and thus photons energy increase and transmitted from valence band (V.B) to conductive band (C.B).

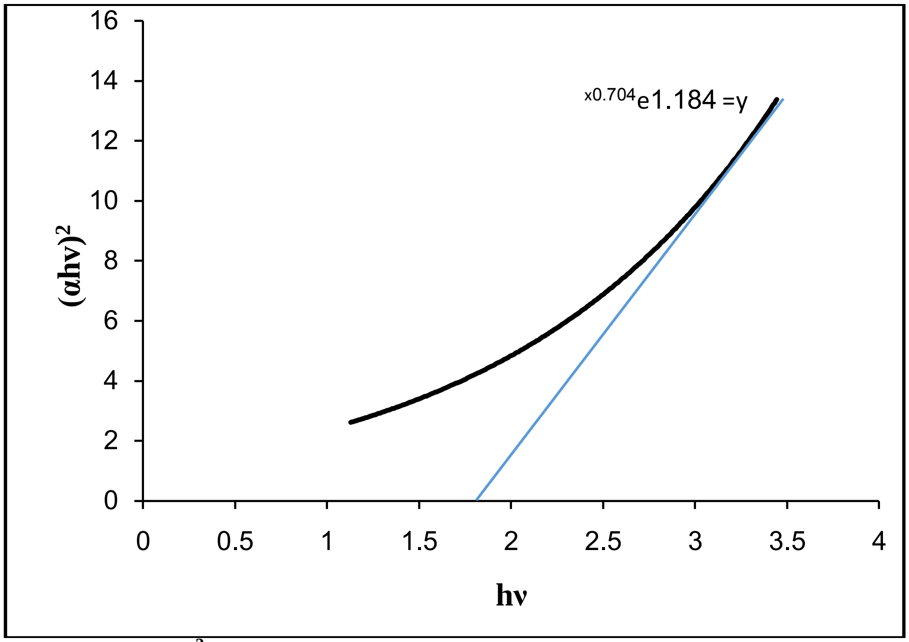

Fig.4: Variation of $(\alpha h\upsilon)^2$ with photon energy (hυ) of Al-Ni-Cr thin film for thickness of 18 nm.

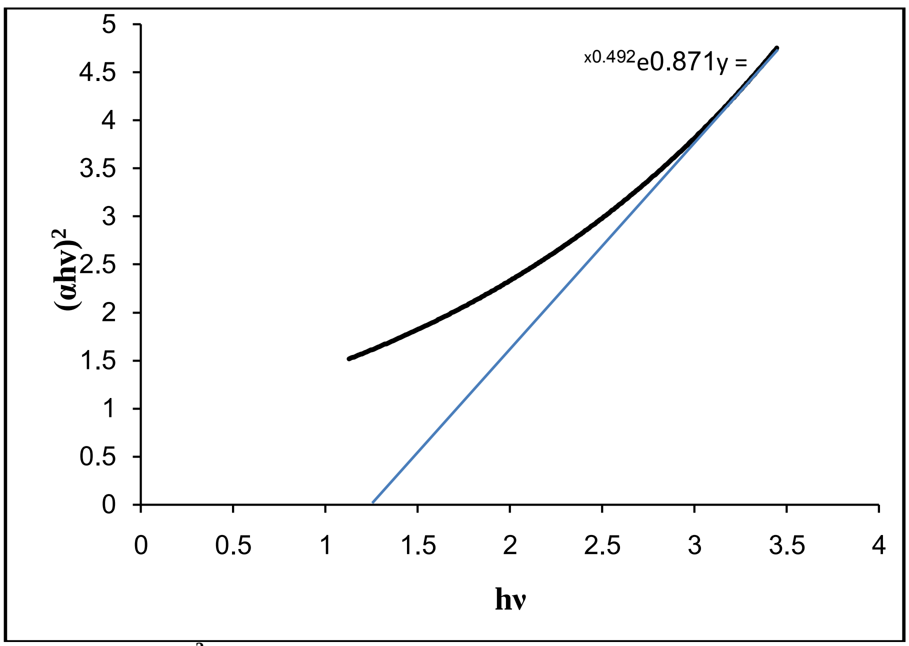

Fig.5: Variation of $(\alpha h\upsilon)^2$ with photon energy (hυ) of Al-Ni-Cr thin film for thickness of 26 nm.

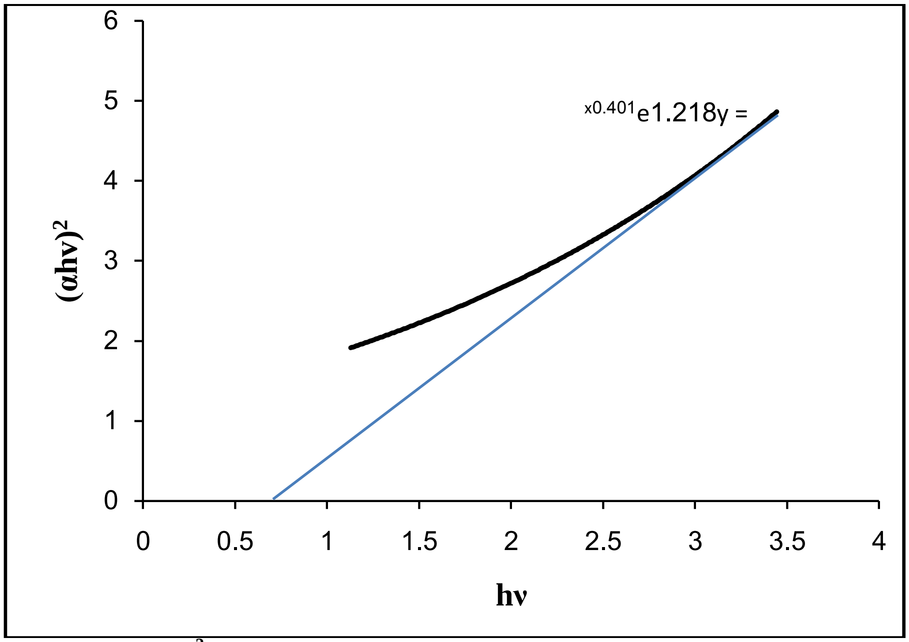

Fig.6: Variation of $(\alpha h\upsilon)^2$ with photon energy (hυ) of Al-Ni-Cr thin film for thickness of 30 nm.

Table1: Fitting parameters and energy gap values of Al-Ni-Cr thin films.

Thickness (nm)	Fitting parameters		Energy gap (eV)
	a	b	
18	1.1849	0.704	1.8
26	0.8716	0.4926	1.25
30	1.2181	0.4018	0.73

Fig. 6 shows the variation of optical conductivity (σ) as a function of wavelength of Al-Ni-Cr thin films with different thicknesses. The optical conductivity ($\sigma_{optical}$) depends directly on the wavelength and absorption coefficient as relation [10]:

$$\sigma_{optical} = \frac{\alpha n c}{4\pi} \qquad (3)$$

The overall optical conductivity spectra increase with the increasing film thickness.

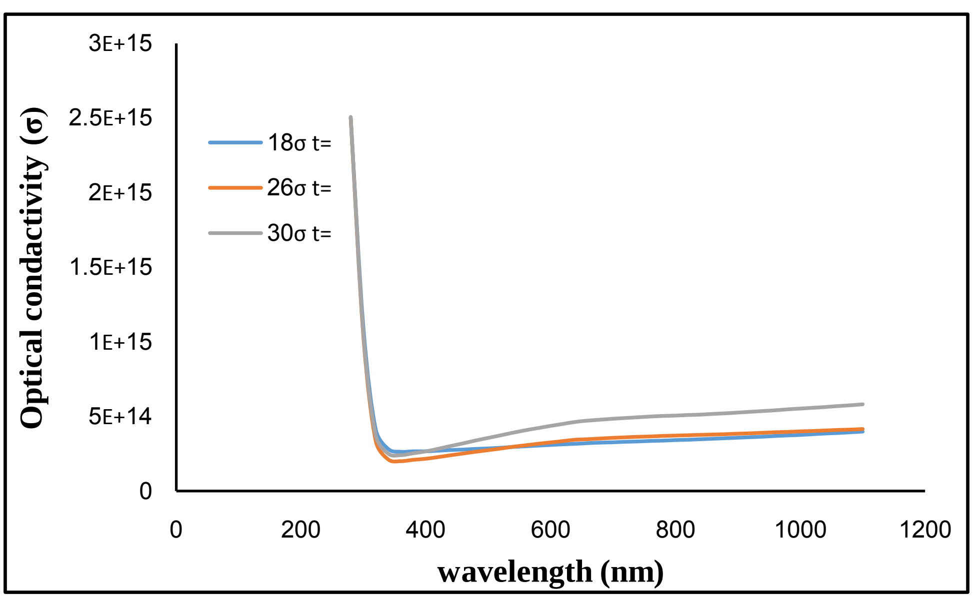

Fig. 7: Optical conductivity spectra of Al-Ni-Cr thin films with different thickness.

4. CONCLUSION

We have been using thermal evaporation technique to deposited Al-Ni-Cr thin films with different thicknesses and study the effect of thickness on its optical properties. The transmittance decreased with increasing of thickness, while the absorbance and reflectance are increased with increasing of thickness. The optical band gap values of Al-Ni-Cr thin films decreased as the film thickness increased in the range of (1.8–0.73) eV when the film thickness increased from 18-30 nm. The optical conductivity increased with increasing thickness.

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