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THE OPTICAL AND RELATED PROPERTIES OF THIN NICKLE FILMS PREPARED BY ION BEAM SUPTTERING

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Abstract

Thin nickel films with thicknesses (2 nm, 5 nm, 10 nm and 60 nm) are prepared by Ion Beam Sputtering (IBS) in a vaccum ($p=10^{-7}$ Torr). The transmittance (T) and reflectance (R) spectra in the ultraviolet, visible and near infrared regions at wavelength ($300 \text{ nm} < \lambda < 2500 \text{ nm}$) are measured. The optical constants are calculated from those measurements as well as the film thickness.

It is found that the refractive index (n) and the absorption coefficient α (w) at angular frequency of radiation (w) are decreased with increasing the film thicknesses. In addition the variation of the refractive index, the extinction coefficient (k) and the real and imaginary parts of dielectric constant (δ_1 and ε_2) versus wavelength are also studied.

الخلاصة :

تم تحضير أغشية النيكل الرقيقة بالاسماك (2 nm, 5 nm, 10 nm و 60 nm) بطريقة الترذيذ للاشعاع الآيوني (IBS) تحت شروط التفريغ وتحت ضغط ($P=10^{-7}$ Torr). وتم حساب النفاذية (T) ومعامل الانعكاس (R) وطيف الاشعة فوق البنفسجية والمناطق القريبة من الاشعة تحت الحمراء للاطوال الموجية ($300 \text{ nm} < \lambda < 2500 \text{ nm}$) وكذلك تم حساب الثوابت البصرية عند هذه الاسماك.

وتم ايجاد معامل الانكسار (n) ومعامل الامتصاص $\alpha(w)$ بتردد زاوي للاشعاع (w) ووجد انها تقل مع زيادة سمك الغشاء. بالاضافة الى تغيرات بمعامل الانكسار ومعامل الخمود (k) والجزء الحقيقي والخيالي من ثابت العزل (δ_2,δ_1) للاطوال الموجية الاخرى كذلك تم دراستها.

Introduction

The field of optical properties of thin film is wide, because optical properties can be defined for any and all substances that interact with light.

Metals in principle have feature of the high density of conduction electronics. Almost the energy falling on surface of the metal is found in the reflected beam. So we can say that metals are almost totally reflecting and almost non absorbing. The optical characteristics of very thin metal film (<100 nm) are different from those of the bulk metal because of the size effect, oxidation and effect of impurities in films.

The optical properties of metals have been the subject of widespread study by many observers [1-6].

However, with the application of quantum mechanics of the solid state, the measurement of the constant (δ) = $\delta_1 + i\delta_2$ where (δ_1) and (δ_2) are the real and the imaginary parts of the dielectric constant respectively has taken on a new significance in recent years.

These constants are related to the index of refraction (n) and the extinction coefficient (k) [7] by the relations

$$\delta_1 = n^2 - k^2 \qquad \ldots\ldots \qquad (1)$$
$$\delta_2 = 2\,n\,k \qquad \ldots\ldots \qquad (2)$$

The reflectance (R) and the transmittance (T) are usually the most important optical properties specified for a film followed by absorption (A).

The absorption coefficient $\alpha(w)$ at angular frequency of radiation (w) defined by [8]

$$[\ln(1 - R/T)]/t = 4\pi k/\lambda \qquad (3)$$

$$\alpha(\omega) = [\ln(1 - R)]/t \qquad (4)$$

where t is the thickness of the films . Then:

$$k = \alpha(\omega)\lambda/4\pi \qquad (5)$$

In the case of the normal incidences, the reflectance (R) can be defined by:

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \qquad (6)$$

This equation allows the direct determination of (n) by [9]

$$n = \frac{1+R}{1-R} \pm \sqrt{\left[\frac{1+R}{1-R}\right]^2 - \left(1 + k^2\right)} \qquad (7)$$

The optical constants for electron beam evaporated films of sixteen metals other than Ni have been determined [10]. The solar optical properties of vacuum evaporated thin Ni films have also been reported [11]. Recently other properties such as magnetic [12] and ESCA [13] are being published at different labs. In this paper the optical properties of thin Ni films with different thicknesses prepared by ion beam sputtering in vacuum of 10^{-7} torr are studied. Other related parameters such as the real and imaginary parts of dielectric constants are also obtained.

Experimental Produce

Thin (Ni) films were prepared by Ion-Beam Sputtering (IBS) in a vacuum of $p=10^{-7}$ torr deposited on corning glass (silica) substrates from a nickel target (purity 99.99%) with thickness of (2 nm, 5 nm, 10 nm, 60 nm). The thickness of the films was obtained by X-ray technique [14].

The technique that used for determining the optical constants is called reflection-transmission (R-T) method. In this method the measurements are taken at room temperature using a lambda-9 spectrophotometer at normal incidence in ultra-violet, visible, and near infrared regions. (300 nm<λ<2500 nm). Equations (1-7) are used to determine n, k, α, δ_1 and δ_2.

Results and Discussion

Reflectance and transmittance spectra

Fig. 1 represent the spectral reflectance of nickel films (at t=2 nm - 64 nm). The figure exhibits that the films have high reflectance in the near infrared region which is related to the large number of free carriers. Also it shows the relation between the reflectance and the thicknesses of the films. The thinnest films shows a different behaviour. Its reflectance increases with increasing wavelength in the range 300 nm < λ< 1000 nm and becomes constant in the region 1000 nm< λ< 2500 nm i.e posses low reflectance due to the fact that the coatings are no longer continuous, but exist as small islands. This is supported by the transmission electron microscope investigation[14]. Fig. (2) shows that the transmittance spectra of those films. It is seen that the transmittance decreases vs wavelength and increasing the thickness due the grain size the films.

The transmittance of sputtered Al-films [11] displayed the same dependence with wavelength.

Optical constants

The optical constants of the film are seriously affected by its microstructure which in turn depends on factors such as the deposition technique, the deposition rate, the temperature of the substrate and the thickness of the thin film. The optical constants become very susceptible to thickness if the film is porous. As a result of this porosity, the thin film could show an apparent thickness dependence. If the thickness of the thin film is reduced to a degree at which it becomes discontinuous and some anomalous properties start to appear. Such thin films are defined as ultra thin films. Fig. (3) represents the relation between refractive index (n) calculated from equation (7) and the wavelength (λ). It has shown that the refractive index has a constant value in the ultra-violet region (300-400) nm and increase with increasing the wavelength up to the near infrared region. The figure shows that the refractive index (n) of the thinnest film (2 nm) decrease with increasing the wavelength in the region 1000 nm < λ <2500 nm Also this figure shows that the value of (n) decreases with increasing the film thickness. However, the film of 2nm thickness had different variation at λ=900 nm. The other optical constant is the extinction coefficient (k) is presented vs λ in fig. (4). It is shown that the value of (k) increases with the wavelength and decreases with the thickness. An acception was noticed for the thinnest film at λ= 900nm.

It also shows that k(w) has a low value in the violet region and become higher in the near infrared region. This is because the intra band transition in the near IR region becomes more important than of the intra-band transition in this region. Feldkamp et al [4] obtained the electron energy loss spectrum of Ni films and used the Kramers-Krolnig analysis to obtain n and k. Film thicknesses were in the range (50-100) nm and the film were a polycrystalline and continuos.

Vehse and Arakkawa [5] obtained for the near normal-incidence reflectance data. from 49.5 nm to 35.4 nm for evaporated nickel films and, some values of reflectance versus angle of incidence measurements were also made at selected wavelengths within this range. The films were (180-220) nm thick and were probably deposited onto the slides at room temperature. A Kramers-Kronig analysis was then done using the n and k values obtained at the selected wavelength values. While lynch et al [6] present the optical data on a single polished crystal at 4 K. {(111) face}. The data were obtained from 49.5 nm to 155000 nm.

Fig (5) shows the spectral variation of the absorption coefficient $\alpha(w)$. It is obvious that there is a peak in the range 400 nm <λ<650 nm which means that there is an absorption band in this region. It also shows a wavelength independence in the longer wavelength constant as increasing with (λ) and decreasing with thickness. Fig. (7) shows the variation of δ_1 and δ_2 with (λ) for thickness (60 nm). The figure displays inverse relation between δ_1 and λ. The dielectric constant is produced by type of polarization called electronic polarization which caused by interacts of the electric field of the electromagnetic wave with the atmos It can displace electron charge clouds with respect to their positive charged center leading to the formation of dipoles.

Conclusions

The results obtained in this work can be summarized in the following:

1- The reflectance of the nickel films are increasing with wavelength and with thickness of the films.

2- The transmittance decreases with wavelength and thickness

3- The optical constants are calculated from the reflection and transmission spectra and the film thicknesses

4- It is found that the refractive index (n), absorption coefficient (α) are decreased with increasing the film thickness

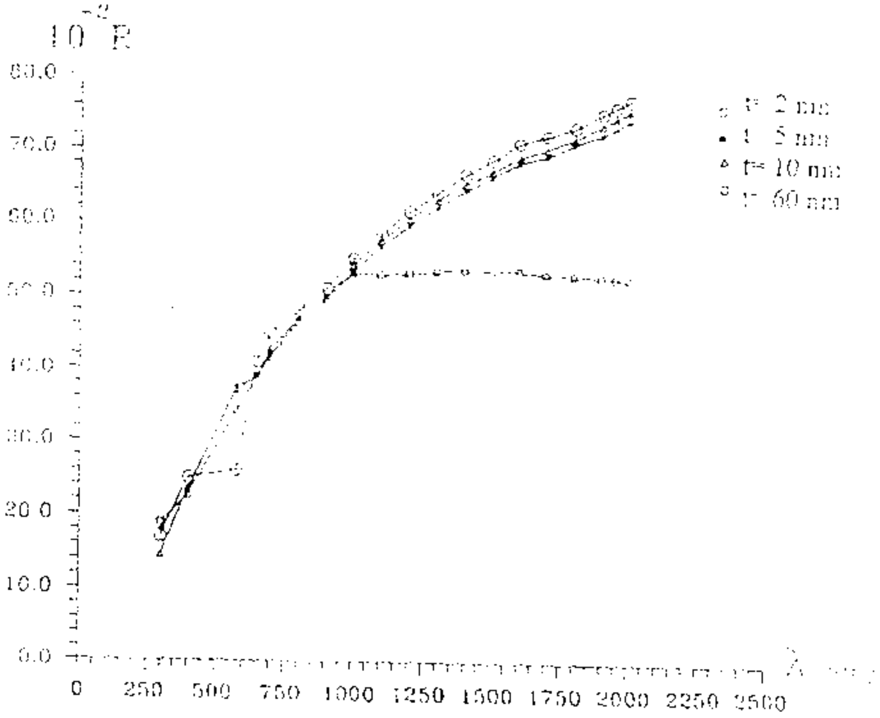

Figure (1) The reflectance spectrum of Ni films in ultra-violet-visible and near infrared regions.

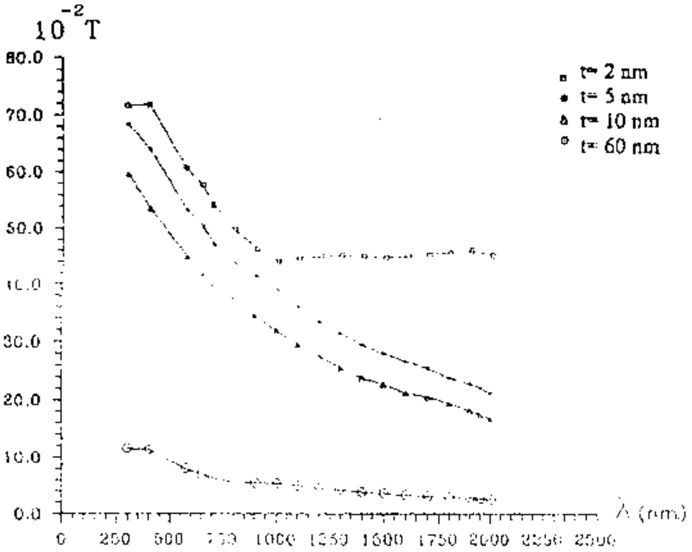

Figure (2) The transmittance spectrum of Ni films in ultra-violet-visible and near infrared regions.

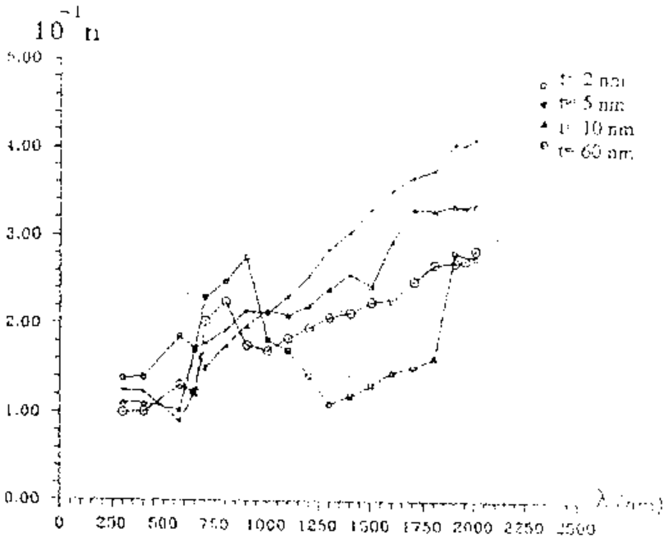

Figure (3) The variation of the refractive index vs. wavelength for thin Ni films.

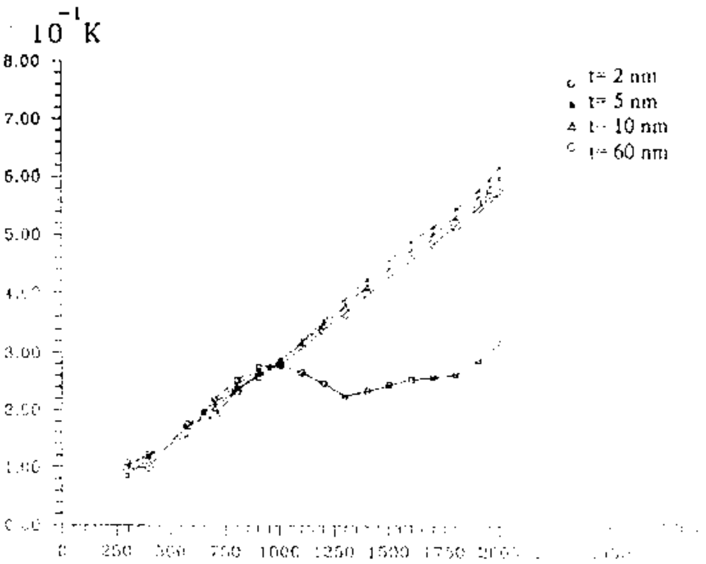

Figure (4) The variation of extinction coefficient vs. wavelength for thin Ni films.

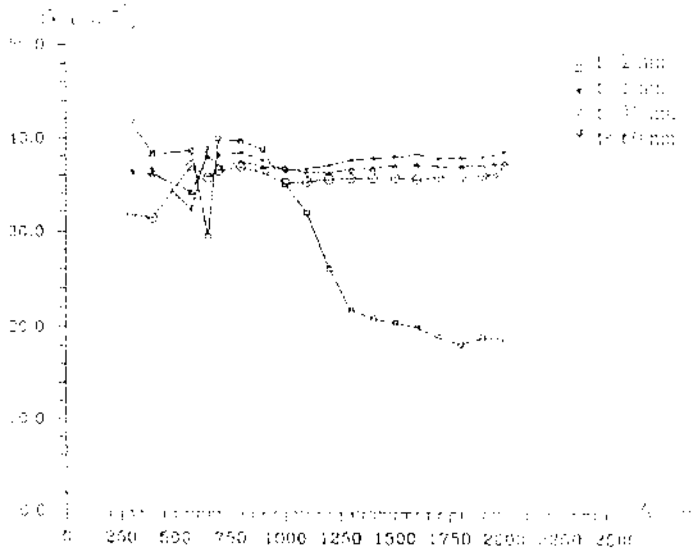

Figure (5) The variation of absorption coefficient vs. wavelength for thin Ni films.

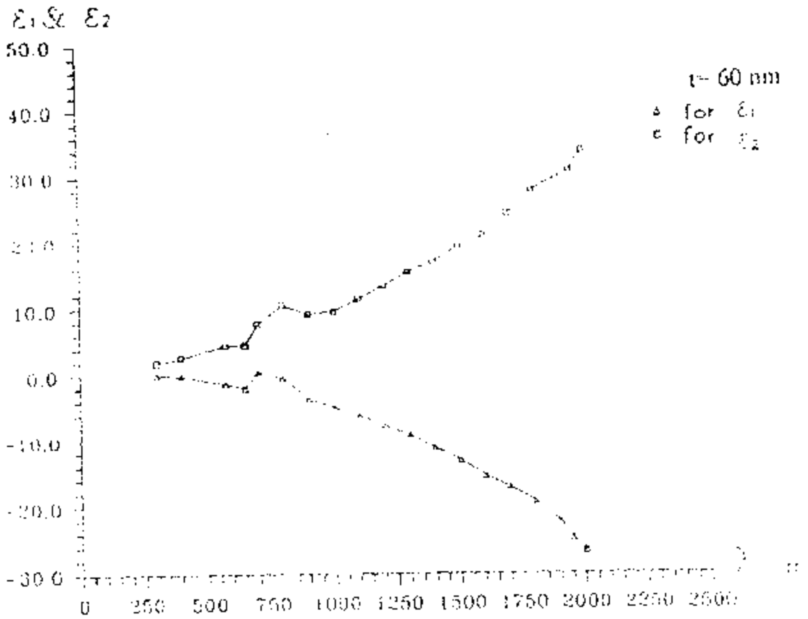

Figure (6) The variation of the real and imaginary parts of the dielectric constant with wavelength for thin Ni film at t = 60 nm.

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