CORRELATION BETWEEN SOME OPTICAL CONSTANTS AND STRUCTURES OF THIN TITANIUM FILMS

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Abstract:

The refractive index, extinction coefficient, optical dielectric constants and energy loss functions of thin titanium films have been determined in the infra-red region from 2.5 μm to 25 μm. these films were prepared by thermal evaporation technique in vacuum of 1.33×10^{-3} Pa, and deposited onto mica substrates maintained at room temperature. The behaviour of the optical constants with photon energy is mainly dependent on the structure of titanium films.

Introduction

The optical properties of titanium (Ti) films were studied by several workers (1-3) where the energy loss spectra of Ti films as well as other transition metals were determined and discussed in details. Moreover. The complex dielectric constant was compared and computed with results obtained by different methods. The aim of the present work is to study the optical constants of Ti films in the infrared region and correlate them with the structure.

Experimental:

The materials used in the present work was spec pure Ti (99.999%). The titanium films were prepared by thermal evaporation technique under high vacuum of 1.33×10^{-3} Pa. The films were deposited onto mica substrates with rate of 0.5 to 0.8 nm/sec. The films thickness was in the range from 11 to 78 nm measured by multiple-beam fizeau fringes method (4). For structural investigation the films were stripped from the mica substrates and fished on copper gride to be ready for investigation by transmission electron microscopy and diffraction techniques. ELMID2 electron microscope of 45KV was used in the present work. Transmission measurements were carried out in the infrared region from 2.5 to 25 um using a Beckman 4220 spectrophotometer.

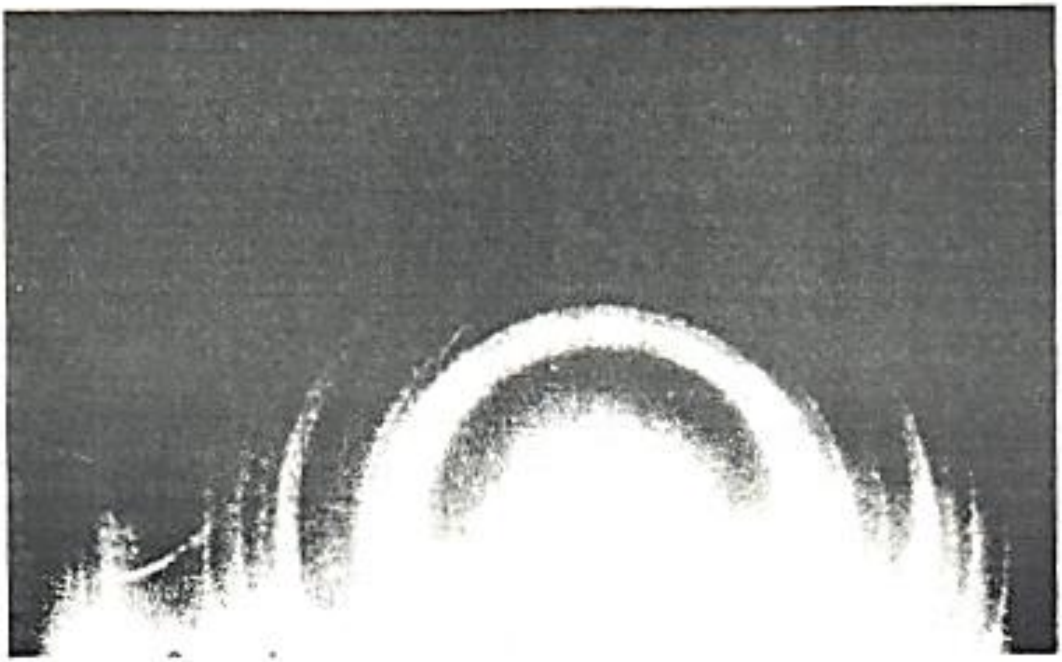

Fig. 1: Electron diffraction pattern of titanium films of thickness 36 nm.

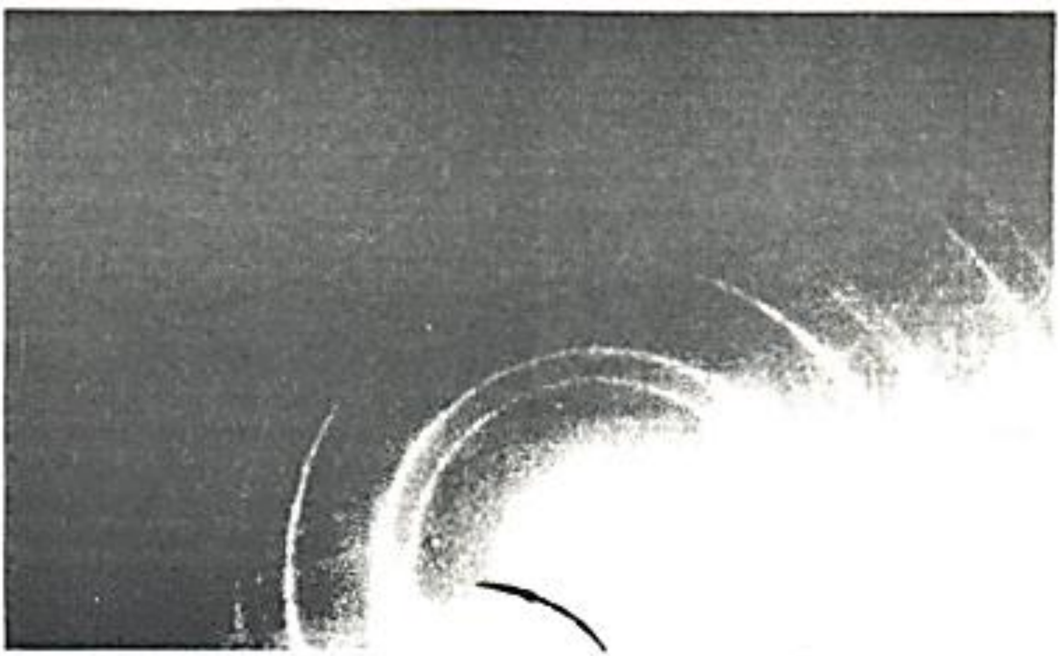

Fig. 2: Electron diffraction pattern of titanium film of thickness 62 nm.

The relations between ϵ_1, ϵ_2 and the values of λ or $\hbar w$ are illustrated in Fig. 5. From this figure we find that in general ϵ_1 and ϵ_2 decrease with increasing or decreasing $\hbar w$ which indicate normal dispersion. Anomalous dispersion takes place for ϵ_1 in the wavelength range (4.3 to 6.6 µm. This corresponds to a minimum negative value of -4 and a maximum positive value of 79. For ϵ_2 anomalous dispersion takes place in the wavelength range 5.7 to 8.1 µm, which corresponds to a minimum value of 1.2 and a maximum value of 37.

From the following equations:

$$-I_m \frac{1}{\epsilon} = \frac{\epsilon_2}{\epsilon_1^2 + \epsilon_2^2} \tag{5}$$

$$-I_m \frac{1}{\epsilon + 1} = \frac{\epsilon_2}{(\epsilon_1 + 1)^2 + \epsilon_2^2} \tag{6}$$

It was possible to calculate the values of photon energy loss at films surface $-I_m (\epsilon + 1)^{-1}$ and photon energy loss at film volume $-I_m (\epsilon)^{-1}$. It is found that in the wavelength range from 2.5 to 6.8 µm the peaks of such energy losses have maximum values at 52 and 51 um respectively, as shown in Fig. 6.

Optical conductivities σ_1 and σ_2 could be calculated from the formula:

$$\sigma_1 = \frac{w \epsilon_2}{4 \pi} \tag{7}$$

and

$$\sigma_2 = \frac{w(\epsilon_1 - 1)}{4 \pi} \tag{8}$$

where σ_1 is the volume conductivity and σ_2 is the surface conductivity. Fig. 7 present the relation between σ_1, σ_2 and the values of wavelength λ or photon energy $\hbar w$. In general σ_1 and σ_2 decrease with increasing λ or decreasing $\hbar w$. Inversion takes place for σ_1 in the spectral range 5.9 µm (minimum) to 9.5 µm (maximum). For σ_2 anomalous behaviour takes place in the range from 5.8 µm (minimum) to 9.5 um (maximum). This minimum corresponds to a negative σ_2 = -1.7 sec^{-1} and a positive peak value of 11.5 sec^{-1}.

From the present study it is found that the values of refractive index ranged between 0.24 and 8.34, while these of the extinction coefficient are in the range from 2.92 to 6.34. The values of K are in reasonable agreement with those found by Carrel and Melmed (8) while the values of n is much higher than the estimated values. The results also indicate that n and K in general behave normally with λ or $\hbar w$ except in the spectral range from 8.3 to 10.6 µm. The different absorption

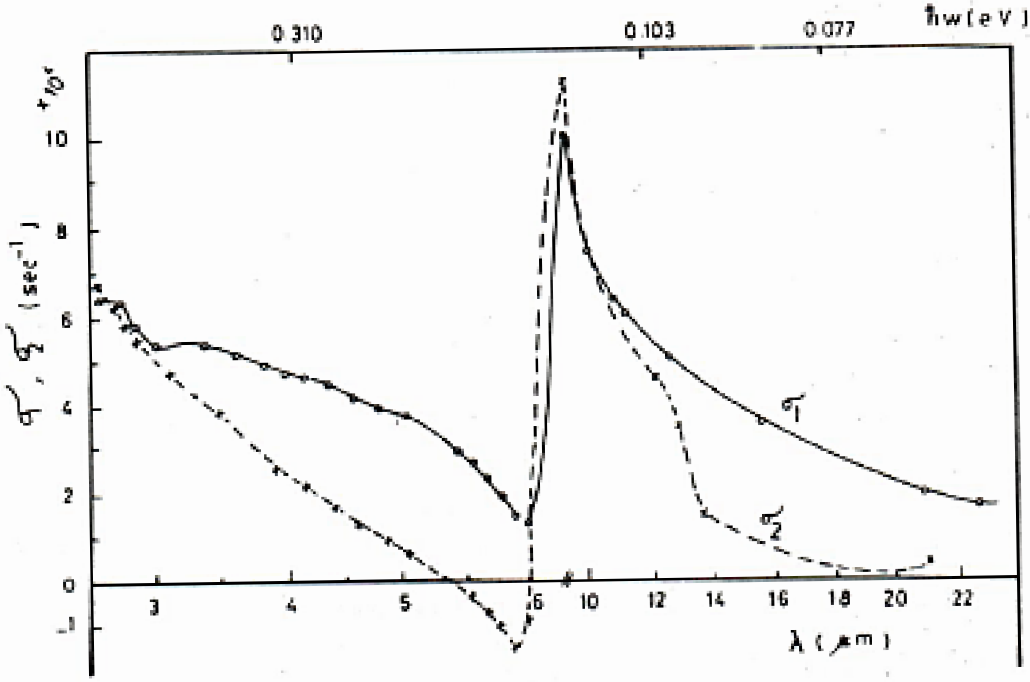

Fig. 7: Relation between optical conductivities σ_1, σ_2 and values of wavelength λ or photon energy $\hbar w$.

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