- Sci. J. Fac. Sci. Menoufia Univ, VoL.VI (1993). 45 - 58

STUDIES ON SOME OPTICAL PROPERTIES OF EVAPORATED TELLURIUM FILMS

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ABSTRACT

The optical phase function $F = 2\delta - \beta_1 - \beta_2$ *was evaluated for Te films of thickness ranging from 83-380 A° for* $\lambda = 5875$ *A°. Its variation with thickness and effect on the intensity distribution of the reflected system of fringes were investigated . The optical constants of thick Te films were determined in the visible and in the near infrared regions.*

INTRODUTION

Studying the phase properties of a thin evaporated film, namely the chnage of phase at reflection and in transmission, attracted many investigators. Barakat et al $^{(1-4)}$ determined the variation of the phase change at reflection air / film, glass / film and in transmission through thin films using two beam fringes formed by a Koster iterference comparator and a Rayleigh refractometer.

The effective refractive index n and coefficient of absorption K of thin Te films were determined by several methods in the spectral range 3700 A° to 20000 A°. Shklyarevskii $^{(5)}$, determined the optical constants of Te thin films in the visible region.

Interest in the infrared application possibility of Te arising from its ability for producing relatively large second harmonic, Patel (6); its laser induced photo effectes, Ribakovs et al (7) and large optical activities, Ades et al (8). This generated a need for reliable values for the optical constants of thin evaporated Te films. Moss (9), Hartig (10), Hodgson (11), and Stuke (12) determined the optical constants for Te in the infrared region.

EXPERIMENTAL PROCEDURE

Tellurium in the form of powder of grade 99.999% was thermally evaporated in Vacuum better than 10^{-5} Torr from Ta boats at room temperature with a rate of 20 A°/ sec. Te films were deposited on optical glass substrates for the phase properties studies at $\lambda = 8575$ A°, and on KBr for the infrared studies. The substrates were held 15 Cm distance tangential to the Ta boat containing Te powdered. Films for different investigations were simultaneously prepared and left in vacum overnight before removed from the vacuum chamber.

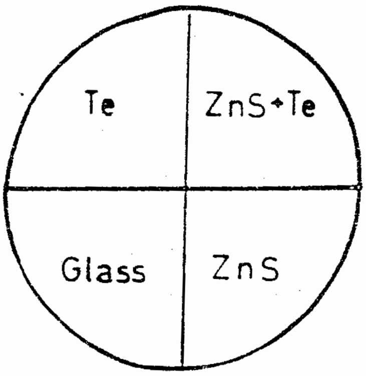
The thickness of Te films were measured by Tolansky's method(13) The choice of the overcoating metallic layer is restricted in this method for measuring the Te thickness to Al since diffusion of Ag takes place in Te.

The experimental procedures for determining the phase change at reflection air / Te β_1, galss / Te β_2 and in trasmission through thin Te films were reported according to references (1-4).

For the determination of the optical constants of a thick layer of Te from the measurements of phase change at reflction glass / Te and ZnS / Te, an optical flat of thickness 11mm and degree of flatness ± 0.001 mm was used as substrate. A cleaved sheet of mica with sharp edge has been used as mask allowing half the substrate to be exposed to evaporated vapours of ZnS under reduced pressure of less than 10^{-5} Torr. After rendering the evaporation chamber to atmospheric pressure the mask was rotated through 90° with its edge adjusted passing by the center of the circular substrate. The usual steps for evaporation of Te were followed and an opaque layer of Te was evaported on the exposed half of the substrate. It was then left to cool under vacuum. The substrate was then divided into four quarters as shown in plate 1(a).

The substrate was then introduced inthe passage of light in Koster comparator, held up-right down such that the incident beam suffered reflections at glass / air, glass/ Te, ZnS / air and ZnS/ Te interfaces.

Plate 1 (b) shows interferograms corresponding to the four quarters for $\lambda = 5015$ A° and 5875 A° respectively. The result of measuring the fringe shift due to ZnS/Te-ZnS / air and that due to glass / Te-glass/ air lead to the determination of the phase change at reflection ZnS / Te and galss / Te, which is β_1 and β_2 respectively.



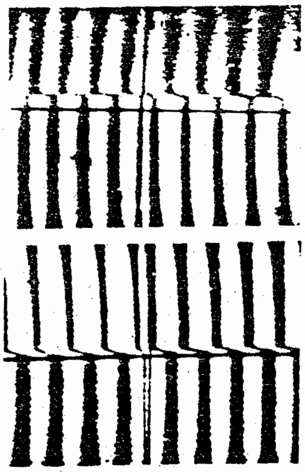


plate (1)

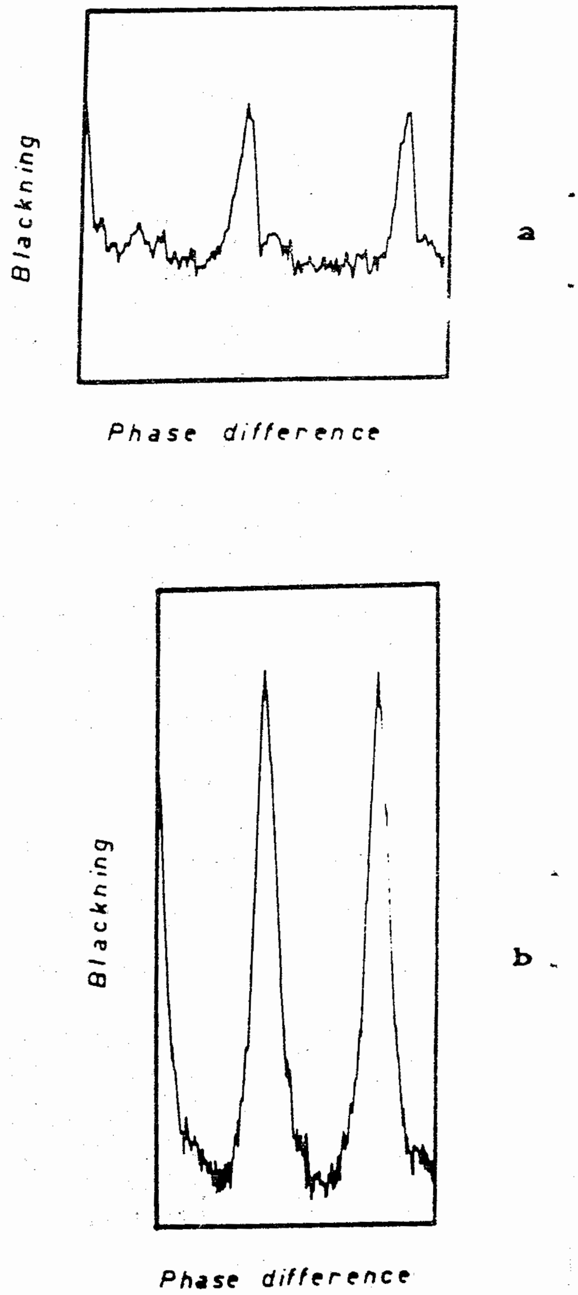


plate (2)

The measurements of the variation of percentage transmission with wavelength were done using Beckman Spectrophotometer IR 4220.

RESULTS AND DISCUSSION

The variations of phase change with thickness at reflection air / Te β_1, glass/ Te β_2 and in transmission through thin films are illustrated in Table (1).

Table (1).

Thickness in A°	β_1	β_2	δ	$F = 2\delta - \beta_1 - \beta_2$
83	1.10π	0.94π	0.15π	-1.73π
110	1.20	1.05	0.15	-1.95
140	1.17	1.07	0.16	-1.92
160	1.21	1.03	0.13	-1.97
169	1.18	1.02	0.11	-1.98
180	1.19	1.04	0.12	-1.99
200	1.24	1.10	0.13	-2.08
232	1.22	1.14	0.17	-2.01
242	1.20	1.08	0.14	-2.00
280	1.32	1.16	0.22	-2.04
300	1.35	1.20	0.24	-2.08
320	1.28	1.15	0.23	-1.97
380	1.55	1.02	0.25	-2.07
423	1.47	1.13	drop in the transmitted intensity	F - values can not be calculated
475	1.77	1.20		
586	1.98	1.14		
660	1.98	1.14		
725	1.98	1.14		
800	1.98	1.14		

For Te thickness t< 423 A° succesive maxima and minima occur due to multi-reflections within Te film. Then β_1 increases with t till saturation occurs at 586 A° where β_1 remains constant at 1. 98 π, while β_2 attain constant value for t > 586 A° indicating that Te films behave like bulk Tellurium. The constancy of the phase change at reflection for films thicker than 586 A° enables the deduction of the optical constants of bulk Te.

Fig. (1) shows the variation of the experimentally determined values of the phase function F of Te films with thickness over the range 83 A° up to 380 A° only, because of the drop in the transmitted intensity. Such curve shows that the F-values for evaporated Te films are within - $(2n\pi \pm 0.05\pi)$ for films of thickness raging from 110 A° to 380 A° and less than - 2π for thickness less than 100A°. The error in the meausrment of phase change is within 1.25%.

This result has been confirmed by forming multiple-beam fringes at reflection using such films as the upper component of the interferometer, facing the incident light. The radiance of the multiple beam reflected fringes was redistributed so that transmission-like fringes appeared for all thicknesses $\geq$ 100 A° at $\lambda = 5875$ A°. The only difference is hte elevation of background as the thickness increases. Plate 2 (a, b) shows the microphotometric tracing for transmission-like fringes with high background and transmission-like fringes respectively.

In the visible region, at λ = 5015 A°, λ = 5875 A° and λ= 6438 A°, a method has been performed for the determination of the optical constants of evaporated Te films of thickness about 1000 A° representing the bulk. This method is based on the experimental determination of phase change at reflection ZnS/Te and glass / Te by using the Koster interferecne comparator followed by calculations based on formulea derived from the electromagnetic theory and given by Born and Wolf (14).

If the film is evaporated on two different substrates of refractive indices n_1& n_2 at a certanin wavelength andβ_1&β_2 gives the change of phase substrate/ film in units of angles at the same wavelength.

Then for a thick bulk film, where only a single reflection at the substrate/ film interface is operative, the formula derived from the electromagnetic theory can be reduced to:

$$\tan\beta_1 = \frac{2n_1K}{n_1^2 - (n^2 + K^2)} \qquad (1)$$

and

$$\tan\beta_2 = \frac{2n_2K}{n_2^2 - (n^2 + K^2)} \qquad (2)$$

thus

$$n^2 + K^2 = \frac{-n_2 \tan\beta_2 + n_1 \tan\beta_1}{n_2 \tan\beta_1 - n_1 \tan\beta_2} \qquad (3)$$

Substituting for $n^2 + K^2$ obtained from (3), using expermintally found β_1 and β_2 values into (1) or (2) calculating n and K. The calculated values of n and K are reported in Table (2). It is seen that the refractive index n increases with increasing the wavelength, while the absorption index k decreases with increasing the wavelength because of decreasing the absorption of tellurium in the near infrared region. This results are in good agreement with the previous published results.

Table (2)

λ in A°	n	k	K
5015	2.63	1.37	3.61
5875	3.78	0.94	3.56
6438	4.81	0.67	3.26

In the range of the I.R. spectrum (2.5-12μ), the optical constants of Te films of thickness 1200 and 1500 A° deposited on KBr substrates were determined by measuring the transmissitivity of these films at different wavelengths.

Figure (2) shows the variation of the percentage transmission T with wavelength in μ for the two film thickness.

According to Heavens (15), the percentage transmission is related to n, K, d and λ by the following equation:

$$T = \frac{16 n_{\circ} n_1 (n^2 + K^2)}{\{(n_1 + n)^2 + K^2\} \{(n_{\circ} + n)^2 + K^2\}} e^{-4\pi \gamma K d} \qquad (4)$$

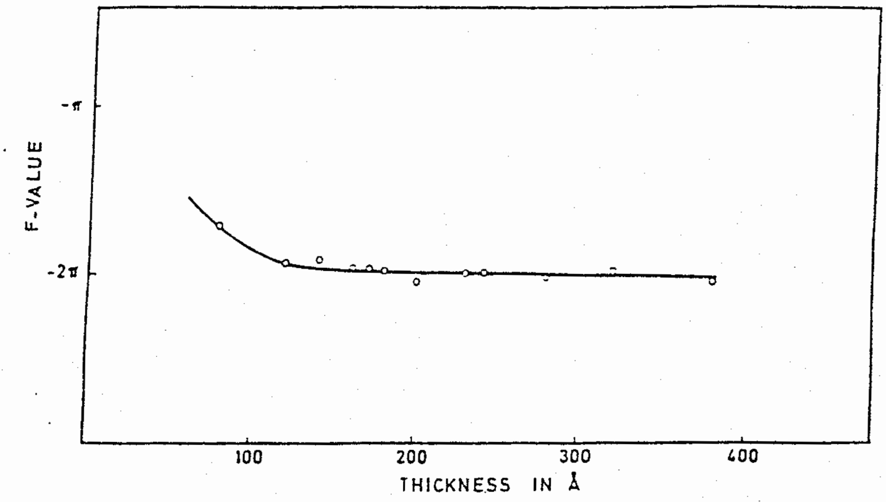


Fig. (1) variation of the phase function with the thickness of evaporated Te film for λ = 5875 A°

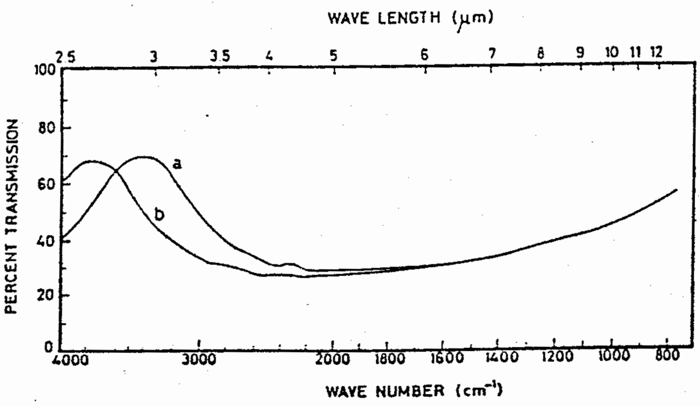


Fig. (2) Infrared spectra of thin tellurium films. (a) Film thickness 120 nm (b) Film thickness 150 nm where n_o and n_1 are the refractive indices of the medium and substrate respectively and d the film thickness.

Taking into account the stability of n and K for thick Te films the values of K were calculated from equation (5) and represented in Fig.(3)

$$K = \frac{\lambda}{4\pi} \frac{\ln 1/T_2 - \ln 1/T_1}{d_2 - d_1} \qquad (5)$$

T_1 and T_2 being the values of percentage transmission for thicknesses d_1 and d_2 respectively and λ the wavelength corresponding to T_1 and T_2. Fig. (3) shows that K have a peak at $\lambda = 3.25\ \mu$, then it decreases gradually and increases again giving another peak at $\lambda = 5.73\mu$

The values of refractive index n can be calculated, using the values of T, K, d, $n_1 = 1.55$ and no =1, from equation (4) and represented in Fig. (4). Such curve shows that, there is a sharp decrease in the values of n to a minimum value at $\lambda = 3.24o\ \mu$ then it increases to maximum at $\lambda = 5.75\ \mu$, and decreases again gradually.

CONCLUSIONS

1- The optical phase function F of the evaporated Te films effect on the intensity distribution of muliple -beam interference fringes at reflection, where for all thickness ≥ 100 A° at $\lambda = 5875$ A°, transmission-like fringes will appear with only difference which is the elevation of the background as the thickness increases.

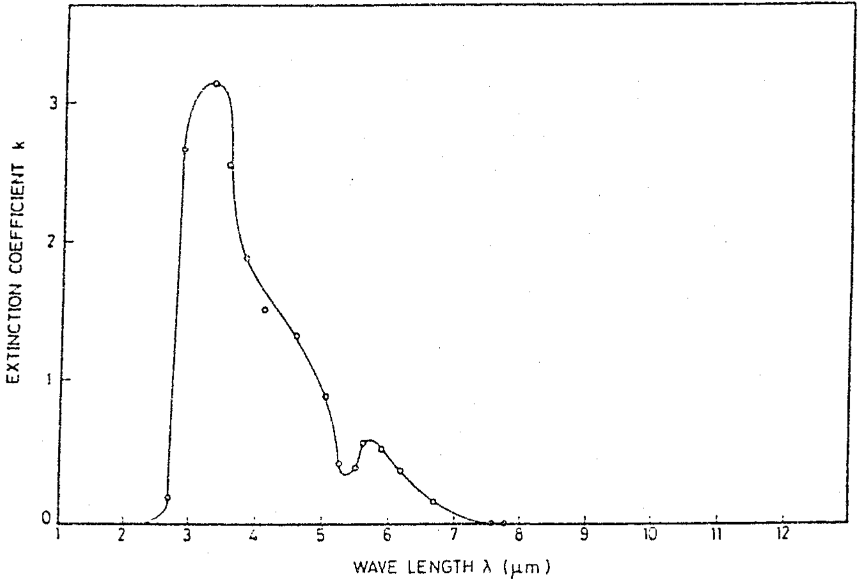


Fig (3) Extinction coefficient K as a function of λ

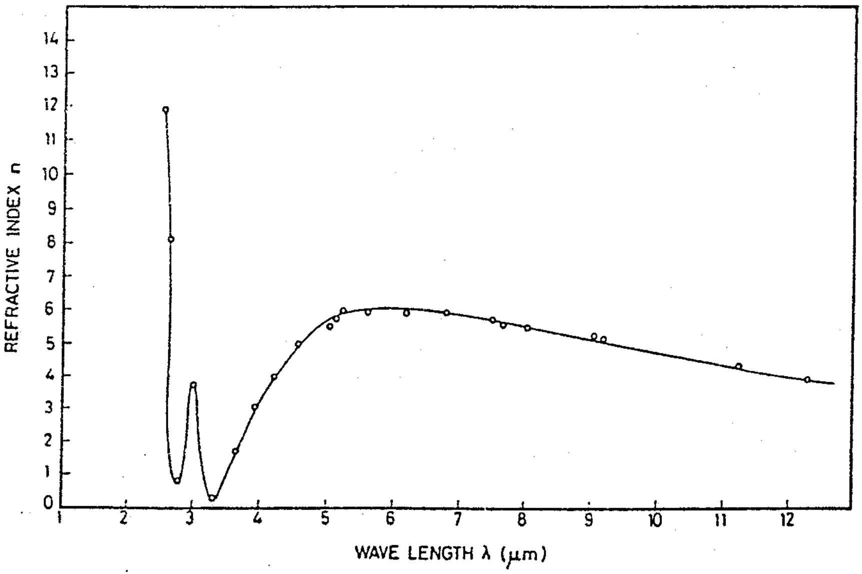


Fig.(4) Refractive index n as function of λ

2- In the visible and near infrared regions, refractive index and extinction coefficient of thick Te films, have been calculated at different wavelengths. The results agree with the previous published data with a slight variation attributed to the difference in mode of preparation.

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دراسة بعض الخواص الضوئية لشرائح من التليريوم مرسبة بطريقة التبخير

محمد السيد البحراوى –محمد عبد الفتاح سبيع

تناول هذا البحث تعيين الخواص الطورية للأشعة المنعكسة والنافذة من وخلال شرائح من التليريوم تم تحضيرها بطريقة التبخير الحرارى تحت ضغط اقل من $١٠^{-٥}$مم / زئبق ثم حساب دالة الطور الضوئية للأشعة وهى $F = 2\delta - \beta_1 - \beta_2$ للشرائح التى يتراوح سمكها من ٨٣ انجستروم الى ٣٨٠ انجستروم عند الطول الموجى ٥٨٧٥ انجستروم.

كذلك تمت دراسة تغير هذه الدالة مع سمك الشريحة وتأثيرها علي توزيع الشده الضوئية لهدب التداخل عند الإنعكاس.

ولقد تم تعيين الثوابت الضوئية لشرائح سميكة من التليريوم عند اطوال موجيه مختلفة فى الطيف المرئى والقريب من الطيف تحت الأحمر غير المرئى.