

Optical Constants Fitting and Application of Ta₂O₅

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Abstract Ta₂O₅ is widely used as a kind of high refractive index film material. The optical constant is vary because of dispersion and absorption as well as different technological conditions. A kind of using electron gun of fabrication of thin film evaporation and ion beam assisted method is introduced. The test based on the Cauchy model of the films in the near ultraviolet to near infrared optical constants are fitted, and illustrates the application of the material in short wavelength pass filter.

Key words materials; optical material; optical constants; thin films; fitting

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Ta₂O₅材料光学常数的拟合及其应用

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摘要 Ta₂O₅作为高折射率材料有着广泛的应用, 由于具有不同的色散和吸收, 以及不同的工艺条件, Ta₂O₅材料的光学常数会出现差异。介绍了一种采用电子枪蒸发并加以离子束辅助技术制备 Ta₂O₅薄膜的方法, 实验基于柯西模型(Cauchy Model)对 Ta₂O₅薄膜在近紫外到近红外的光学常数进行了拟合, 并说明了 Ta₂O₅材料在短波通滤光片中的应用。

关键词 材料; 光学材料; 光学常数; 薄膜; 拟合

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1 Introduction

Ta₂O₅ is a kind of good high refractive index coating material, it has to do with combination of anti-reflection coating film, reflective film, interference by the filter, bandpass filter membrane layer is firm, good chemical stability and the laser damage resistance is strong, which is widely used in the optical communications, lasers, solar cells and other components. Membrane layer with high dielectric constant is an important material of manufacturing thin film capacitor. Under different process conditions, the optical constants of the films will be difference, in the same process conditions, film optical constants as a function of wavelength. Precision optical constants of securing material is the premise of the preparation of high precision optical thin films.

2 Material test

Material test in film coater Oporun OTFC 1300 of Japan, deposition temperature is 200 °C in the process

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of preparation. Background vacuum is superior to 3×10^{-3} Pa in the vacuum chamber. Experimental basement using quartz glass, thin film deposition rate is about 1.5 nm/s, sedimentation process with vacuum chamber filling the 15 mL/min flow of oxygen and uses the ion beam bombardment. Experimental samples ultraviolet/visible/near infrared spectrophotometer measurements in LAMBDA950 of PerkinElmer company.

3 Fitting of optical constants

Material is mainly used to near ultraviolet to the near infrared wave band, so the material is fitting for the range from 350 to 1100 nm. Material test is conducted on quartz glass substrates, first of all to fitting the basal optical constants. The blank substrate transmissibility test diagram of curves are shown in Fig. 1.

It can be seen from the figure, basal itself exists must absorb in the near ultraviolet band, but as long as to the size of the accurate calculation of absorption, does not affect the optical constants fitting. Because of substrate absorption, when fitting substrate optical constants, general dispersion model, such as Cauchy model, Cauchy index model, the Sellmeier model, etc., there are some shortcomings. Here, Lorentz oscillator model is chosen as the substrate of the dispersion model, the substrate is obtained by fitting the optical constants are shown in $n-k$ curve below:

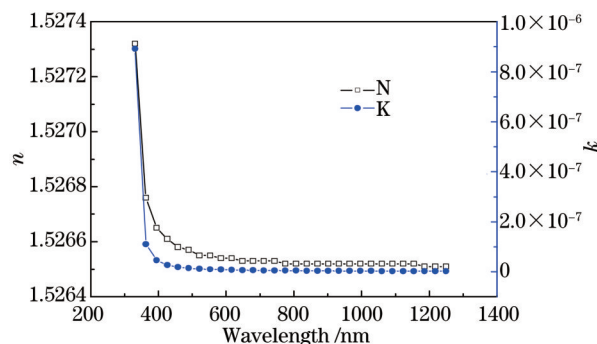
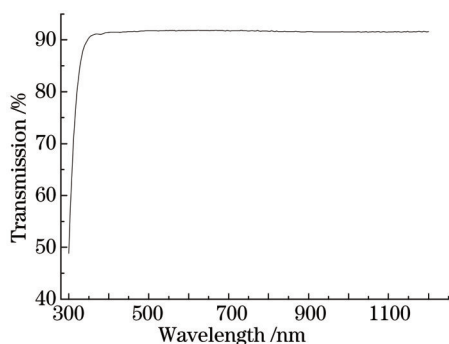


Fig.1 Blank substrate transmissibility test diagram of curve

Fig.2 Fitting obtains the basis optical constant the $n-k$ curves

After determining the basement of the optical constants, can rule out the dispersion and absorption of optical constants of basal fitting and the influence of interference. Near ultraviolet to the near infrared wave band for basic material without absorption area, a commonly used method of Cauchy model can fit the requirements, in the process of fitting, which was optimized by using Simplex method to get the material of $n-k$ curve as shown in Fig.3 below.

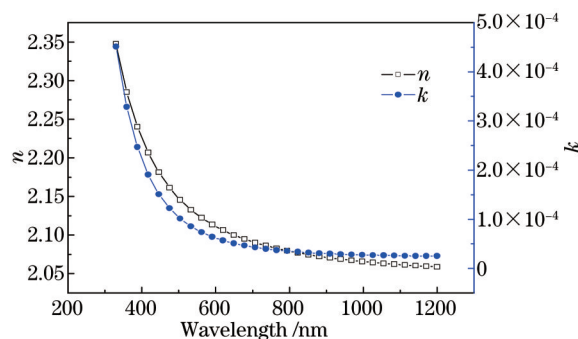


Fig.3 Ta_2O_5 material $n-k$ curves

Figure 3 shows that Ta_2O_5 material was positively dispersion characteristics, the refractive index is 2.35 in short wave, the refractive index is steady after the 600 nm to near infrared wave band, extinction coefficient of materials began to increase at about 2.05 and before the 500 nm, present obvious in near ultraviolet absorption, But the extinction coefficient is just 10^{-4} orders of magnitude; after the 500 nm until the near infrared region has no absorption area.

4 Preparation of short wave pass filter

Optical constants of Ta_2O_5 materials after fitting are obtained, which are used as a high refractive index material preparation a cover near ultraviolet to the near infrared region of short-wave communication interference by the filter, on the one hand, testing and verifying the reliability of testing materials, on the other hand, illustrating the application of Ta_2O_5 material at these wavelengths. Filter base for gems, selected Ta_2O_5 as high refractive index material (n_H), SiO_2 as a low refractive index material (n_L), choosing MgF_2 as the matching material (n_M) is used to compress passband ripple^[1-4]. Optical constants of Ta_2O_5 materials has been completed, SiO_2 and MgF_2 materials of optical constants in the same ways. Using (0.5 L H 0.5 L) structure as basic cycle, because in the long wave region, the refractive index of Ta_2O_5 material is not high, only 2.05 or so, to ensure that there are wide as band, using double membrane reactor for stack. Take the center wavelength $\lambda_0 = 750 \text{ nm}$, the initial film system is:

$$(0.5 \text{ L H } 0.5 \text{ L})^{11} (0.6 \text{ L } 1.2 \text{ H } 0.6 \text{ L})^{11}$$

Using optimized choice MgF_2 as the matching material, film system is as follows:

$$0.6 \text{ M } (0.5 \text{ L } 1.1 \text{ H } 0.56 \text{ L})^9 (0.48 \text{ L } 1.04 \text{ H } 0.62 \text{ L})^2 (0.54 \text{ L } 1.12 \text{ H } 0.63 \text{ L})^9 (0.59 \text{ L } 1.15 \text{ H } 0.57 \text{ L})^2$$

The filter and material test are prepared on the same device. When the vacuum chamber vacuum reaches to $9 \times 10^{-3} \text{ Pa}$, and baking temperature is set at $200 \text{ }^\circ\text{C}$, baking for 1.5 h, 15 SCCM filling flow into the vacuum chamber of the Ar gas, open the ion source, anode voltage sets to 200 V, anode current sets szto 4 A, the substrate at 15 min. The innermost MgF_2 materials using resistance evaporation, evaporation current is 220 A, due to the MgF_2 plating system in the process of ion assisted them can lead to material absorption defluorization, therefore, do not use ion assisted. SiO_2 adopts 6 kV electron gun evaporation, evaporation beam is 40 mA, with 8 kV electron gun evaporation, evaporation beam is 80 mA, in order to avoid the above material in the process of evaporation loss of oxygen system to the vacuum chamber during the process of filling the 15 mL/min O_2 gas flow, secondary ion source is opened, to ensure the fastness and compactness of film^[5].

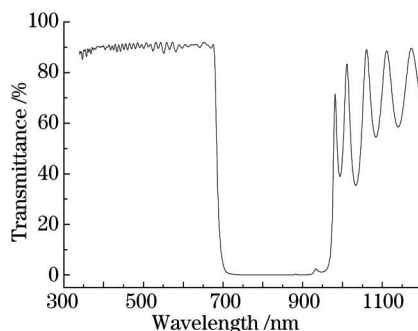


Fig.4 Light filter actual diagram of curve

Figure 4 shows that the whole bandpass filter are flat, through rate is about 90%, in the near ultraviolet transmittance declined, mainly due to the absorption of the material, that with the proposed materials and optical constants.

5 Conclusion

Using a variety of optical constants of Ta_2O_5 thin film dispersion model fitting, near ultraviolet to the near infrared wave band optical constants are obtained. Visible to near infrared area, Ta_2O_5 material maintains a stable low refractive index and absorption, near ultraviolet band, material dispersion increases obviously, extinction coefficient is increased. Choosing Ta_2O_5 and SiO_2 as high and low refractive index materials respectively, covering nearly prepared by ultraviolet to the near infrared wave band interference by the filter. Experimental results show that Ta_2O_5 material in the near ultraviolet to

the near infrared region is a kind of superior performance and high refractive index material.

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