J. Fiz. UTM. Vol. 2 (2007) 1- 4

TRANSMISSION PROPERTIES OF LITHIUM NOBATE AND FUSED QUARTZ AS ACOUSTO OPTIC MATERIAL

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ABSTRACT

Laser beam can be modulated by acousto optic modulator using a suitable acousto optic material. UV-VIS Spectrophotometer was utilized to investigate the transmission spectrum of two non linear acousto optic materials that are lithium niobate and fused quartz. From the spectrum it shows that transmittance for fused quartz and lithium niobate were 90% and 68% respectively. The absorption coefficient α is calculated and plotted versus photon energy. It was found that α increases linearly with photon energy in the range of 3.50 eV to 4.0 eV for fused quartz and 3.15 eV to 4.0 eV for lithium niobate. The estimated optical energy band gap was 2.97 eV for lithium niobate and 3.69 for fused quartz. From the transmission properties obtained in this study, it can be summarized that fused quartz is a better choice to be an acousto optic material.

Keywords: acousto optic, Spectrophotometer, transmission spectrum, absorption coefficient

INTRODUCTION

An acousto optic device requires a material with good acoustic and optical properties and high optical transmission. Acousto optic materials (AOM) can modulate light which pass through it when influenced by acoustic field. Lithium niobate and fused quartz are examples of AOM. Lithium niobate continues to be a material of interest for various optical and surface acoustic wave applications due to its unique combination of piezoelectric and optical properties [1]. Fused quartz**,** the crystalline form of silicon dioxide, is transparent over a wide frequency region [2]. Prior to their used as AOM, the information about optical properties are essential to be known. The purpose of this paper is to study the optical transmission, the dependence of absorption coefficient on incident photon energy and to obtain the optical energy band gap.

THEORETICAL

The most common optical properties of the material are optical transmission, optical absorption and energy band gap. It is essential to investigate the dependence of absorption coefficient on incident photon energy. In order to estimate the absorption coefficient, required the information on transmission of the material is required.

The linear transmission in normal incidence through a transparent material, assuming that no interference occurs between reflections from front and back surfaces, is given by [1, 3]

$$T = (1-R)^2 e^{-\alpha d}\left(1+R^2 e^{-2\alpha d}\right) \tag{1}$$

where α the absorption coefficient, d the crystal thickness, and R the normal-incidence reflectance. Here absorption losses are assumed to include scattering as well as electronic absorption. If the reflectivity is weak, then the $R^2e^{-2\alpha d}$ term can be neglected in the above equation, and it becomes

$$T \approx (1-R)^2 e^{-\alpha d} \tag{2}$$

Electronic transition between the valance and conduction band in the crystal start at the absorption edge which correspond to the minimum energy difference E_g between the lowest minimum of the conduction band and the highest maximum of the valance band. For interband electronic transitions near the fundamental absorption edges, α is given by [4]

$$\alpha \propto (h\nu - E_g)^n \tag{3}$$

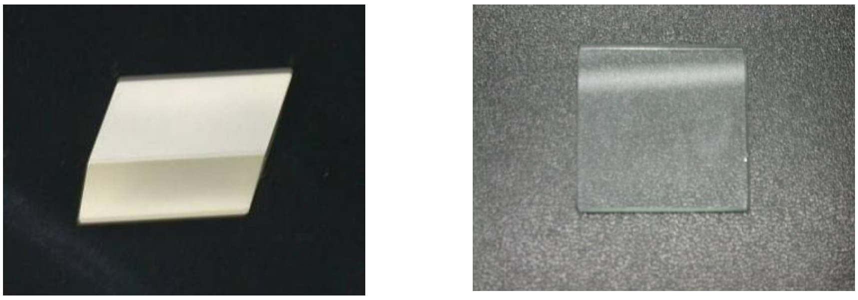
where E_g is the band gap of the material and $h\nu$ is the photon energy. The exponent n have different values like non integer 1/2 for direct band gap materials and integer 2 for indirect band gap materials. The absorption coefficient for an indirect band gap material near the fundamental absorption edge can be written as

$$\alpha \propto (h\nu - E_g^{ind} \pm h\Omega)^2 \tag{4}$$

where $h\Omega$ is the photon energy associated with the transition.

METHODOLOGY

The specimens employed as acousto optic material are lithium niobate and fused quartz. The dimension for lithium niobate is 30 × 25 ×15 mm^3 and for fused quartz is 33 ×33 × 2 mm^3, as shown in Figure 1. The optical transmission spectra were recorded with unpolarized light at normal incidence and room temperature using Perkin Elmer Spectrophotometer in the wavelength range 200 nm to 1100 nm.



(a) (b)

Figure 1: (a) Lithium niobate crystal (b) Fused quartz plate

RESULT AND DISCUSSSION

Figure 2 shows the transmission spectra from lithium niobate crystal and fused quartz glass in the UV-VIS-NIR region. The maximum transmittance obtained is 68% for the lithium niobate and 90% for fused quartz.

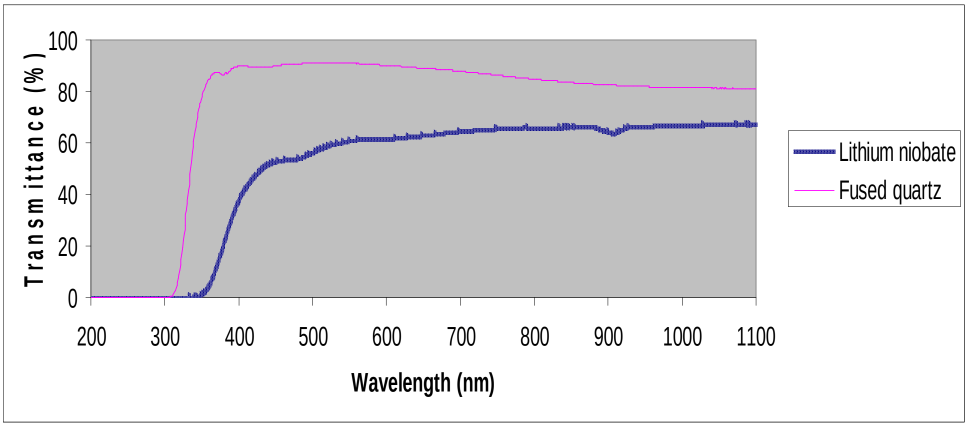
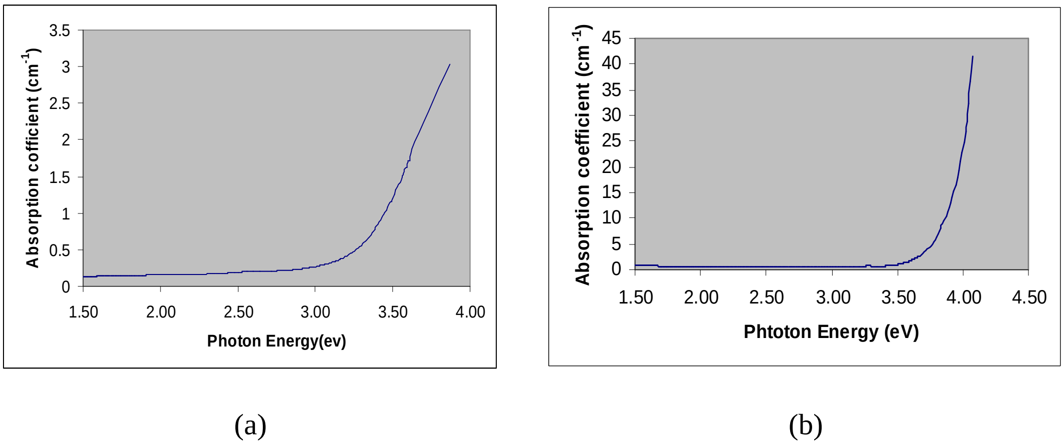


Figure 2: Transmission spectra for lithium niobate and fused quartz.

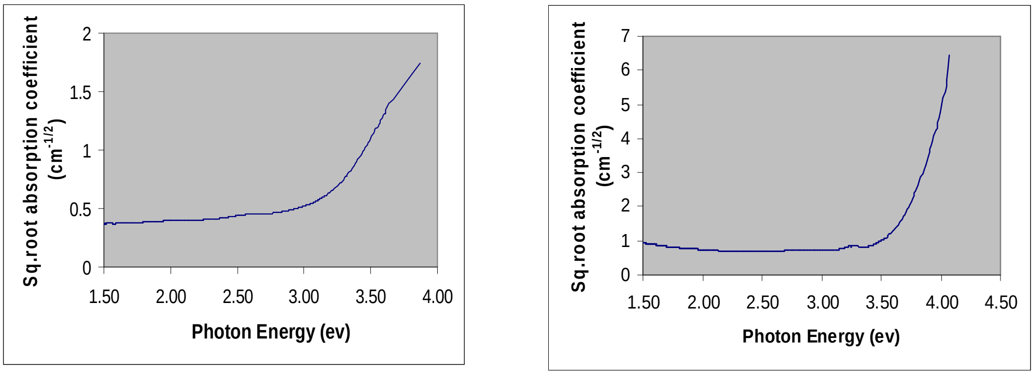
Figure 3 shows the absorption coefficient as a function of the incident photon energy. The values of absorption coefficient, α were calculated using equation (2). It can be seen that in both samples, the absorption coefficient increased slowly with the incident energy. It suddenly increased rapidly at threshold energy, 3.15 eV for lithium niobate and 3.50 eV for fused quartz. The gradual increased in absorption coefficient at higher photon energies is due to interband electronic transitions associated with bound electrons. The exponential shape of the curves near the absorption edge is commonly known as the Urbach tail.



(a) (b)

Figure 3: Absorption coefficient versus photon energy for (a) Lithium niobate (b) Fused quartz

Figure 4 shows a plot of square root of absorption coefficient ($\alpha^{1/2}$) against photon energy ($h\nu$), for both samples. The straight-line fitting near the absorption edge in the plot indicates indirect allowed transitions. The optical band gap (E_g) values were determined by extrapolating the linear part of the transmittance curves although there is some rounding curvature near the minimum transmittance. The optical band gap for lithium niobate is found to be 2.97 eV and for fused quartz is 3.69 eV.



(a)

(b)

Figure 4: Square root of absorption coefficient against photon energy for (a) Lithium niobate (b) Fused quartz.

CONCLUSIONS

The transmission properties for AOM were successfully studied. Transmittance for fused quartz is better than lithium niobate. The absorption coefficient of both spectra is found increases with respect to the photon energy. The optical energy band gap for fused quartz is also higher than lithium niobate. Hence fused quartz is a better material to be chosen as AOM.

ACKNOWLEDGEMENT

The authors would like to express their thanks to Universiti Teknologi Malaysia and the Government of Malaysia through IRPA vote number 74533 for the financial support in this project.

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