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Influence of Different Substrates on the Nonlinear Refractive Index of Chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ Thin Films

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Abstract

In the current work, the influence of various substrates on the nonlinear refractive index (n_2) of thin films made of the chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ was investigated. Bulk samples of the substance under examination were prepared using the melt quenching process. On glass, quartz, and mica substrates, thin films are deposited using the well-known thermal evaporation process. The Swanepoel method, which made use of transmission spectra, is used to determine the linear refractive index (n). Utilizing linear refractive index(n) and Abbe number (V_d), Boling's formula has been used to get the nonlinear refractive index (n_2). The acquired value of n_2 is found to be greater than pure silica. This material is beneficial for a variety of technical applications due to its higher nonlinear refractive index value.

Keywords: *Chalcogenide thin films, linear refractive index, nonlinear refractive index.*

Introduction

Very effective nonlinear optical materials are needed for a variety of optical device applications, such as optical switching and optical signal processing. Infrared transmission and significant third order optical nonlinearity, which is 27,000 times more than that of silica glasses, are distinctive properties of amorphous chalcogenide glasses[1,2]. Due to their extremely low two-photon absorption and lack of free carrier absorption at telecommunication wavelengths, chalcogenide glasses are one of the most crucial materials in all-optical signal processing[3,4].

In a recent work, we looked at how the kind of substrate affected the nonlinear refractive index of thin films made of the chalcogenide $Se_{82}Te_{15}Bi_{3.0}$. The nonlinear refractive index (n_2) has been described using Boling's rule[5].

Experimental Details

The melt quench procedure was employed to create the chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ glass that was used in the current investigation. The components are assembled into quartz ampoules and then vacuum-sealed at a pressure of 10^{-4} Pa. Depending on the components of the composition, the sealed ampoules were heated in a rocking boiler for 24 hours between 900 and 1000°C to ensure the homogeneity of the melt. Ice-cold water was used for the quenching process.

Using a thermal evaporation process, thin films of the matching bulk glass were formed on glass, quartz, and mica substrates at a base pressure of around 10^{-4} Pa. During the

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substrate-dependent investigation, the film thickness was maintained at 500–50 nm. The transmission spectra in the spectral range 400-1200 nm of the studied samples were recorded by UV-Vis-NIR spectrophotometer.

Results and Discussion

Linear Refractive Index: Figure 1, 2 and 3 represents the transmission spectra of chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ thin films prepared on glass, quartz and mica substrates, respectively.

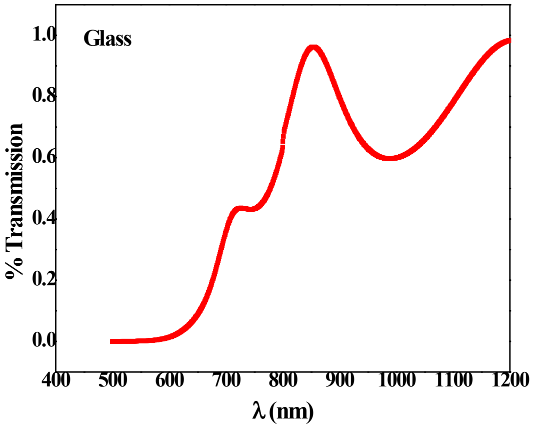

Figure 1. Transmission spectra of chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ thin film for glass substrate.

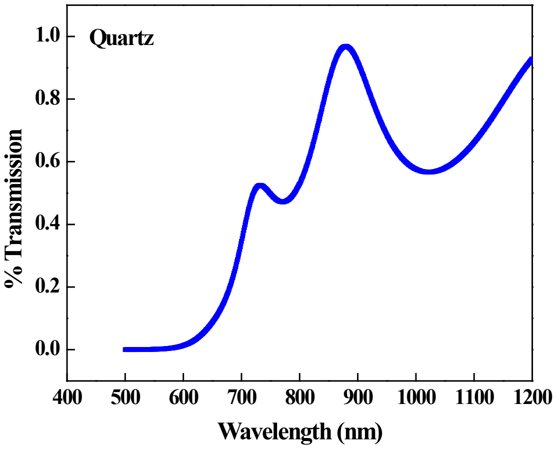

Figure 2. Transmission spectra of chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ thin film for quartz substrate.

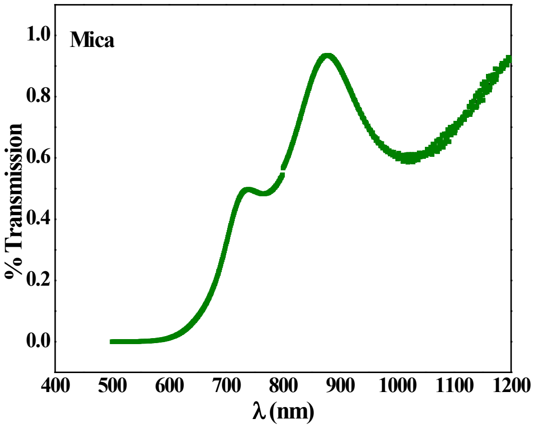

Figure 3. Transmission spectra of chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ thin film for mica substrate.

The well-known envelope approach has been used to calculate the linear refractive index (*n*) [6]. The tangents of the maximum and minimum fringes are used in the envelope technique to produce the upper and lower envelopes to the ellipsometric curves.

Using minimal transmittance (T_m) in the transparent zone, *n* of the films is calculated, and the result is provided by

$$n = [N + (N^2 - s^2)^{1/2}]^{1/2} \tag{1}$$

Where

$$N = 2s/T_m - (s^2 + 1)/2 \tag{2}$$

Here *s* is the refractive index of the different substrates; *s* for microscope glass = 1.51, *s* for quartz = 1.46, *s* for mica= 1.56.

The transmittance maxima (T_M) and transmittance minima (T_m) are used to compute *n* in the weak and medium absorption zone, when transmission declines as a result of absorption. In this instance, N in the equation above is given by

$$N = 2s\,[(T_M - T_m)/T_M T_m] + (s^2 + 1)/2 \tag{3}$$

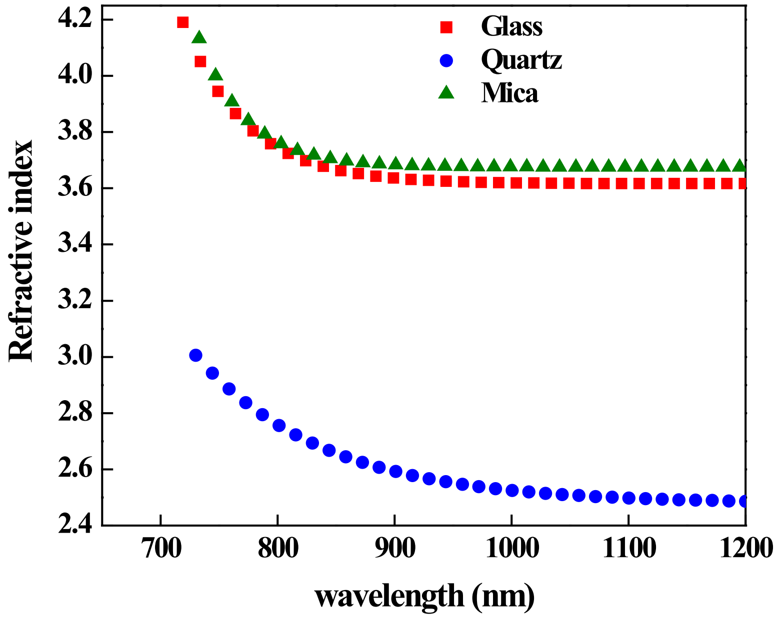

Figure 4. Variation of *n* with λ for $Se_{82}Te_{15}Bi_{3.0}$ thin film for glass, quartz and mica substrates.

Figure 4 shows behaviour of *n* for glass, quartz, and mica substrates and observed that for glass, quartz, and mica substrates, *n* decreases as wavelength increases. The acquired value of the linear refractive index (*n*) at 800 nm for the three substrates is given in Table 1, which shows that the value of *n* is greatest for the mica substrate and minimum for quartz. The order of *n* mica, *n* microscope glass, and *n* quartz is the trend. The growth of disorder and the internal strain in the films may be the causes of the highest value of *n* for mica substrate. The collected results of *n* are subsequently employed for the investigation of nonlinear optical characteristics.

There are numerous models that use linear parameters to predict the nonlinear refractive index. Boling et al.[5] used the linear refractive index (*n*) and Abbe number (V_d) to get the following simpler empirical equation for n_2:

$$n \quad = G\frac{n_d\ -}{V_d\ \ /} \tag{4}$$

G is an empirical constant of value 391. In order to show how the refractive index changes with wavelength, V_d (Abbe number) measures the dispersion. The following relation is used to calculate V_d using three refractive indices at Frounhoffer wavelengths: f = 0.48613 m, d = 0.58756 m, and c = 0.65627 m. The results are included in Table I.

$$V_d \quad \frac{(n_d \quad 1)}{(n_f \quad n_c)} \tag{5}$$

where n_f, n_d and n_c are linear refractive indices at the wavelengths λ_f, λ_d and λ_c, respectively.

Table 1. Values of linear refractive index *(n)*, Abbe number (V_d) and nonlinear refractive index (n_2) and comparison of n_2 with pure silica for glass, quartz and mica substrate for chalcogenide $Se_{82}Te_{15}Bi_{3.0}$ thin films.

$Se_{82}Te_{15}Bi_{3.0}$	Glass	Quartz	Mica
n	3.74	2.76	3.78
V_d	4.85	5.3	5.6
n_2	2.19×10^{-11} esu	1.65×10^{-11} esu	1.32×10^{-11} esu
$n_2/n_{2\ silica}$	296	223	178

The calculated values of V_d and n_2 are tabulated in Table 1 and observed that n_2 for glass is maximum than quartz and mica. The measured value of n_2 for substrates made of glass, quartz, and mica is compared with that of pure silica[7] . The comparison reveals that the n_2 of the thin films under investigation for the glass substrate has a value that is 296 times more than that of pure silica, while the value is 223 times greater for the quartz substrate. The researched thin film is advantageous for industrial applications due to the larger value of n_2.

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