Calculation of the optical density and relaxation time in BSO crystal

حساب الكثافة البصرية وزمن ألأسترخاء لبلورة BSO

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Abstract:

The change of optical density in a pure bismuth silicate oxide crystal that exposed to the radiations with wavelengths (510, 530, 540 and 560nm) are studied. It was shown that the change of optical density in the crystal increase with decreased incident wavelengths. The effect of the intensity of the incident radiations on the change optical density is studied. The relaxation time of this crystal has been discussed.

Keywords: optical density, BSO crystals, photorefractive materials, photochromic effect, photo-induced absorption

الملخص:

ان تغير الكثافة البصرية في بلورة البزموث سيليكات اوكسايد النقية المعرضة لاشعة ذات أطوال موجية مختلفة(510,530,5140و 560nm) قد درست. خلال البحث تم مناقشة التغير في الكثافة البصرية في البلورة حيث يزداد مع نقصان الطول الموجي .أن تاثير شدة الاشعة المحرضة على التغير في الكثافة ألبصرية تم دراستها . زمن الاسترخاء في هذه البلورة تم مناقشته.

الكلمات الاسترجاعية: الكثافة البصرية ، ألمواد الكاسرة للضوء، بلورات BSO، ألظاهرة ألفوتولونية،الامتصاص الضوئي المحتث

1. Introduction

The photo-induced absorption can be referred to as the change of the absorption of light, which is resulted from irradiation. The light effect on the interior structure of the photorefractive crystals, which is related to energy relocation of charge carries, can alter the absorption. The time-based and expansion of this behavior of this influence depends heavily on the energy levels and the relaxation features of materials. Most of the effects of the characteristics are often overlooked in the quasi-stationary experiments due to their short lifetime about 1-100 ps, or weak exposure intensities [1]. At times, the prompted absorption may have various lifetimes ranging from seconds to days. The selenite group crystals manifested long-term energetic photo-induced variations, which were examined since the 90's and defined as the cause for absorption gratings [2,3]. Martin et al. reported, during 1991-1993, about empirical examination and the collation of the photochromic influences in unadulterated and activated (with Al and Fe) $\mathbf{Bi_{12}SiO_{20}}$ and $\mathbf{Bi_{12}GeO_{20}}$ crystals[4,5]. Kobozev et al. examined in 1999 the light-induced absorption in $\mathbf{Bi_{12}TiO_{20}}$ [6] .

The most prevailing advantages of the photorefractive features are recognized in crystals of the sillenite group. Crystal developing technology has been enhanced within the years. One is capable of achieving large boules and components with high optical quality. Sillenites can be impurified by several types of impurities. Because of to the different impurities (Ce, Fe, Rh, Cu, Co, Al, Cr, Mo), one can alter the features of crystals [7, 8, 9].

The development of greatly profound and steady assessing systems for trustworthy finding of highly small physical measures under actual empirical circumstances in the existence of unbridled fluctuating exterior aspects is a significant way in the problem of technical construction of health monitoring, identifying of materials, investigating biological items, etc. These measuring systems depended on photorefractive media includes the interferometric rules of extremely delicate finding

with adjustment to the noise effect. $Bi_{12}SiO_{20}$ (BSO), $Bi_{12}GeO_{20}$ (BGO), and $Bi_{12}TiO_{20}$ (BTO) crystals are among many photorefractive materials with the sillenite structure attract great attention. Because of their substantial photoconduction features, these crystals can be used for applications in optical memory devices, dynamic holography, integrated and nonlinear optics, and in adaptive information-measuring systems [10-16]. The physical characteristics of a crystal (the impurity type and concentration, the impurity energy level diagram, stoichiometric composition, etc.) define the two main criterion of devices: their photorefractive sensitivity and response time. However, the material criteria of the crystal are speciéed throughout its development and cannot be altered later. Bi12M(M=Si,Ge,Ti)O20 are Sillenite crystals well known as exceptional photoconductors and due to their outstanding great photosensitivity and charge carrier mobility, these are among the fastest photorefractive materials for real-time image processing and associated dynamic purposes [17-19].

2. Optical density in a BSO crystal

In this paper we investigated the change of optical density in crystals of bismuth silicate oxide when it irradiated with laser pulses of different intensities and at different wavelengths, to study the effects of induced absorption in bismuth silicate crystals used 2.1 mm thick crystal, which were irradiated it by a nanosecond laser radiation. We studied the change of optical density (αpi l) in a pure BSO crystal irradiated by 510nm, 530nm,540nm and 560 nm from Nd-YA G laser with different powers. The pulse duration was 20ns, the pulse repetition rate was 10Hz, pulse energy was 1-10 mJ and the length of crystal was l=1.5mm, Figure1.shows the experimental setup for measuring optical density.

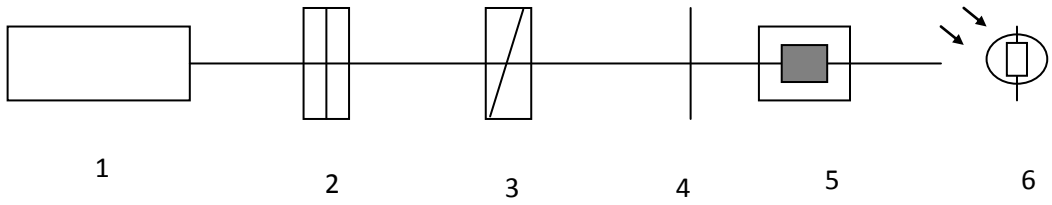


Fig. 1.Schem of experimental setup for measuring optical density .1 – Pulsed Nd: YAG laser with a parametric prefix; 2 – a set of filters (SES-23 ESS-16, LS-17); 3-Nicolas prism ; 4 – diaphragm; 5 – BSO crystal, 6 – bolometer.

The forbidden band of crystal BSO equals to 3.21 eV [20]. The position and life time of electrons in the levels depend on the defects in the crystal structure and its impurity concentration [21]. The electrons are stimulated by laser beams and go back to certain levels in band gap or to the valance band. The change of the concentration of electrons in the levels is described by the following equations:

$$\frac{\partial n1}{\partial t} = aI^2 + n_2 I - r_{31} n_1 (n_1 + n_2) - r_{32} n_1 (1 - n_2) \quad (1)$$

$$\frac{\partial n2}{\partial t} = -In_2 + r_{32}\, n_2 (1 - n_2) - r_{21} n_2 (n_1 + n_2) \quad (2)$$

$$\alpha = n_1 \delta_{n_1} + n_2 \delta_{n_2}$$

n_1, n_2 are the concentration of the charge carries(electrons) at the levels in conducting band and at levels in band gap respectively . δ is ionization cross section, r_{31}, r_{32}, r_{21} are recombination coefficients,a is a constant, α is absorption coefficient. I is the intensity of light . The photo-induced absorption in BSO crystal illustrated by figure2.

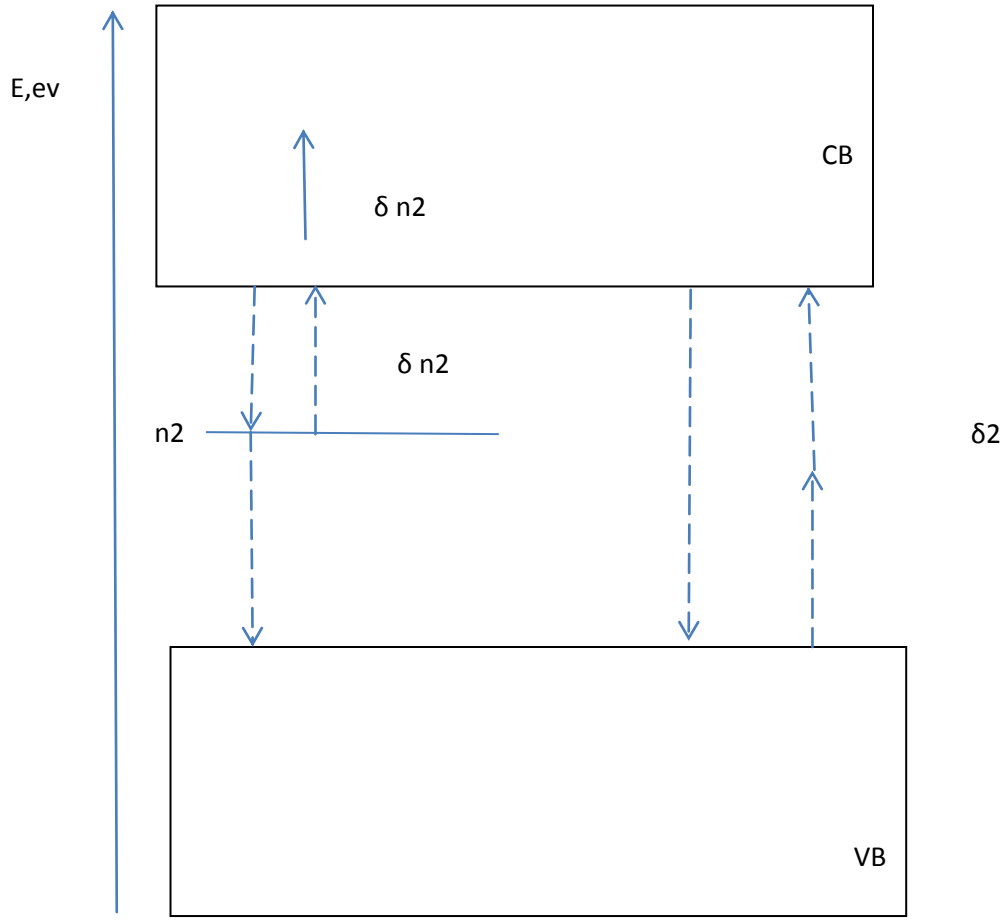
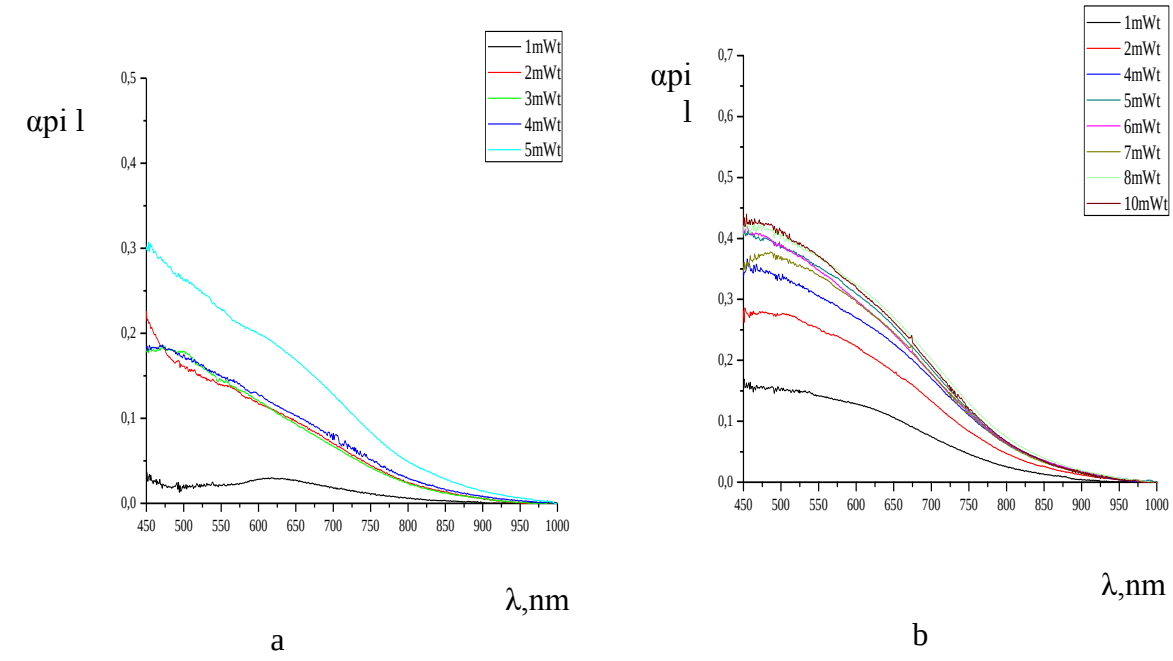


Fig. 2. Schematic illustration of electron transitions between levels of the photo-induced absorption in BSO

during the laser irradiation a defect region produced in the crystal with different transmission in visible and near infrared spectrum. The absorption spectra were recorded by spectrometer , the magnitude of absorption determined as a difference spectra of the crystal before and after irradiation . Spectral dependence of induced absorption obtained at different intensities and wavelengths of exciting radiation . For a fixed excitation wavelength value of the induced absorption depend strongly on the intensity. As shown in fig3 , an increase in intensity in the range from 0.1 to 1 MW/cm2 initially leads to linear increase of induced absorption , and then to its saturation .Moreover, the maximum achievable value of the induced absorption depend on the wavelength of the exciting radiation.

If we compare the curves obtained with laser excitation at different wavelengths and powers, figures 3a(530),3b,(510),3c(540),3d(560), then we have for the excitation



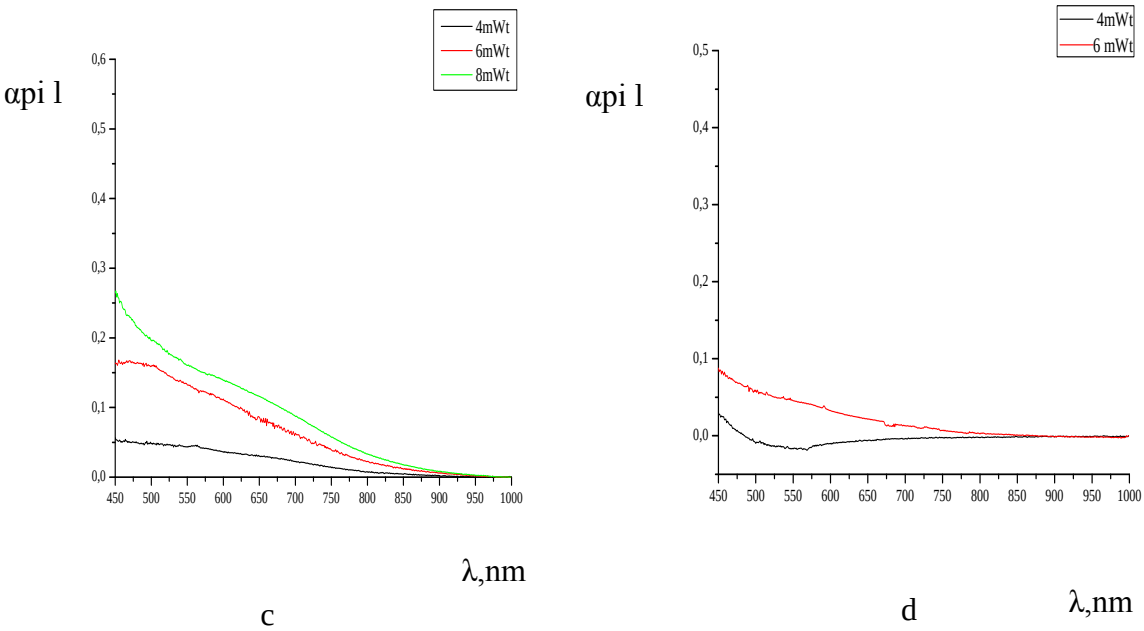


Figure 3- The change of the induced optical density of the crystal BSO under illumination at a wavelength of 530nm (a),510nm(b),540nm(c),560nm(d)

wavelength λ=530nm the limit of change in optical density αpi l=0.3,for the excitation wavelength λ=510nm the limit of change in optical density αpi l=0.44 , for the excitation wavelength λ=540nm the limit of change in optical density αpi l=0..26,and for the excitation wavelength λ=560nm the limit of change in optical density αpi l=0.058. Analysis of the spectral characteristics of the photochromic effect in bismuth silicate crystals depending on the conditions of the laser allowed to determine the range of the excitation wavelengths and intensities, leading to long-lived trapped occupancy levels and the increase in optical density over a wide spectral range. The magnitude of the induced absorption increases with decreasing wavelength and increasing the intensity of the exciting radiation. For each intensity there is a limiting wavelength above which the photochromic effect does not occur.

3.Relaxation time

The laser radiation was focused to a spot size of o.18mm BSO crystal, crystal showed slow relaxation characteristics and keeps the absorption induced during the exposition by laser pulses with intensity (1 MW/cm2) till 60 h. The induced absorption in Vis and its dynamics of relaxation can be seen in Fig 4.

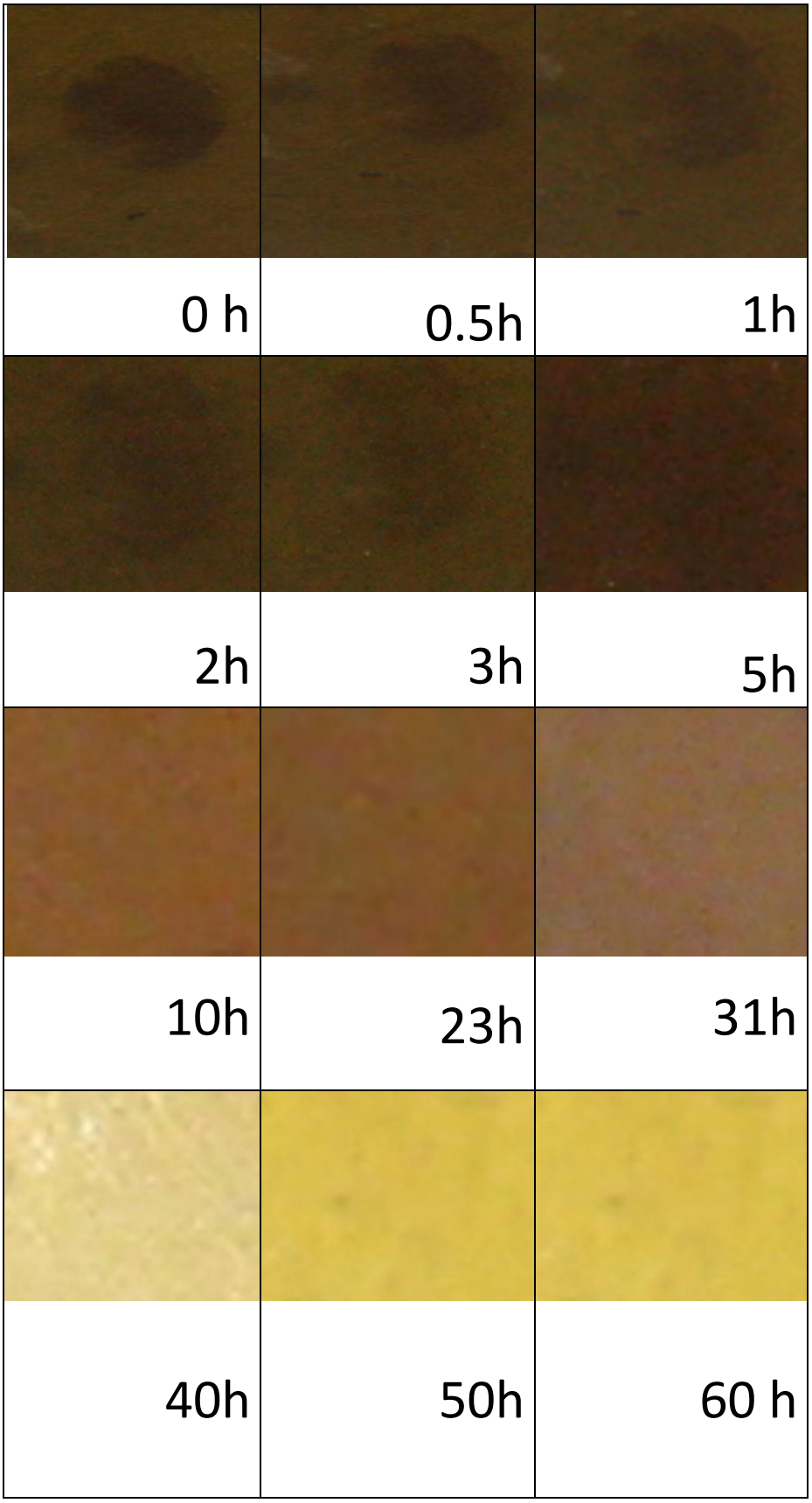


Figure4.View of the crystal with photo-induced absorption in its center

4. Conclusion

The range of wavelengths and intensities lead to long-lived trapped occupancy levels and an increase in optical density. It is shown that the amount of induced absorption increases with decreasing wavelength and increasing the intensity of the exciting radiation. For each intensity there is a limiting wavelength above it the photochromic effect does not occur, the limit of change optical density increases with increasing of the exciting wavelength.After exposed BSO crystal with intensity 1Mw/cm2 we conclude that the crystal has slow relaxation and the absorption induced during exposition by laser pulse till 60h.

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