Optic and electric characterization of Nb and Tb doped BTO single crystals.

T. O. dos Santos, J. F. Carvalho and T. M. Amaral

Instituto de Física, Universidade Federal de Goiás, CP 131, CEP 74001-970, Goiânia, GO, Brazil.
e-mail: tatiane@fis.ufg.br

Abstract

BTO:Tb and BTO:Nb single crystals were grown by the Top Seeded Solution Growth Technique (TSSG). Good quality crystalline samples were studied by photocurrent and electro-optical measurements and the results demonstrated that these properties can be modified by terbium and niobium impurities.

Introduction

The sillenite structure has a body centered cubic unit cell with space group I23 [1]. The general formulae of the sillenite compounds can be written as $Bi_{12}MO_{20}$, where the cation M can be Ge, Si, Ti, and others, or an isomorphic mixtures of (Bi,Ga), (Bi,V) and others [2]. Sillenite crystals exhibit a number of interesting properties, including piezoelectric, electro-optical, elasto-optical, optical activity and photoconductive properties. The combination of the electro-optical effect and photoconductivity results in the so-called photorefractive effect, consisting of a reversible light-induced change in the refractive index [3]. This effect is responsible for the major interest in sillenite crystals, making them useful for many advanced and promising applications, such as reversible recording medium for real-time holography or image processing [4].

$Bi_{12}TiO_{20}$ (BTO) crystals have been considered as the most adequate sillenite material because of its practical advantages for photorefractive applications, such as lower optical activity, higher electro-optic coefficient and increased sensitivity to red light [5]. The influence of impurities on growth conditions and on optical, electrical and spectroscopic properties of BTO crystals has been subject of many other papers [6-9]. In this work, we investigated the optic and electric properties of niobium (Nb) and terbium (Tb) doped BTO crystals using photocurrent and electro-optical measurements.

Experimental

The terbium and niobium doped BTO crystals were grown by using the Top Seeded Solution Growth technique (TSSG) from the liquid phase with composition $10Bi_2O_3 : (1-x)TiO_2 : x/4Tb_4O_7$ (x = 0.05 and 0.10) for BTO:Tb and $10\,Bi_2O_3 : x\,TiO_2 : (1-x)/2\,Nb_2O_5$ (x = 0.95 and 0.90) for BTO:Nb [6].

The photocurrent response was measured in a planar configuration consisting of two parallel silver electrodes deposited 1.0 mm apart on the same polished surface. A voltage of 100 V dc was applied between the electrodes and a Keythley 602 electrometer connected to a data acquisition system was used to detect the current.

To evaluate the electro-optic coefficient of BTO:Tb and BTO:Nb crystals, we used the method described in reference [10], which allows the effect of the optical activity to be discriminated from that of the field induced birefringence upon light polarization. This is very important due to the high optical rotatory power of sillenite crystals [9]. Two He-Ne lasers beams at 633 and 532.8 nm wavelength were used. Silver electrodes were deposited on the lateral faces (transverse to the light propagation) in samples with thickness of 3.8mm, height of 6.3mm and interelectrode distance of 4.8mm for BTO:Tb (x = 0.10) and thickness of 3.4mm, height of 4.71mm and interelectrode distance of 4.38mm for BTO:Nb (x = 0.95, labeled BTO:Nb-03.01).

Results and discussion

The grown crystals by TSSG technique were of good crystalline quality, as shown in figures 1 (BTO:Tb) and 2 (BTO:Nb).

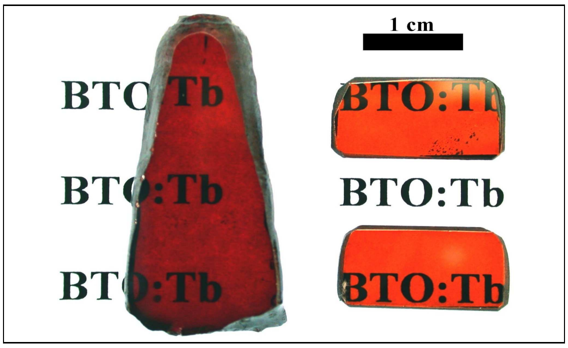

Figura 1: BTO:Tb single crystals.

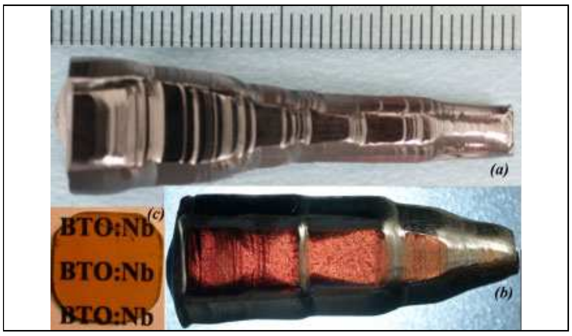

Figura 2: BTO:Nb single crystals: (a) BTO:Nb-03.01, (b) BTO:Nb-03.03, (c) polished sample.

The photocurrent responses for BTO:Tb and BTO:Nb are shown in figures 3 and 4, respectively. The terbium strongly affects the of BTO in the whole investigated spectral range. The response of Tb doped crystal is two orders of magnitude smaller than that of undoped BTO crystal, and a pronounced shoulder is observed between around 450 e 400 nm. The reduction in the photocurrent signal can be due the competition between Tb^{4+} and Bi^{3+} ions for the partial occupation of the M site in the crystal structure, reducing the density of the intrinsic defect (Bi^{3+} + h^+) responsible for the photoconductivity in nominally pure BTO.

Doping with niobium produce an increase in the photosensitivity in the spectral range of about 500 to 400 nm, but in the remaining investigated region no sensible difference is observed between the photocurrent spectral response of pure and Nb-doped crystal.

Concerning electro-optic effect, our preliminary results show that terbium and niobium do not significantly affect the electro-optic coefficients of BTO. However, further experiments are necessary to conclude this study.

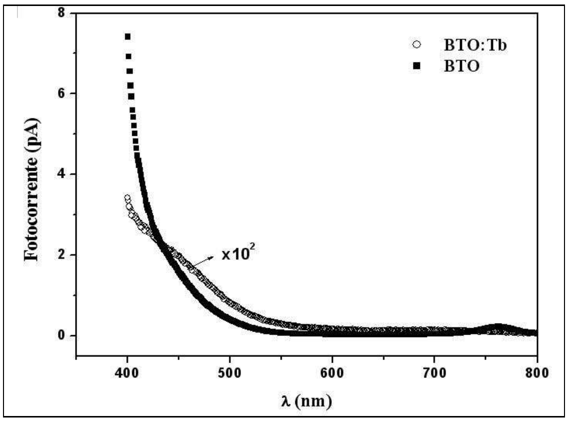

Figura 3: Photocurrent spectral of BTO:Tb.

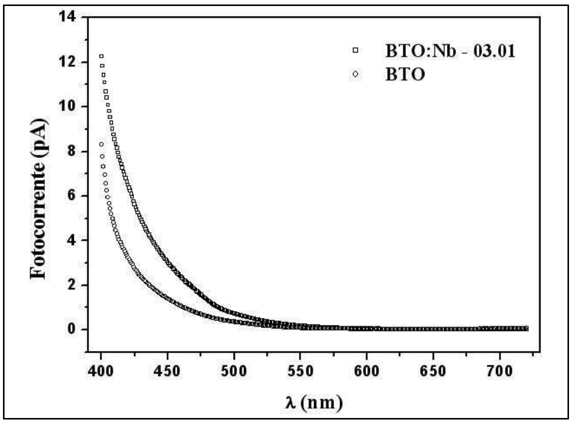

Figura 4: Photocurrent spectral of BTO:Nb 03.01

Conclusion

Tb- and Nb-doped BTO crystals were grown by the TSSG technique presenting good crystalline quality. Preliminary results of photocurrent and electro-optic coefficient measurements shown that these dopants affect the photoconductivity response, but produce little effect on the electro-optic behavior. The terbium effect is more evident, changing not only the strength of photocurrent response, but also its profile near 450 nm.

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