concentration is the main parameter of microcrystals, which is responsible for the parameters of the sensors manufactured on their base. When irradiated up to the fluence 10^{14} n·cm^{-2} InSb microcrystals have high radiation resistance: the change in their carriers concentration does not exceed 0.01 %.

Obtained microcrystals are sensitive elements of Hall effect based magnetic field sensors. An intelligent magnetic measuring system for magnetic field monitoring with the high accuracy in radiation conditions of LHC-type charged particle accelerators was developed on the base of such microsensors with the dimensions (0.06×0.03×0.01) mm^3. Due to its minimal dimensions, weight and power consumption as well as radiation resistance, such microsensors are already applied in magnetic systems of orientation and stabilization of the spacecraft.

REFERENCES

[1] Bolshakova I. Improvement of radiation resistance of magnetic field microsensors // Sensors & Actuators: A. Physical. – 1999. - V.76. - P.152-155.

[2] Bolshakova I., Moskovets T., Krukovsky S., Zayachuk D. Radiation resistant microcrystals and thin films of III-V semiconductors // Materials Science & Engineering. – 2000. – B 69-70. - P. 441-443.

[3] Bolshakova I., Koptsev P., Melnyk I., Moskovets M., Krukovsky S., Zayachuk D. Control of parameters of III-V compound microcrystals and epitaxial layers by means of complex doping // Crystal Research and Technology. - 2001. V. 36. - № 8-10. – P. 989-997.

[4] Zaitov F., Isayev F., Polyakov A., Kuzmin A. Influence of penetrating radiation on the properties of indium antimonide and indium arsenide. – Baku, 1984. – 205 p.

[1]V.T. Adamiv, [1]Ya.V. Burak, [1]I.Yu. Martynyuk-Lototska, [1]M.E. Kostyrko, [1,2]R.O. Vlokh, [1]G.M. Romanyuk, [3]W. Shranz

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OPTICAL, ELASTICAL AND PIEZOOPTICAL PROPERTIES OF THE β-BAB$_2$O$_4$ AND LI$_2$B$_4$O$_7$ BORATE CRYSTALS

Keywords: borate crystal, optical and piezooptical properties

The optical, elastic and piezooptical properties of the borate crystals have been investigated. The dispersions of the indexes refraction of the $Li_2B_4O_7$ crystals have been determinated in wavelength range 350 - 650 nm. The results of the measurement velocity of the longitudinal and transverse ultrasonic waves on borate crystals are presented. Using ultrasonic velocity measurements the components of the elastic matrix C_{mn} of these crystals have been determined. Using the determined values of the elastooptical tensor components the acoustooptical quality M_2 of β-BaB_2O_4 crystals has been calculated.

INTRODUCTION

The borate crystals: β-BaB_2O_4 (BBO, point group of symmetry 3m) are known as efficient material for the optical applications [1,2] and $Li_2B_4O_7$ (point group of symmetry 4mm) are used in the acoustoelectronics techniques [3]. But the elastic and piezooptical properties of these crystals have been scarcely investigated. In the present paper we report the results of the investigation optical, elastic and piezooptical properties of borate crystals.

EXPERIMENTAL

The optically qualitative single crystals of $Li_2B_4O_7$ were grown by the Czochralsky technique. The β-BaB_2O_4 crystals were grown by the modify Czochralsky melt-solution method. The composition of melt solution has been 78 mol % BaB_2O_4 and 22 mol % Na_2O. The rate of the temperature reduction has been made up 2 degrees within twenty-four hours and the speed of the pull out has been made up 2 mm within twenty-four hours. The crystallographic axes of the both crystals were determinated by the X-ray diffraction method.

The dispersions of the indexes refraction of the $Li_2B_4O_7$ crystals have been determinated for samples with size 8x10x0.98 mm^3 by Oreimov`s diffraction method with the accuracy $2x10^{-4}$.

The elastic and piezooptical investigations were performed for oriented samples direct and X/45^o cut from qualitative BBO and $Li_2B_4O_7$ crystals with size 4x5x6 mm^3 (XxYxZ).

Acoustic measurement velocity of the longitudinal and transverse ultrasonic waves have been performed on single BBO and $Li_2B_4O_7$ crystals by the pulse-echo overlap method [4]. The accuracy of the absolute velocity determination was about 0.5 %. The acoustic waves in samples were excited by $LiNbO_3$ transdusers with a resonance frequency of f = 10 MHz, bandwidth Δf = 0.1 MHz and acoustic power P_a = 1 to 2 W.

The all piezooptical tensors components π_{im} for BBO crystals have been measured using the interferometric technique and two-fold diagonal measured method.

RESULTS AND DISCUSSION

The indexes refraction of the $Li_2B_4O_7$ crystals were determinated directly in to the region 350 - 650 nm. The data are shown in Fig. 1.

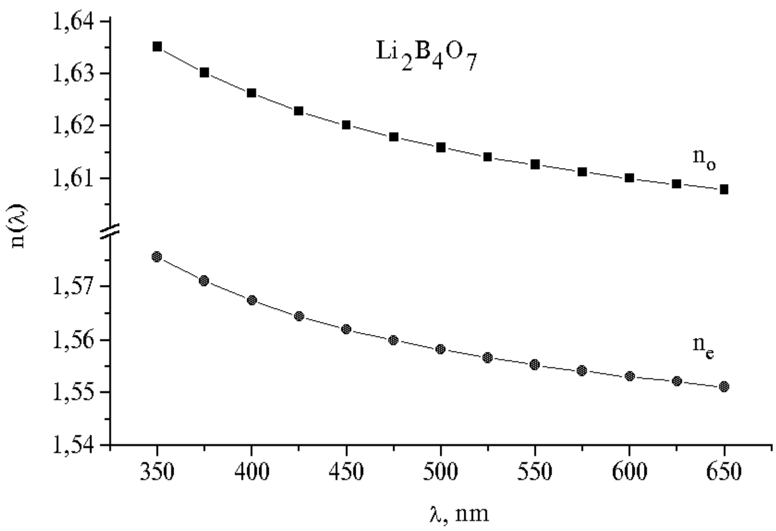

Fig. 1. The refraction indecies of the $Li_2B_4O_7$ crystals

The elastic properties of the borate crystals were determinated via measurements of the ultrasonic velocities along different crystallographic directions. There are six independent nonzero elastic constants for BBO and $Li_2B_4O_7$ crystals. These are C_{11}, C_{33}, C_{44}, C_{12}, C_{14} and C_{13} for BBO crystals of the trigonal symmetry 3m. For the $Li_2B_4O_7$ crystals of tetragonal symmetry 4mm these are C_{11}, C_{33}, C_{44}, C_{66}, C_{12} and C_{13}. The relationships between measured ultrasonic velocities, V_m, and the elastic constants, C_{mn}, follow from the Cristoffel equation (see, for example, Prawer *et al.* 1985). Direct and simple relations between measured velocities and elastic constants are possible only diagonal elements of the elastic constant matrix. All other constants occur coupled together in more complicated relationships and must be determinated from ultrasonic velocities mesured in the slanting samples. The measured velocities of the longitudinal and transverse ultrasonic waves in $Li_2B_4O_7$ and BBO crystals are presented in Tabl. 1 and Tabl. 2, respectively.

Table 1

Ultrasonic wave velocities in $Li_2B_4O_7$ crystals.
PT pure transverse, PL pure longitudinal, QL quasilongitudinal

Direction of wave propagation	Approximate wave displacement direction	Velocity at 293 K (m/s)	Type
[100]	[100]	7358	PL
[001]	[001]	5036	PL
[100]	[010]	4448	PT
[100]	[001]	4769	PT
[110]	[110]	7313	QL
[101]	[101]	7430	QL

Table 2

Ultrasonic wave velocities in BBO crystals.
PT pure transverse, PL pure longitudinal, QT quasitransversal

Direction of wave propagation	Approximate wave displacement direction	Velocity at 293 K (m/s)	Type	Light wave direction and polarization	$M_2 \times 10^{15}$, s^3 / kg
[100]	[100]	5410	PL	[010], ‖ [001], ⊥	1,3 0,9
[010]	[010]	5805	PL	[100], ‖ [001], ⊥	1,1 0,7
[001]	[001]	3500	PL	[100], ⊥ [010], ⊥ [100], ‖	0,5 0,5 0,2
[100]	[010]	2900	PT	–	–
[100]	[001]	880	PT	[010], ⊥	49,4
[010]	[100]	2880	PT	–	–
[010]	[001]	940	PT	[100], ⊥ [001], ⊥, ‖	40,9 0,3
[100]	[011]	874	QT	[010], ⊥, ‖	15,1
[100]	$[0\bar{1}\bar{1}]$	2742	QT	[010], ⊥, ‖	0,5
[011]	$[0\bar{1}\bar{1}]$	2585	QT	–	–
$[0\bar{1}\bar{1}]$	[100]	879	QT	–	–

Using ultrasonic velocity measurements the components of the the elastic constants C_{mn} of the borate crystals have been determined. The values of these constants for BBO crystals are C_{11}=123,8x10^9Pa, C_{12}=60,3x10^9Pa, C_{13}=49,4x10^9Pa, C_{14}=12,3x10^9Pa, C_{33}=53,3x10^9Pa, C_{44}=7,8x10^9Pa and C_{66}=1/2(C_{11} - C_{12})=31,8x10^9Pa. For the $Li_2B_4O_7$ crystals these constants are C_{11}=131,0x10^9Pa, C_{33}=61,4x10^9Pa C_{44}=55x10^9Pa, C_{66} =47,9x10^9Pa, C_{12}=33,1x10^9Pa and C_{13}=55,6x10^9Pa.

The results of measurement of piezooptical coefficients of BBO crystals have been published in our work [5]. Using these coefficients the all values of the elastooptical tensor components p_{in} have been calculated according to known formula $p_{in}= \pi_{im} S^{-1}{}_{mn}$, where $S^{-1}{}_{mn}$ - inverse matrix of elastic complients coefficients. The elastooptical cofficients values are: p_{11}= -0,195; p_{12}= -0,197; p_{13}= -0,059; p_{31}= -0,112; p_{33}= 0,039; p_{14}= -0,005; p_{41}= -0,007; p_{44}= -0,078. Thus, the great values of elastooptical coefficients, small acoustic wave velosities, small values of density (ρ=3840 kg/m^3) and refractive index n= 1,6673 [6] provide the high value of acoustooptical quality $M_2 = p^2{}_{ef} n^6/\rho v^3$ [7] of the BBO crystals. E.g. the measured value of velocity for transverse acoustic wave with directions of propagation [100] and [001] polarization is v = 880 m/c, the effective value of elastooptical coefficient is p_{ef}= p_{44}= -0,078 for the direction of light wave propagation [010]. The value of acoustooptical quality is M_2 = 49,4x10^{-15} s^3/kg that exceed the corresponding coefficients of fused quartz and KDP crystals. Besides, the small light absorbtion in the wide wavelength range, the hight radiation stability and the possibility for obtaining the large samples with high optical quality make possible the practical choice of BBO crystals as efficient photoelastical material. For the LTB crystals we can only estimate the value of acoustooptical quality, since the piezooptical coefficients π_{11} and π_{33} are unknown (the magnitudes of the π_{12} , π_{13} and π_{31} where taken from [8]). For the slowest acoustical transverse wave (v=4448m/s) with the direction of propagation [100] and polarisation [010] estimated value of M_2 is of the order of 10^{-14} s^3/kg and is of the same order as in BBO crystals due to the larger value of photoelastic constants.

Present investigations was supported by the STCU (project N1712).

REFERENCES

1. C. Chen, Yi Wu, Kurong Li, J. Cryst. Growth, 99, 790 (1990)
2. J. Liebertz. Z. Krist., 182, 307 (1988).
3. Whatmore R.W., Shorrocks N.M., Hara C.O. et al.Electron. Lett. 17 11 1981.
4. E. P. Papadakis., J. Acoust. Soc. Amer., 42, 1045 (1967)
5. A.S. Andrushchak, V.T. Adamiv, O.M.Krupych, I.Yu. Martynyuk-Lototska, Ya.V.Burak and R.O. Vlokh. Ferroelectrics, 2000, 238, p. 299-305.
6. Eimerl D., Davis L., Velsko S., Graham E.K., Zalkin A. J.Appl. Phys. 62 1968 (1987)
7. Balakshiy V.I., Parygin V.N., Chircov L.E. Physical basis of acoustooptics. Moscow "Radio i svyaz" (1985) 279 (in Russian).
8. Burak Y.V. Growth technology and properties of nonlinear optics, water free borate single crystals. Doctor thesis. Institute of Physical optics. Lviv. (2000) 343.