Vol. 92 (1997) ACTA PHYSICA POLONICA A No. 1

Proceedings of the ICSC-F'96 Jaszowiec '96

ELASTOOPTIC CONSTANTS OF $SrLaAlO_4$ AND $SrLaGaO_4$ SINGLE CRYSTALS DETERMINED BY BRILLOUIN SCATTERING

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In this paper we report the elastooptic constants p_{ij} of strontium lanthanum aluminate, $SrLaAlO_4$ and strontium lanthanum gallate $SrLaGaO_4$ single crystals, which were determined at room temperature using Brillouin scattering method. In order to investigate the elastooptic constants of $SrLaAlO_4$ and $SrLaGaO_4$ single crystals, a substitution method proposed by Cummins and Schoen, and developed by Nelson and Lax was used. The obtained results are also discussed in terms of the nature defects which might arise in these crystals during growth process.

PACS numbers: 33.20.Fb, 78.35.+c, 63.20.-e

1. Introduction

Strontium lanthanum aluminate, $SrLaAlO_4$ (SLA) and strontium lanthanum gallate $SrLaGaO_4$ (SLG) single crystals belong to the group of compounds with the general formula $ABCO_4$, where A = Ca or Sr, B = Y or rare-earth elements and C = Al, Ga or some transition element [1, 2]. SLA and SLG single crystals are interesting as substrates for high temperature superconducting thin films from the standpoint of lattice matching and their elastic and elastooptic properties [3, 4]. Some physical properties of these crystals have been reported recently, but still a little is known about their elastic and elastooptic properties [2, 5–10].

In this paper we report the elastooptic constants p_{ij} of SLA and SLG single crystals, which were determined at room temperature using Brillouin scattering method.

2. Theoretical summary

In order to investigate the elastooptic constants of SLA and SLG single crystals, we used a substitution technique proposed by Cummins and Shoen [11] and developed by Nelson and Lax [12]. In this method the Brillouin spectrum of the crystal under study is compared to that of a standard scatterer whose Rayleigh ratio R_{st} is known. If I_x is the observed (integrated) intensity of the Brillouin intensity in the sample spectrum while I_{st} is the intensity of the Brillouin line in the spectrum of the standard scatterer, the Rayleigh ratio R_x of the sample is given by

$$R_x = R_{st}(I_x/I_{st}) = R_{st}J. \tag{1}$$

Using Nelson and Lax's approach [12], the formulae for Rayleigh ratio can be written as

$$R = (\pi^2 kT/2\lambda^4)BCF, \tag{2}$$

where, for 90-degree scattering geometry, C is given by

$$C = (n^i n^s)^3 \cos\delta^i \cos\delta^s/\rho V^2 \tag{3}$$

and F is given by

$$F = |d^s_m p_{mnkl} d^i_n b_k a_l|. \tag{4}$$

In Eqs. (2)–(4), B is a geometric factor which is assumed to be equal for the unknown sample and the standard, δ is the angle between the Poynting vector and the incident wave front, d^s_m, d^i_n describe the polarization of the scattered and incident fields, respectively, n is the appropriate refractive index, p is the effective elastooptic constant, b_k is the component of the atomic displacement vector and a_l is the component of the phonon propagating vector.

The appropriate elastooptic constant p_{ij} can be determined from the equation

$$F_x/F_{st} = JC_{st}/C_x, \tag{5}$$

where index x refers to the sample under study and st refers to the standard.

3. Experiment

Single crystals of SLA and SLG used in Brillouin scattering experiment were grown by Czochralski method described by Gloubokov et al. [5]. Samples of sizes about $3 \times 5 \times 6$ mm were cut from as grown yellow colored single crystals. The samples used in the Brillouin experiment were ground and polished, so their surfaces had an optical transparency.

The Brillouin polarized spectra were measured at room temperature using experimental procedure described elsewhere [8]. As a standard we employed quartz for which the Rayleigh ratio R_{st} of the longitudinal phonon propagating along [1,0,0] direction is known from the literature [11]. The calculation of the Brillouin lines parameters was performed using curve-fitting method. To ensure greater certainty we made minimum 3 separate recordings for each scattering geometry.

4. Results and discussion

SLA and SLG compounds crystallize in the perovskite-like, tetragonal K_2NiF_4-type structure of $I4/mmm$ space group [5, 13]. They have seven independent elastooptic constants: $p_{11} = p_{22}$, p_{33}, $p_{44} = p_{55}$, p_{66}, $p_{13} = p_{23}$, $p_{31} = p_{32}$ [14]. Their values have not been measured so far.

The data for the determination of the elastooptic constants of SLA and SLG crystals obtained from the Brillouin spectra, were taken in a number of scattering geometries. They are summarized in Table I. Our Brillouin study yielded a com-

TABLE I

The data which served as a basis for the determination of the elastooptic constants p_{ij} of SLG and SLA crystals at room temperature.

SLG							
a	d^i	d^s	b	Mode	ρv^2†	p_{ij}	p_{ij}
[–110]	[010]	[001]	[001]	T2 Vh	9.22	0.053	p_{44}
[110]	[100]	[0–10]	[110]	L Hh	27.23	0.019	p_{66}
[– 101]	[010]	[010]	[–101]	L Vv	27.6	0.029	p_{12}
[–100]	[001]	[001]	[–100]	L Vv	27.17	0.022	p_{31}
[–100]	[110]	[001]	[001]	T2 Vh	9.25	0.05	p_{44}
[010]	[110]	[001]	[001]	T2 Vh	9.29	0.033	p_{44}
[010]	[110]	[–110]	[010]	L Hh	25.52	0.081	$p_{11} - p_{12}$
[00–1]	[101]	[–101]	[00–1]	L Hh	26.48	0.072	$p_{13} + p_{33}$
SLA							
a	d^i	d^s	b	Mode	ρv^2†	p_{ij}	p_{ij}
[110]	[001]	[0–10]	[001]	T2 Hv	10.15	0.044	p_{44}
[100]	[101]	[010]	[010]	T1 Vh	10.13	0.015	p_{66}
[–101]	[010]	[010]	[–101]	L Vv	27.15	0.038	p_{12}
[–100]	[001]	[001]	[–100]	L Vv	26.99	0.021	p_{31}
[010]	[110]	[–110]	[010]	L Hh	26.3	0.071	$p_{11} - p_{12}$
[00–1]	[101]	[–101]	[00–1]	L Hh	27.68	0.073	$p_{13} + p_{33}$

†$[10^{10}\ N/m^2]$

plete set of the elastooptic constants of SLA and SLG crystals. Their values are listed in Table II. The estimated error of p_{ij} does not exceed 5% in the values.

We can discuss the obtained results in terms of the nature of defects which might arise in these crystals during growth process. As can be seen from Table I, for SLG single crystals, the observed integrated intensity of the Brillouin line representing TA phonons propagating in (001) plane is different in a and b directions. Typical Brillouin spectra for the TA phonon propagating in these directions are presented in Fig. 1. The lower value of the integrated intensity of the phonon propagating in b direction with its component of the atomic displacement

TABLE II

Elastooptic constants p_{ij} of SLG and SLA crystals at room temperature.

p_{ij}	p_{11}	p_{12}	p_{31}	p_{44}	p_{66}	$p_{13}+p_{33}$
SLG	0.112	0.029	0.022	0.053	0.019	0.072
SLA	0.109	0.039	0.023	0.046	0.015	0.073

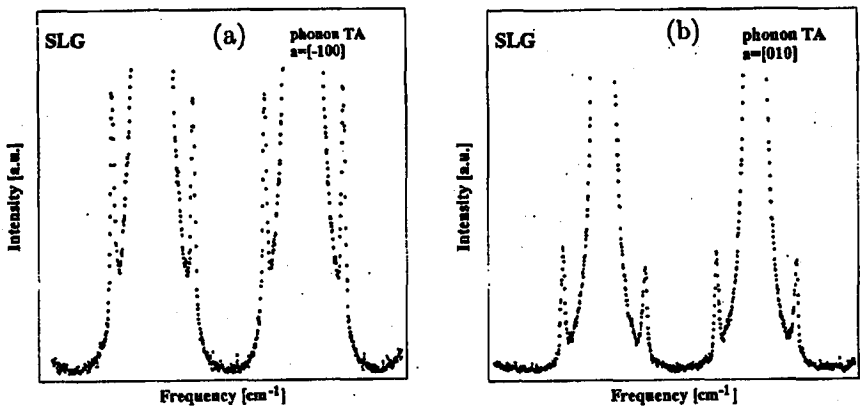

Fig. 1. Typical Brillouin spectra of SLG single crystal obtained for the TA phonon propagating in a and b direction with wave vector $a = [-100]$ (a) and $a = [010]$ (b), respectively.

vector in [001] direction is involved in lower value of the appropriate elastooptic constant p. It is probably caused by the smaller elastooptic interaction between appropriate atoms in the unit cell due to existence of some kind of oxygen point defects and structural imperfections which can be created in SLG crystals during growth process. It is known from literature that in the $ABCO_4$ lattice the physical properties in some directions can be affected by partial ordering of A–B atoms with respect to their uniformly arranged sites in the unit cell, deformation of oxygen octahedrons surrounding C-type ions along c direction accompanied by the random distribution of Sr^{2+} ions and La^{3+} ions in the sites of C_{4v} symmetry [2, 5–8, 15]. The obtained results seem to confirm our recent study of the elastic properties of SLG single crystal using Brillouin scattering method [8].

Acknowledgments

This work was supported in part by the Committee for Scientific Research under grant No. 8T 11B03810.

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