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Evaluation of $Ca_3Ta(Ga_{0.5}Al_{0.5})_3Si_2O_{14}$ Single Crystal by the Ultrasonic Microspectroscopy Technology

超音波マイクロスペクトロスコピー技術による $Ca_3Ta(Ga_{0.5}Al_{0.5})_3Si_2O_{14}$ の評価

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1. Introduction

Langasite-type ($La_3Ga_5SiO_{14}$: LGS) single crystals are promising materials for pressure sensors operating under high temperature environment as well as high stability oscillators for future communication applications. However, prices of raw materials composed of rare-earth and rare-metal elements are rising due to increasing their demand for various applications. Although $Ca_3TaGa_3Si_2O_{14}$ (CTGS) and $Ca_3NbGa_3Si_2O_{14}$ (CNGS) [1, 2] have no rare-earth elements unlike previous langasite-type crystals such as LGS and $La_3Ta_{0.5}Ga_{5.5}O_{14}$ (LTG), they still include expensive element of Ga. So, we recently have grown Al-doped CTGS single crystal [$Ca_3Ta(Ga_{0.5}Al_{0.5})_3Si_2O_{14}$: CTGAS] to reduce Ga[3].

In this paper, we examined acoustical properties for CTGAS single crystal and determined its acoustical physical constants using the ultrasonic micro-spectroscopy (UMS) technology[4-6].

2. Specimens

We grew $Ca_3Ta(Ga_{0.5}Al_{0.5})_3Si_2O_{14}$ (CTGAS) single crystal, substituting Ga with Al by 50%, by Czochralski method pulling along *Y*-axis[3]. Crystal size is 1 inch$^{\Phi}$ × 60 mm^{L}. We prepared five specimens of *X*-, *Y*-, *Z*-, 35.25°*Y*-, and 139.74°*Y*-cut with 2-mm thickness for measurements of bulk wave velocities and two specimens of *X*- and *Z*-cut with 0.5-mm thickness for measurements of dielectric constants.

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3. Experiments

At first, we measured angular dependences of leaky surface acoustic wave (LSAW) velocities for CTGAS specimens using the line-focus-beam ultrasonic material characterization (LFB-UMC) system [4, 5] which plays central role of the UMS technology. Results for *X*-, *Y*-, and *Z*-cut specimens are shown in **Fig. 1**. To examine Al-substitution effect, measurement results for CTGS are also shown in Fig. 1. LSAW velocities for all propagation directions in Fig. 1 increase due to Al substitution effect.

Using the plane wave (PW) UMC system[6], which is one of the main system of the UMS technology, we measured longitudinal wave velocities at 50-450 MHz and shear wave velocities at 40-200 MHz at 23°C. We could not observe any velocity dispersions in these frequency ranges for all results.

We obtained dielectric constants from the capacitance measurements. Density was measured at 23°C based on the Archimedes method.

4. Discussion

According to the procedure of the constant determination[7], we obtained acoustical physical constants at 23°C from the velocities of longitudinal and shear waves measured by the PW-UMC system. Results are shown in **Table I**. Dielectric constants and density decrease due to Al substitution effect. Although piezoelectric constant e_{11} increases, e_{14} decreases.

5. Summary

We examined basic acoustic properties for CTGAS and determined a full set of acoustical physical constants.

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Table I Acoustical physical constants at 23°C.

	CTGAS	CTGS[8]
Elastic constant [10^{11} N/m^2]		
c^E_{11}	1.576	1.564
c^E_{12}	0.740	0.746
c^E_{13}	0.774	0.776
c^E_{14}	-0.007	0.006
c^E_{33}	2.328	2.273
c^E_{44}	0.482	0.417
Piezoelectric constant [C/m^2]		
e_{11}	0.380	0.317
e_{14}	-0.363	-0.587
Dielectric constant		
$\varepsilon^S_{11}/\varepsilon_0$	13.72	15.31
$\varepsilon^S_{33}/\varepsilon_0$	18.11	22.04
Density [kg/m^3]	4324.0	4624.1

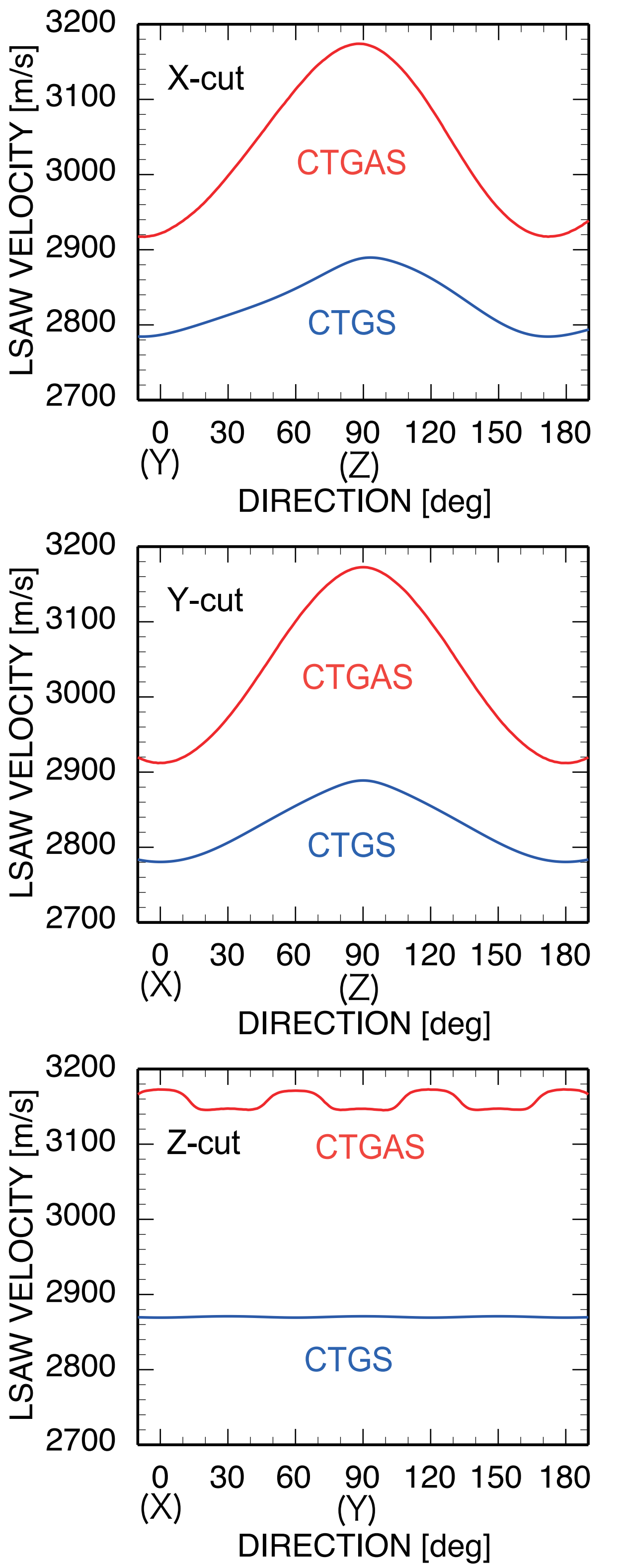

Fig. 1 Comparison of angular dependences of LSAW velocities for CTGS and CTGAS.