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Elastic anomaly of anorthite at high temperature and high pressure

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To understand the elastic properties of subducted crustal minerals at P-T conditions of crust and upper mantle, we performed in situ measurement of the elastic wave velocities of anorthite at temperatures up to 1373 K at less than 2.0 GPa and up to 273 K at 2.0-7.0 GPa. A fine grained polycrystalline anorthite was synthesised by using gas pressure apparatus installed at magma factory in Tokyo Tech. The experiments were performed using the SPEED-1500 apparatus installed on beam line BL04B1 at SPring-8. Pressure was generated by eight 26 mm tungsten carbide anvils with 11 mm truncated edge length. A Co-doped semi-sintered MgO octahedron with an 18 mm edge length was used as a pressure medium. The sample was enclosed in a BN sleeve container, and was placed in the central part (hot spot) of the furnace. Platinum foils (2.5 um in thickness) were inserted at the both side of the sample for determination of sample length by using X-ray radiographic imaging techniques. An Al_2O_3 rod (5.3 mm in length and 2.0 mm in diameter) was used as buffer rod which transmit ultrasonic wave to the sample. Temperature was measured by a W97Re3-W75Re25 thermocouple. MgO was used as a pressure marker, and it was mixed with BN to prevent grain growth at high temperatures. The ultrasonic signals were generated and received by 10 degree Y-cut $LiNbO_3$ transducer of 50 um in thickness and 3.2 mm in diameter. We used the ultrasonic wave of the frequencies 30-60 MHz with 3-5 cycles. Diffracted X-ray from the sample was measured simultaneously with the measurement of elastic wave velocities. A solid-state detector connected to a multi-channel analyzer combined with incident white X-ray beam was used for data collection. The X-ray diffractions were collected at a fixed 2 theta angle (= 2.961 degree).

In this study, we found temperature induced elastic anomaly. That is increase of elastic velocities and elastic moduli with increasing temperature in the range of 500-900 K at pressure of ~1 GPa. Based on the phase relation, it considered that this elastic anomaly is occurred in the high-temperature I(-1) phase stability field. Here we suggest a hypothesis that the tilting behavior of corner shared TO_4 tetrahedra in three dimensional frameworks causes the elastic anomaly of anorthite at higher temperature more than 500 K. In general, elasticity of solid materials depends on the bond length of atoms; the materials are hardened with decrease of bond length. Noritake et al (unpublished data) found that T-O-T angle increases and bond length of Si-O decreases with increasing temperature for high temperature I(-1) structure, although that is constant for low temperature structure (= P(-1)). This structure changes reasonably explains that the elastic wave velocities of anorthite increase with increasing temperature in the range of 500-900 K. Above 900 K, effect of the thermal expansion may reveal the reduction of elastic constants.

We also found pressure induced elastic anomaly. Elastic wave velocities of anorthite have a negative correlation with density at pressure more than 4.0 GPa. We consider that the pressure induced elastic anomaly is also caused by the tilting of TO_4 tetrahedra. Plagioclase feldspars are one of most abundant minerals of subducted crustal rocks on the Earth. Plagioclase may survive in subducted slab at higher pressure as a metastable phase if the temperature of the slab is low. Therefore we consider that plagioclase feldspar might be one of the causes for low velocity anomaly of slab.

Keywords: plagioclase, anorthite, elastic wave velocity, elastic anormaly, subducted slab, crust