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授与した学位	博　士
専攻分野の名称	学　術
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学位授与の要件	博士の論文提出者 （学位規則第４条第２項該当）
学位論文の題目	Experimental study on anelastic properties of core and mantle materials （核，マントル物質の非弾性効果の実験的研究）
論文審査委員	教授　芳野　極　　教授　神崎　正美　　准教授　山﨑　大輔　　教授　WANG YANBIN

学位論文内容の要旨

The heterogeneities and discontinuities observed from seismic waves are important information to understand the structure and composition of the Earth's interior. Resolution of those from the seismic waves requires the knowledge of the anelastic properties of Earth's material. The present study focuses on the anelasticity measurement of Earth's materials under high temperature and high pressure in the seismic frequency range.

The anelastic experiments of iron-sulfur system samples and olivine with different water concentrations were conducted at different pressures and different temperatures with periods of 0.5- 1000 s. The anelastic experiments of the iron-sulfur system samples show that there is a large Q^{-1} drop at eutectic temperature (~1200 K) with a large melting ratio (14 wt. % S-bearing sample), which is caused by the loss of contribution from the relaxed shear moduli. The relaxed Young's moduli of short periods drop to that of long periods at the eutectic temperature and the relaxed Young's moduli become the same in different periods above eutectic temperature. Those results show that the frequency dependence of seismic waves mostly comes from the relaxed shear moduli, and there is no frequency dependence of relaxed bulk moduli. Those conclusions could help guide seismologists for the inversion of observation of seismic waves in different frequencies, especially in the melt-bearing system. The oscillation measurements, with new reference materials, flexible graphite, accurately determine the effect of water on anelasticity of olivine aggregate at 3 GPa and1223 to 1373 K. Water could enhance the attenuation and reduce the relaxed shear modulus of olivine aggregates. There is an attenuation peak at an oscillation period of 5 to 10 sec. To quantitively determine the effect of water on anelasticity, a modified generalized Burger's model has been established. The results show that water could enhance the strength of relaxation by diffusion accommodated grain boundary sliding with a water content exponent of 0.68(2) and enhance the strength of relaxation peak in Gaussian distribution by water content exponent of 1.4(2). Extrapolation of the model based on present experimental results, and thermal profiles and grain size in the upper mantle shows that the sudden drop of the velocity of the seismic waves at lithosphere and asthenosphere boundary in old plates regions is caused by the difference in water content between lithosphere and asthenosphere. The effect of water on anelasticity of olivine was also studied at 6 GPa and 8 GPa. The experimental results combing with that at 3 GPa show that effect of water on anelasticity has the maximum at around 6 GPa in the present model. Based on the model, the experimental results could potentially explain the Lehmann discontinuity at the depth of ~200 km observed in the upper mantle of the Earth's interior.

論文審査結果の要旨

Chao Liu has studied anelastic properties of the core and mantle minerals in the earth's interior during 5-years PhD course. Since anelastic properties greatly affect the velocity structure of the Earth's interior observed by seismic waves, it is important to know the response due to internal friction of the mantle and core materials. Furthermore, seismic tomography studies have made it possible to give 3D distribution of attenuation factor (Q^{-1}). However, experimental measurements on energy dispersion as a function of frequency are insufficient in particular effect of water on Q^{-1} and elastic properties under high pressure. He studied the effect of water on the anelastic properties of olivine in order to clarify the reason why the discontinuity of S wave velocity is observed at the boundary between the lithosphere and the asthenosphere (LAB).

To constrain effect of water on anelastic properties of olivine aggregates, cyclic loading tests of olivine aggregates with different water concentrations were conducted at 3 GPa and 1223 to 1373 K with a wide range of oscillation periods (0.5–1000 s). For this purpose, the new type of reference material, flexible graphite, was introduced and this material greatly improved the detection limit of anelastic measurement. The experimental results show that water can enhance the attenuation and reduce the relaxed shear modulus. For hydrous samples, attenuation peak appears at shorter oscillation period around 5–10 sec. To systematically understand the effect of water on anelastic properties of olivine aggregates, a modified generalized Burger's model has been established as a function of water content. This model shows that water could enhance the strength of relaxation time by diffusion accommodated grain boundary sliding and enhance the strength of relaxation peak. The significant amount of water in the asthenosphere could explain the observed sudden drop of velocity and increment of attenuation at the LAB beneath old oceanic plate.

Ph D. defense for Chao Liu was held on 10th February. We considered that this thesis is the first report on significant effect of water on attenuation process of the upper mantle material and gives a new constraint on water distribution of the upper mantle. The presentation was made in English and there were no problems with the academic ability of the language. Abstract, editorial mistakes and typos require correction prior to final submission. Finally, we judged that this thesis is suitable to be accepted as a dissertation of Doctor of Philosophy in Okayama University.