Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)
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SIT04-02 会場:106 時間:5 月 27 日 15:30-15:45

多結晶体の非弾性の実験的研究と上部マントル地震波構造への応用
Experimental study on polycrystal anelasticty with implications for upper mantle seismic structure

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Rock anelasticity causes dispersion and attenuation of seismic waves. Therefore, for the quantitative interpretation of seismic low velocity and/or low Q regions in the upper mantle, understanding of rock anelasticity is necessary. Recent experimental studies have shown that anelasticity of polycrystalline materials is subject to the Maxwell frequency f_M scaling: $Q^{-1}(f/f_M)$. However, the applicability of this scaling to the seismic waves has not been guaranteed because experimental frequencies normalized to f_M of the laboratory samples are usually much lower than the seismic frequencies normalized to f_M in the upper mantle ($10^6 \leq f/f_M \leq 10^9$). In this study, by using polycrystalline organic borneol as an analogue to mantle rock, we measured anelasticity up to $f/f_M \cong 10^8$ and found that the Maxwell frequency scaling is not fully applicable at $f/f_M > 10^4$. A closer examination of our data showed that each of the relaxation spectra obtained under various temperature, grain size, and chemical composition can be represented by the superposition of a background dissipation which is subject to the Maxwell frequency scaling and a peak dissipation which is always centered at $f/f_M = 10^3$. Significant increases of the peak amplitude and width with increasing temperature, grain size, and impurity (dyphenylamine) content result in failure of the Maxwell frequency scaling at $f/f_M > 10^4$, where the peak dissipation dominates over the background dissipation. To quantitatively estimate the dispersion and attenuation of seismic waves, it is important to understand the behavior of the peak dissipation.

The addition of impurity (diphenylamine) to borneol significantly reduces the melting (solidus) temperature from T_{melt} = 477 K to T_{melt} = 316 K. Therefore, we have speculated that the observed variation of the peak dissipation with impurity and temperature can be scaled by the normalized temperature T/T_{melt}, such that the peak amplitude and width increase with increasing T/T_{melt}. The significant broadening of the peak observed near (but below) the solidus temperature (T/T_{melt} = 0.93) means that seismic velocity and Q are considerably lowered even without melt and has important implications for upper mantle seismic structure. We further investigated the detailed behavior of the peak dissipation at near solidus temperatures ($0.88 \leq T/T_{melt} \leq 1.01$), and found that the peak amplitude saturates at about T/T_{melt} = 0.95, but that the peak width continuously increases up to the supersolidus temperature T/T_{melt} = 1.01. The obtained result was formulated in terms of the two nondimensional parameters f/f_M and T/T_{melt} and preliminarily applied to the seismic waves in the upper mantle. The result shows that low V and low Q occur at near solidus temperatures even without melt. At the onset of melting, seismic wave velocity shows a discrete reduction due to the poroelastic effect of melt, but the seismic attenuation does not show a discontinuous change.

キーワード: 非弾性, 地震波減衰, 上部マントル
Keywords: anelasticity, seismic attenuation, upper mantle