Temperature dependence of polycrystal anelasticity at near-solidus temperatures: toward clarification of the underlying mechanism and applications to seismology

*Hatsuki Yamauchi[1], Yasuko Takei[1]

1.Earthquake Research Institute, The University of Tokyo

For a quantitative interpretation of seismic structures, it is needed to assess the effects of temperature, melt fraction, and grain size on the rock anelasticity. However, due to the limited understanding on the underlying mechanism, it is difficult to apply the experimental data to the condition of the mantle. To address this lack, we performed forced oscillation tests on the rock analogue (polycrystalline aggregates of organic “borneol”) and measured modulus and attenuation over a wide frequency range.
Attenuation spectra obtained from polycrystalline materials are generally represented by the superposition of a monotonic “background” and a broad “peak” which exists at relatively high frequencies. The background, which has been observed robustly in all experiments, follows the Maxwell frequency ($f_M = M_U/eta$, M_U = unrelaxed modulus, *eta* = diffusion creep viscosity) scaling. This shows that the mechanism of the background is “diffusionally accommodated grain boundary sliding,” which is rate-limited by matter diffusion in the same manner as the diffusion creep. Although we have a general consensus about the scaling law and mechanism of the background, those for the peak are still controversial. It is crucial to better understand the peak, because it dominates the background at seismic frequencies.
We focus on the relationship between peak and partial melting, such that a large peak is obtained for melt-bearing rocks. Recent data obtained from the analogue samples show that even at subsolidus temperatures the amplitude and width of the peak increase with increasing T/T_m (T_m: solidus temperature) [Takei et al., 2014]. This result suggests that, even without melt, low Q and low V can occur at near-solidus temperatures. However, their data are limited to T/T_m =< 0.93. In order to understand the effect of partial melting on the peak, it is important to investigate anelasticity at both subsolidus and supersolidus temperatures.
We measured anelasticity of the rock analogue at near-solidus temperatures ranging from subsoilidus to supersolidus temperatures (0.88 =< T/T_m =< 1.01). In addition to the forced oscillation tests at $2*10^{-4}$ Hz =< f =< 100 Hz, we performed the ultrasonic test to measure the unrelaxed modulus and the creep test to measure the diffusion creep viscosity to calculate f_M. Also, from the reduction of the ultrasonic velocity by partial melting, we estimated the total relaxation strength which exists at higher frequencies than the ultrasonic frequency (> 700 kHz). The results are as follows. (1) Although the total relaxation strength of the background is constant regardless of various experimental conditions, that of the peak increases with increasing T/T_m, showing the breakdown of the Maxwell frequency scaling in the peak. (2) The increase of the total relaxation strength of the peak starts at the subsolidus temperature (T/T_m = 0.93), indicating that the mechanism of the peak is some solid-state mechanism. This result is also supported by the ultrasonic data which show that the relaxation by the melt squirt flow mechanism occurs at much higher frequencies than the peak (> 700 kHz). (3) Samples which experienced partial melting sometimes show a hysteresis such that the large peak observed in the partially molten state remains even below the solidus temperature. This implies that even after the solidification a connected network of grain-edge tubules works as a fast diffusion path and enhances the peak. These results provide a key to clarify the mechanism of the peak. We further discuss the implications to seismology.

Keywords: anelasticity, seismic wave velocity and attenuation, partial melting

