The effect of sintering pressure on the anelastic properties of pyrope

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Much of our understanding of the interior of the Earth comes from interpreting the behaviour of seismic waves. Grain-boundaries form a finite volume fraction of the Earth's mantle but their effects on the seismic properties of the mantle are not fully understood. Grain-boundaries undergo a fundamental change in their properties between ambient and 'high' pressure. The changes are attested to by, among other effects, the disappearance of the 'grain-boundary' component in electrical conductivity measurements at high pressure and the increase of microhardness with sintering pressure in both pure metals (Edalati & Horita, 2010, Mat. Trans., 51, 1051) and polycrystalline diamond-SiC composites (Osipov et al 2004, Mat. Res., 7, 335). These phenomena imply that grain-boundaries properties become more "lattice-like" with increasing pressure.

To test the potential consequences of this for the Earth, we performed anelasticity measurements on pyrope samples sintered at pressures between 4 and 15 GPa. All recovered samples had a similar grain size of ~2μm but the 15 GPa samples were much lighter in colour than those sintered at lower pressures. All samples were deformed by small sinusoidal strains under identical conditions of ~3 GPa, 500 to 1300°C and at periods between 10 and 1000s. At <900 °C and short periods the effective Young's modulus is the same as that predicted using the elastic constants of pyrope and the quality factor (Q) is high. At higher temperatures the samples sintered at low pressure show significant reduction of the effective Young's modulus and Q, whist the samples sintered > 10 GPa maintain a high Q value.

Our results indicate that grain boundaries in pyrope equilibrated at high pressure can be recovered to ambient conditions but the sintering pressure strongly affects the anelastic behaviour of ceramic materials. We interpret this as a pressure-induced inhibition of the elastically accommodated grain-boundary sliding mechanism due to enhanced strength of grain boundaries created at high sintering pressures.