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Elastic Properties of Nano-crystalline MgO Powder to High Pressures by Brillouin Light Scattering

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Brillouin scattering on polycrystalline materials promises to be a direct way to obtain aggregate (bulk and shear) moduli of those compounds. Results on both sintered polycrystalline materials and pressed powders have recently been reported for a number of lower mantle Mg-endmember phases, including periclase, perovskite, and post-perovskite. Many of these studies have been performed at high-pressures in the diamond-anvil cell. However, recent Brillouin results on the sound wave velocities of pressed MgO powder under non-hydrostatic conditions show velocities that are around 20% lower than expected from single-crystal data (Gleason et al. 2011). These results question the reliability of Brillouin scattering of polycrystalline materials and illustrate that several poorly understood processes might affect the derived sound wave velocities, including a preferred orientation of the crystallites (texturing), non-hydrostatic conditions in the diamond-anvil cell, and grain size effects. Understanding of these processes and their effect on the derived Brillouin frequency shift is required to adequately interpret the derived data and relate them to geophysical models.

Here, we report the elastic moduli of nano-crystalline MgO powder measured by Brillouin scattering to pressures above 30 GPa. We find the velocities to be significantly lower than reported data on single-crystal MgO. We carefully characterized the crystallite sizes in our sample material by synchrotron x-ray diffraction and high-resolution scanning and transmission electron microscopy. At pressures above roughly 6 GPa, the average crystallite size stabilizes to about 7 nm. The small crystallite size has a profound effect on the elastic properties and is causing the observed low velocities in MgO. We show that this effect prevails at high pressures.

Based on our data analysis, both bulk and shear modulus of the intercrystalline phase are substantially reduced compared to MgO single-crystal data. The effect of grain size on the measured velocities is by far exceeding any effects of non-hydrostaticity and texturing. Based on our observations it seems reasonable posing the question whether high-pressure Brillouin scattering of non-sintered polycrystalline samples does always measure bulk material properties or a combination of those of bulk (crystallite cores) and intergranular material. Our findings imply that a thorough characterisation of the crystallite size distribution is crucial for the interpretation of Brillouin scattering results from polycrystalline materials.

Gleason, A., H. Marquardt, et al. (2011). "Anomalous sound velocities in polycrystalline MgO under non-hydrostatic compression " Geophys. Res. Lett. accepted.