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Deep mantle mineralogy and novel materials synthesis using multianvil high-pressure technology (Robert Wilhelm Bunsen Medal Lecture)

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Phase relations in mantle and slab materials have been studied using Kawai-type multianvil apparatus (KMA) under pressure and temperature conditions of the mantle transition region and the uppermost lower mantle of the Earth. The associated density and sound velocity changes of these materials have also been determined using the KMA technology combined with synchrotron in situ X-ray and ultrasonic interferometry measurements. The results show that the mantle transition region is made of a pyrolitic composition, while the presence of a harzburgite-rich layer is suggested in the lower parts of this region. Use of sintered diamond anvils for KMA has allowed expansion of these measurements toward deeper region of the lower mantle. Our preliminary results of such measurements indicate that at least upper part of the lower mantle is made of the pyrolitic composition contrary to a recent study based on Brillouin scattering measurements in diamond anvil cell, which concluded a more Si-rich lower mantle. On the other hand, we have been applying KMA technology to synthesis of novel functional materials utilizing its capability of producing very high static pressures and homogeneous temperatures in relatively large sample volumes. These include ultrahard nano-polycrystalline diamond (NPD) directly converted from graphite, which is now being used for applications to abrasive and cutting tools as well as for some scientific applications such as anvils for some high-pressure devices. Another example of such a novel material is hard and tough nano-polycrystalline stishovite (NPS), which is also potentially important for some industrial applications. Moreover, we recently succeeded in making highly transparent nano-polycrystalline garnet (NPG), which is ideal for the measurements of sound velocities by various methods, such as Brillouin scattering and GHz ultrasonic interferometry. Thus, the KMA technology opens the door to the synthesis of transparent nano-polycrystalline ceramics, in addition to its use for the studies in deep Earth mineralogy.