Low Melting Temperature of Anhydrous Mantle Materials at the Core–Mantle Boundary

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The heat stored in the Earth's deep interior has been the primary fuel for a range of global processes from mantle convection to surface tectonics, but quantitative estimation of the heat remains uncertain. The melting temperature of mantle materials is one of the key parameters to understanding the thermal evolution and present-day state of the Earth's interior, but it has been poorly constrained, with recent measurement discrepancies as large as 600 K. The central challenges in accurately estimating the mantle melting temperature include the efficiency in the melt generation and the sensitivity of the probe for melt detection. Here, we report melting temperatures of mantle compositions measured over a wide range of pressures expected for the lower mantle. To address the challenges of accurate estimation, we used an anhydrous near eutectic mantle composition, which can produce a large amount of melt, and multi-channel collimator (MCC) filtered X-ray diffraction (XRD) in the laser-heated diamond-anvil cell (LHDAC), which can enhance the sensitivity of melt detection. Our in situ detection of diffuse scattering from melt determined an anhydrous melting temperature of 3302±100 K at 119±6 GPa. Fitting our melting data over the range of 46-145 GPa led to estimates of 3430±130 K as the upper bound temperature at the core-mantle boundary (CMB). This CMB temperature is approximately 700 K lower than the previous estimates, implying much faster secular cooling of the region than previously believed. As the temperature at the topmost outer core should also be lower because of the expected small temperature offset across the CMB, higher concentrations of S, C, O, and/or H are expected to explain the liquid state of the region. Furthermore, our solidus curve constrained for a wide pressure range was strongly non-linear, predicting the last solidified region of the magma ocean at the CMB, and thus supports the basal magma ocean hypothesis.