# New experimental constraints on the nature of D″

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## Partial melting

Recent findings of 'Ultra-Low Velocity Zones Near the Core-Mantle Boundary' (1) have been interpreted as being due to partial melting. This interpretation is in agreement with our latest measurements of the solidus temperatures of a realistic multi-component system in the laser-heated diamond cell at lower mantle conditions. The previous measurements of the melting temperatures of the possible end-member component of the lower mantle Mg-Si-perovskite, magnesiowüstite, and Ca-Si-perovskite led to melting temperatures that were much higher than the core temperature, which is estimated from the melting measurements of iron and its oxygen and sulphur components to be around 4000 K at the core-mantle boundary. It was previously assumed, that Mg-Si-perovskite, the major component in the lower mantle is near the eutectic composition. However, the melting behaviour of the lower mantle components is much more complicated than previously assumed: the perovskites having very steep melting curves, and magnesiowüstite a shallow melting curve. Thus, the eutectic composition is likely to change significantly in the pressure range of the lower mantle (24–134 GPa). For the measurement of the solidus at high pressure a new method was developed. To verify the onset of melting we monitored the surface topography of the recovered samples using atomic force and scanning electron microscopy. Data were taken to about 60 GPa and a smooth extrapolation yields a solidus temperature at the core-mantle boundary of slightly above 4000 K. This is in very good agreement with a recent shock melting measurement (2) on olivine near 130 GPa. The data not only allow melting of mantle material in the near vicinity of the core but have further implications on the chemical composition: Our melting data imply that the composition of the partial melt is most likely magnesiowüstite-rich. This material is almost 2% more dense than the major component Mg-Si-perovskite. This density contrast and partial melting may cause chemical segregation at the bottom of the lower mantle. This change in chemical composition combined with the steep thermal gradient in D″ will add to the complexity of the nature of this region.

## Stability of Mg-Si-perovskite

Current experimental findings on the stability of the major lower mantle component are highly contradictive. Some recent measurements in laser-heated diamond cells suggested that this material decomposes to its oxides Mg(Fe)O and $SiO_2$ (3,4). This controversy may be mainly due to the high pressure and temperature gradients present in those experiments. In order to solve this problem we heated mixtures of MgO (and (Mg,Fe)O) and $SiO_2$ with a defocussed high power $CO_2$-laser to about 3000 K in a hydrostatic argon pressure medium at pressures up to 100 GPa. This technique avoids both large pressure and temperature gradients. In all experiments Mg(Fe)-Si-perovskites were formed, which unambiguously shows that this phase is stable under lower mantle conditions. We also heated single crystals of this phase at similar *P-T* conditions and the Raman spectra gave no hint of a decomposition. In further experiments we added a small amount of $Cr^{3+}$, which in the case of a decomposition would produce a strong fluorescence spectrum of $MgO:Cr^{3+}$. The results were negative. These experiments are a strong indication that decomposition of perovskite in the lower mantle is highly unlikely and is not the cause for unusual seismic patterns.

## Core-mantle reactions

Previous observations in laser-heated diamond cells were indicative of strong chemical interaction between molten iron and Mg-Si-perovskite (5). The conditions in these experiments, however, were not well constrained (high temperature gradients, water content), and the chemical analysis was qualitative. We therfore started to systematically invesigate chemical interactions relevant to the core-mantle boundary under variable conditions including the effects pressure, temperature, water, sulphur, and Mg(Fe)O content (see this volume). Our preliminary results show only an insignificant solubility of both oxygen and silicon in molten iron, with maximum oxygen contents around 1%, and even lower silicon contents. In experiments with silicon rich iron-metal as starting material a significant lowering of the silicon content in the metal phase was observed. From these experiments we make the preliminary conclusion that the complex nature of D″ is most likely not a result of direct chemical interaction between the core and the silicate (oxide) lower mantle. We also conclude from a reinterpretation of shock measurements on iron that the requirement of light elements in the core may be substantially reduced.

## Ni-Co partitioning

Nickel and Cobalt are elements of comparable siderophile character and similar cosmochemical volatility. Their abundances in the Earth's mantle are in contrast to the experimentally observed partitioning of these elements between metal and silicates at 0.1 MPa. Moreover, the ratio of the Ni- and Co-abundances of the upper mantle is close to their chondritic value, while the measured partition coefficients at 0.1 MPa imply a ratio which is ten times higher. There are a number of suggestions reconciling the observations from rocks and laboratory measurements, but these measurements have only been made at upper mantle conditions. We show, using a laser-heated diamond cell, that the siderophile character of Ni and Co decreases drastically at the pressure and temperature conditions of the deep mantle. An Fe-Co-Ni alloy was equilibrated with a single crystal of $Mg(Fe)SiO_3$-perovskite at pressures up to 80 GPa and temperature of 2000 K. The recovered samples were then analysed with an ion probe with high spacial resolution. Chemical equilibrium between silicate and metal was evident from 1) flat composition profiles in both, the radial and axial directions of the recovered samples, 2) the independence of the Fe-Ni-Co concentrations from the run duration, and 3) from the consistency of these concentrations with those obtained from reversal experiments in which recovered and analysed samples were reequilibrated at different run conditions and reanalysed. The Ni- and Co-partitioning between iron and perovskite decreases strongly with pressure approaching a value of one. The ratio between the partition coefficients of Ni and Co of $1.1(\pm 0.4)$ is nearly constant with pressure. From our data we estimated the Ni content of the lower mantle and the core under equilibrium conditions assuming a chondritic bulk Earth using the observed Ni content of the upper mantle (0.2 wt.%). The estimate results in a higher Ni content of the lower mantle with respect to the upper mantle. On the other hand, if there is whole mantle convection and the upper and the lower mantle have the same Ni content, then there is drastic non-equilibrium between the present lower mantle and the core. In these models the Ni content observed in upper mantle rocks implies that the D″-layer would be strongly enriched in Ni (5 wt.%) and Co and would bear the character of a chemical boundary layer.

## References

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