Oxidation state of majoritic garnet inclusions in diamond

EKATERINA S. KISEEVA[1,*], DENIS M. VASIUKOV[2], BERNARD J. WOOD[1], CATHERINE MCCAMMON[2], THOMAS STACHEL[3], ALEXANDER CHUMAKOV[4], LEONID DUBROVINSKY[2]

[1] Department of Earth Sciences, University of Oxford, Oxford OX1 3AN, UK, kate.kiseeva@earth.ox.ac.uk, berniew@earth.ox.ac.uk

[2] Bayerisches Geoinstitut, University of Bayreuth, D-95440, Bayreuth, Germany, vasyukov@physics.msu.ru, catherine.mccammon@uni-bayreuth.de, leonid.dubrovinsky@uni-bayreuth.de

[3] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, Canada, tstachel@ualberta.ca

[4] European Synchrotron Radiation Facility (ESRF), F-38043, Grenoble, France, chumakov@esrf.fr

Diamond inclusions are the only samples from the mantle transition zone (410-660 km) and the lower mantle. Majoritic garnet is a rare inclusion, limited to pressures of ~8-20 GPa with Si content being indicative of depth of re-equilibration. These garnet inclusions can therefore provide information on properties of the transition zone such as oxidation state.

In this study, we used Synchrotron Mössbauer Source (SMS) to determine the ferric-ferrous ratios of 13 small (30 to 100 micrometers diameter) majoritic inclusions in diamonds from Jagersfontein. The studied inclusions have pyroxenitic affinities [1], with compositions intermediate between typical peridotite and eclogite. They contain 4.62-11.2 wt% CaO, 0.03-0.34 wt% Cr_2O_3 and Mg# of 0.65-0.81. Minimum pressures for their equilibration using Beyer and Frost [2] barometer are between 8 and 18 GPa with at least 4 of these inclusions being formed in the transition zone.

The Fe^{3+}/Fe_{total} ratios in the garnets increase from 0.08±0.01 to 0.30±0.03 with increasing pressure. These values define a clear extension of the trend apparent in the data from peridotite xenoliths crystallised at lower pressures.

Thermodynamic calculations suggest that these high ferric contents correspond to oxygen fugacities above the Fe-FeO (IW) buffer, which means that the high Fe^{3+} contents were not generated by disproportionation of Fe^{2+} to Fe^{3+} and Fe^0. It is more likely that carbonate was the oxidising agent responsible for generating the high Fe^{3+} of these garnets.

[1] Kiseeva, E. S. et al. (2013). Geology 41, 883-886.
[2] Beyer, C. & Frost, D. J. (2017). EPSL 461, 30-39.